J. Cons. int. Explor. Mer, 46: 121–128. 1990

Comparison of the MOCNESS and IYGPT pelagic samplers for the capture of 0-group cod (*Gadus morhua*) on Georges Bank

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Potter, D. C., Lough, R. G., Perry, R. I., and Neilson, J. D. 1990. Comparison of the MOCNESS and IYGPT pelagic samplers for the capture of 0-group cod (*Gadus morhua*) on Georges Bank. – J. Cons. int. Explor. Mer, 46: 121–128.

Two samplers commonly used to capture pelagic 0-group gadids are the International Young Gadoid Pelagic Trawl (IYGPT) and the 10-m^2 Multiple Opening and Closing Net Environmental Sensing System (MOCNESS). To evaluate the comparability of data collected by each sampler, a paired trawling experiment was conducted in June 1986 on the Northeast Peak of Georges Bank. This study compared the estimates of abundance, the length frequencies, and size of retention of Atlantic cod (*Gadus morhua*), 10–60 mm, by these two samplers. Over a 48-h period, 25 paired sets were completed, 14 during daylight and 11 at night. Between gears, standardized abundance estimates were statistically greater from the MOCNESS during the night but not during the day, indicating an undersampling of the 0-group cod at night by the IYGPT. Comparisons of the length frequencies show a trend for the IYGPT to catch larger individuals, both day and night, than the MOCNESS. However, vertical distribution studies and submarine observations suggest that a greater sampling depth by the IYGPT during these paired sets may be responsible for this increase in mean length. The lower size limit of retention by the IYGPT was found to be approximately 25 and 35 mm, day and night, respectively. The upper size limits of retention by the MOCNESS appeared to be obscured by the sampling design.

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Introduction

Two types of gear commonly used in ICES convention waters for the capture of pelagic juvenile fishes are the International Young Gadoid Pelagic Trawl (IYGPT) and the Multiple Opening and Closing Net Environmental Sensing System (MOCNESS). The IYGPT was developed in 1969 at the Marine Laboratory, Aberdeen, Scotland, to survey pelagic 0-group gadids (Hislop, 1970) and by 1973 was being used as part of a multi-nation North Sea 0-group gadid survey (Holden, 1981). The MOCNESS was developed by Wiebe *et al.* (1976, 1982, 1985) originally for the capture of large euphausiids (*Meganyctiphanes* sp.) and has since been used extensively for the collection of larval and juvenile pelagic fishes. The principal advantages of the MOCNESS over the IYGPT are its constant mouth opening and mesh size with instantaneous measurements of the volume filtered, and its ability to collect multiple discrete depth samples. The principal advantages of the IYGPT are its large mouth opening and its faster towing speed, allowing it to sample a large volume of water.

In 1981, the US National Marine Fisheries Service began a research initiative focusing on the recruitment of juvenile cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) on Georges Bank. The basic sampling strategy was to determine the distribution and abundance of juveniles on the bank and, in areas of high abundance, to study their vertical distribution within the associated predator and prey fields. The primary sampling gear for this study was the 10-m^2 MOCNESS (Wiebe, 1982) system. In 1983, the Canadian Department of Fisheries and Oceans began a sampling program for juvenile gadids on the Scotian Shelf (Koeller *et al.*, 1986), which was later extended to include the Northeast Peak of Georges Bank. The principal sampling gear for this program was the IYGPT. A cooperative research program between the United States and Canada on Georges Bank concerning the ecology of juvenile gadids began in 1984 and used both types of gear. To compare results, it was necessary to conduct a comparative fishing experiment to investigate the relative performance of the MOCNESS and IYGPT samplers.

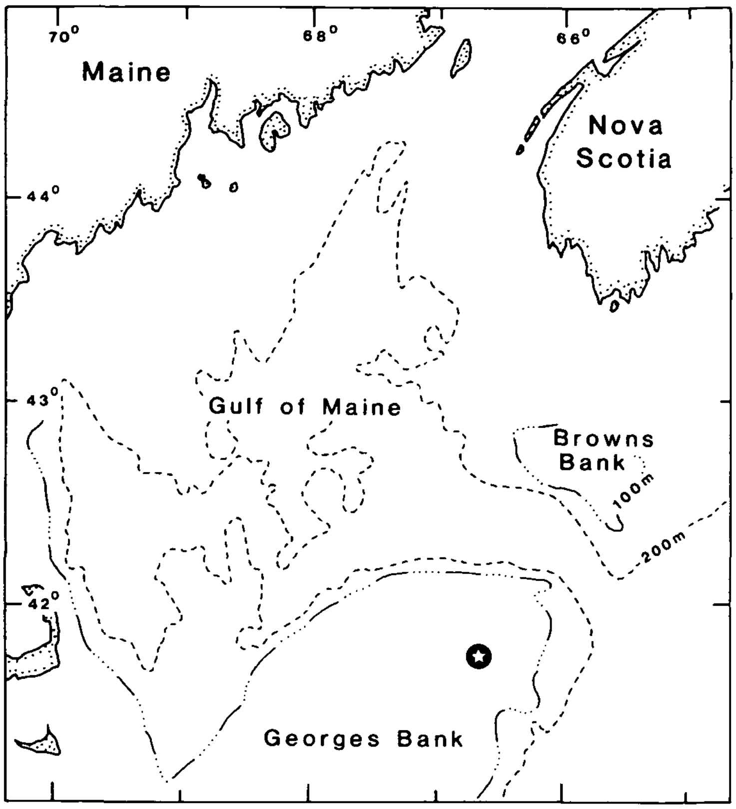

Figure 1. Map of the Gulf of Maine and Georges Bank. Star indicates location of the comparative gear experiment, June 1986.

The objectives of this study were to compare the estimates of abundance and size of cod and haddock caught with the 10-m² MOCNESS with a larger and relatively faster net which may define the size above which fish successfully avoid capture by the net. Similarly, comparison of the IYGPT with the MOCNESS catches could identify the lower size limit of gadids retained by the IYGPT.

Materials and methods

The study was conducted from the RV "Albatross IV" (USA, Cruise 86-03) and the MV "Lady Hammond" (Canada, Cruise LH-155) on 20–21 June 1986, on the Northeast Peak of Georges Bank at approximately 41°40'N latitude, 66°49'W longitude (Fig. 1). A comparison of the specifications of each gear is given in Table 1.

Table 1. Specifications of the 10-m² MOCNESS and the IYGPT trawl.

Specification	MOCNESS	IYGPT
Mouth height (m)	3	11.5
Mouth width (m)	3.3	11.75
Mouth area (m²)	10	104
Bar mesh size (mm)	3	150-5 graded mesh
Trawling speed (knots) ..	1.5–2	3–3.5

This station was chosen for its abundance of juvenile cod, previously determined during a systematic survey of the bank. Paired trawling was conducted as follows: The IYGPT trawl on board the MV "Lady Hammond" was rigged according to Koeller and Carrothers (1981), set to a depth of 50 m (headrope depth), and secured for 30 min. As soon as the IYGPT trawl reached 50 m the time of deployment was radioed to the RV "Albatross IV". On board the RV "Albatross IV", the MOCNESS was shot to 52 m (believed to center the MOCNESS within the mouth opening of the IYGPT trawl), with the operator matching the set-time received from the MV "Lady Hammond". At the end of the 30-min haul, the IYGPT net was retrieved by the MV "Lady Hammond" and the retrieval time transmitted to RV "Albatross IV". Following the completion of the 30-min MOCNESS set, its retrieval was again adjusted to match the retrieval time of the IYGPT trawl. This procedure eliminated any bias due to contamination that may have occurred during the set or recovery of the nets as both nets fished for an equal amount of time.

The MV "Lady Hammond" began the IYGPT sets approximately 700–1000 m astern of the RV "Albatross IV", with both vessels on the same course and heading, and towed the IYGPT net at 6.5 km/h

(3.5 knots). This is faster than the North Sea International 0-Group Gadoid Surveys standardized towing speed; however, it was defined as optimal by Koeller and Carrothers (1981). The RV "Albatross IV" towed the MOCNESS at 3.7 km/h (2 knots). This configuration placed the two ships abeam and less than 0.5 km apart at the mid-point of the set. The performance of the IYGPT was monitored by an acoustic-link (SCANMAR) net mensuration system. This device measured the mouth opening both vertically and horizontally as well as the headrope depth and water temperature. The MOCNESS system electronically measured the distance towed through the water (flowmeter), temperature, salinity, depth, and net angle.

On board each vessel, all fish captured were identified to species, counted and measured from the snout to the caudal penduncle (standard length), and recorded to the next millimeter above. Few haddock were caught, so analyses were based on cod alone.

Estimates of abundance (number per 10 000 m^3) were made for both gears using the number of cod collected and the calculated volume filtered for the set. The volume filtered for the MOCNESS was continuously computed during the set as a function of the instantaneous net angle (mouth height = cosine{angle}×5 m) and the flowmeter counts. The volume filtered by the IYGPT was calculated from the average mouth opening (measured acoustically) and the distance travelled at 6.5 km/h for the length of the set (i.e., time from surface to surface). To exclude erroneously small measurements and the occasional large fish, length measurements less than 10 mm and greater than 60 mm were excluded from this analysis (<1 % of the total catch).

Catches were summarized for each net by calculating the arithmetic mean length and estimating the abundance (no./10 000 m^3) for each set. Estimates were square-root transformed, as a Kolmogorov–Smirnov one-sample test indicated this best achieved a normal distribution ($p = 1$). Results were compared using standard ANOVA and paired *t*-tests, as Bartlett's test for homogeneity of variances indicated variances of mean length and square-root transformed abundances for both gears were homogeneous ($p > 0.01$). Variability of mean length and abundance between gears was examined with regression analysis.

After the 48-h gear comparison experiment was concluded, a series of 18 Yankee 36 bottom trawls over 24 h was made at the same station to describe the demersal predator field. Catches were treated according to standard NMFS Groundfish Survey protocol (Grosslein, 1974). These bottom trawl sets also collected juvenile fish and are included for comparison with the pelagic catches. The codend mesh size of the Yankee 36 is 6.35 (bar mesh) mm and comparable to the 5 mm (bar mesh) codend of the IYGPT.

A predictive model for the smallest size class of retention was applied to the codend mesh of all three samplers. The model is based on the stretch mesh, and body height to length regression for cod.

Results

During this study, the water column was isothermal (9.3 °C) and isohaline (salinity 33.15 p.s.u.), with a bottom depth of 65 m. During the time period 0011 h, 20 June to 2328 h, 21 June, 25 paired sets were completed. In two of the daytime sets, no cod were caught by the MOCNESS, while the IYGPT caught 75 and 97 cod. These two paired sets have been excluded from the calculations of mean length but were used for abundance estimates.

Prior to these paired comparisons, the mouth opening of the IYGPT was believed to be approximately 16–18 m in width and 7–8 m in height. Hence, the MOCNESS was set to 52 m while the IYGPT was set to

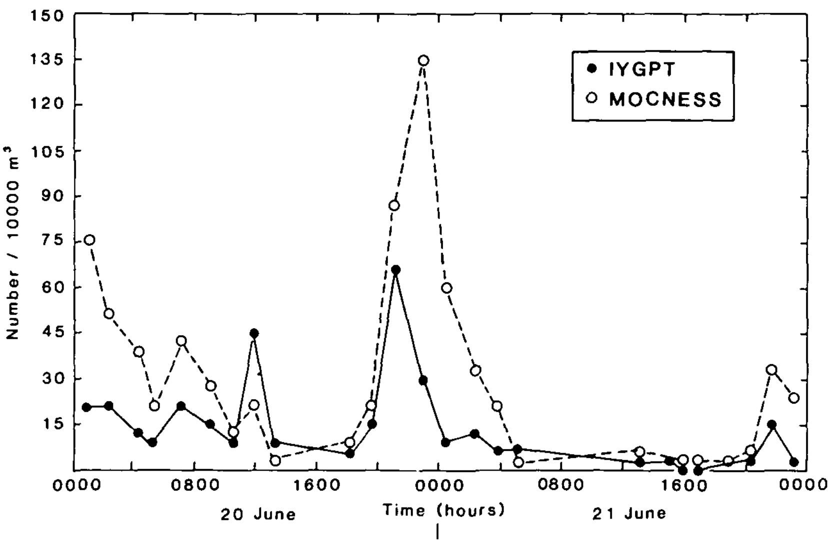

Figure 2. Distribution of standardized abundances (number/ 10 000 m^3) of age-0 cod over time for IYGPT and MOCNESS-10 samplers, June 1986.

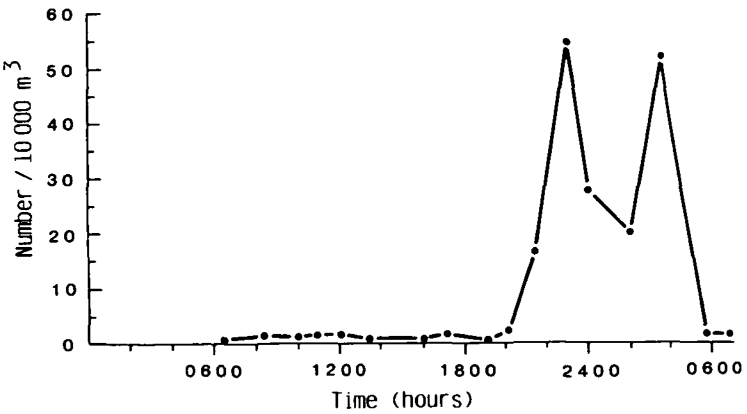

Figure 3. Distribution of standardized abundance (number/10 000 m^3) of age-0 cod over time for the Yankee 36 bottom trawl, 22 June 1986.

50 m in the belief that this would place the MOCNESS in the center of the depth range sampled by the IYGPT. However, results from the SCANMAR mensuration equipment mounted on the IYGPT revealed an 11.5-m wide by 11.75-m high mouth opening. This placed the MOCNESS in the upper portion of the IYGPT's depth strata, with the IYGPT sampling 2 m shallower and 6.75 m deeper than the MOCNESS.

In total, 13 163 0-group cod were caught over the 48-h experiment, 11 766 by the IYGPT and 1397 by the MOCNESS. The catches were standardized for the volume filtered by each gear (on average 33.8×10^4 m^3 for the IYGPT and the MOCNESS respectively) and are shown with time in Figure 2 and summarized as:

	Mean no. per 10 000 m^3		
	MOCNESS	IYGPT	Yankee 36
Combined (night + day)	31.8	14.9	8.2
Night sets	49.5	18.1	34.1
Day sets	15.6	12.0	1.0

For both night and day sets, the mean estimates of abundance were greater from the MOCNESS than the IYGPT. Mean standardized abundances per tow were significantly different ($p < 0.05$) between the MOCNESS and the IYGPT samplers for the combined (night and day) and night samples but not for the day samples ($p > 0.05$) according to the ANOVA and paired *t*-tests.

Comparison of the standardized abundances between night and day sets for each gear indicated that they were statistically different for the MOCNESS ($p < 0.05$, *t*-test) but not for the IYGPT ($p > 0.05$, *t*-test). Abundance estimates for the bottom trawl samples increased over an order of magnitude between day and night sets (Fig. 3).

Regression analyses to examine the variability of the standardized abundances between pelagic gears indicated a positive slope which was significantly different from 0 for the combined, night, and day collections. Regression coefficients (r^2) were 0.58, 0.60, 0.57, for the combined, day, and night samples, respectively.

The mean length of 0-group cod collected by the two samplers over time is shown in Figure 4 and summarized

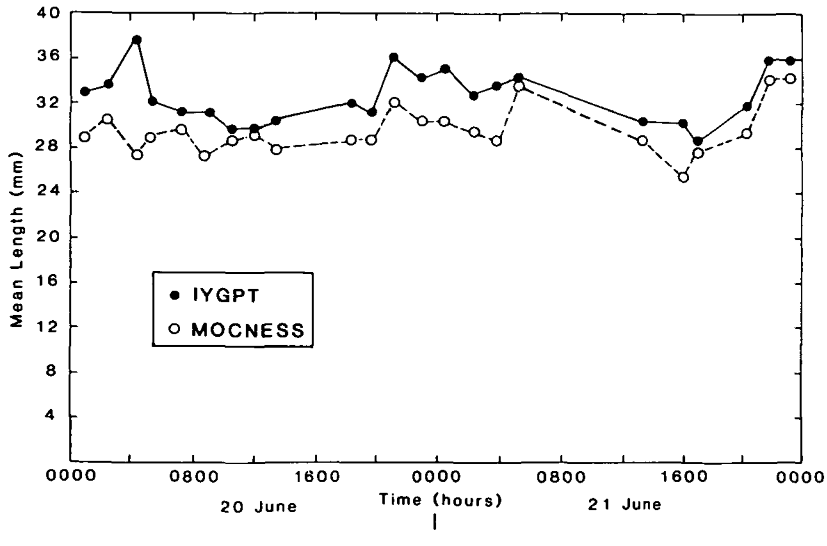

Figure 4. Distribution over time of mean length per tow of age-0 cod caught by the MOCNESS-10 and IYGPT samplers, June 1986.

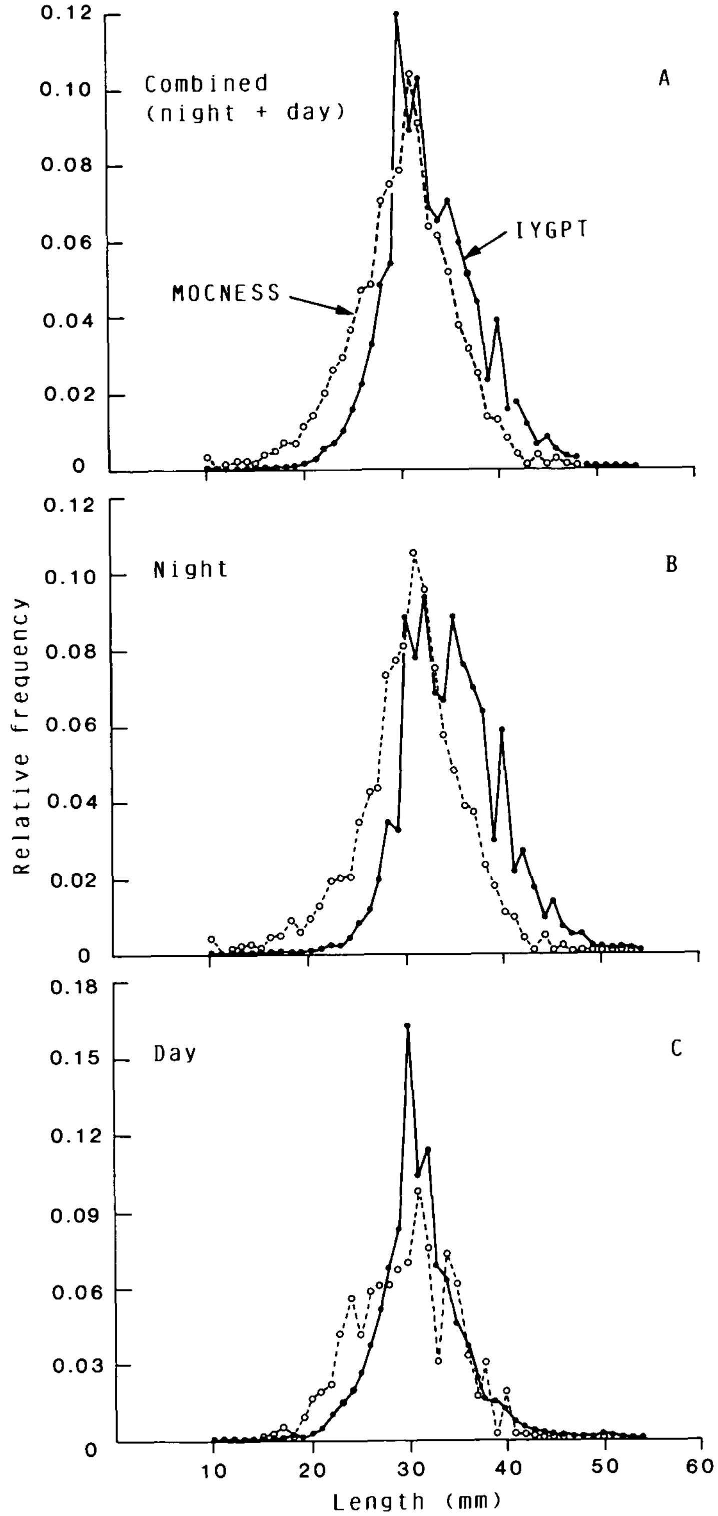

Figure 5. Relative length-frequency distributions of age-0 cod caught by each gear in the time periods: (A) Combined (night + day): MOCNESS total number = 1397, IYGPT total number = 11 594; (B) Night: MOCNESS total number = 1041, IYGPT total number = 6745; and (C) Day: MOCNESS total number = 356, IYGPT total number = 4849.

below. In each paired tow, the mean length was larger in the IYGPT than the MOCNESS samples. Mean lengths were greater still in the subsequent Yankee 36 bottom trawls.

	Mean length (mm)		
	MOCNESS	IYGPT	Yankee 36
Combined (night + day)	29.6	32.6	45.1
Day sets	28.9	30.9	46.2
Night sets	30.4	34.4	42.3

With each pelagic gear, larger cod were caught during the night than during the day. These differences, when tested using a paired *t*-test were significant for the IYGPT samples ($p < 0.05$) but not for the MOCNESS ($p > 0.05$). The Yankee 36 bottom trawl caught larger juvenile cod during the day than during the night, but the difference was not statistically significant ($p > 0.05$).

Regression analyses of mean length data indicated positive slopes which were significantly different from 0 ($p < 0.05$) for the combined and day samples, but not so for the night samples ($p > 0.05$).

Length-frequency distributions of 0-group cod caught with the two pelagic gears are shown in Figure 5. At night, the IYGPT caught fewer of the smaller juveniles (<25 mm) and more of the larger (>35 mm) individuals than the MOCNESS. During daytime, the MOCNESS continued to catch more of the smaller length classes than the IYGPT while the larger individuals were collected in generally similar abundance by both gears.

To define the size limits of retention by the IYGPT, the ratio of abundance estimates between the two samplers was used. The standardized abundance per 2-mm size classes is shown (Table 2) for the combined, day, and night catches and the associated ratio (IYGPT/MOCNESS). Underlined ratios (ratios >1.0) indicate greater abundance estimates for the IYGPT than the MOCNESS for that size class. Asterisks (*) denote the size class at which the ratios become greater than 0.5. Since the MOCNESS in general caught twice as many cod per unit volume filtered as the IYGPT, this value represents the size class above which proportionally more cod were retained by the IYGPT. It occurred at a smaller size class during daytime sets than at night. These data are also presented as selection ogives in Figure 6.

Discussion

Given the larger mouth opening, greater volume filtered, faster towing speed, and greater sampling depth, it is not surprising that the IYGPT captured an order of magnitude more fish, and of larger average size, than the MOCNESS. However, when standardized for the volume filtered, the MOCNESS estimates of abundance were greater during both night and day, although not statistically different during the day. This suggests that cod (10–60 mm) were either able to avoid the IYGPT, particularly at night, or were extruded through the graded mesh, most likely the larger (150 mm) mesh nearer the mouth. Considering the faster speed, larger mouth opening, and the capture of these fish by the MOCNESS, the latter explanation seems most likely.

Table 2. Abundance estimates (per 10 000 m^3 filtered) of cod captured by the MOCNESS and IYGPT samplers separated into 2-mm size classes, and their associated ratio (IYGPT/MOCNESS) for combined, day, and night time periods. Underlined ratios indicate greater abundance estimates given by the IYGPT in that size class. Asterisks denote the size class at which the ratios exceed 0.5.

Length (cm)	Combined (night + day)			Day			Night		
	MOCNESS	IYGPT	Ratio	MOCNESS	IYGPT	Ratio	MOCNESS	IYGPT	Ratio
10–11	3.2	0.0	0.00	0.0	0.0	0.00	3.2	0.0	0.00
12–13	2.6	0.0	0.00	0.0	0.0	0.00	2.8	0.0	0.00
14–15	2.1	0.0	0.00	0.0	1.0	0.00	2.1	0.0	0.00
16–17	6.8	0.0	0.00	1.6	0.0	0.00	5.3	0.0	0.00
18–19	10.0	0.3	0.03	2.1	0.2	0.10	7.9	0.1	0.01
20–21	19.0	1.4	0.07	6.8	1.0	0.14	12.1	0.4	0.03
22–23	33.7	4.4	0.13	12.1	3.5	0.29	21.6	0.9	0.04
24–25	48.4	8.9	0.18	18.4	6.5	0.35	30.0	2.5	0.08
26–27	69.5	18.9	0.27	22.6	12.7	0.56*	46.8	6.2	0.13
28–29	106.3	34.9	0.33	24.2	21.5	0.89	82.1	13.3	0.16
30–31	133.2	71.0	0.53*	21.6	38.0	1.76	101.6	33.1	0.33
32–33	113.2	58.5	0.52	20.0	28.1	1.31	93.2	32.4	0.35
34–35	82.6	46.2	0.56	25.3	15.5	0.61	57.4	30.7	0.53*
36–37	50.5	37.6	0.74	9.5	8.7	0.92	41.1	28.9	0.70
38–39	28.4	22.7	0.80	6.3	4.5	0.71	22.1	18.3	0.83
40–41	15.3	18.6	1.22	4.2	2.8	0.85	11.1	15.8	1.43
42–43	3.2	9.9	3.13	1.1	1.2	1.15	2.1	8.7	4.11
44–45	3.2	5.2	1.64	0.0	0.7	>1.0	3.2	4.4	1.41
46–47	2.8	2.7	1.01	1.1	0.4	0.39	1.6	2.3	1.42
48–49	0.5	1.3	2.45	0.0	0.2	>1.0	0.5	1.2	2.17
50–51	0.5	0.5	1.00	0.5	0.1	0.11	0.0	0.5	>1.0
52–53	0.5	0.2	0.40	0.0	0.0	0.0	0.5	0.2	0.40

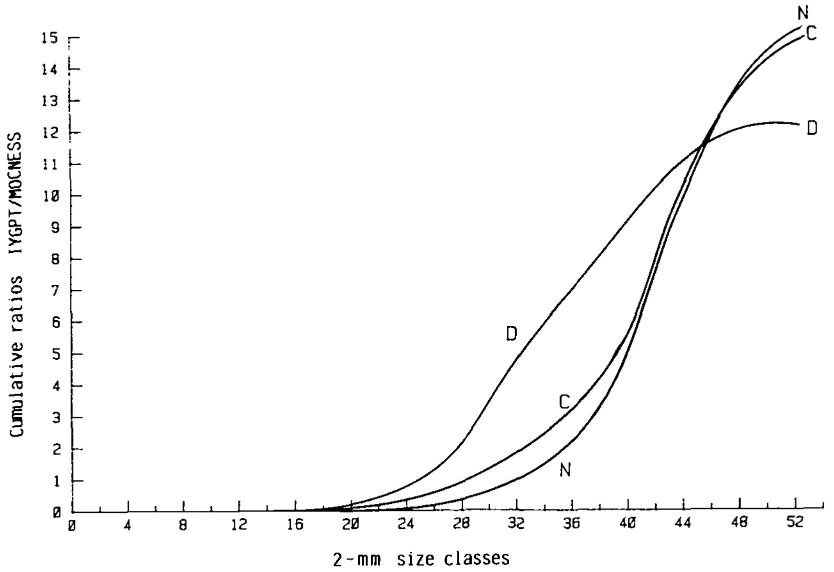

Figure 6. Abundance estimate ratios from Table 2 plotted as selection ogives for Day (D), night (N), and combined (C) samples, June 1986.

The estimated smallest size of retention, based on the predictive model, was 15–16, 25–26, and 31–35 mm for the MOCNESS, IYGPT, and Yankee 36 bottom trawl, respectively. Catches below these predicted minimum size classes were low for each sampler.

When separated into 2-mm size classes (Table 2), the ratios of the estimates of abundance between the MOCNESS and IYGPT show that cod ≤25 mm were underrepresented in the catch of the IYGPT during the day as predicted, but at night this critical size limit increased to 35 mm. This increase at night in the length of 0-group cod retained by the IYGPT is believed to be a result of a decrease in the ability of the net to herd fish towards the codend compared with daytime sets. During the day, the visual effect of the net surrounding the fish may have caused them to swim farther into the net (and towards the smaller mesh) and therefore be retained at a smaller size. At night, however, with no visual cues, these small fish were able to pass through the large 150-mm meshes in the forward part of the net and hence increase the lower size class of retention.

The combined estimates of abundance were statistically different in the MOCNESS day versus night but not the IYGPT. This difference occurred in the MOCNESS because of an overall increase in 0-group cod available to the gear at night and its collection of them. However, at night, the IYGPT apparently undersampled the smaller individuals collected (≤35 mm) which make up the bulk of the population, while collecting more of the larger (>40 mm) cod. Statistically larger mean lengths of individuals collected at night versus day for the IYGPT and not for the MOCNESS support this conclusion. These larger cod may have been closer to the bottom than the depth range sampled by the MOCNESS.

One of the original purposes of this experiment was to define the upper size limit for retention of 0-group gadids by the MOCNESS. The IYGPT/MOCNESS ratios (Table 2) for the combined data indicate an upper size limit of 40 mm for the MOCNESS; i.e., at that size class and above, the ratio exceeds 1. When separated into day–night sets, the same upper size limit is seen at night; however, it is less distinguishable during the daytime. Several possible explanations fit these data.

The first is that the larger 0-group cod may have been capable of avoiding both samples during the daytime, but at night were able to avoid only the MOCNESS. Second, the 0-group cod may have been unavailable (i.e., hard on the bottom) to both gears during the day, and at night, the relatively scarce, larger individuals were caught more frequently by the IYGPT because of its much greater volume filtered.

The third explanation is that the 0-group cod were close to the bottom (<2 m) during the daytime and hence unavailable to both gears. At night these juveniles rise off the bottom sufficiently to make themselves available to the IYGPT but not high enough to make them available to the MOCNESS. This explanation is supported with two independent observations: vertical distribution studies completed prior to the 48-h experiment, and with *in situ* submarine observations during the summers of 1986 and 1987.

Data from the vertical-distribution studies (Lough and Potter, in press) indicate that as juvenile cod approach the transition stage from their pelagic to demersal phase of life, they are found deeper in the water column with increasing length. Additionally, they are collected in greater numbers at night than in daytime at lengths from 20 to 50 mm. Observations from two submersible cruises in August 1986 and July 1987 found 0-group cod (estimated 40–120 mm) close to the substrate (<0.5 m) during the day and a portion of the population rising off the bottom 1–5 m at sunset, drifting passively with the current. The Yankee 36 bottom-trawl catches (Fig. 3) reflect this behavior, the supposition being that the bottom trawl passes over most of the 0-group cod during the day and catches greater numbers at night when the period off the bottom begins. Ancillary data from a second paired-trawling experiment involving the IYGPT (fishing about 10 m off bottom) and the Yankee 36 completed in 1987 also indicated that cod caught by the bottom trawl were significantly larger than those retained by the IYGPT (N = 18, ANOVA, $p < 0.0001$) regardless of the time of day when the comparison was made. This supports the inference that differences in the depth of fishing biased the comparison between the MOCNESS and the IYGPT in 1986.

We conclude that the lower size limit for retention of the IYGPT was approximately 25 and 35 mm, day and night, respectively. Collections of 0-group cod made at or below these size limits may be an underestimate. Determination of the upper size limit of retention by both nets was obscured by the unintentionally greater depth of sampling by the IYGPT and the diel vertical behavior of 0-group cod.

Acknowledgments

We wish to thank Dr M. Grosslein for initiating this study and J. Green and R. Losier for their assistance at sea and with analyses of the data. The reviews and suggestions of Dr R. Stephenson and Dr K. Sherman are gratefully appreciated. Finally, the assistance of the officers and crews of the RV "Albatross IV" and the MV "Lady Hammond" is gratefully acknowledged.

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