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Comparative survey between Digby and Miracle drag gear for scallop surveys in the Bay of Fundy

Relevés comparatifs entre les engins à drague de type Digby et Miracle pour les relevés sur les pétoncles dans la baie de Fundy

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ABSTRACT

Annual surveys using four-gang Digby style drag gear have been used to monitor the scallop grounds in the Bay of Fundy and Approaches since 1989. This gear had been originally designed for the Canadian Coast Guard vessel *J.L. Hart*, which was used for the surveys until it was retired in 2004. Surveys were conducted on the fishing vessel *Royal Fundy* from 2005 to 2011 with this same gear. The decision was made to replace the survey gear in 2012 with the more modern nine-gear Miracle gear in response to the fishing industry's concern about the effect of the widespread distribution of the bryozoan *Flustra foliacea* on the performance of the Digby gear and the anticipation that heavier gear would be required for the new Coast Guard vessel being built to replace the *J.L. Hart*. In the end, the new Coast Guard vessel was not delivered to the Maritimes Region and another fishing vessel with the new Miracle gear was used under contract for the survey in 2012. A comparative fishing experiment was conducted during the 2012 survey to compare the Digby and Miracle gears. The results presented here show that, for scallops, there were no significant differences between the two gears in terms of numbers caught or shell height frequencies when corrected for the same swept area, and, therefore, abundance estimates from the new time series with the new vessel and gear can be used as is with the previous time series of survey estimates. While differences between gears for the catch of skates were found, these differences were only significant when the Digby gear towed first. For all non-scallop species recorded during the scallop survey, it was not possible to determine a conversion factor. Therefore, survey trends for these other species including skate should be treated as separate time series by gear.

RÉSUMÉ

Les relevés annuels utilisant un engin de type Digby à quatre jeux de filets à dragues à pétoncles ont été utilisés pour surveiller les lieux de pêches du pétoncle dans la baie de Fundy et ses abords depuis 1989. Cet engin avait été conçu à l'origine pour le navire de la Garde côtière canadienne *J.L. Hart*, qui était utilisé pour les relevés jusqu'à ce qu'il ait été mis hors service en 2004. Les relevés ont été menés sur le bateau de pêche *Royal Fundy* de 2005 à 2011 avec le même engin. On a décidé de remplacer l'engin de relevé en 2012 par un train de pêche plus moderne composé de neuf engins Miracle en réponse aux préoccupations de l'industrie de la pêche concernant l'effet de la distribution répandue des bryozoaires *Flustra foliacea* sur le rendement de l'engin Digby et en réponse à la prévision qu'un engin plus lourd serait requis pour le nouveau navire de la Garde côtière en construction pour remplacer le *J.L. Hart*. En fin de compte, le nouveau navire de la Garde côtière n'a pas été livré dans la région des Maritimes et un autre bateau de pêche avec le nouvel engin Miracle a été utilisé sur une base contractuelle pour le relevé en 2012. Une expérience de pêche comparative a été menée durant le relevé de 2012 afin de comparer les engins Digby et Miracle. Les résultats présentés ci-après démontrent que, pour les pétoncles, il n'y avait pas de différence importante entre les deux engins en matière de nombres de pétoncles capturés ou des hauteurs de coquilles une fois corrigées pour la même aire balayée et, par conséquent, les estimations d'abondance pour les nouvelles séries chronologiques pour le nouveau navire et le nouvel engin peuvent être utilisées de la même manière que pour les séries chronologiques précédentes des estimations du relevé. Bien que des différences entre les engins en matière de captures de raies aient été constatées, ces différences n'étaient importantes que lorsque l'engin Digby a effectué un trait en premier. Pour toutes les autres espèces consignées durant le relevé des pétoncles, il n'était pas possible de déterminer un facteur de conversion. Donc, les tendances dans les relevés pour ces autres espèces, y compris les raies, devaient être traitées comme des séries chronologiques distinctes par engin.

INTRODUCTION

Annual scallop surveys in the Bay of Fundy and Approaches are the main source of monitoring data for the stock assessment. The current population model depends on the survey estimates of commercial size (shell height ≥80 mm), and recruit (65–79 mm) scallops for population trends over time (Smith et al. 2012). Digby drags (2.5 ft wide) with rubber washers (1981, steel washers) and without teeth have been the standard fishing gear for survey operations since 1981 (Lundy, unpublished manuscript). A seven-gang configuration was used when the survey was conducted on commercial fishing boats but was redesigned as a four-gang configuration when the Canadian Coast Guard Ship (CCGS) *J.L. Hart*[1] was used for the survey starting in 1989. Liners made from 38 mm polypropylene stretch mesh were inserted in alternate drags to target catches of scallops with shell heights less than 80 mm.

The four-gang Digby gear continued to be used after the CCGS *J.L. Hart* was retired from service in 2004 and replaced with a commercial fishing vessel under charter in 2005. The fishing vessel (F/V) *Royal Fundy* (O'Neil Fisheries) was used for the survey from 2005 to 2011. At the same time, plans were underway to build new inshore research vessels for the Department of Fisheries and Oceans (DFO), with delivery expected in either late 2011 or early 2012. The new vessel for the Maritimes Region was designed to be larger (72 ft versus 64 ft) and more powerful than the *J.L. Hart*, and there were concerns that the four-gang Digby gear would not fish properly off of the new vessel. In addition, concerns were raised by the scallop industry that the current configuration was not fishing properly with the proliferation over the last 15 or so years of the bryozoan *Flustra foliacea,* known as lemonweed by the fishermen. In anticipation of receiving the new vessel, discussions were held with members of the fishing industry on a new gear configuration. In the end, the new Coast Guard vessel scheduled for the Maritimes Region was deployed to another region and the system of chartering fishing vessels has continued.

The charter for the 2012 survey was awarded to the F/V *Brittany & Madison III* (LBM Fisheries) and new fishing gear based on designs currently used in the fishery (nine-gang Miracle 2 ft drags) was built for the survey. In this report, results of the comparative fishing experiment conducted July 3 to 7, 2012, between the F/V *Brittany & Madison III* using the Miracle gear and the F/V *Royal Fundy* using the four-gang Digby gear were compared. The main purpose of this study was to determine if conversion factors were required to adjust survey estimates for the changes in gear and vessel.

MATERIAL AND METHODS

FISHING VESSELS AND GEAR

The annual scallop survey of the Bay of Fundy and Approaches has been conducted from 2005 to 2011 using the side-dragger F/V *Royal Fundy* (Figure 1, left panel). While this vessel is capable of carrying full size gear, the surveys were conducted using the gear previously used on the J.L. Hart. That is, Digby drags (2.5 ft width) in a four-gang configuration with rubber washers, 3 1/4 inch rings and no teeth (Figure 2, left panel). Two of the drags were lined with 38 mm polypropylene stretch mesh and two were left unlined. Scallop catches from the lined drags are used to estimate the catch rates for scallops with shell heights less than 80 mm, while

[1] Originally FRV *J.L. Hart* before Coast Guard became a part of DFO and became responsible for all vessels in the Department.

the catches from the unlined gear are used for the catch rates for scallops with shell heights ≥80 mm.

The F/V *Brittany & Madison III* is a stern scallop dragger (Figure 1, right panel) and can also operate as a lobster boat. New gear was purchased for the 2012 survey consisting of Miracle drags (2 ft × 1 ft) with 5 2-inch teeth and 3 1/4 inch rings in a nine-gang configuration (Figure 2, right panel). Each drag had eight rings along front and back with steel washers and three rings along the sides with rubber washers (22 around and 7 deep). There were two rows of two rubber tire chafers. Two drags were lined with 38 mm polypropylene stretch mesh.

EXPERIMENTAL DESIGN

The comparative survey was conducted while the *Brittany & Madison III* was engaged in the Bay of Fundy survey. All the tows made by this vessel were included in the survey estimates for 2012.

On the first day of the comparative survey experiment, each vessel towed a set of assigned stations recording the tow tracks using the OLEX[2] navigation system. On the second day, each vessel towed the stations conducted by the other vessel on the first day sticking as close as possible to the original tow tracks. This alternation was continued for the third and fourth day. On the fifth day, the *Royal Fundy* conducted seven tows in the morning and the *Brittany & Madison III* repeated those stations in the afternoon, and the sampling was complete (Appendix A, Table A1).

At each station, each vessel conducted an 8-minute tow at a speed of 2.5–3.5 knots. For each tow, the tow track, a distance coefficient, start and end location, bearing, tide cycle, depth, amount of wire out, volume of catch, bottom type, and shell height frequency of scallops caught in the lined and unlined gear were recorded. In addition to scallop, length measurements were also taken for all commercial fish species, squid, lobster, and octopus caught in the survey by each vessel. For lobster and octopus, detailed sampling of the sex and carapace or mantle length was also conducted. Biological scallop samples used to calculate condition factor were only taken on the *Royal Fundy* from catches in the four-gang gear. Catches of both scallop and the other species recorded from both vessels were standardized to 800 m tow length and a tow width of 17.5 ft (5.334 m); the standard procedure for survey catches used in the scallop stock assessments.

The impact of lemonweed on the relative performance of the two gears was evaluated by developing a qualitative scale of the amount of lemonweed in gear after the tow based on photographs taken during the survey (examples in Figure 3). Four levels for this scale were defined as no lemonweed, low (some lemonweed in gear), medium (lemonweed and other material in gear) and high (completely filled with lemonweed).

STATISTICAL ANALYSIS

The numbers of scallops caught by each gear (y_{ij}) were characterized by a generalized linear model using a gamma distribution for the numbers caught and a log link for the linear predictor. That is,

$$E[y_{ij}] = \exp(\alpha + \gamma_j),$$

[2] OLEX AS Pirsenteret N-7462 Trondheim, Norway, http://www.olex.no/index_e.html.

where α is the overall mean catch and γ_j is a four-level factor defined as:

1. Catches from Miracle gear | Digby towed first
2. Catches from Digby gear | Digby towed first
3. Catches from Miracle gear | Miracle towed first
4. Catches from Digby gear | Miracle towed first

This model was fit to catch for all sizes combined and then catches for commercial size scallops (shell height≥80 mm), recruits (65–79 mm) and pre-recruits (<65 mm). In the standard fit of this kind of model, results are given for contrasts between each of the levels 2, 3 and 4, against level 1 testing the null hypothesis that all levels were not significantly different from level 1. For the purposes of this study, the pertinent contrasts were actually between levels 1 and 2, and levels 3 and 4. These contrasts were tested using a-posterior multiple comparison tests available in the R package multcomp (Hothorn et al. 2008).

The impact of the different levels of the density of lemonweed were evaluated by regressing the catch from the Miracle gear on that from the Digby for each paired tow within the combination of factors for which gear was towed first and the four-level factor for lemonweed density described above. The null hypothesis in this case was that the slope of the regression was equal to 1.0.

RESULTS

A total of 72 stations were completed but only 71 tows were used in the analysis because the tow tracks from one of the tows by the two vessels did not coincide and was not close enough to be considered a comparative tow (Table 1). Tow locations were selected to reflect a range of scallop densities based on the 2011 survey (Figure 4). The scallop survey database had not been designed to accommodate comparative survey experiments, and changes will need to be made to deal with these kinds of data, as well as other changes to the surveys that have been made over time (see Appendix B).

Mean numbers per tow over all 71 tows for all sizes and for size classes routinely used in the stock assessment indicated that there were minor differences between catches from the two gears when standardized to the same tow length and tow width (Table 2). However, there were indications that there were larger differences between mean numbers per tow when tows were grouped by those where the Digby gear or the Miracle gear was the first gear used at the survey station (Table 3). The differences between catches conditional on which gear was towed first were not significantly different (contrasts 1 and 2 in Table 4). The contrasts for Miracle catches compared to Digby catches for all size classes were always positive when the Miracle gear was towed first and negative when the Digby gear was towed first, possibly due to depletion effects. In addition, these contrasts were not significantly different between gears suggesting that these potential depletion effects were independent of gear type (contrasts 1-2 in Table 4).

SHELL HEIGHT FREQUENCIES

Mean shell height frequencies from the two gear types were similar, with both picking up pre-recruits in the 25 to 45 mm range and the bulk of the catches being in the 80 mm and larger size classes (Figure 5). Cumulative frequencies for combined catches indicated that the Miracle gear may have been less efficient at catching scallops over a range of sizes (Figure 6), but, as for the previous analysis of numbers per aggregate size classes, the order of which gear was used first needs to be taken into account. Again depletion effects appear to be evident in the shell height frequencies with each gear tending to catch more at many size classes when it was used first at a survey tow location (Figures 7, 8).

Tow by tow comparisons indicated that standardized cumulative frequencies were very similar between gear types in most cases (Figure 9). Those tows that did differ tended to reflect possible depletion effects due to tow order.

LEMONWEED

The relationships between total numbers of scallop caught by the Miracle gear and the Digby gear did not suggest any differences due to the density of lemonweed in the gear (Figure 10). The only slope estimates that were significantly different from 1.0 were for the relationships between the two gears when the Digby gear was towed first for tows without lemonweed and the Miracle gear was towed first for low lemonweed density (Table 5). In the latter case, the largest tow for the Digby gear was highly influential on the results and the p-value for the test statistic increased to 0.111 when this point was removed from the analysis. For the former case, the higher catches in the Digby gear when the Digby gear was towed first were consistent with the depletion effect identified earlier.

CATCHES OF OTHER SPECIES

A comparison of standardized abundance per tow by species group can be found in Table 6. For both gear types combined, a total of 16 species groups were caught; 10 unique species groups were caught by tows with Digby gear and 13 unique species groups were caught by tows with Miracle gear. Due to the overlap between species group *Leucoraja* <35 cm and species groups little skate and winter skate, an additional summary of All Skate Combined was conducted (Table 6).

The most significant difference observed between the catch of other species between gear types was the catch of skate species. This was apparent in both the number per tow for the individual skate species groups, as well as the combined group (Table 6). For all skate species combined, Miracle gear caught approximately five times the number of skate caught by Digby gear (1.94 skate per tow versus 10.55 skate per tow; Table 6).

Of the 16 species groups recorded during the comparative survey, only 7 were caught in both gear types: lobster, *Leucoraja* <35 cm (small winter/little skate <35 cm), octopus, thorny skate, winter flounder, winter skate, and witch flounder (Table 6). However, of these 7 species groups, there were only 6 matching tows that caught lobster in both gear types, 1 matching tow that caught octopus, 4 matching tows that caught winter flounder, and 0 matching tows that caught witch flounder. This resulted in detailed comparisons of catch between gear types limited to the species groups *Leucoraja* <35 cm, thorny skate, and winter skate. For the purpose of maximizing the sample size from which a detailed analysis could be conducted, these 3 species groups were combined and a generalized linear model (GLM) similar to that described above for scallops was fitted to the standardized abundance.

As indicated by the differences in the number per tow, the results of the GLM show that there were more skate (*Leucoraja* <35 cm, thorny skate, and winter skate combined) caught in the Miracle gear than by the Digby gear; however, this difference was only significant when the Digby gear was towed first (Table 7).

DISCUSSION

SCALLOP

Changes in vessel and gear will occur periodically for long term surveys of fishery resources as vessels need to be replaced and gear needs to be modernized due to difficulties in obtaining parts as older gears are phased out by the fishing industry. The common method for calibrating the changes to gears, vessels or both for resource surveys using towed gear is to conduct paired-towed experiments (e.g., Fanning 1985, Fowler and Showell 2009, Cadigan and Power 2011, Miller et al. 2010; but see Cotter 2001 for a model-based method for calibrating independent surveys of the same area). These experiments consist of side-by-side tows as close as safely possible and assume that differences in catches reflect differences in vessel/gear catchability and not differences in the local densities fished by either vessel.

Pelletier (1998) reviewed a number of intercalibration or comparative survey programs and found that distances between vessels varied between 0.25 and 1.0 nautical mile. Cadigan and Dowden (2010) noted that, depending upon the distribution of the target species, paired tows may not be close enough to eliminate small scale heterogeneity in spatial distribution, and any estimate of relative catchability from the experiment may be contaminated by these differences requiring analysis methods that can account for them (see also Ehrich 1991). These experiments also assume that the behaviour of each vessel/gear combination is consistent and controlled over all tows to allow an overall relative catchability estimate. Koeller and Smith (1983) provided a list of other potential problems that can complicate the estimation of relative fishing coefficients including, the effects of depth, warp to depth ratios, towing distance, speed, and other physical constraints.

Lewy et al. (2004) proposed comparison tows on the same track line to avoid the spatial heterogeneity problems of side-by-side tows. While this approach should result in the two vessels fishing the same area, issues with spatial distribution are replaced with the impacts of disturbance to the fish distribution (attraction or repulsion) and depletion effects caused by the first vessel towing through the area. The proposed method randomly assigns vessel to the first tow but all also includes tows where the same vessel tows twice to estimate the disturbance/depletion effect.

The design of the scallop comparative survey follows that of towing on the same track line to reduce spatial differences. While in the fish case, it is impossible to disentangle fish disturbance from actual depletion effects, the more sedentary nature of scallops would result in differences being due to depletion only assuming that the tows overlapped on the same track line. Overall, the results appeared to demonstrate depletion effects consistent with which gear was towed first in a location.

The scallop experiment differed from the other comparative experiments in that it analysed the catches after they had been corrected for tow length and standardized to a common tow width. It was expected that a four-gang gear should catch less than a nine-gang gear on average, but here the null hypothesis was that this difference was simply due to the area covered by the gear and not due to any intrinsic differences in vessel/gear behaviour. Rejection of this null hypothesis by finding differences after these corrections have been made would imply that the two gears fished differently. The results presented here show that, once the depletion effect had been accounted for, there were no differences between the two gears in terms of numbers caught or shell height frequencies and, therefore, abundance estimates from the new time series with the new vessel and gear can be used as is with the previous time series of estimates.

CATCHES OF OTHER SPECIES

Since 2001, commercial groundfish have been recorded as part of the inshore scallop surveys in addition to lobster, squid, and octopus. Survey data on the catches of species other than scallops were reviewed in Smith et al. (2012) to evaluate potential bycatch species in the scallop fishery.

With the exception of the combined skate group of *Leucoraja* <35 cm, thorny skate, and winter skate, a detailed analysis of the differences in catches of other species (i.e., non-scallop species) between the two gear types was not possible due to the lower frequency at which these other species were caught and the limited number of tows where a given species was caught by both gear types. Since all other species recorded during the scallop survey are mobile, it is not surprising that their occurrence within the scallop survey is more variable than observed for scallops.

For most other species, the standardized number per tow did not show large differences between the two gear types with the exception of skates. All skate species groups, except thorny skate, were caught in higher numbers by the Miracle gear than with the Digby gear. Although detailed analysis between the two gear types by species was not possible, the detailed analysis on the combined group of *Leucoraja* <35 cm, thorny skate, and winter skate showed that there was an increased catch of skate by Miracle gear; however, this difference was only significant when the Digby gear towed first. It is possible that this was due to the larger size of the Miracle gear. Although the abundances are standardized to the same width and tow length, the Miracle gear used is almost twice as wide as the Digby gear (18 ft versus 10 ft). Skate are known to be opportunistic predators and scavengers. It is possible that, when the first gear is towed, the resulting bottom disturbance attracted an increased number of skate. Although an increase in the presence of skate may occur regardless of which gear is towed first, if the skate initiate an escape response at the same distance away from either gear when the second tow occurs, the probability of being caught by the Miracle gear could be higher due to the additional distance the skate must travel to avoid being captured.

For all non-scallop species groups recorded during the scallop survey, it was not possible to determine a conversion factor relating catches from Digby gear to Miracle gear. Therefore, survey trends for these other species should be treated as separate time series.

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REFERENCES

Cadigan, N.G., and Dowden, J.J. 2010. Statistical inference about relative efficiency from paired-tow survey calibration data. Fish. Bull. 108: 15–29.

Cadigan, N.G., and Power, D. 2011. Vessel calibration results for redfish (*Sebastes sp.*) from comparative fishing between the CCGS *Teleost* research vessel and the MV *Cape Beaver* fishing vessel. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/062. iv + 17 p.

Cotter. A.J.R. 2001. Intercalibration of North Sea international bottom trawl surveys by fitting year-class curves. ICES J. Mar. Sci. 58: 622–632.

Ehrich, S. 1991. Comparative fishing experiments by research trawlers for cod and haddock in the North Sea. J. Cons. Int. Explor. Mer. 47: 275–283.

Fanning, L.P. 1985. Intercalibration of research survey results obtained by different vessels. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 85/3.

Fowler, G.M., and Showell, M.A. 2009. Calibration of bottom trawl survey vessels: Comparative fishing between the *Alfred Needler* and *Teleost* on the Scotian Shelf during the summer of 2005. Can. Tech. Rep. Fish. Aquat. Sci. 2824: iv + 25 p.

Hothorn, T., Bretz, F., and Westfall, P. 2008. Simultaneous inference in general parametric models. Biom. J. 50: 346–363.

Koeller, P., and Smith, S.J. 1983. Preliminary analysis of *A.T. Cameron – Lady Hammond* comparative fishing experiments 1979–1981. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 83/59.

Lewy, P., Nielsen, J.R., and Hovgård, H. 2004. Survey gear calibration independent of spatial fish distribution. Can. J. Fish. Aquat. Sci. 61: 636–647.

Miller, T.J., Das, C., Politis, P.J., Miller, A.S., Lucey, S.M., Legault, C.M., Brown, R.W., Rago, P.J. 2010. Estimation of *Albatross IV* to *Henry B. Bigelow* calibration factors. Northeast Fish. Sci. Cent. Ref. Doc. 10-05. 233 p. Available at [Internet]: http://www.nefsc.noaa.gov/publications/crd/crd1005/ (accessed 17 December 2012).

Pelletier D. 1998. Intercalibration of research survey vessels in fisheries: A review and an application. Can. J. Fish. Aquat. Sci. 55: 2672–2690.

Smith, S.J., Hubley, B., Nasmith, L., Sameoto, J., Bourdages, H., and Glass, A. 2012. Scallop Production Areas in the Bay of Fundy: Stock status for 2011 and forecast for 2012. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/009. vi + 123 p.

Table 1. Details on locations of comparative scallop survey tows, July 3 to 7, 2012.

SPA	Strata number	Strata name	No. Tows
4	3	2-8 MILES DIGBY GUT (DG)	2
4	4	2-8 MILES DELAPS COVE (DC)	7
4	5	2-8 MILES PARKERS COVE (PC)	7
1A	6	2-8 MILES YOUNGS COVE (YC)	1
4	10	2-8 MILES BETWEEN DIGBY GUT AND DELAPS COVE (DGDC)	3
1A	13	8-16 MILES DIGBY GUT (DG)	1
1A	14	8-16 MILES DELAPS COVE (DC)	8
1A	15	8-16 MILES PARKERS COVE (PC)	9
1A	16	8-16 MILES YOUNGS COVE (YC)	12
1A	17	8-16 MILES HAMPTON (HT)	7
1A	20	8-16 MILES BETWEEN DIGBY GUT AND DELAPS COVE (DGDC)	8
1B	38	Mid Bay North	3
1B	53	UPPER BAY 28C	4
		Total	72

Table 2. Mean number (standard error) per tow for different size class from comparative tows conducted using the Digby and Miracle gear. All catches corrected for standard length of tow of 800 m and gear width of 5.334 m.

Size class	Digby	Miracle
All sizes	134.66 (23.9)	134.55 (17.4)
Commercial size (≥80 mm)	92.63 (12.9)	94.05 (9.1)
Recruits (65–79 mm)	9.56 (3.0)	11.52 (2.9)
Pre-recruit (<65 mm)	32.47 (9.3)	28.98 (7.2)

Table 3. Mean number of scallops per tow by size class by gear for comparative tows where the Digby gear or the Miracle gear was towed first.

		Mean Number per tow	
First Tow	Size class	Digby	Miracle
Digby	Total	179.04	158.26
	Commercial	117.93	101.00
	Recruits	14.81	15.88
	Pre-recruits	46.30	41.38
Miracle	Total	77.41	103.96
	Commercial	59.98	85.07
	Recruits	2.79	5.89
	Pre-recruits	14.62	12.99

Table 4. Results of fitting a generalized linear model (family=Gamma, link=log) to mean number by tow by size class to determine differences due to gear type by tow order. Contrasts tested refer to a-posteriori multiple comparison tests for null hypothesis of zero differences between catches.

Size class	Contrasts tested	Estimate	Std. Error	Z value	Pr(>|Z|)
Total	1 (Miracle-Digby)|Miracle first	0.295	0.268	1.10	0.47
	2 (Miracle-Digby)|Digby first	-0.208	0.246	-0.84	0.64
	1-2 = 0	0.087	0.364	0.24	0.81
Commercial	1 (Miracle-Digby)|Miracle first	0.349	0.213	1.65	0.19
	2 (Miracle-Digby)|Digby first	-0.269	0.197	-1.37	0.31
	1-2 = 0	0.080	0.289	0.28	0.78
Recruits	1 (Miracle-Digby)|Miracle first	0.746	0.479	1.56	0.23
	2 (Miracle-Digby)|Digby first	-0.188	0.363	-0.52	0.84
	1-2 = 0	0.558	0.601	0.93	0.35
Pre-recruits	1 (Miracle-Digby)|Miracle first	-0.173	0.466	-0.37	0.92
	2 (Miracle-Digby)|Digby first	-0.036	0.393	-0.09	0.99
	1-2 = 0	-0.208	0.609	-0.34	0.73

Table 5. Evaluating the impact of lemonweed (Flustra foliacea) on the performance of the two gears used in the comparative study. Test statistics and p-values are for the null hypothesis that slope of relationship between total catches of Miracle gear as a function of Digby gear was equal to 1.0. Density of lemonweed determined qualitatively from photographs of gear after tow. There are too few observations in the medium lemonweed bottom to test the slope estimates.

First tow	Lemonweed	Slope estimate	Std. Error	t value	Pr(>|t|)
Miracle	No	0.476	0.299	-1.754	0.085
Digby		0.699	0.039	-7.713	p<0.001
Miracle	Low	0.585	0.161	-2.578	0.013
Digby		1.002	0.373	0.007	0.995
Miracle	High	1.223	0.493	0.452	0.653
Digby		1.061	0.320	0.190	0.850

Table 6. Mean number (standard error) per tow for different size class from comparative tows conducted using the Digby and Miracle gear. Corrected for length of tow and swept area.

Species Group	Digby		Miracle	
	Mean (SE)	Tows with Presence	Mean (SE)	Tows with Presence
AMERICAN LOBSTER	0.43 (0.16)	8	0.49 (0.11)	19
BRILL/WINDOWPANE	0 (0)	0	0.07 (0.04)	4
COD (ATLANTIC)	0 (0)	0	0.09 (0.04)	6
CUSK	0 (0)	0	0.03 (0.02)	2
LEUCORAJA <35cm	0.96 (0.28)	16	4.34 (1.80)	50
LITTLE SKATE	0 (0)	0	2.42 (0.52)	41
OCTOPUS	0.14 (0.06)	5	0.11 (0.06)	5
SMOOTH SKATE	0 (0)	0	0.08 (0.06)	2
THORNY SKATE	0.19 (0.07)	7	0.05 (0.03)	3
WHITE HAKE	0 (0)	0	0.11 (0.04)	7
WINTER FLOUNDER	0.25 (0.10)	7	0.43 (0.09)	22
WINTER SKATE	0.78 (0.15)	23	3.67 (1.05)	42
WITCH FLOUNDER	0.03 (0.03)	1	0.03 (0.03)	1
SHORT-FIN SQUID	0.03 (0.03)	1	0 (0)	0
SILVER HAKE	0.06 (0.04)	2	0 (0)	0
SQUIRREL OR RED HAKE	0.17 (0.08)	5	0 (0)	0
ALL SKATE COMBINED	1.94 (0.38)	NA	10.55 (1.25)	NA

Table 7. Results of fitting a generalized linear model (family=Gamma, link=log) to the mean number by tow of skate combined from the species groups Leucoraja <35 cm, thorny skate, and winter skate to determine differences due to gear type by tow order. Contrasts tested refer to a-posteriori multiple comparison tests for null hypothesis of zero differences between catches.

Species	Contrasts tested	Estimate	Std. Error	Z value	Pr(>|Z|)
Skate Combined	1 (Miracle-Digby)|Miracle first	0.177	0.376	0.47	0.87
	2 (Miracle-Digby)|Digby first	1.792	0.325	5.51	<0.001*
	1-2 = 0	1.969	0.497	3.96	<0.001*

* indicates a significant difference.

Figure 1. Fishing vessels used in comparative survey. Left Panel: F/V Royal Fundy (2005–2011), Right Panel: Brittany & Madison III (2012).

Figure 2. Fishing gear used in comparative survey. Left Panel: Four-gang Digby drags (1989–2011), Right Panel: Nine-gang Miracle gear (2012).

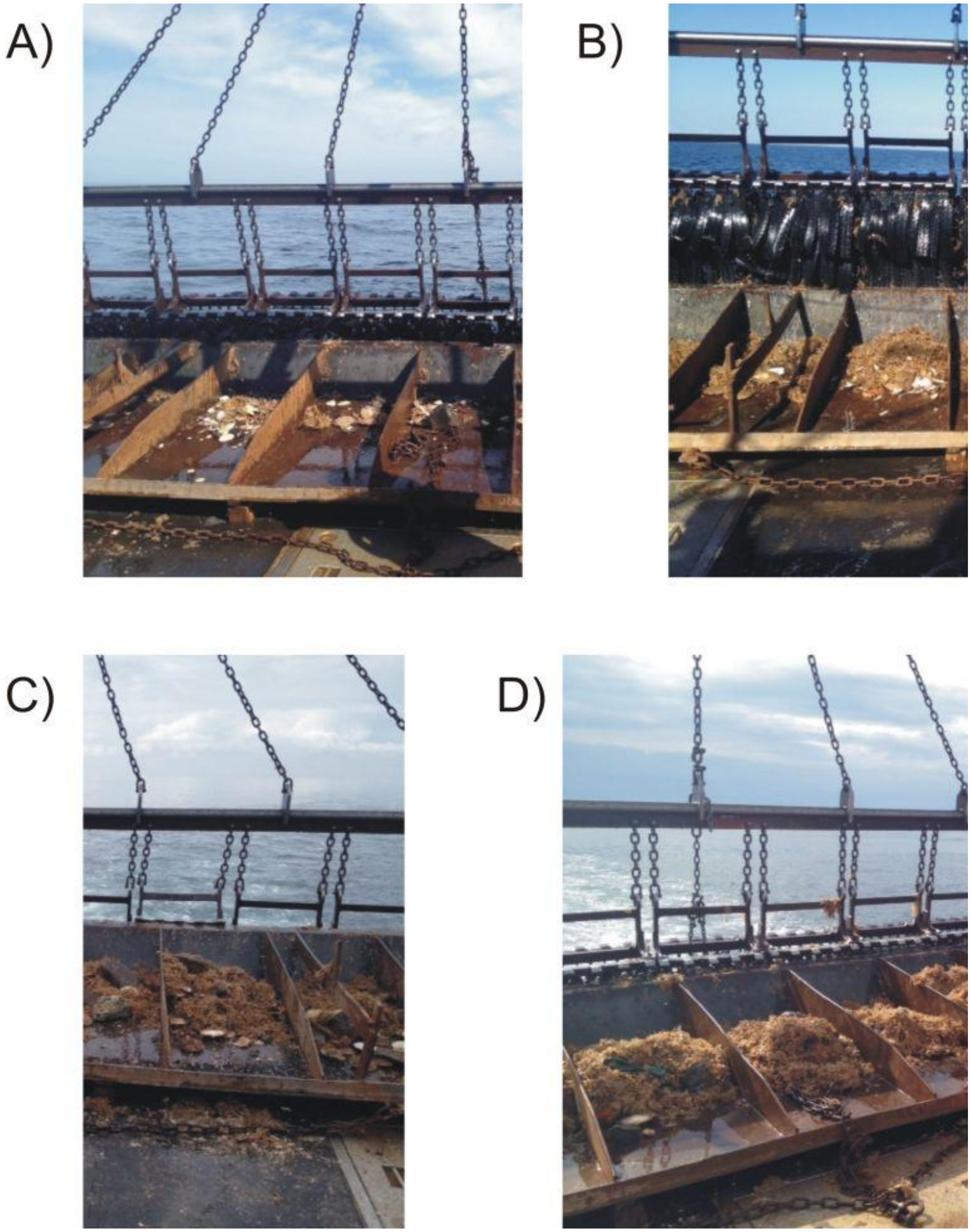

Figure 3. Examples of photographs used to define qualitative scale of lemonweed (Flustra foliacea) density in gear for the comparative survey tows. A) no lemonweed, B) low density, C) medium density, and D) high density.

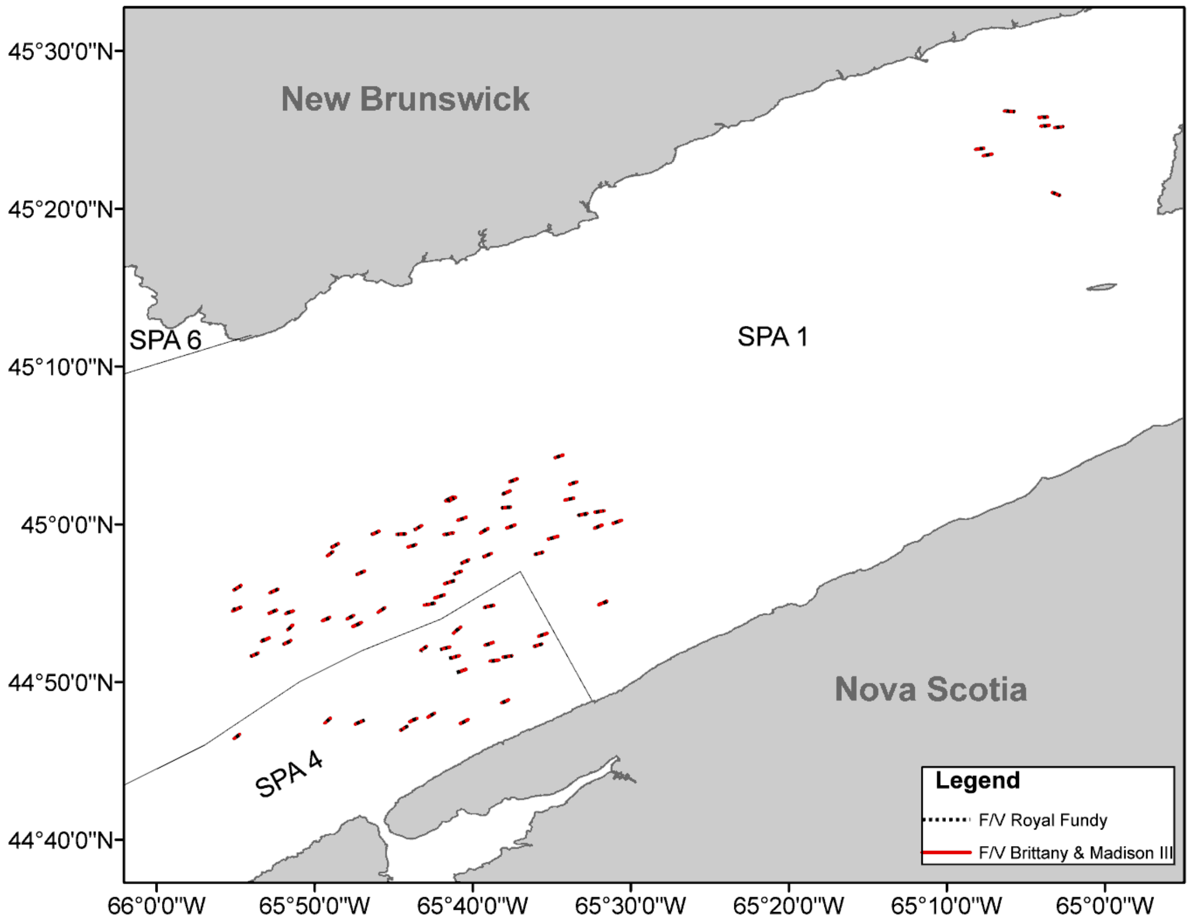

Figure 4. Locations of comparative tows for each vessel from comparative fishing experiment conducted in July 2012: the F/V Royal Fundy (four-gang Digby gear), and the F/V Brittany & Madison III (nine-gang Miracle gear).

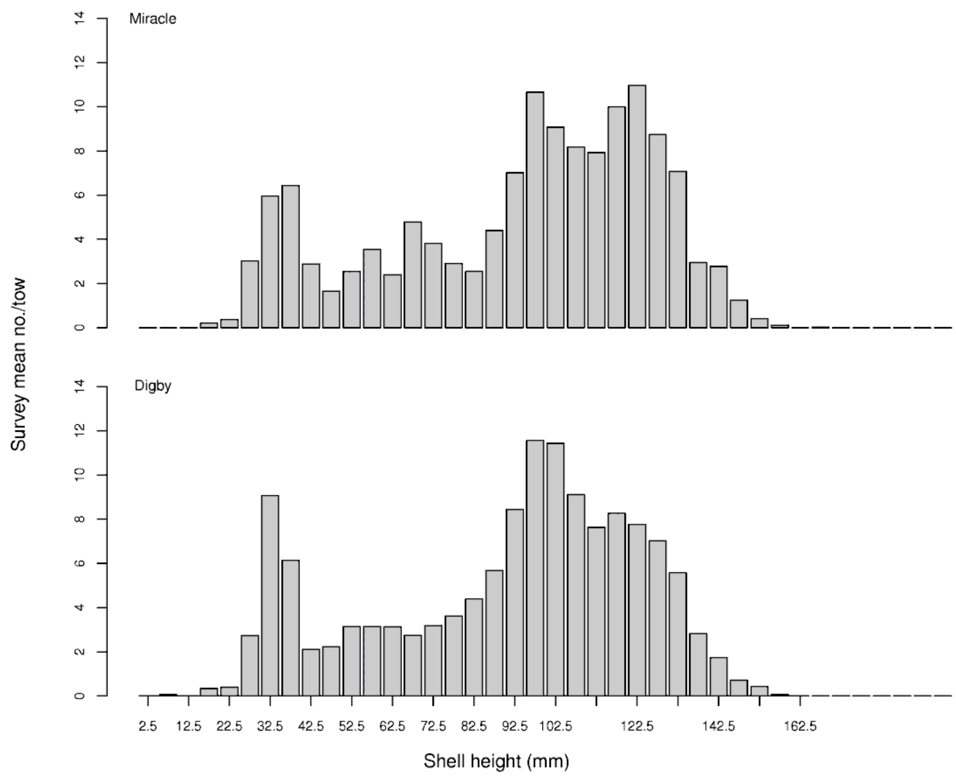

Figure 5. Mean shell height frequencies over all tows for each gear from comparative fishing experiment.

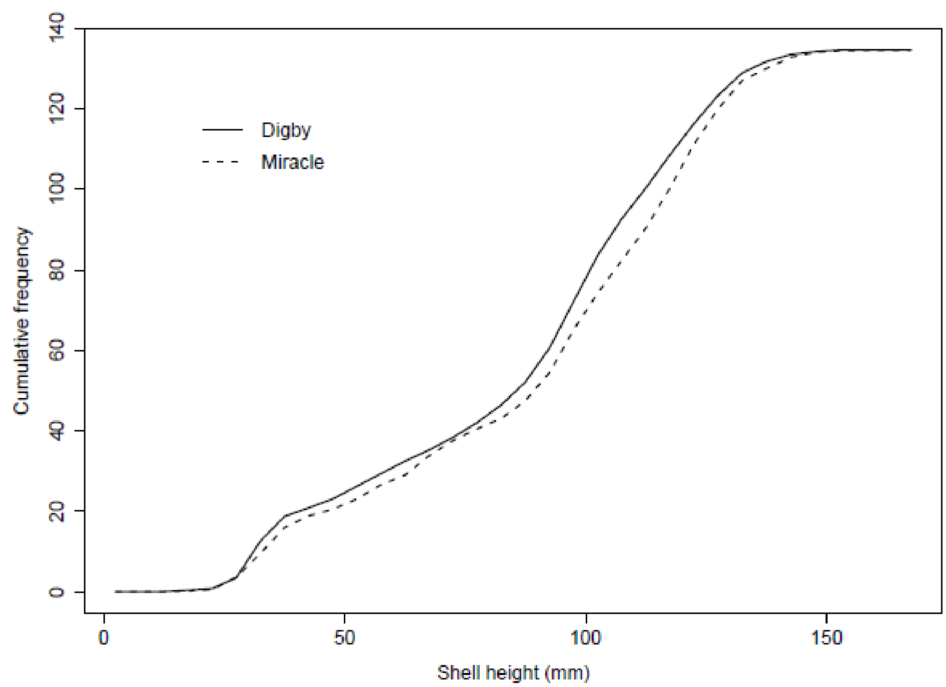

Figure 6. Cumulative mean shell height frequencies over all tows for each gear from comparative fishing experiment.

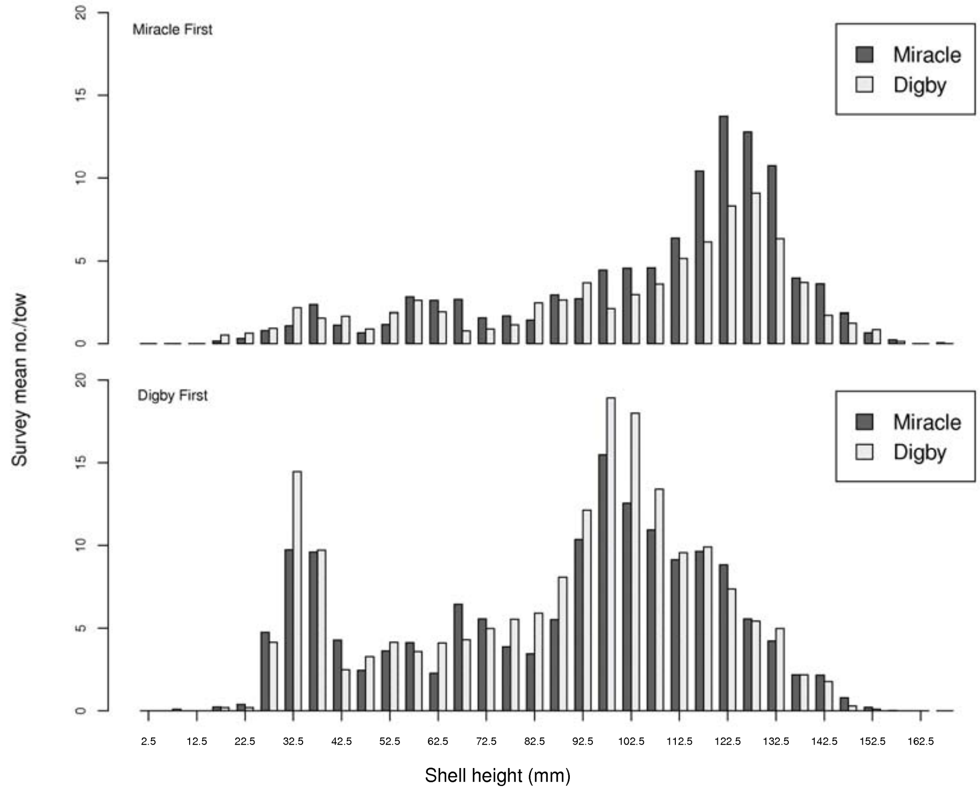

Figure 7. Mean shell height frequencies over all tows for each gear by which gear was towed first in the comparative fishing experiment.

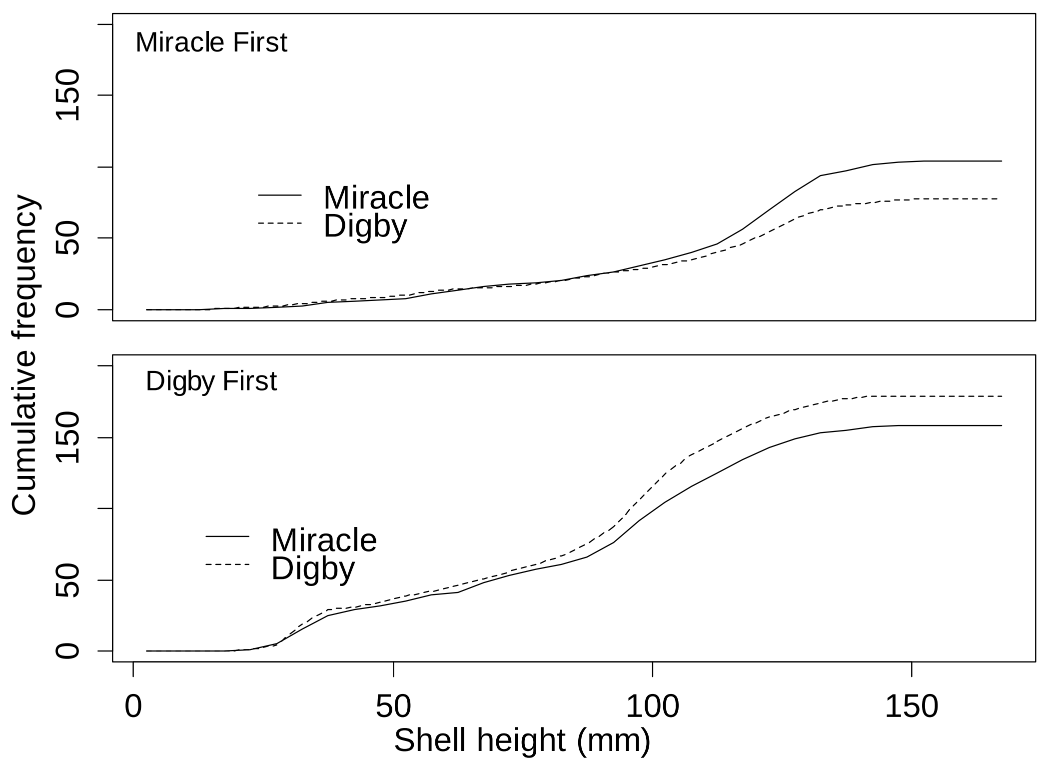

Figure 8. Cumulative frequencies by gear and by which gear was towed first in the comparative fishing experiment.

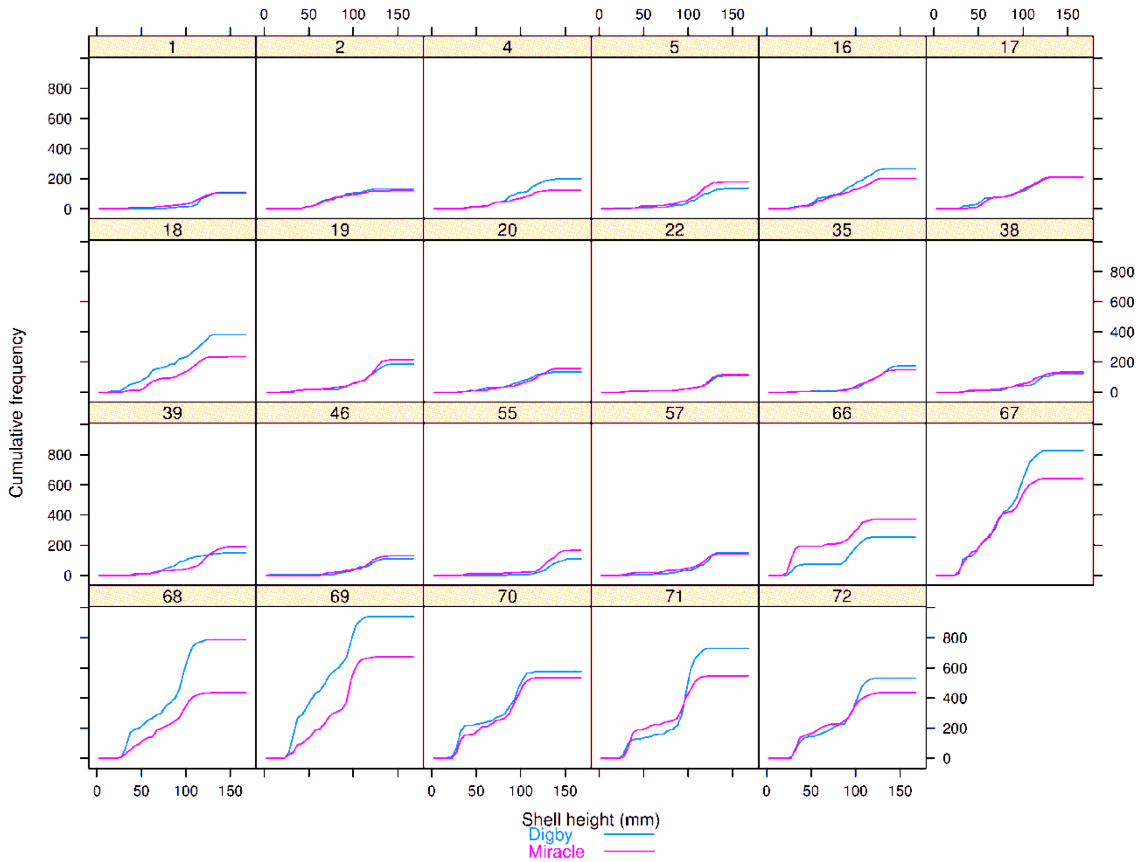

Figure 9. Cumulative shell height frequencies for each set of comparative tows from the comparative fishing experiment for tows where the minimum catch of either tow was greater than 100 scallops when corrected for tow length and swept area. Numbers in panel headers refer to the tow number for the F/V Royal Fundy survey.

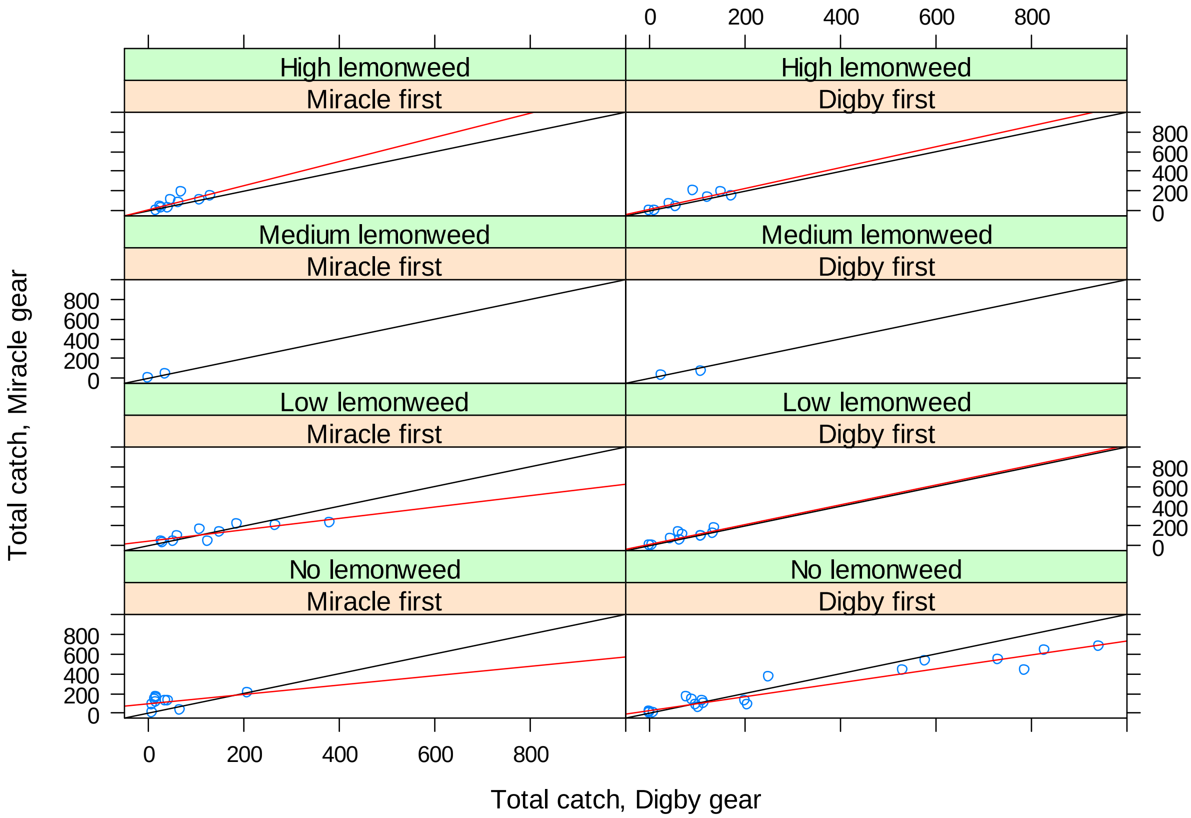

Figure 10. Relationship between total catch (numbers, all sizes) from Miracle gear and Digby gear categorized by which gear towed first at a tow location and the density of lemonweed (Flustra foliacea) in the gear at the end of the tow. The density of lemonweed determined qualitatively from photographs of the gear after the tow. The black diagonal line refers to the slope equal to 1.0, while the red line corresponds to the fitted line from a regression model. There were too few observations to fit a line for the medium density tows.

APPENDIX A

Table A.1. Associated tows from the comparative survey. Cruise identifier BF2012 corresponds to the F/V Brittany & Madison III where the cruise identifier RF2012 corresponds to the F/V Royal Fundy.

CRUISE_T	TOW_NO_T	CRUISE_P	TOW_NO_P	STATION_NO
BF2012	65	RF2012	23	110
BF2012	66	RF2012	24	107
BF2012	67	RF2012	25	105
BF2012	68	RF2012	26	104
BF2012	69	RF2012	27	150
BF2012	70	RF2012	28	96
BF2012	71	RF2012	22	156
BF2012	72	RF2012	21	155
BF2012	73	RF2012	20	151
BF2012	74	RF2012	19	154
BF2012	75	RF2012	16	147
BF2012	76	RF2012	17	148
BF2012	77	RF2012	18	149
BF2012	78	RF2012	62	108
BF2012	79	RF2012	61	109
BF2012	81	RF2012	60	106
BF2012	82	RF2012	11	117
BF2012	83	RF2012	12	128
BF2012	84	RF2012	13	122
BF2012	85	RF2012	14	127
BF2012	86	RF2012	15	121
BF2012	87	RF2012	1	130
BF2012	88	RF2012	2	131
BF2012	89	RF2012	3	124
BF2012	90	RF2012	5	120
BF2012	91	RF2012	4	118
BF2012	93	RF2012	7	119
BF2012	94	RF2012	8	116
BF2012	95	RF2012	9	113
BF2012	96	RF2012	10	114
BF2012	97	RF2012	63	115
BF2012	98	RF2012	64	112
BF2012	99	RF2012	65	125
BF2012	100	RF2012	48	40
BF2012	102	RF2012	51	88
BF2012	103	RF2012	52	87
BF2012	104	RF2012	53	56
BF2012	105	RF2012	54	49
BF2012	106	RF2012	55	53
BF2012	107	RF2012	56	51
BF2012	108	RF2012	57	54
BF2012	109	RF2012	58	48
BF2012	110	RF2012	59	55
BF2012	112	RF2012	50	85
BF2012	113	RF2012	49	47

Table A.1 continued. Associated tows from the comparative survey. Cruise identifier BF2012 corresponds to the F/V Brittany & Madison III where the cruise identifier RF2012 corresponds to the F/V Royal Fundy.

CRUISE_T	TOW_NO_T	CRUISE_P	TOW_NO_P	STATION_NO
BF2012	114	RF2012	42	59
BF2012	115	RF2012	43	66
BF2012	116	RF2012	41	69
BF2012	117	RF2012	40	70
BF2012	118	RF2012	39	381
BF2012	119	RF2012	38	123
BF2012	120	RF2012	37	126
BF2012	121	RF2012	36	135
BF2012	122	RF2012	35	133
BF2012	123	RF2012	34	137
BF2012	124	RF2012	32	132
BF2012	125	RF2012	33	136
BF2012	126	RF2012	44	339
BF2012	127	RF2012	45	60
BF2012	128	RF2012	46	64
BF2012	129	RF2012	47	61
BF2012	130	RF2012	29	129
BF2012	131	RF2012	30	138
BF2012	132	RF2012	31	134
BF2012	144	RF2012	72	242
BF2012	145	RF2012	71	361
BF2012	146	RF2012	66	334
BF2012	147	RF2012	67	360
BF2012	148	RF2012	68	319
BF2012	149	RF2012	69	328
BF2012	150	RF2012	70	228

APPENDIX B

Database Issues

When the inshore scallop survey database (SCALLSUR) was first designed, gear code and whether the gear was lined or unlined was recorded as a single data entry field as *gear*. In this sense, the definition of gear was the ordered number of the gangs where it was assumed that there were four gangs in total and that they remained in the following order with the associated attribute of being lined or unlined: gear 1 = lined, gear 2 = unlined, gear 3 = lined, gear 4 = unlined. When data is loaded to SCALLSUR, and the attribute *gear* was entered with a number between 1 and 4, it would be assigned to the above category of being lined or unlined. If *gear* was outside this range (e.g., if there was five gangs and the fifth gang was assigned gear = 5), then this gear code would receive a lined code of null.

Over time, the practice of recording the order of the gang relative to the total number of gangs ended and the use of *gear* became restricted to just gear = 1 for lined gear, and gear = 2 for unlined; however, no formal changes to the definition or the use of gear were ever conducted in SCALLSUR. However, it is critically important that the gear field is entered (i.e. gear = 1 for lined gear, and gear = 2 for unlined) and that is it properly labelled as this field populates the field *lined* in SCGEARS, which in turn is used to separate which shell height frequencies are used for which shell frequency bins in the prorated views (SCLIVERES and SCLIVEDEAD). Currently, the recording of gear type when loading survey data is only indicative of whether the gear used is lined or unlined and not a true reflection of the order of the gang sampled or the actual gear type used (e.g., Digby drag, Miracle gear). No field captures the actual gear type in SCALLSUR; therefore, documentation of the differences in gear type (Digby drag versus Miracle gear for the associated surveys) cannot be, and is not, explicitly captured in SCALLSUR.

The database SCALLSUR was not built to accommodate recording data related to the survey design type 'Sampling with Partial Replacement', and no modifications were made to the database to capture this information until 2011, although this survey design has been used since 2006. In 2011, a new table was added called SCREPEATEDTOWS to record associated tows required for analysis for this design. In addition, a new code type, 'repeated tow', was added to the table SCTOWTYPECODES to identify tows associated with the sampling with partial replacement design.

During the comparative survey, two comparative survey tows conducted by the F/V *Brittany & Madison III* were also repeat tows from the previous year, and these tows were also selected to be used with the sampling with partial replacement survey design. The tow type, which identifies the survey type associated with a given tow, is a mutually exclusive field, in that a tow can only belong to a single survey type (e.g. comparative survey or sampling with partial replacement survey, not both). Therefore, tows conducted as part of the comparative survey that were also chosen as part of the sampling with partial replacement design could only be assigned a single tow type in SCALLSUR. These tows were assigned the tow type 'repeated tow' rather than 'comparative tow'. Therefore, a selection on only tows corresponding to the tow type 'comparative tow' will not retrieve the full set of comparative tows. To document all comparative tows and record the associated tows between the two survey vessels, the associated cruise and tow number for all comparative tows is recorded in the comment field in the table SCTOWS in SCALLSUR. In addition, the list of associated tows between the two survey vessels is listed in Appendix A. Any future work on analysing the comparative survey tows should use this list when selecting data from SCALLSUR.