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Assessing the By-catch of Groundfish in the Monkfish Fishery

Final Report submitted to:

Northeast Regional Office, NMFS
Northeast Cooperative Research Programs Initiative
One Blackburn Drive
Gloucester, MA 01930-2298

Gulf of Maine Research Institute
Science. Education. Community.

MANOMET
Center for Conservation Sciences

Submitted by:

The Gulf of Maine Research Institute
Portland, ME

And

Manomet Center for Conservation Sciences
Manomet, MA

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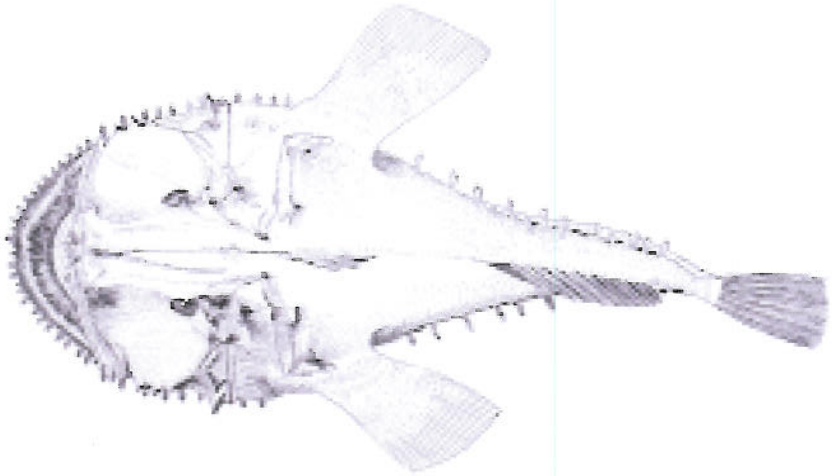

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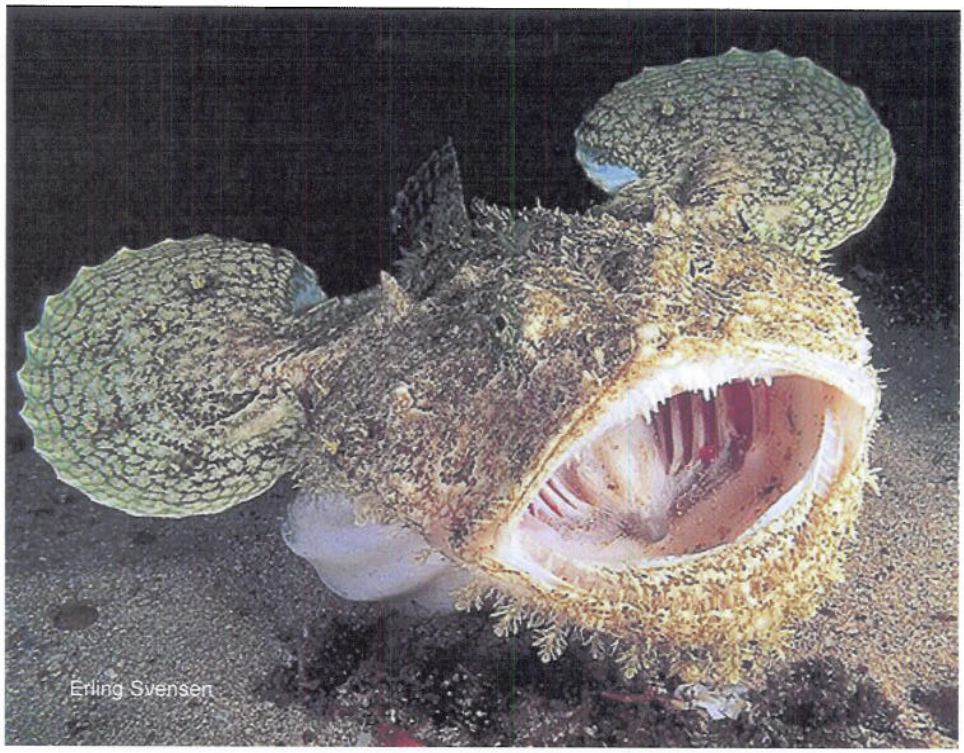


Frontispiece. Images of monkfish illustrating some morphometric characteristics that hinder size selective fishing.

Executive Summary

Monkfish, unlike most other finfish, have a scaleless skin that is slippery and a large head tapering to a narrow tail. They reside on the ocean floor and can be found from inshore waters out to 435 fathoms (Richards, 2000). An exploratory analysis of selectivity patterns of trawls and scallop dredges was performed for the SARC 31. In addition, the NMFS 2001 Cooperative Goosefish Survey included video camera observations of trawling to evaluate the catchability of monkfish by the three different nets used in the cooperative survey (standard trawl gear). These videos showed no escape responses by the monkfish or herding behavior in response to the gear. The monkfish flip up into the water column when hit by the tickler chain and drift passively into the net (NEFSC, 2002). We aimed at expanding on this work by designing and testing gear that will reduce by-catch of both groundfish and undersize monkfish.

This study designed 2 bottom trawl nets to reduce by-catch of groundfish and of undersize monkfish, and tested them at sea on commercial fishing vessels. Based on monkfish measurements collected during 2 dedicated trips, it was established that a mesh opening of 20x10 cm was required to release undersized monkfish. This opening translated into a 12" square mesh net, which was tested at sea in direct comparison with a standard net, in 2003. The results showed that the experimental large mesh net was very effective at releasing undersize monkfish: only 1% of the bycatch was monkfish, compared to 48% in the control net. However, the large mesh net also let a sizable portion (48%) of marketable monkfish escape.

In an attempt to understand this mechanism, a second experimental net was designed with a body of 6.5" square meshes and the codend of 12' square (mixed mesh) and tested at sea, in 2004, comparing it directly to the large mesh codend. Both nets proved effective at limiting bycatch of undersized monkfish to 1-3% of overall bycatch, but 25% of the monkfish catch of the mixed mesh was still undersized, while 36% of overall marketable fish was still lost.

In general, the presence of large 12" mesh greatly reduced bycatch of undersized monkfish, virtually eliminating them when the whole net was made of large mesh. However, a considerable amount of marketable fish was lost through the large meshes. A mixed mesh net still lost a substantial quantity of marketable fish, while retaining more undersized monkfish than the large mesh net, but a direct comparison between a conventional net and the mixed mesh net is undermined by the disparity in overall catches observed in the two field seasons.

Introduction

Monkfish, also know as goosefish or angler (*Lophius amicanus*), saw a steady increase in landings from the late 1980s and early 1990s. Landings since 1993 have fluctuated near 26,000 mt (NEFSC, 2002). Trawls, scallop dredges and gillnets are the primary gear types used to catch monkfish, with trawl gear landing about 75% of total landings (NEFMC, 2001).

Beginning in January 2000, the New England and Mid-Atlantic Fishery Management Councils (NEFMC and MAFMC) have jointly managed the monkfish fishery, with the New England Management Council having lead authority. The first framework adjustment to the Monkfish Fishery Management Plan (FMP) was completed in February 2002 and specified optimum yield (OY) and management area catch targets (TAC) for Year 4 of the rebuilding plan, starting May 1, 2002 (NEFMC, 2002). In Framework 1 to the FMP, the Councils recommended delaying the default measures that would have eliminated the directed monkfish fishery and reduced incidental catch limits.

The vast majority of monkfish limited access permit holders also possess multispecies or scallop limited access permits. Current gear restrictions for monkfish differ between permit categories and are based on the type of gear and the other permits the vessel possesses. If fishing on a multispecies DAS, a trawl net must have the minimum mesh size allowed under for under the NE Multispecies FMP, currently 6.5 inch diamond or 6.5 inch square. However, gillnets fishing on a monkfish DAS and trawl nets on a monkfish DAS only (not combined with a scallop or multispecies DAS), have minimum mesh size of 10-inch diamond mesh and 10-inch square/12-inch diamond, respectively (50 CFR Part 648.91). The current minimum size for monkfish tails is 11 inches (28 cm) (see Figure 1) and for whole monkfish is 17 inches (43 cm) within the northern region (Gulf of Maine and northern Georges Bank.) In the southern region (southern Georges Bank and Mid-Atlantic) the minimum sizes are 14 inches (35.5 cm) for monkfish tails and 21 (53.5 cm) inches for whole monkfish.

The Monkfish SAFE Report for the FY 2001 (NEFMC, 2002), describes the bycatch in the monkfish fishery in relation to trip type, i.e. 'directed' vs. 'non-directed' and to gear used. In directed trips using trawl standard gear, discard of monkfish accounted for 20% of all discarded species by weight. The discard ratio (monkfish discarded/monkfish landed) was approximately 25%. Most of these discards were 'regulatory', i.e. individuals were below the minimum landing size. In non-directed trips, monkfish accounted for 6% of all discards by weight, but the discard ratio was very high, equal to the amount landed. Interestingly, in directed gill nets using meshes larger that 10", most monkfish discards were due to damage from other fish, while discards in gill nets with meshes smaller than 10" were due to size limits.

Figure 1. Cut monkfish tails.

It is clear that the directed monkfish fishery is a lucrative and important fishery (see Anon., 1997, 2000). It is also clear that there is bycatch and discard of undersized monkfish and other groundfish species in the fishery. In order to maintain and improve the fishery there is a clear need to design and test fishing gear that will reduce by-catch of both groundfish and undersize monkfish while maintaining catch of target fish.

Objectives

The overall goal of this project was to increase fishing gear selectivity and reduce regulatory discards of both groundfish and undersize monkfish by designing and testing innovative bottom trawl fishing gear based on monkfish morphology and observation of monkfish behavior in relation to fishing gear.

The specific objectives were to:

- Document reaction and behavior of monkfish to trawl gear modifications.
- Collect morphological data on monkfish.
- Utilize the collected morphological data to design a mesh size/shape to enhance selectivity for monkfish.
- Design a net incorporating the new mesh size/shape and test it at sea on commercial fishing vessels.
- Assess potential of newly designed fishing gear of reducing by-catch and discards of undersized monkfish and all groundfish in the New England monkfish fishery.

Approach

The gear design and testing process proceeded as follows:

1. Collect information on length, maximum girth, width and height of adult monkfish;
2. Perform modeling studies to determine the appropriate mesh size and configuration to reduce by-catch;
3. Test the net design and assess results of at-sea trials
4. Re-evaluate net design on basis of first year results;
5. Design net modifications and test modified net at sea;
6. Collect behavioral information;

The field work for this study was conducted in 3 separate stages. In the first stage (2003), 2 trips were taken in order to collect morphological data on monkfish. In the second stage (2003), a net (body + codend) made entirely of large mesh (12 inch mesh, diamond body with a square mesh codend) was compared to a commercial net (body 6 inch diamond + codend 6.5 inch square). In the third stage (2004), the large mesh net, was compared to a net made of a body of 6 inch diamond netting and a codend made of 12 inch square netting (referred to as a mixed mesh net). The comparisons were obtained by using two

separate vessels, each towing a different net configuration on the same day and in the same area.

Table I gives a summary of all trips performed for this study, including vessel name, date of trip, number of tows and gear used. Note that the data collected during the 2 'morphology' trips was also used in the second stage of the project, to compare a regular net with the large mesh net.

First stage: Collection of morphological data on monkfish and subsequent use of such data to design a mesh size/shape that will enhance selectivity for monkfish.

During the first 2 trips, morphological measurements (Total length, TL, Maximum Girth, MG, Width, W, and Height, H) were collected for all monkfish caught, (n=99). Fish were measured to the nearest cm, using a combination of measuring board and tape. Linear regressions were computed, relating MG, W and H to TL. Figure 2 shows the regression plots, with the relative regression lines and equations. The R^2 (coefficient of determination) ranges from 0 to 1 and indicates how closely the estimated values of the regression (trend-line) match the actual data. Values close to 1 indicate a good match, as in the case of MG. Figure 3 illustrates some of the morphometric measuring techniques employed in the preliminary studies.

For monkfish ranging from 43 to 48 cm TL (n=14), the Mean, Standard Deviation, Median and Mode of MG, W and H were also calculated, as shown in Table IIa. These descriptive statistics are helpful in visualizing the actual measurements of fish around the minimum landing size (MLS), set at 43 cm for a whole fish, since the overall objective of the project was to design a net that would release undersize monkfish, while retaining marketable ones.

However, legal size tails of monkfish are more frequently taken from larger fish, usually 48 cm Total Length and above. So the same descriptive statistics were calculated for monkfish ranging from 48 to 52 cm TL (n=8), as shown in Table IIb. On the basis of both these data sets, it appeared that undersized monkfish would be best able to escape from a mesh with an opening as large as their largest body circumference. This would correspond with their maximum girth, but in terms of a mesh formed by straight sides, it seems reasonable to adopt the width and height of the fish as parameters for the minimum mesh opening. Thus, for this dataset, a mesh with an opening of 20x10cm was deemed likely to release below MLS monkfish, accounting in particular for monkfish smaller than 48 cm TL.

Even though these numbers are based on a small number of fish, these results are well supported by other morphological measurements collected for monkfish in the same period in another project by MCCS (see Appendix 1 for details). In this data set (using a covered codends technique) 233 monkfish were measured

Table I
MONKFISH **2003/2004**

	Gear 1 (6.5 SQ)	Gear 2 (12 SQ)	Gear 3 (6/12 SQ)
# TOWS Total	24	41	20
North Star	0	41	0
Tenacious	24	0	20

Trip ID	Vessel	Date	# Tows	Gear #	Comments	
TFM01	Tenacious	########	3	1	Morphology	
TFM02	Tenacious	11/3/2003	2	1	Morphology	
C16M01	Tenacious	########	2	1		
C16M02	Tenacious	########	3	1		
C16M03	Tenacious	########	3	1		
C16M04	Tenacious	11/6/2003	2	1	Paired	
C16M05	Tenacious	11/7/2003	1	1	Paired	
C16M06	Tenacious	########	2	1		
C16M07	Tenacious	########	1	1	Paired	
C16M08	Tenacious	########	2	1	Paired	
C16M09	Tenacious	########	2	1	Paired	
C16M10	Tenacious	########	1	1	Paired	
D05M01	North Star	########	3	2		
D05M02	North Star	########	2	2		
D05M03	North Star	########	3	2		
D05M04	North Star	########	1	2		
D05M05	*North Star*	*11/6/2003*	*2*	*2*	*Paired*	***1 invalid haul
D05M06	North Star	11/7/2003	1	2	Paired	
D05M07	North Star	########	2	2		
D05M08	North Star	########	1	2	Paired	
D05M09	North Star	########	2	2	Paired	
D05M10	North Star	########	3	2	Paired	
D05M11	North Star	########	2	2	Paired	
D05M12	North Star	6/1/2004	2	2	Paired	
D05M13	North Star	6/3/2004	2	2		
D05M14	North Star	6/4/2004	2	2		
D05M15	North Star	6/7/2004	1	2		
D05M16	North Star	6/10/2004	3	2		
D05M17	North Star	6/11/2004	3	2		
D05M18	North Star	6/12/2004	2	2		
D05M19	North Star	6/17/2004	2	2		
C16M19	North Star	8/26/2004	2	2	Video	
C16M11	Tenacious	6/1/2004	3	3	Paired	
C16M12	Tenacious	6/3/2004	3	3		
C16M13	Tenacious	6/4/2004	2	3		
C16M14	Tenacious	6/7/2004	2	3		
C16M15	Tenacious	6/8/2004	2	3		
C16M16	Tenacious	6/10/2004	3	3		
C16M17	Tenacious	6/11/2004	3	3		
C16M18	Tenacious	6/12/2004	2	3		

Table II Descriptive statistics of monkfish morphological measurements

Table IIa	Monkfish with TL ranging from 43 to 48cm			
MEAN	46.13	38.00	17.88	9.44
ST DEV	1.36	2.45	1.09	0.81
MEDIAN	46.00	38.00	18.00	9.50
MODE	46.00	40.00	18.00	10.00
N	14.00			

Table IIb	Monkfish with TL ranging from 48 to 52cm			
	Total length	Max. Girth	Width	Height
MEAN	49.25	41.00	18.75	10.63
ST DEV	1.39	2.51	1.58	1.30
MEDIAN	49.00	41.00	19.50	10.50
MODE	48.00	40.00	20.00	12.00
N	8.00			

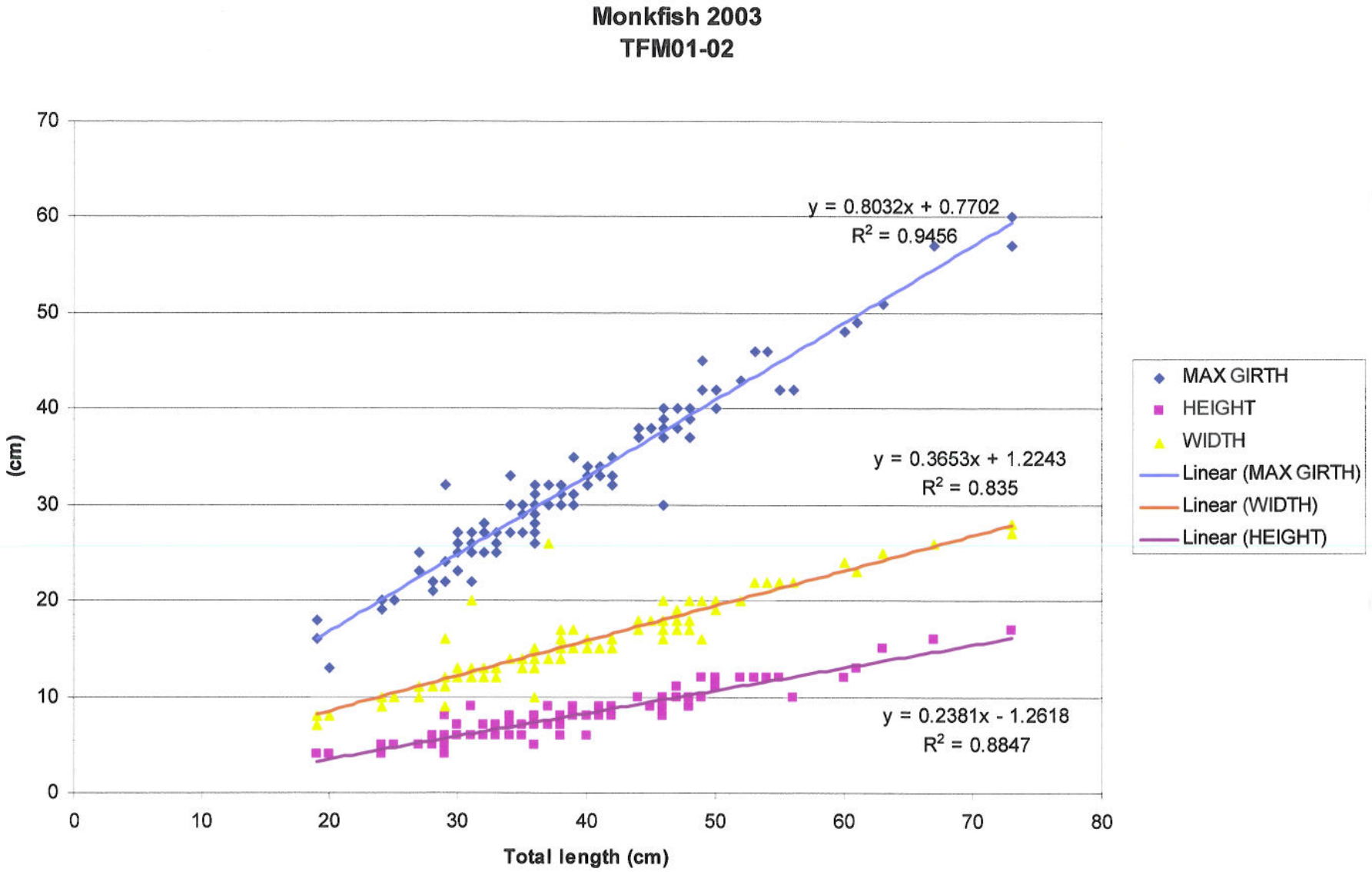


Figure 2. Relationship between total length, height, width and maximum girth for monkfish

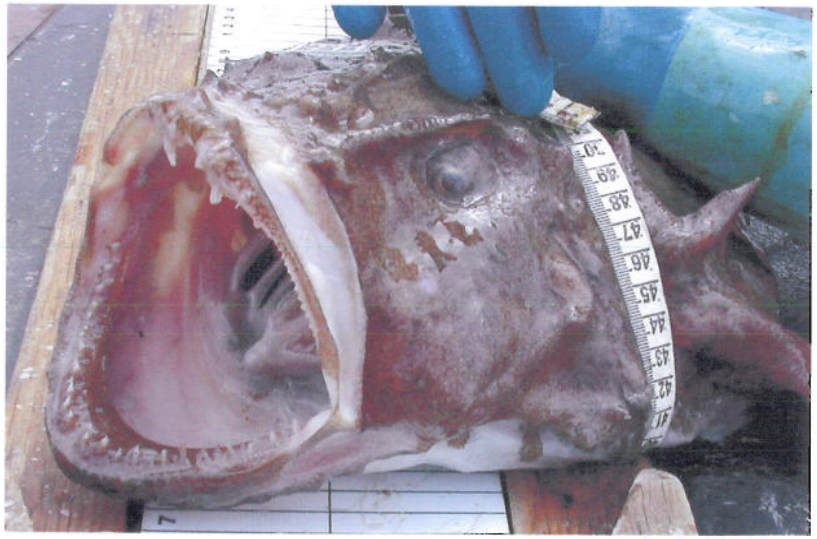
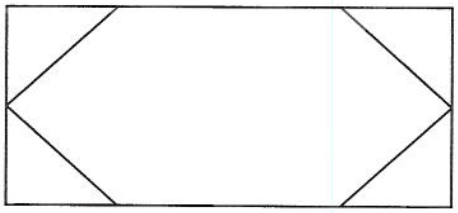


Figure 3 a, b and c. Photographs illustrating morphometric measuring techniques employed in preliminary studies.

using the same criteria. The monkfish in the TL range 43-48 cm (n=47) showed similar values for H (9 cm) and W (19), while for TL range 48-52 (n=30), the observed values were H=10 and W=20. These results also suggest that a mesh with an opening of 20x10cm would release all undersized monkfish. In the covered codend study, monkfish measurements were pooled from catches obtained with a variety of codends (6.5" diamond mesh, 7" square mesh, 7" square/6.5" diamond and 7" square/7"diamond). However, restricting the comparison to monkfish caught exclusively by the 6.5" diamond mesh codend yields sample sizes too small to be evaluated (n=4 for TL range 43-48, n=2 for TL range 48-52).

Mesh design

Ideally a mesh opening of 20x10 cm for releasing monkfish would be achieved by a rectangular shape or even better an elongated hexagonal shape.



However, neither rectangular nor hexagonal meshes are used extensively by the fishing industry. Although hexagonal netting can be custom manufactured to specified measurements, its cost is currently considered prohibitive for consideration by the fishing industry in the Northeast region. The most widely available netting which maintains open meshes while under strain, therefore guaranteeing an opening when the net is towed under water is square mesh netting. To ensure an opening of a least 10x 20 cm, the diagonal of the square mesh must be a minimum of 20 cm, which corresponds approximately to 8 inches. This diagonal implies that each side of the square is at least 5.7 inches. However, the space taken up by knots at the four corners of the square reduce the opening by a significant fraction, so sides of 6 inches long, including knots are required. Since the traditional method of measuring a square mesh is to measure two consecutive sides of the square, this mesh is defined as a 12 inch square mesh.

Net Construction

The first experimental net was built following general guidelines developed by the ad hoc Monkfish Working Group assembled by the New England Fishery Management Council (2002) outlining size and general construction required for directed monkfish fisheries. In this case, the net was constructed with 12" mesh

throughout (diamond mesh in the body of the net with a square mesh codend) as suggested by the morphology and mesh modeling study outlined above (see Figure 4). Table III lists some of the characteristics of the control and experimental nets used during this study. The overall size/shape of the nets was as similar as could be achieved within technical limits.

Table III Detail of the control and two experimental nets designed for testing in this study.

	Control net		Experimental Net 1 (large mesh net)		Experimental Net 2 (mixed mesh net)	
Mesh size (inches)	Body 6" diamond	Codend 6 ½" square	Body 12" diam.	Codend 12 " square	Body 6" diam.	Codend 12" square
Twine	3 mm		4 mm		4mm	
Fishing circle (mesh No.)	240		120		240	
Head rope (feet)	108		106		108	
Foot rope (feet)	119		117		118	
Doors ($m^{2)}$	1.7		1.7		1.7	
Ground cables (fathoms)	30 fa		30 fa		30 fa	
Chafing gear	no		tracer			
Sweep	On ½ " steel wire, with 3 " cookies in between 10"+8" rock hoppers, floppy discs 8" apart,		On ½ " steel wire, with 3 " cookies in between 10"+8" rock hoppers, floppy discs 8" apart,		On ½ " steel wire, with 3 " cookies in between 10"+8" rock hoppers, floppy discs 8" apart,	

Experimental fishing Phase 1: 2003

Trip and haul info

In 20 out of 23 trips, the fishing vessel towing the experimental 12" net (F/V North Star) and the F/V trawling the control net (F/V Tenacious, Figure 5) fished on the same day and in the same area, as shown by table I and by map (Figure 6). The

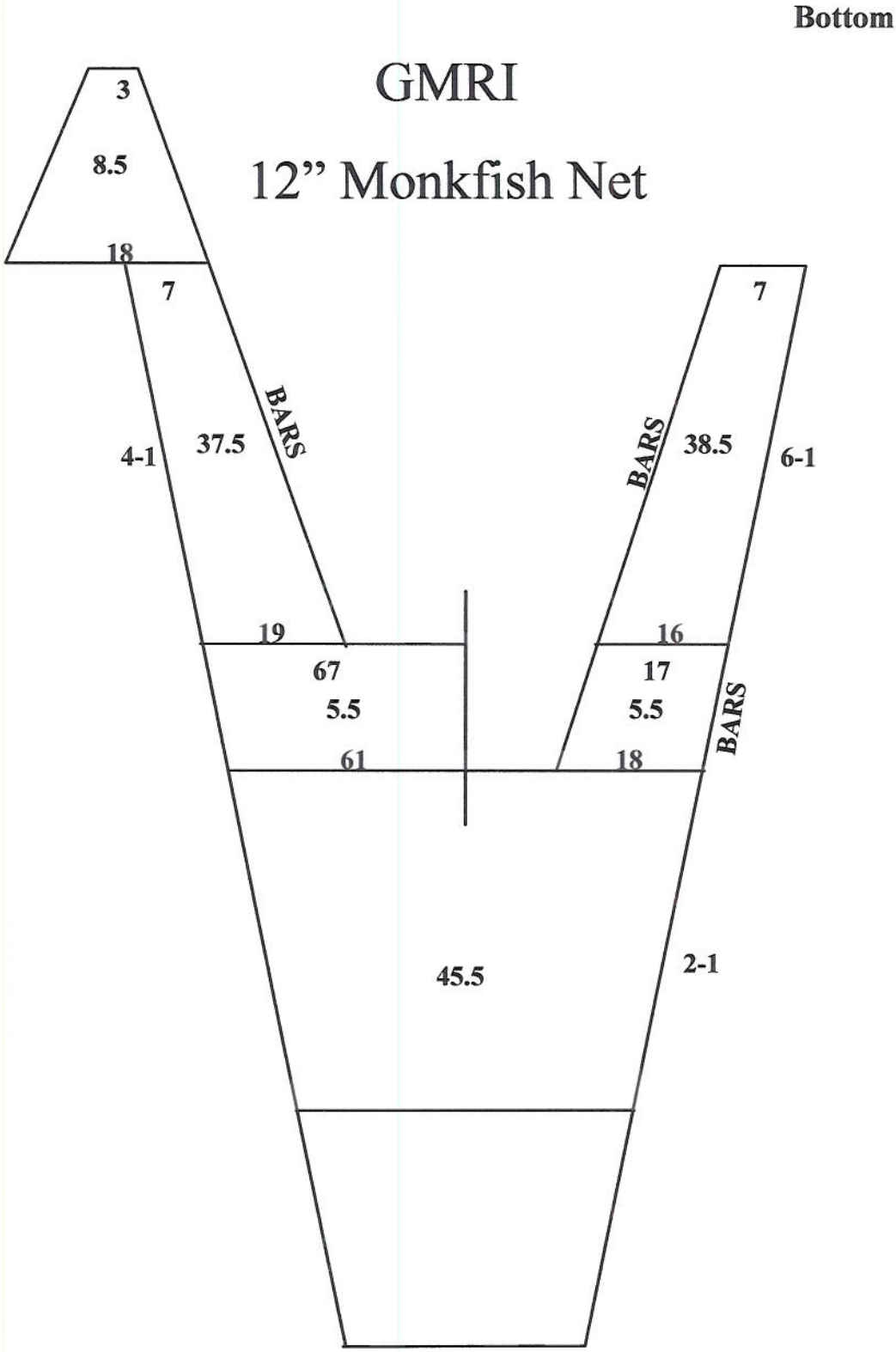


Figure 4. Net diagram of experimental monkfish net as fished on F/V North Star. The net was constructed with 12" mesh throughout, including the codend.

Figure 5. F/V Tenacious preparing to put fish the control (6 1/2" square mesh codend) net.

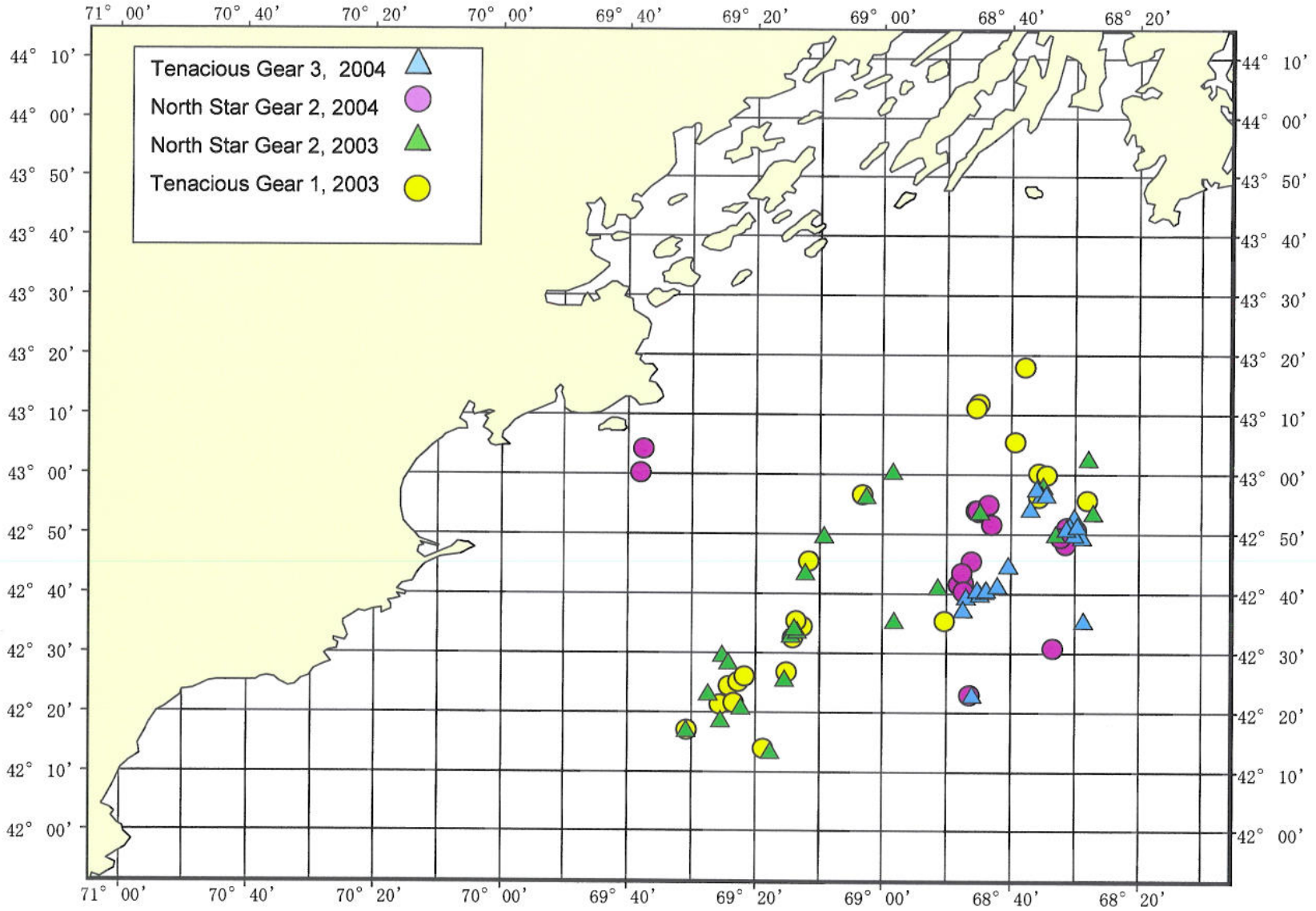


Figure 6. Experimental fishing locations by vessel and season.

hauls were not strictly paired, but the same number of hauls was achieved by each vessel on each day, with the exception of trip D05M10 (North Star), where there was one extra haul.

Table IV shows details of each haul, including the gear used, where and when the haul was taken, tow speed and wire out and depth. The total weight of the catch, as well as lbs. kept and discarded, and the Catch Per Unit Effort (CPUE) are also displayed in table IV.

Total catch

Table V displays some basic statistics performed on the total, kept and discarded catch, as well as on haul duration and CPUE for the control and the experimental net. It is immediately obvious that, in approximately the same amount of time, the control net catches 3 times as much as the experimental net. Also, the proportion of discard is higher in the control net than in the experimental net, by approximately 50%.

A series of T-tests comparing total, kept and discard catch, and CPUE, between the control and experimental net result consistently in highly significant differences, as shown in table VI.

Table VI

Control (6.5") vs. Experimental (12")	*p*
Total catch	0.000
Kept catch	0.000
Discard catch	0.000
CPUE	0.000

A paired Two Sample for means (t-Test) was also used to compare kept versus discarded catch within each set of trips (control vs. experimental). As shown by table VII, there was no significant difference between kept and discarded catch, in terms of weight, in the control trips, but discard was significantly less than kept catch in the experimental trips.

Table VII

Kept vs. Discard	*p*
Control (6.5")	0.852
Experimental (12")	0.003

Monkfish catch

Table VIII shows a breakdown, haul by haul, of the monkfish caught in the control and the experimental net, in terms of number of fish and weight (lbs.). Since the goal of the project was to test whether bycatch of undersized monkfish was reduced by using the large mesh codend, the information is presented in terms of

Table IV

MONKFISH 2003

TRIPID	VESSEL	GEAR TYPE	HAUL	START TIME	END TIME	START LAT	START LONG	END LAT	END LONG	TOW SPEED	WIRE OUT	DEPTH	BOTTOM TEMP	HAUL DURATION	LBS KEPT	LBS DISCARD	TOT LBS CONTROL	CATCH/UNIT EFFORT (LBS/HOUR)	TOT LBS EXPERIMENTAL	CATCH/UNIT EFFORT (LBS/HOUR)	PAIRED TO
TFM01	Tenacious	6.5SQ	1	7:18	8:42	43.3360	69.5840	43.3221	69.5736	2	175	60	0	1:24	94.0	255.2	349.2	249.43			
TFM01	Tenacious	6.5SQ	2	9:32	12:24	43.3035	69.5586	43.3141	69.5392	2	175	64	0	2:52	436.0	1188.0	1624.0	566.51			
TFM01	Tenacious	6.5SQ	3	13:34	15:36	43.3024	69.5555	43.2995	69.5570	2	175	64	0	2:02	353.0	523.0	875.0	430.33			
TFM02	Tenacious	6.5SQ	1	8:24	10:24	43.3339	69.5832	43.3392	69.5902	2	175	60	0	2:00	174.0	185.5	359.5	179.75			
TFM02	Tenacious	6.5SQ	2	11:30	13:40	43.3340	69.5854	43.3372	69.5889	2	175	60	0	2:10	200.0	221.9	421.9	194.72			
C16M01	Tenacious	6.5SQ	1	8:29	10:49	43.3533	69.5649	43.3161	69.5626	2	150	51	0	2:20	176.5	385.0	561.5	240.64			
C16M01	Tenacious	6.5SQ	2	11:26	14:29	43.3182	69.5607	43.3152	69.5635	2	150	61	0	3:03	275.0	554.5	829.5	271.97			
C16M02	Tenacious	6.5SQ	1	8:35	10:27	43.2036	70.0903	43.1987	70.0885	2	175	64	0	1:52	515.5	193.7	709.2	379.93			
C16M02	Tenacious	6.5SQ	2	10:55	12:53	43.1954	70.0000	43.2091	70.0845	2	175	67	0	1:58	328.0	269.0	597.0	303.56			
C16M02	Tenacious	6.5SQ	3	14:57	15:58	43.2101	70.0653	43.2348	70.0601	2	200	66	0	1:01	176.0	157.0	333.0	327.54			
C16M03	Tenacious	6.5SQ	1	8:50	10:53	43.2055	70.0863	40.1938	70.0886	2	175	60	0	2:03	483.0	272.5	755.5	368.54			
C16M03	Tenacious	6.5SQ	2	11:16	13:16	43.1948	70.0940	43.2108	70.0869	2	175	62	0	2:00	606.0	414.0	1020.0	510.00			
C16M03	Tenacious	6.5SQ	3	14:02	15:12	43.2620	70.0564	43.2877	70.0428	2	175	67	0	1:10	198.0	231.0	429.0	367.71			
C16M04	Tenacious	6.5SQ	1	8:16	11:14	43.2260	70.0631	43.1815	70.1066	2	200	71	0	2:58	544.0	559.0	1103.0	371.80			D05M05/1
C16M04	Tenacious	6.5SQ	2	13:28	16:00	43.1829	70.1081	43.2205	70.0623	2	200	61	0	2:32	475.0	481.0	956.0	377.37			D05M05/2
C16M05	Tenacious	6.5SQ	1	7:42	11:37	43.2935	70.0338	43.2094	70.0619	2	200	59	0	3:55	567.0	1040.0	1607.0	293.36			D05M06/1
C16M06	Tenacious	6.5SQ	1	7:45	10:32	43.2920	69.5589	43.2287	70.0020	2	200	66	0	2:47	408.0	560.0	968.0	347.83			
C16M06	Tenacious	6.5SQ	2	11:13	14:18	43.2340	69.5987	43.2896	69.5413	2	225	85	0	3:05	461.0	761.0	1222.0	396.32			
C16M07	Tenacious	6.5SQ	1	7:45	10:32	43.2920	69.5589	43.2287	70.0020	2	200	66	0	2:47	1005.0	503.5	1508.5	541.98			D05M08/1
C16M08	Tenacious	6.5SQ	1	8:15	10:48	43.2316	70.0588	43.1696	70.0750	2	200	74	0	2:33	841.0	304.5	1145.5	449.22			D05M09/1
C16M08	Tenacious	6.5SQ	2	11:23	13:57	43.1740	70.0757	43.2348	70.0648	2	200	76	0	2:34	623.0	265.0	888.0	344.81			D05M09/2
C16M09	Tenacious	6.5SQ	1	8:18	10:15	43.2342	70.0618	43.1915	70.0711	2	200	72	0	1:57	343.0	195.0	538.0	275.90			D05M10/1
C16M09	Tenacious	6.5SQ	2	10:51	12:51	43.1957	70.0879	43.2108	70.0881	2	200	66	0	2:00	867.0	343.0	1210.0	605.00			D05M10/2
C16M10	Tenacious	6.5SQ	1	7:29	10:50	43.2905	69.5379	43.2737	69.5674	2	200	72	0	3:21	621.0	621.0	1242.0	370.75			D06M11/1
D05M01	North Star	12SQ	1	8:57	11:00	43.2859	69.5834	43.3156	69.5410	2	175	68	0	2:03	106.0	129.0			235.0	114.63	
D05M01	North Star	12SQ	2	11:37	14:37	43.3107	69.5372	43.2954	69.5614	2	200	59	0	3:00	196.0	108.0			304.0	101.33	
D05M01	North Star	12SQ	3	15:01	17:03	43.2976	69.5568	43.2900	69.5699	2	175	64	0	2:02	66.0	56.0			122.0	60.00	
D05M02	North Star	12SQ	1	10:15	12:39	43.2576	70.0574	43.3035	70.0230	2	200	66	0	2:24	192.0	94.0			286.0	119.17	
D05M02	North Star	12SQ	2	13:04	15:23	43.3042	70.0204	43.3092	70.0136	2	175	59	0	2:19	25.0	0.0			25.0	10.79	***
D05M03	North Star	12SQ	1	8:24	10:36	43.2191	70.0927	43.1860	70.0955	2	200	63	0	2:12	308.0	84.0			392.0	178.18	
D05M03	North Star	12SQ	2	10:59	13:04	43.1881	70.0936	43.1917	70.0878	2	200	67	0	2:05	66.0	70.0			136.0	65.28	
D05M03	North Star	12SQ	3	15:05	16:09	43.2075	70.0664	43.2320	70.0209	2	200	68	0	1:04	238.0	37.0			275.0	257.81	
D05M04	North Star	12SQ	1	14:18	16:22	43.2745	70.0496	43.3126	70.0102	2	175	66	0	2:04	87.0	26.0			113.0	54.68	
D05M05	North Star	12SQ	1	8:20	11:23	43.2280	70.0637	43.1836	70.1091	2	200	70	0	3:03	324.0	122.0			446.0	146.23	
D05M05	North Star	12SQ	2	13:28	16:05	43.1834	70.1085	43.2197	70.0661	2	200	62	0	2:37	333.0	143.0			476.0	181.91	
D05M06	North Star	12SQ	1	7:41	11:47	43.2936	70.0316	43.2272	70.0643	2	200	60	0	4:06	261.0	183.0			444.0	108.29	
D05M07	North Star	12SQ	1	8:15	11:20	43.2348	70.0198	43.2776	69.5481	2	225	76	0	3:05	347.0	337.0			684.0	221.84	
D05M07	North Star	12SQ	2	12:03	14:54	43.2750	69.5510	43.2441	70.0188	2	225	77	0	2:51	179.0	346.0			525.0	184.21	
D05M08	North Star	12SQ	1	8:03	12:30	43.2153	70.0902	43.2189	70.0640	2	225	60	0	4:27	263.0	225.8			488.8	94.11	
D05M09	North Star	12SQ	1	8:23	10:53	43.2303	70.0808	43.1704	70.0762	2	225	73	0	2:30	131.0	101.5			232.5	93.00	
D05M09	North Star	12SQ	2	11:22	14:02	43.1233	70.0723	43.2334	70.0643	2	225	77	0	2:40	141.0	61.0			202.0	75.75	
D05M10-	North Star	12SQ	1	8:10	10:12	43.2315	70.0622	43.1888	70.0748	2	200	71	0	2:02	66.0	42.0			108.0	53.11	
D05M10-	North Star	12SQ	2	10:51	12:53	43.1941	70.0850	43.2043	70.0944	2	200	69	0	2:02	195.0	23.0			218.0	107.21	
D05M10-	North Star	12SQ	3	13:17	15:20	43.2010	70.0990	43.2171	70.0915	2	175	61	0	2:03	192.0	64.0			256.0	124.88	
D05M11-	North Star	12SQ	1	6:37	9:38	43.2506	70.0015	43.2903	69.5284	2	225	75	0	3:01	382.0	334.0			716.0	237.35	
D05M11-	North Star	12SQ	2	10:07	12:09	43.2851	69.5354	43.2542	69.5844	2	225	81	0	2:02	131.0	184.0			315.0	154.92	

*** This haul will be eliminated from further analysis because of technical problems that rendered it invalid.

Table V

MONKFISH 2003

TOTAL CATCH

			TOT LBS	KEPT	DISCARD	Haul Duration	CPUE	Total catch
Tenacious	6.5SQ Control	**tot**	20791.30	10770.00	10483.30	56.40		8764.95
		mean	866.30	448.75	436.80	2.35		365.21
		stddev	369.34	237.20	265.37	0.69		110.95
		n				24		
North Star	12SQ Experimenta	**tot**	6904.30	4204.00	2733.90	53.38		2733.90
		mean	328.78	200.19	130.19	2.54		131.92
		stddev	174.34	99.42	60.66	0.76		101.92
		n				21		

Table VIII

		Monkfish						
6.5		No. of fish			Weight (Lbs)			
Trip	Haul	Kept	Discard	total	Kept	Discard	total	hrs
TFM01	1	16.00	120.00	136.00	87.00	206.00	293.00	1.40
TFM01	2	63.00	170.00	233.00	361.00	351.00	712.00	2.87
TFM01	3	43.00	113.00	156.00	312.00	217.00	529.00	2.03
TFM02	1	39.00	119.00	158.00	170.00	180.00	350.00	2.00
TFM02	2	35.00	117.00	152.00	196.00	186.00	382.00	2.17
C16M01	1	26.00	157.00	183.00	169.00	254.00	423.00	2.33
C16M01	2	40.00	216.00	256.00	250.00	368.00	618.00	3.05
C16M02	1	53.00	42.00	95.00	337.00	110.00	447.00	1.87
C16M02	2	46.00	63.00	109.00	278.00	131.00	409.00	1.97
C16M02	3	23.00	37.00	60.00	137.00	80.00	217.00	1.02
C16M03	1	59.00	87.00	146.00	372.00	165.00	537.00	2.05
C16M03	2	63.00	107.00	170.00	406.00	192.00	598.00	2.00
C16M03	3	18.00	78.00	96.00	97.00	136.00	233.00	1.17
C16M04	1	77.00	141.00	218.00	480.00	286.00	766.00	2.97
C16M04	2	63.00	155.00	218.00	356.00	304.00	660.00	2.53
C16M05	1	74.00	282.00	356.00	458.00	536.00	994.00	5.48
C16M06	1	63.00	150.00	213.00	341.00	274.00	615.00	2.78
C16M06	2	69.00	154.00	223.00	365.00	265.00	630.00	3.08
C16M07	1	161.00	137.00	298.00	860.00	207.00	1067.00	2.78
C16M08	1	80.00	66.00	146.00	474.00	112.00	586.00	2.55
C16M08	2	82.00	96.00	178.00	430.00	146.00	576.00	2.58
C16M09	1	32.00	49.00	81.00	167.00	81.00	248.00	1.95
C16M09	2	60.00	111.00	171.00	304.00	184.00	488.00	2.00
C16M10	1	74.00	154.00	228.00	385.00	220.00	605.00	3.35
	tot	1359.00	2921.00	4280.00	7792.00	5191.00	12983.00	57.97
	average	56.63	121.71	178.33	324.67	216.29	540.96	2.42
	stdev	29.94	56.08	69.58	164.21	103.73	214.47	0.89
	n	24.00						

		Monkfish						
12		No. of fish			Weight (Lbs)			
Trip	Haul	Kept	Discard	total	Kept	Discard	total	hrs
D05M01	1	19.00	0.00	19.00	106.00	0.00	106.00	2.05
D05M01	2	27.00	1.00	28.00	196.00	2.00	198.00	3.00
D05M01	3	9.00	0.00	9.00	66.00	0.00	66.00	2.03
D05M02	1	30.00	0.00	30.00	192.00	0.00	192.00	2.40
D05M03	1	39.00	0.00	39.00	308.00	0.00	308.00	2.20
D05M03	2	8.00	0.00	8.00	66.00	0.00	66.00	2.08
D05M03	3	30.00	0.00	30.00	238.00	0.00	238.00	1.07
D05M04	1	13.00	0.00	13.00	87.00	0.00	87.00	2.07
D05M05	1	45.00	0.00	45.00	324.00	0.00	324.00	3.05
D05M05	2	52.00	0.00	52.00	333.00	0.00	333.00	2.62
D05M06	1	42.00	0.00	42.00	261.00	0.00	261.00	4.10
D05M07	1	61.00	0.00	61.00	347.00	0.00	347.00	3.08
D05M07	2	30.00	0.00	30.00	179.00	0.00	179.00	2.85
D05M08	1	53.00	2.00	55.00	263.00	4.00	267.00	5.19
D05M09	1	22.00	1.00	23.00	131.00	2.00	133.00	2.50
D05M09	2	23.00	0.00	23.00	141.00	0.00	141.00	2.67
D05M10	1	10.00	0.00	10.00	66.00	0.00	66.00	2.03
D05M10	2	25.00	0.00	25.00	161.00	0.00	161.00	2.03
D05M10	3	28.00	0.00	28.00	192.00	0.00	192.00	2.05
D05M11	1	57.00	1.00	58.00	382.00	2.00	384.00	3.02
D05M11	2	19.00	0.00	19.00	131.00	0.00	131.00	2.03
		642.00	5.00	647.00	4170.00	10.00	4180.00	54.13
		30.57	0.24	30.81	198.57	0.48	199.05	2.58
		16.05	0.54	16.24	99.78	1.08	100.03	0.86
		21						

t-Test: Two-Sample Assuming Unequal Variances

	total w 6.5	total w 12
Mean	540.958	191.136
Variance	45997.433	10908.790
Observatic	24.000	22.000
Hypothesi	0.000	
df	34.000	
t Stat	7.122	
P(T<=t) on	0.000	
t Critical o	1.691	
P(T<=t) tw	0.000	
t Critical tw	2.032	

t-Test: Two-Sample Assuming Unequal Variances

	total no 6.5	total no 12
Mean	178.333	30.955
Variance	4841.623	294.617
Observatic	24.000	22.000
Hypothesi	0.000	
df	26.000	
t Stat	10.048	
P(T<=t) on	0.000	
t Critical o	1.706	
P(T<=t) tw	0.000	
t Critical tw	2.056	

t-Test: Paired Two Sample for Means
6.5 no

	Kept	*Discard*
Mean	56.625	121.70833
Variance	896.505	3145.346
Observatic	24.000	24
Pearson C	0.238	
Hypothesi	0.000	
df	23.000	
t Stat	-5.600	
P(T<=t) on	0.000	
t Critical o	1.714	
P(T<=t) tw	0.000	
t Critical tw	2.069	

t-Test: Paired Two Sample for Means
6.5 w

	Kept	*Discard*
Mean	324.667	216.29167
Variance	26963.971	10759.694
Observatic	24.000	24
Pearson C	0.243	
Hypothesi	0.000	
df	23.000	
t Stat	3.094	
P(T<=t) on	0.003	
t Critical o	1.714	
P(T<=t) tw	0.005	
t Critical tw	2.069	

t-Test: Paired Two Sample for Means
12 no

	Kept	*Discard*
Mean	29.364	0.227273
Variance	277.481	0.279221
Observatic	22.000	22
Pearson C	0.353	
Hypothesi	0.000	
df	21.000	
t Stat	8.293	
P(T<=t) on	0.000	
t Critical o	1.721	
P(T<=t) tw	0.000	
t Critical tw	2.080	

t-Test: Paired Two Sample for Means
12 w

	Kept	*Discard*
Mean	190.682	0.454545
Variance	10852.037	1.116883
Observatic	22.000	22
Pearson C	0.244	
Hypothesi	0.000	
df	21.000	
t Stat	8.586	
P(T<=t) on	0.000	
t Critical o	1.721	
P(T<=t) tw	0.000	
t Critical tw	2.080	

t-Test: Two-Sample Assuming Unequal Variances

	Kept 6.5	*Kept 12*
Mean	56.625	29.36364
Variance	896.5054	277.4805
Observatic	24	22
Hypothesi	0	
df	37	
t Stat	3.856606	
P(T<=t) on	0.000222	
t Critical o	1.687094	
P(T<=t) tw	0.000444	
t Critical tw	2.026192	

t-Test: Two-Sample Assuming Unequal Variances

	Discard 6.5	*Discard 12*
Mean	121.708	0.227273
Variance	3145.346	0.279221
Observatic	24.000	22
Hypothesi	0.000	
df	23.000	
t Stat	10.611	
P(T<=t) on	0.000	
t Critical o	1.714	
P(T<=t) tw	0.000	
t Critical tw	2.069	

monkfish kept vs. monkfish discarded. Figures 7a and b show Captain Vincent Balzano (F/V North Star) with the experimental (12" square mesh codend) net and its associated catch. Figure 7b shows the catch to be almost exclusively monkfish and skates. At the bottom of the table, basic descriptive statistics are shown. Several things are immediately noticeable from this table: 1) the monkfish catch is much higher in the control gear than in the experimental gear (3 times in terms of weight, nearly 8 times in terms of numbers); 2) the number of monkfish discarded using a regular net is twice as high as the number of kept fish (in terms of weight, the weight of kept fish is higher that that of discarded); 3) the number of monkfish discarded using the experimental net is virtually non-existent.

Table IX shows the basic descriptive statistics regarding monkfish catch, including the average CPUE and its respective standard deviation.

The differences between the monkfish catch of the two nets were all statistically significant, as shown in table X.

Table X

MF total weight 6.5" *vs.* 12"	t-test (unequal var.)	*p*	0.000
MF total no. 6.5" *vs.* 12"	t-test (unequal var.)	*p*	0.000
MF kept no. 6.5" *vs.* 12"	t-test (unequal var.)	*p*	0.000
MF discard no. 6.5" *vs.* 12"	t-test (unequal var.)	*p*	0.000
MF in 6.5" (no.) kept *vs.* discard	t-test (paired samples)	*p*	0.000
MF in 6.5" (lbs.) kept *vs.* discard	t-test (paired samples)	*p*	0.005
MF in 12" (no.) kept *vs.* discard	t-test (paired samples)	*p*	0.000
MF in 12" (lbs.) kept *vs.* discard	t-test (paired samples)	*p*	0.000

Table XI and XII show a breakdown of the total catch species by species. Table XI refers to the trips conducted with the 6"/6.5" net, while table XII to those with the 12" net. Each of these tables is divided into two categories (***a*** and ***b***), where ***a*** shows the total weight of each species in each haul, and ***b*** the weight kept and discarded of each species in each haul.

It is immediately apparent that, while a variety of species were routinely caught with the control codend (monkfish, cod, grey sole, dab, lumpfish, spiny dogfish, smooth and thorny skate, lobster), the experimental codend only caught monkfish, thorny skate and occasionally lumpfish. In each haul, for both gears, monkfish were the most abundant species in weight, with one exception, where thorny skate were more than monkfish. In the 6"/6.5" net, monkfish ranged from 40% to 97% of total catch by weight, with an average of 64%. In the 12" net, monkfish ranged from 34% to100%, with an average of 62%.

Appendix 2 shows the length frequency distributions (LFDs) of monkfish in each haul of the study. Kept and discarded fish are identified by a different color.

Figure 7a and b. Captain Vincent Balzano (F/V North Star with the experimental (12" square mesh codend) net and its associated catch. Figure 7b shows the catch to be almost exclusively monkfish and skates.

Table IX

6.5	Monkfish			
	No. of fish		**Weight (Lbs)**	
	Kept	Discard	Kept	Discard
tot	1359.00	2921.00	7792.00	5191.00
average	56.63	121.71	324.67	216.29
stdev	29.94	56.08	164.21	103.73
n	24.00			
hours (decima	57.97			
CPUE avg	23.44	50.39	134.41	89.55
stdev	9.74	15.33	54.91	26.29

12	Monkfish			
	No. of fish		**Weight (Lbs)**	
	Kept	Discard	Kept	Discard
tot	642.00	5.00	4170.00	10.00
average	30.57	0.24	198.57	0.48
stdev	16.05	0.54	99.78	1.08
n	21.00			
hours (decima	54.13			
CPUE avg	12.05	0.07	80.53	0.14
stdev	6.06	0.15	46.31	0.29

Table XIa

MONKFISH 2003 **Weight (Lbs)**

	C16M01/1	C16M01/2	C16M02/1	C16M02/2	C16M02/3	C16M03/1	C16M03/2	C16M03/3	C16M04/1	C16M04/2	C16M05/1	C16M06/1	C16M06/2	C16M07/1	C16M08/1	C16M08/2	C16M09/1	C16M09/2	C16M10/1	TFM01/1	TFM01/2	TFM01/3	TFM02/1	TFM02/2
	Total Weight (Lbs)																							
monkfish	423	618	447	409	217	537	598	233	766	660	994	615	630	1067	586	576	248	488	605	293	712	529	350	382
cod	0	14	152	27	25	76	170	96	21	78	46	16	0	79	346	167	171	539	190	0	6	0	0	0
winter flounder	0	1	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0.5	0
grey sole	0.5	1	36.5	45	19	50	56	6	43	74	68	67	178	41	38	37	9	36	101	1	69	56	1.5	1.3
yellowtail	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2	0	0	0
dab	9.5	15	4	11	3	8	11	5	16	25	36	20	23	24	17	12	8	9	32	8.2	33	19	7.5	5
windowpane	0.5	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
fourspot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0
haddock	0	0	2.2	3	0	4	0	0	0	0	0	0	4	0	0	0	0	0	0	0	14	10	0	0
red hake	1.5	1	1	4	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	4	1	0	0
white kake	0	0	0	0	0	0	0	0	14	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
lumpfish	1	5	30	36	30	24	14	13	40	27	51	70	52	74	69	20	10	6	13	0	6	0	0	0
redfish	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	1.5	0	0	0	0	0	0	0	0	0
pollock	0	0	0	0	0	0	0	0	0	0	10	0	0	46	0	0	0	0	0	0	0	0	0	0
sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1
sea raven	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
spiny dogfish	106	86	9	8	10	26	106	31	89	6	87	38	54	117	10	10	0	24	78	22	655	150	0	0
skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	101	108	0	0.3
winter skate	8	10	0	0	0	4	0	0	0	0	5	1	0	0	0	8	0	5	0	0	0	0	0	0
barndoor skate	0	3	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0	0	0
smooth skate	0	2	0	0	9	0	6	2	11	4	32	18	13	10	3	2	10	10	14	0	0	0	0	0
thorny skate	0	10	18	38	20	15	23	30	98	73	224	113	254	12	65	36	41	81	176	0	0	0	0	0
silver hake	0.5	0	3	2	0	1	2	0	5	3	0	0	0	8	3	2	1	0	0	0	2	3	0	0
torpedo ray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	20	0	0	0
debris	0	40	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
jonah crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
true crab, nk	6	23	2	10	0	2	4	6	0	2	10	3	2	0	2	3	6	0	6	2	0	0 nk		14
snow crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lobster	4	0	4	6	0	0.5	0	6	0	4	21	7	8	27	5	11	33	5	20	0	0	0 nk		18
Illex	1	0.5	0.5	1	0	0	0	0.5	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0

Table XIb

MONKFISH 2003
6.5 sq

Weight (Lbs) Kept/Discard

6.5 sq	C16M01/1		C16M01/2		C16M02/1		C16M02/2		C16M02/3		C16M03/1		C16M03/2	
	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc
monkfish	169	254	250	368	337	110	278	131	137	80	372	165	406	192
cod	0	0	14	0	152	0	25	2	25	0	76	0	162	8
winter flounder	0	0	1	0	0	0	0	0	0	0	0	0	0	0
grey sole	0	0.5	0	1	26.5	10	20	25	13	6	28	22	32	24
yellowtail	0	0	0	0	0	0	1	0	0	0	0	0	0	0
dab	7.5	2	10	5	0	4	4	7	1	2	3	5	6	5
windowpane	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
fourspot	0	0	0	0	0	0	0	0	0	0	0	0	0	0
haddock	0	0	0	0	0	2.2	0	3	0	0	4	0	0	0
red hake	0	1.5	0	1	0	1	0	4	0	0	0	0	0	0
white kake	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lumpfish	0	1	0	5	0	30	0	36	0	30	0	24	0	14
redfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pollock	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sea raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0
spiny dogfish	0	106	0	86	0	9	0	8	0	10	0	26	0	106
skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0
winter skate	0	8	0	10	0	0	0	0	0	0	0	4	0	0
barndoor skate	0	0	0	3	0	0	0	0	0	0	0	4	0	0
smooth skate	0	0	0	2	0	0	0	0	0	9	0	0	0	6
thorny skate	0	0	0	10	0	18	0	38	0	20	0	15	0	23
silver hake	0	0.5	0	0	0	3	0	2	0	0	0	1	0	2
torpedo ray	0	0	0	0	0	0	0	0	0	0	0	0	0	0
debris	0	0	0	40	0	0	0	0		0	0	0	30	0
jonah crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0
true crab, nk	0	6	0	23	0	2	0	10	0	0	0	2	0	4
snow crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lobster	0	4	0	0	0	4	0	6	0	0	0	0.5	0	0
Illex	0	1	0	0.5	0	0.5	0	1	0	0	0	0	0	0

6.5 sq	C16M03/3		C16M04/1		C16M04/2		C16M05/1		C16M06/1		C16M06/2		C16M07/1		C16M08/1		C16M08/2	
	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc
monkfish	97	136	480	286	356	304	458	536	341	274	365	265	860	207	474	112	430	146
cod	96	0	18	3	74	4	46	0	16	0	0	0	71	8	346	0	167	0
winter flounder	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
grey sole	4	2	26	17	38	36	29	39	40	27	85	93	20	21	16	22	20	17
yellowtail	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
dab	1	4	6	10	7	18	13	23	9	11	11	12	7	17	5	12	6	6
windowpane	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
fourspot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
haddock	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
red hake	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
white kake	0	0	0	14	0	0	0	5	0	0	0	0	0	0	0	0	0	0
lumpfish	0	13	0	40	0	27	0	51	0	70	0	52	0	74	0	69	0	20
redfish	0	0	0	0	0	0	0	0	0	0	0	0	1	0.5	0	1.5	0	0
pollock	0	0	0	0	0	0	10	0	0	0	0	0	46	0	0	0	0	0
sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sea raven	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
spiny dogfish	0	31	0	89	0	6	0	87	0	38	0	54	0	117	0	10	0	10
skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
winter skate	0	0	0	0	0	0	0	5	0	1	0	0	0	0	0	0	0	8
barndoor skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
smooth skate	0	2	0	11	0	4	0	32	0	18	0	13	0	10	0	3	0	2
thorny skate	0	30	0	98	0	73	0	224	0	113	0	254	0	12	0	65	0	36
silver hake	0	0	0	5	0	3	0	0	0	0	0	0	0	8	0	3	0	2
torpedo ray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
debris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
jonah crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
true crab, nk	0	6	0	0	0	2	0	10	0	3	0	2	0	0	0	2	0	3
snow crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lobster	0	6	0	0	0	4	0	21	0	7	0	8	0	27	0	5	0	11
Illex	0	0.5	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0

6.5 sq	C16M09/1		C16M09/2		C16M10/1		TFM01/1		TFM01/2		TFM01/3		TFM02/1		TFM02/2	
	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc
monkfish	167	81	304	184	385	220	87	206	361	351	312	217	170	180	196	186
cod	168	3	539	0	183	7	0	0	6	0	0	0	0	0	0	0
winter flounder	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0
grey sole	4	5	19	17	40	61	1	0	38	31	26	30	0.5	1	0	1.3
yellowtail	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0
dab	4	4	4	5	13	19	6	2.2	15	18	7	12	3	4.5	4	1
windowpane	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3
fourspot	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0
haddock	0	0	0	0	0	0	0	0	14	0	8	2	0	0	0	0
red hake	0	0	0	0	0	1	0		0	4	0	1	0	0	0	0
white kake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lumpfish	0	10	0	6	0	13	0	0	0	6	0	0	0	0	0	0
redfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pollock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sculpin	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1
sea raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
spiny dogfish	0	0	0	24	0	78	0	22	0	655	0	150	0	0	0	0
skate	0	0	0	0	0	0	0	1	0	101	0	108	0	0	0	0.3
winter skate	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
barndoor skate	0	0	0	4	0	3	0	0	0	0	0	0	0	0	0	0
smooth skate	0	10	0	10	0	14	0	0	0	0	0	0	0	0	0	0
thorny skate	0	41	0	81	0	176	0	0	0	0	0	0	0	0	0	0
silver hake	0	1	0	0	0	0	0	0	0	2	0	3	0	0	0	0
torpedo ray	0	0	0	0	0	0	0	22	0	20	0	0	0	0	0	0
debris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
jonah crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
true crab, nk	0	6	0	0	0	6	0	2	0	0	0	0	0	nk	0	14
snow crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lobster	0	33	0	5	0	20	0	0	0	0	0	0	0	nk	0	18
Illex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table XIIa

MONKFISH 2003 **Weight (Lbs)**

	D05M01/1	D05M01/2	D05M01/3	D05M02/1	D05M03/1	D05M03/2	D05M03/3	D05M04/1	D05M05/1	D05M05/2	D05M06/1	D05M07/1	D05M07/2	D05M08/1	D05M09/1	D05M09/2	D05M10/1	D05M10/2	D05M10/3	D05M11/1	D05M11/2
Total Weight (Lbs)																					
monkfish	106	198	66	192	308	66	238	87	324	335	263	347	179	267	133	141	66	161	192	384	131
cod	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	0	0	0
winter flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
grey sole	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0
yellowtail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
dab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
windowpane	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
fourspot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
haddock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
red hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white kake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lumpfish	0	4	0	0	14	10	6	0	33	23	8	54	36	0	61	32	16	13	5	10	10
redfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pollock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sea raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
spiny dogfish	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
winter skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
barndoor skate	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
smooth skate	1	7	2	0	0	0	0	0	0	0	4	4	2	2	2	1	4	0	2	4	6
thorny skate	128	93	54	94	66	60	31	26	89	118	162	279	308	153	36	28	16	10	51	308	160
silver hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
torpedo ray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
debris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
jonah crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2
true crab, nk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
snow crab	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	6
lobster	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	6	0	5	3	0
Illex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0

Table XIIb

MONKFISH 2003 **Weight (Lbs) Kept/Discard**

12" Sq	D05M01/1		D05M01/2		D05M01/3		D05M02/1		D05M03/1		D05M03/2		D05M03/3		D05M04/1		D05M05/1		D05M05/2		D05M06/1		D05M07/1		D05M07/2		D05M08/1		D05M09/1		D05M09/2		D05M10/1		D05M10/2		D05M10/3		D05M11/1		D05M11/2	
	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc
monkfish	106	0	196	2	66	0	192	0	308	0	66	0	238	0	87	0	324	0	333	2	261	2	347	0	179	0	263	4	131	2	141	0	66	0	161	0	192	0	382	2	131	0
cod	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	0	0	0	0	0	0	0
winter flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
grey sole	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellowtail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
dab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
windowpane	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
fourspot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
haddock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
red hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
white kake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lumpfish	0	0	0	4	0	0	0	0	0	14	0	10	0	6	0	0	0	33	0	23	0	8	0	54	0	36	0	0	0	61	0	32	0	16	0	13	0	5	0	10	0	10
redfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
pollock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sea raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
spiny dogfish	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
winter skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
barndoor skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
smooth skate	0	1	0	7	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	0	2	0	2	0	2	0	1	0	4	0	0	0	2	0	4	0	6
thorny skate	0	128	0	93	0	54	0	94	0	66	0	60	0	31	0	26	0	89	0	118	0	162	0	279	0	308	0	153	0	36	0	28	0	16	0	10	0	51	0	308	0	160
silver hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
torpedo ray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
debris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
jonah crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	2
true crab, nk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
snow crab	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	6
lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	5	0	3	0	0
Illex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0

Aggregate Data Analysis

The data from all the trips in 2003 were pooled into two categories, control (from the 6.5" codend) and experimental (from the 12" codend).

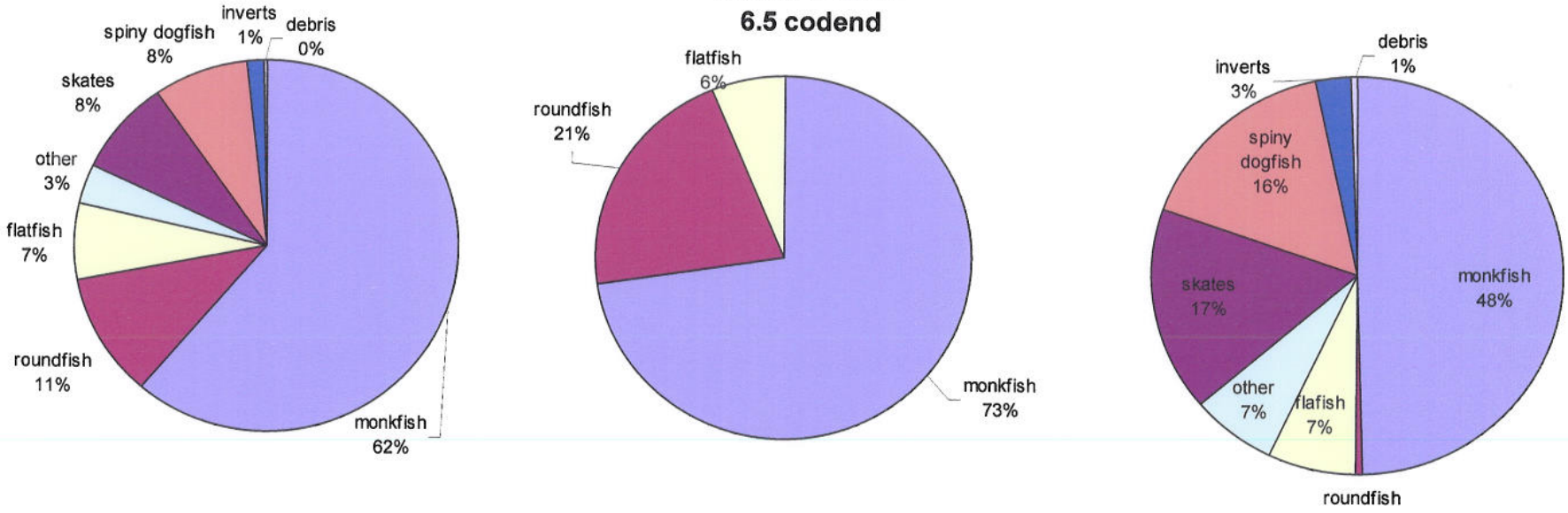
Figures 8a and 8b show the pooled catches in weight, in terms of total catch, kept catch and discarded catch for the control category (Figure 8a) and the experimental category (Figure 8b). The composition of each catch is also shown, in terms of species and their relative percentage. By comparing Figure 8a to Figure 8b, it is apparent that the percentage of monkfish in the total catch is approximately the same between the two gears (61% to 62%). However, the control gear has a lower percentage of monkfish in the kept catch than the experimental (73% to 99%) and a higher percentage of discarded monkfish (48% to 1%). This reflects accurately the results obtained in the haul by haul data analysis.

Figure 9 shows the pooled length frequency distribution (LFD) of monkfish caught in experimental and control gear. Once again, it is obvious that the experimental gear catches fewer fish, but nearly exclusively all of marketable size, while the control net catches more monkfish, 46% of which are discarded. However, there appears to be a sizable number of fish of marketable size that are caught in the control net but not in the experimental net, in lengths ranging from 40 cm to 58 cm. This number corresponds approximately to 48% of all the fish above 43 cm long caught during this part of the study.

Monkfish reaction behavior

Underwater video recordings were made during three separate trips during the course of this project and a total of 6 hours of videotape were obtained. The overall quality of the images is generally poor due to the lack of ambient underwater illumination and poor underwater visibility. However, enough footage was obtained to enable the investigators to determine that the experimental net was fishing correctly and to confirm previously reported results (Milliken pers. comm.) that monkfish showed little or no directed responses to the approaching net. Monkfish were observed being hit by the approaching ground gear and being flipped up into the approaching net. Given this behavior it is quite possible – although it was not observed here – that fishing nets may pass over the top of some fish thereby reducing overall fishing efficiency. Future work would be needed to determine the potential effect of this non-reaction on fishing efficiency.

Figure 8a
monkfish 2003
6.5 codend



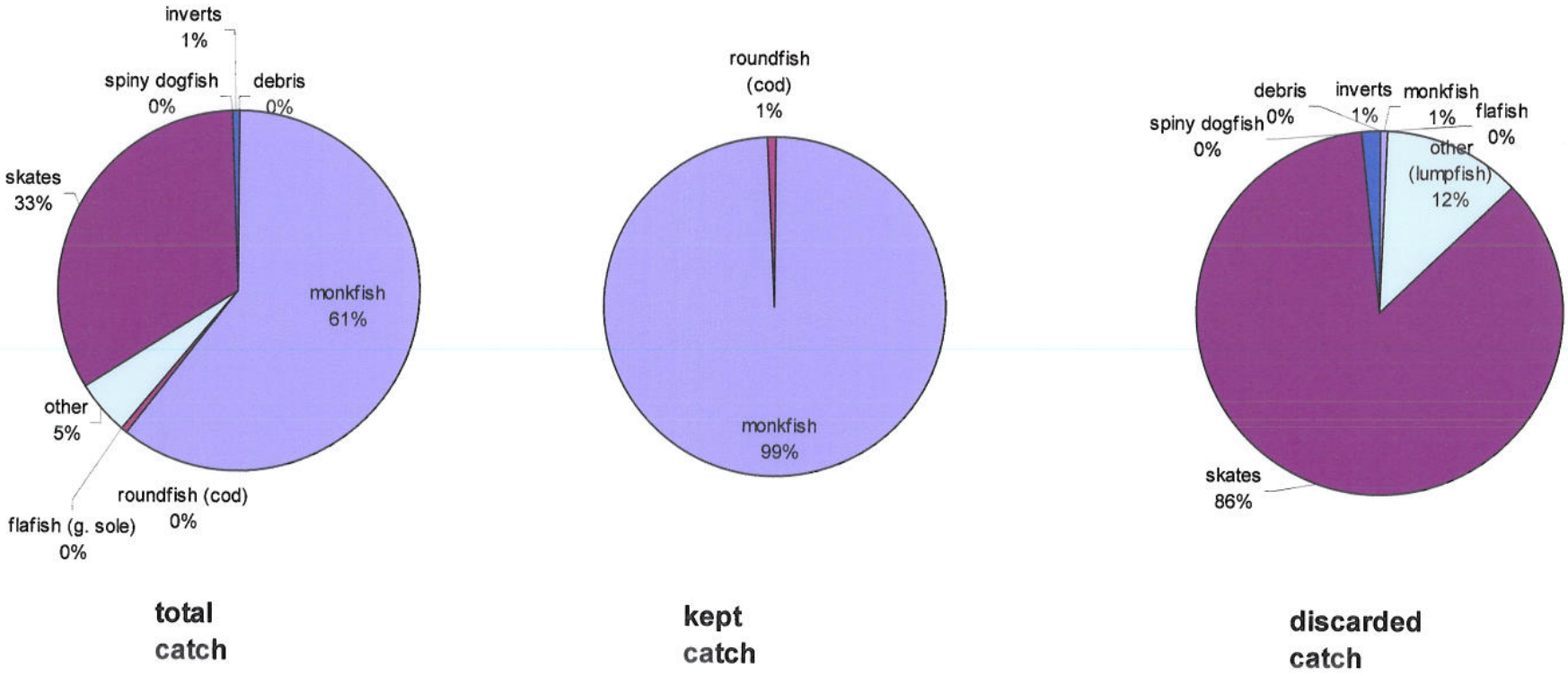
total catch

kept catch

discarded catch

Figure 8a. Pooled catch (weight) showing disposition of total catch, kept catch and discarded catch using the control 6.5" codend.

Figure 8b
monkfish 2003
12 codend



total catch

kept catch

discarded catch

Figure 8b. Pooled catch (weight) showing disposition of total catch, kept catch and discarded catch using the control 12" experimental net.

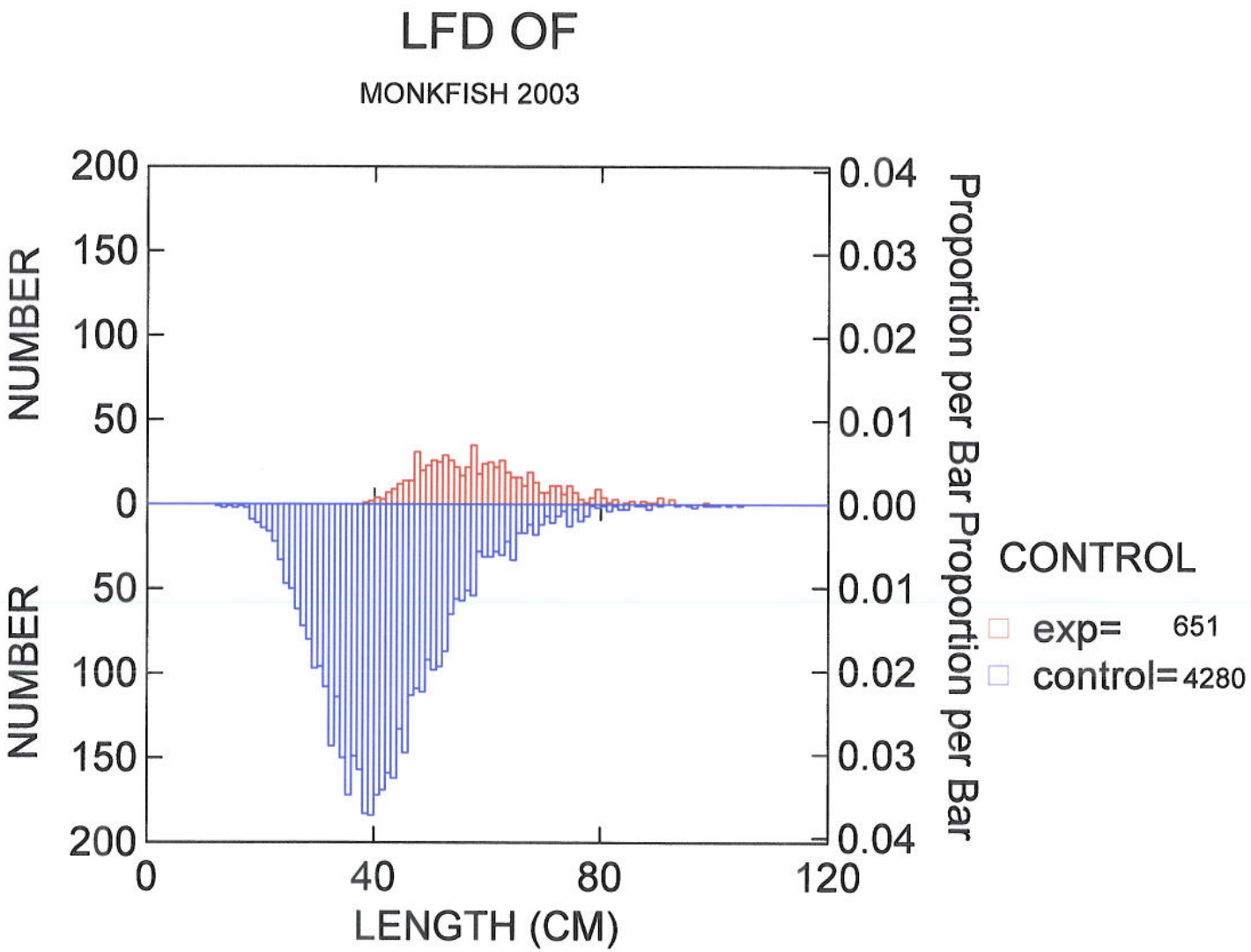


Figure 9. Length frequency distribution of kept and discarded monkfish comparing experimental and control nets (2003 sampling period).

Experimental fishing Phase 2: 2004

Trip and haul info

In the second part of the project, a net made entirely by 12 inch square mesh was compared to a net made by a body of 6 inch meshes and a codend made by 12 inch mesh. This change in protocol followed discussion with industry members who saw the utility in the large mesh codend but argued that the cost of replacing an entire net could prove prohibitive and therefore prevent adoption of the new design. If equivalent results could be achieved by merely replacing a conventional codend with a larger mesh codend, the new design would be more acceptable.

As in 2003, the hauls were not strictly paired, but 15 tows made by the 12 inch net were matched on the same day and in the same area by the 6+12 inch net. In addition, the F/V North Star performed 2 unmatched fishing tows and 2 extra video tows with the 12 inch codend, while the F/V Tenacious performed 5 unmatched tows with the 6+12 inch net. Table XIII shows details of each haul, including the gear used, where and when the haul was taken, tow speed and wire out and depth. The total weight of the catch, as well as lbs. kept and discarded, and the CPUE are also displayed in table II 2004.

Total catch

Table XIV displays some basic statistics performed on the total, kept and discarded catch, as well as on haul duration and CPUE for the control and the experimental net. The CPUE shows that the 6+12 inch net catches approximately the double of the 12 inch net, and that both nets have a discard rate of more than 50%.

A series of T-tests comparing total, kept and discard catch, and CPUE, between the 6+12 inch and the 12 inch net result consistently in highly significant differences, as shown in table XV.

Table XV

6"+12" vs. 12"	*p*
Total catch	0.000
Kept catch	0.001
Discard catch	0.006
CPUE	0.001

A paired Two Sample for means (t-Test) was also used to compare kept versus discarded catch within each set of trips (6+12 vs. 12). As shown by table XVI, kept and discarded catches were significantly different in weight for both gears tested.

Table XIII

Monkfish 2004

TRIPID	VESSEL	GEAR TYPE	HAUL	START TIME	END TIME	START LAT	START LONG	END LAT
C16M11	Tenacious	6SQ+12SQ	1	7:31	9:30	43.2830	69.5430	43.2484
C16M11	Tenacious	6SQ+12SQ	2	11:00	12:58	43.2737	69.5401	43.2446
C16M11	Tenacious	6SQ+12SQ	3	13:38	15:19	43.2458	69.5894	43.2800
C16M12	Tenacious	6SQ+12SQ	1	6:31	8:31	43.2790	69.5453	43.2487
C16M12	Tenacious	6SQ+12SQ	2	9:03	11:01	43.2471	69.5830	43.2807
C16M12	Tenacious	6SQ+12SQ	3	11:32	13:26	43.2754	69.5436	43.2508
C16M13	Tenacious	6SQ+12SQ	1	7:20	9:22	43.2874	69.5622	43.2440
C16M13	Tenacious	6SQ+12SQ	2	9:57	11:57	43.2484	69.5811	43.2867
C16M14	Tenacious	6SQ+12SQ	1	7:24	9:29	43.2938	69.5571	43.2492
C16M14	Tenacious	6SQ+12SQ	2	10:01	12:05	43.2496	69.5847	43.2876
C16M15	Tenacious	6SQ+12SQ	1	6:08	8:08	43.2779	69.5469	43.2569
C16M15	Tenacious	6SQ+12SQ	2	8:40	10:40	43.2604	69.5712	43.2735
C16M16	Tenacious	6SQ+12SQ	1	5:35	7:35	43.2965	69.5591	43.2506
C16M16	Tenacious	6SQ+12SQ	2	8:06	10:06	43.2495	69.5805	43.2854
C16M16	Tenacious	6SQ+12SQ	3	10:39	12:39	43.2792	69.5423	43.2865
C16M17	Tenacious	6SQ+12SQ	1	6:00	8:02	43.2351	69.5391	43.1965
C16M17	Tenacious	6SQ+12SQ	2	8:40	10:30	43.2002	69.5868	43.2338
C16M17	Tenacious	6SQ+12SQ	3	11:02	13:04	43.2398	69.5902	43.2856
C16M18	Tenacious	6SQ+12SQ	1	5:46	7:46	43.2940	69.5553	43.2496
C16M18	Tenacious	6SQ+12SQ	2	8:21	10:22	43.2516	69.5756	43.2911
C16M19	*North Star*	*12SQ*	*1*	*10:09*	*10:23*	*43.3049*	*70.1268*	*43.3021*
C16M19	*North Star*	*12SQ*	*2*	*11:13*	*11:38*	*43.3032*	*70.1281*	*43.3082*
D05M12	North Star	12SQ	1	9:17	10:10	43.2856	69.6840	43.2685
D05M12	North Star	12SQ	2	12:22	14:23	43.2700	69.5471	43.2535
D05M13	North Star	12SQ	1	8:17	10:20	43.2618	69.5874	43.2832
D05M13	North Star	12SQ	2	11:58	13:42	43.2769	69.5426	43.2532
D05M14	North Star	12SQ	1	6:57	8:59	43.2523	69.5906	43.2818
D05M14	North Star	12SQ	2	9:23	11:23	43.2781	69.5467	43.2534
D05M15	North Star	12SQ	1	13:32	15:39	43.2859	69.5821	43.2807
D05M16	North Star	12SQ	1	7:30	9:32	43.2516	69.5928	43.2772
D05M16	North Star	12SQ	2	9:57	11:59	43.2734	69.5496	43.2590
D05M16	North Star	12SQ	3	12:24	13:26	43.2567	69.5912	43.2608
D05M17	North Star	12SQ	1	7:06	9:07	43.1997	69.5877	43.2275
D05M17	North Star	12SQ	2	9:36	11:37	43.2212	69.5529	43.2438
D05M17	North Star	12SQ	3	12:05	13:55	43.2479	69.5905	43.2753
D05M18	North Star	12SQ	1	6:17	8:19	43.2860	69.5850	43.2800
D05M18	North Star	12SQ	2	8:41	10:44	43.2796	69.5783	43.2794
D05M19	North Star	12SQ	1	8:46	10:49	43.2858	69.5847	43.2833
D05M19	North Star	12SQ	2	11:18	12:56	43.2883	69.5797	43.2833

Table XIV

Monkfish 2004

TOTAL CATCH

			TOT LBS	KEPT	DISCARD	HaulDuration	CPUE TOTAL CATCH
Tenacious	6SQ+12SQ	**tot**	3610.80	1158.75	2452.05	39.57	1828.38
		mean	180.54	57.94	122.60	1.98	91.42
		stddev	70.25	25.73	59.27	0.09	35.43
		n	20.00				
North Star	12SQ	**tot**	1671.50	486.50	1185.00	31.52	914.17
		mean	98.32	28.62	69.71	1.85	53.77
		stddev	50.05	22.86	50.70	0.36	26.38
		n	19.00			19.00	

Table XVI

Kept vs. Discard	*p*
6"+12"	0.000
12"	0.013

Monkfish catch

Table XVII shows a breakdown, haul by haul, of the monkfish caught in the control and the experimental net, in terms of number of fish and weight (in lbs.).

At the bottom of the table, basic descriptive statistics are shown. Several things are immediately noticeable from this table: 1) the monkfish catch is higher in the 6+12" net than in the 12" net (approximately twice in terms of weight and 3 times in terms of number); 2) the number of monkfish discarded using the 6+12"net is twice as much the number of kept fish (in terms of weight, the weight of kept fish is higher that that of discarded); 3) the number of monkfish discarded using the 12" net is virtually non-existent.

Table XVIII shows the basic descriptive statistics about monkfish catch, including the average CPUE and its respective standard deviation.

The differences between the monkfish catch of the two nets were all statistically significant, as shown in table XIX.

Table XIX

MF total weight 6+12" *vs.* 12"	t-test (unequal var.)	*p*	0.002
MF total no. 6+12" *vs.* 12"	t-test (unequal var.)	*p*	0.000
MF kept no. 6+12" *vs.* 12"	t-test (unequal var.)	*p*	0.001
MF discard no. 6+12" *vs.* 12"	t-test (unequal var.)	*p*	0.000
MF in 6+12" (no.) kept *vs.* discard	t-test (paired samples)	*p*	0.001
MF in 6+12" (lbs.) kept *vs.* discard	t-test (paired samples)	*p*	0.000
MF in 12" (no.) kept *vs.* discard	t-test (paired samples)	*p*	0.000
MF in 12" (lbs.) kept *vs.* discard	t-test (paired samples)	*p*	0.000

Table XX and XXI show a breakdown of the total catch species by species. Table XX refers to the trips conducted with the 6+12" net, while table XXI to those with the 12" net. Each of these table is split in two categories (***a*** and ***b***), where ***a*** shows the total weight of each species in each haul, and ***b*** the weight kept and discarded of each species in each haul. It is immediately apparent that, while a variety of species were routinely caught with the 6+12" net (monkfish, dab, several species of skate and crab), the 12" net only caught monkfish, smooth and thorny skate. In the 6+12" net, monkfish ranged from 15% to 52% of total catch by weight, with an average of 28%. In the 12" net, monkfish ranged from 0% to 95%, also with an average of 31%.

Table XVIII

6SQ+12SQ	Monkfish			
	No. of fish		Weight (Lbs)	
	Kept	Discard	Kept	Discard
tot	113.00	47.00	891.00	79.00
average	5.65	2.35	44.55	3.95
stdev	2.48	2.37	21.24	4.04
n	20.00			
CPUE avg	2.86	1.20	22.58	2.02
stdev	1.26	1.19	10.73	2.07

12SQ	Monkfish			
	No. of fish		Weight (Lbs)	
	Kept	Discard	Kept	Discard
tot	47.00	1.00	437.00	2.00
average	2.76	0.06	25.71	0.12
stdev	2.41	0.24	20.52	0.49
n	17.00			
CPUE avg	2.21	0.14	22.84	0.28
stdev	2.26	0.58	31.53	1.15

Table XVII

6SQ+12SQ		Monkfish						
		No. of fish			Weight (Lbs)			
Trip	Haul	Kept	Discard	total	Kept	Discard	total	hrs
C16M11	1	9	4	13	67	10	77	1.98
C16M11	2	11	1	12	77	1	78	1.97
C16M11	3	5	4	9	42	8	50	1.68
C16M12	1	3	0	3	26	0	26	2.00
C16M12	2	9	0	9	79	0	79	1.97
C16M12	3	4	3	7	31	4	35	1.90
C16M13	1	5	1	6	61	1	62	2.03
C16M13	2	8	0	8	80	0	80	2.00
C16M14	1	5	0	5	25.5	0	25.5	2.08
C16M14	2	8	5	13	63	9	72	2.06
C16M15	1	4	0	4	25	0	25	2.00
C16M15	2	5	1	6	32.5	1	33.5	2.00
C16M16	1	6	1	7	38	2	40	2.00
C16M16	2	4	0	4	44.5	0	44.5	2.00
C16M16	3	1	4	5	5	8.5	13.5	2.00
C16M17	1	2	9	11	15	11.5	26.5	2.03
C16M17	2	7	3	10	49	7.5	56.5	1.83
C16M17	3	5	4	9	48	7.5	55.5	2.03
C16M18	1	6	3	9	41.5	2.5	44	2.00
C16M18	2	6	4	10	41	5.5	46.5	2.01
	tot	113	47	160	891	79	970	39.57
	average	5.65	2.35	8.00	44.55	3.95	48.50	1.98
	stdev	2.48	2.37	3.01	21.24	4.04	20.86	0.09
	n	20						

12 SQ		Monkfish						
		No. of fish			Weight (Lbs)			
Trip	Haul	Kept	Discard	total	Kept	Discard	total	hrs
D05M12	1	2	0	2	31	0	31	0.23
D05M12	2	2	1	3	17	2	19	0.42
D05M13	1	1	0	1	5	0	5	0.88
D05M13	2	3	0	3	41	0	41	2.01
D05M14	1	1	0	1	11	0	11	2.05
D05M14	2	8	0	8	73	0	73	1.73
D05M15	1	7	0	7	51	0	51	2.03
D05M16	1	0	0	0	0	0	0	2.00
D05M16	2	5	0	5	22	0	22	2.12
D05M16	3	1	0	1	6	0	6	2.03
D05M17	1	1	0	1	5	0	5	2.03
D05M17	2	3	0	3	22	0	22	1.03
D05M17	3	0	0	0	0	0	0	2.01
D05M18	1	5	0	5	36	0	36	2.01
D05M18	2	5	0	5	32	0	32	1.83
D05M19	1	1	0	1	44	0	44	2.03
D05M19	2	2	0	2	41	0	41	2.05
C16M19	1	NA	NA	NA	NA	NA	NA	2.05
C16M19	2	NA	NA	NA	NA	NA	NA	1.63
		47	1	48	437	2	439	32.17
		2.76	0.06	2.82	25.71	0.12	25.82	1.69
		2.41	0.24	2.40	20.52	0.49	20.48	0.59
		17						

Table XXa

6SQ+12SQ	C16M11/1	C16M11/2	C16M11/3	C16M12/1	C16M12/2	C16M12/3	C16M13/1	C16M13/2	C16M14/1	C16M14/2	C16M15/1	C16M15/2	C16M16/1	C16M16/2	C16M16/3	C16M17/1	C16M17/2	C16M17/3	C16M18/1	C16M18/2	
	Total Weight																				
monkfish	77	78	50	26	79	35	62	80	25.5	72	25	33.5	40	44.5	13.5	26.5	56.5	55.5	44	46.5	970
cod	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
grey sole	0	0	0	0	0	2	1.5	0	0.5	1	0	0	0	2	1.5	4	0	3	1	3.5	
yellowtail	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	
dab	10	9	7	7.5	6	5	8.5	6.5	12	10.5	7	13	40.5	13.5	12.5	12.5	7.5	19	21	16	
haddock	0	4	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	
lumpfish	0	0	0	0	0	0	0	0	0	8	0	14.5	8	0	0	0	0	31	0	22.5	
redfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0.5	0	0	0	
sea raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
spiny dogfish	18	0	35	0	0	0	5	10	0	6.5	0	0	12	0	8	0	0	9	0	11	
skate	0	0	0	0	0	0	0	0	22	79	44	47	61	125	72	89	112	92	34	204	
winter skate	0	0	14	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
smooth skate	10	8	6	13	1	7	10	4	0	0	0	0	0	0	0	0	0	0	0	0	
thorny skate	192	131	52	77	40	102	68	154	0	0	0	0	0	0	0	0	0	0	0	0	
silver hake	0	0	0	0	0	0	0	0	1.5	3	1	0.1	3.5	1	2.5	0	1	3	4	5.5	
wolfish	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
true crab, nk	7	8	3	13	10	10	2	2	3.5	13	5	12	9	4	4	32	8	5	7	8	
lobster	10	3.5	0	0	0	0	0	0	5	5	0	0	7	0	0	0	0	3	0	0	
scallop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	
	324	275.5	167	136.5	152	172	157	256.5	70	198	82	120.1	183	190	119	173.2	185.5	220.5	111	317	3609.8
	24%	28%	30%	19%	52%	20%	39%	31%	36%	36%	30%	28%	22%	23%	11%	15%	30%	25%	40%	15%	28%

Table XXb

12" Sq	D05M12/1	D05M12/2	D05M13/1	D05M13/2	D05M14/1	D05M14/2	D05M15/1	D05M16/1	D05M16/2	D05M16/3	D05M17/1	D05M17/2	D05M17/3	D05M18/1	D05M18/2	D05M19/1	D05M19/2	
	Total Weight																	
monkfish	31	19	5	41	11	73	51	0	22	6	5	22	0	36	32	44	41	439
cod	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
grey sole	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
yellowtail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
dab	0	0	0	0	4	0	0	0	2.5	0	0	0	0	0	5	0	1	
haddock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
lumpfish	0	0	0	0	0	0	15	0	0	0	0	0	0	0	24	4	0	
redfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
sea raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
spiny dogfish	0	0	0	0	0	6	0	12	0	0	0	0	0	0	0	0	0	
skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
winter skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
smooth skate	0	0	0	2	18	6	2	4	5	0	0	5.5	0	2	1.5	0	1	
thorny skate	18	72	82	74	71	135	13	109	37	26	188	86	70	0	14	51	17	
silver hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
wolfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
true crab, nk	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	
lobster	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	
scallop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	86	91	87	117	106	230	81	125	66.5	32	193	113.5	70	38	76.5	99	60	
	36%	21%	6%	35%	10%	32%	63%	0%	33%	19%	3%	19%	0%	95%	42%	44%	68%	31%

Table XXIa

Weight Kept/Discard

6SQ+12SQ	C16M11/1		C16M11/2		C16M11/3		C16M12/1		C16M12/2		C16M12/3		C16M13/1		C16M13/2		C16M14/1		C16M14/2		C16M15/1		C16M15/2		C16M16/1		C16M16/2		C16M16/3		C16M17/1		C16M17/2		C16M17/3		C16M18/1		C16M18/2	
	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc
monkfish	67	10	77	1	42	8	26	0	79	0	31	4	61	1	80	0	25.5	0	63	9	25	0	32.5	1	38	2	44.5	0	5	8.5	15	11.5	49	7.5	48	7.5	41.5	2.5	41	5.5
cod	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
grey sole	0	0	0	0	0	0	0	0	0	0	1	1	1.5	0	0	0	0	0.5	1	0	0	0	0	0	0	0	1.75	0.25	0	1.5	2.5	1.5	0	0	3	0	1	0	1.5	2
yellowtail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
dab	8	2	9	0	6	1	7	0.5	4	2	2	3	6	2.5	6.5	0	9.5	2.5	9.5	1	4.5	2.5	11.5	1.5	27	13.5	9.5	4	9	3.5	7.5	5	6.5	1	14	5	15	6	12.5	3.5
haddock	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
lumpfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	14.5	0	8	0	0	0	0	0	0	0	0	0	31	0	0	0	22.5
redfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0.5	0	0	0	0	0	0
sea raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
spiny dogfish	0	18	0	0	0	35	0	0	0	0	0	0	0	5	0	10	0	0	0	6.5	0	0	0	0	0	12	0	0	0	8	0	0	0	0	0	0	0	0	0	0
skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	79	0	44	0	47	0	61	0	125	0	72	0	89	0	112	0	92	0	34	0	204
winter skate	0	0	0	0	0	14	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
smooth skate	0	10	0	8	0	6	0	13	0	1	0	7	0	10	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
thorny skate	0	192	0	131	0	52	0	77	0	40	0	102	0	68	0	154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
silver hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	3	0	1	0	0.1	0	3.5	0	1	0	2.5	0	0	0	1	0	3	0	4	0	5.5
wolfish	0	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
true crab, nk	0	7	0	8	0	3	0	13	0	10	0	10	0	2	0	2	0	3.5	0	13	0	5	0	12	0	9	0	4	0	4	0	32	0	8	0	5	0	7	0	8
lobster	0	10	0	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	3	0	0	0	0
scallop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0

Table XXIb

Weight Kept/Discard

12" Sq	D05M12/1		D05M12/2		D05M13/1		D05M13/2		D05M14/1		D05M14/2		D05M15/1		D05M16/1		D05M16/2		D05M16/3		D05M17/1		D05M17/2		D05M17/3		D05M18/1		D05M18/2		D05M19/1		D05M19/2	
	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc	kept	disc
monkfish	31	0	17	2	5	0	41	0	11	0	73	0	51	0	0	0	22	0	6	0	5	0	22	0	0	0	36	0	32	0	44	0	41	0
cod	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
grey sole	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
yellowtail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
dab	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	2.5	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	1	0
haddock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lumpfish	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	4	0	0
redfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sea raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
spiny dogfish	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
winter skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
smooth skate	0	0	0	0	0	0	0	2	0	18	0	6	0	2	0	4	0	5	0	0	0	0	0	5.5	0	0	0	2	0	1.5	0	0	0	1
thorny skate	0	18	0	72	0	82	0	74	0	71	0	135	0	13	0	109	0	37	0	26	0	188	0	86	0	70	0	0	0	14	0	51	0	17
silver hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
wolfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
true crab, nk	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
lobster	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
scallop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table XXII

12 square mesh

2003 VESSEL	GEARTYPE		HaulDur	TOT LBS	CPUE_C	KEPT	DISCARD
North Star	12SQ		2.05	235.00	114.63	106.00	129.00
North Star	12SQ		3.00	304.00	101.33	196.00	108.00
North Star	12SQ		2.03	122.00	60.00	66.00	56.00
North Star	12SQ		2.40	286.00	119.17	192.00	94.00
North Star	12SQ		2.20	392.00	178.18	308.00	84.00
North Star	12SQ		2.08	136.00	65.28	66.00	70.00
North Star	12SQ		1.07	275.00	257.81	238.00	37.00
North Star	12SQ		2.07	113.00	54.68	87.00	26.00
North Star	12SQ		3.05	446.00	146.23	324.00	122.00
North Star	12SQ		2.62	476.00	181.91	333.00	143.00
North Star	12SQ		4.10	444.00	108.29	261.00	183.00
North Star	12SQ		3.08	684.00	221.84	347.00	337.00
North Star	12SQ		2.85	525.00	184.21	179.00	346.00
North Star	12SQ		4.45	418.80	94.11	263.00	225.80
North Star	12SQ		2.50	232.50	93.00	131.00	101.50
North Star	12SQ		2.67	202.00	75.75	141.00	61.00
North Star	12SQ		2.03	108.00	53.11	66.00	42.00
North Star	12SQ		2.03	218.00	107.21	195.00	23.00
North Star	12SQ		2.05	256.00	124.88	192.00	64.00
North Star	12SQ		3.02	716.00	237.35	382.00	334.00
North Star	12SQ		2.03	315.00	154.92	131.00	184.00
		tot	**53.38**	**6904.30**	**2733.90**	**4204.00**	**2770.30**
		mean	**2.54**	**328.78**	**130.19**	**200.19**	**131.92**
		stddev	**0.76**	**174.34**	**60.66**	**99.42**	**101.92**
		n	**21**				

VESSEL 2004	GEAR TYPE	HAUL	Duration Decimal	TOT LBS EXP 1	CATCH/UNIT EFFORT (LBS/HOUR)	LBS KEPT	LBS DISCARD
North Star	12SQ	1	0.88	86.0	97.36	68.00	18.00
North Star	12SQ	2	2.01	91.0	45.12	17.00	74.00
North Star	12SQ	1	2.05	87.0	42.44	5.00	82.00
North Star	12SQ	2	1.73	117.0	67.50	41.00	76.00
North Star	12SQ	1	2.03	106.0	52.13	15.00	91.00
North Star	12SQ	2	2.00	230.0	115.00	73.00	157.00
North Star	12SQ	1	2.12	81.0	38.27	51.00	30.00
North Star	12SQ	1	2.03	125.0	61.48	0.00	125.00
North Star	12SQ	2	2.03	66.5	32.70	24.50	42.00
North Star	12SQ	3	1.03	32.0	30.97	6.00	26.00
North Star	12SQ	1	2.01	193.0	95.70	5.00	188.00
North Star	12SQ	2	2.01	113.5	56.28	22.00	91.50
North Star	12SQ	3	1.83	70.0	38.18	0.00	70.00
North Star	12SQ	1	2.03	38.0	18.69	36.00	2.00
North Star	12SQ	2	2.05	76.5	37.32	37.00	39.50
North Star	12SQ	1	2.05	99.0	48.29	44.00	55.00
North Star	12SQ	2	1.63	60.0	36.73	42.00	18.00
		tot	**31.52**	**1671.50**	**914.17**	**486.50**	**1185.00**
		mean	**1.85**	**98.32**	**53.77**	**28.62**	**69.71**
		stddev	**0.36**	**50.05**	**26.38**	**22.86**	**50.70**
		n	**17.00**				

Appendix 2 shows the length frequency distributions (LFDs) of monkfish in each haul of the study. Kept and discarded fish are identified by a different color.

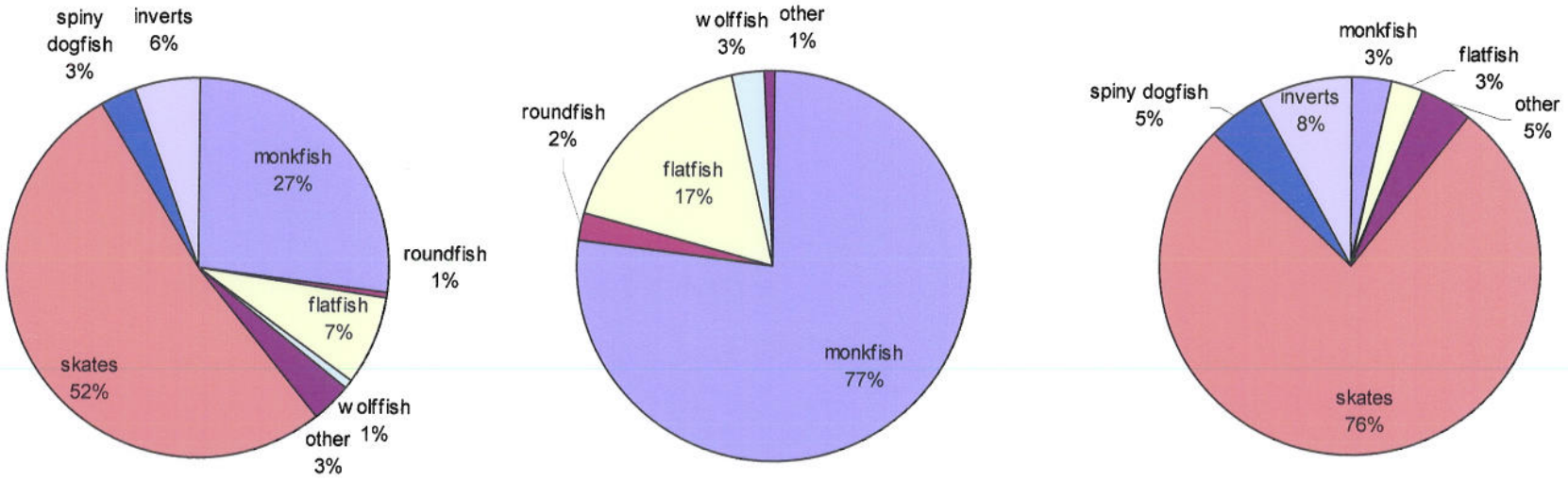
Aggregate Data Analysis

The data from all the trips in 2004 (except directed video trips) were pooled in two categories, mixed mesh (from the 6+12 inch net) and large mesh (from the 12 inch net, equivalent to the experimental codend in 2003).

Figures 10a and 10b show the pooled catches in weight, in terms of total catch, kept catch and discarded catch for the 6+12" (or mixed mesh) category (Figure 10a) and the 12" (or large mesh) category (Figure 10b). The composition of each catch is also shown, in terms of species and their relative percentage. By comparing the two figures, it is apparent that the percentage of monkfish in the total catch is approximately the same between the two gears (26% to 27%). However, the mixed mesh net has a lower percentage of kept monkfish than the large mesh net (77% to 89%). Both nets have low discard rates of monkfish (0% to 3%).

Figure 11 shows the pooled LFD of monkfish caught in the mixed mesh and the large net. While the two distributions are not significantly different (K-S Two sample test, $p=0.068$), it is apparent that the mixed mesh net has a bycatch of undersized monkfish equal to approximately 25% of its total catch (in terms of number of individuals), while the large mesh net has virtually no bycatch. However, the mixed mesh net also catches more marketable fish than the large mesh net. This number corresponds approximately to 40% of all the fish above 40 cm caught in both gears during this part of the study.

Figure 10a
Monkfish 2004
6+12 inch net



total catch

kept catch

discard catch

Figure 10a. Pooled catch (weight) showing disposition of total catch, kept catch and discarded catch using the mixed mesh experimental net.

Figure 10b
Monkfish 2004
12 " net

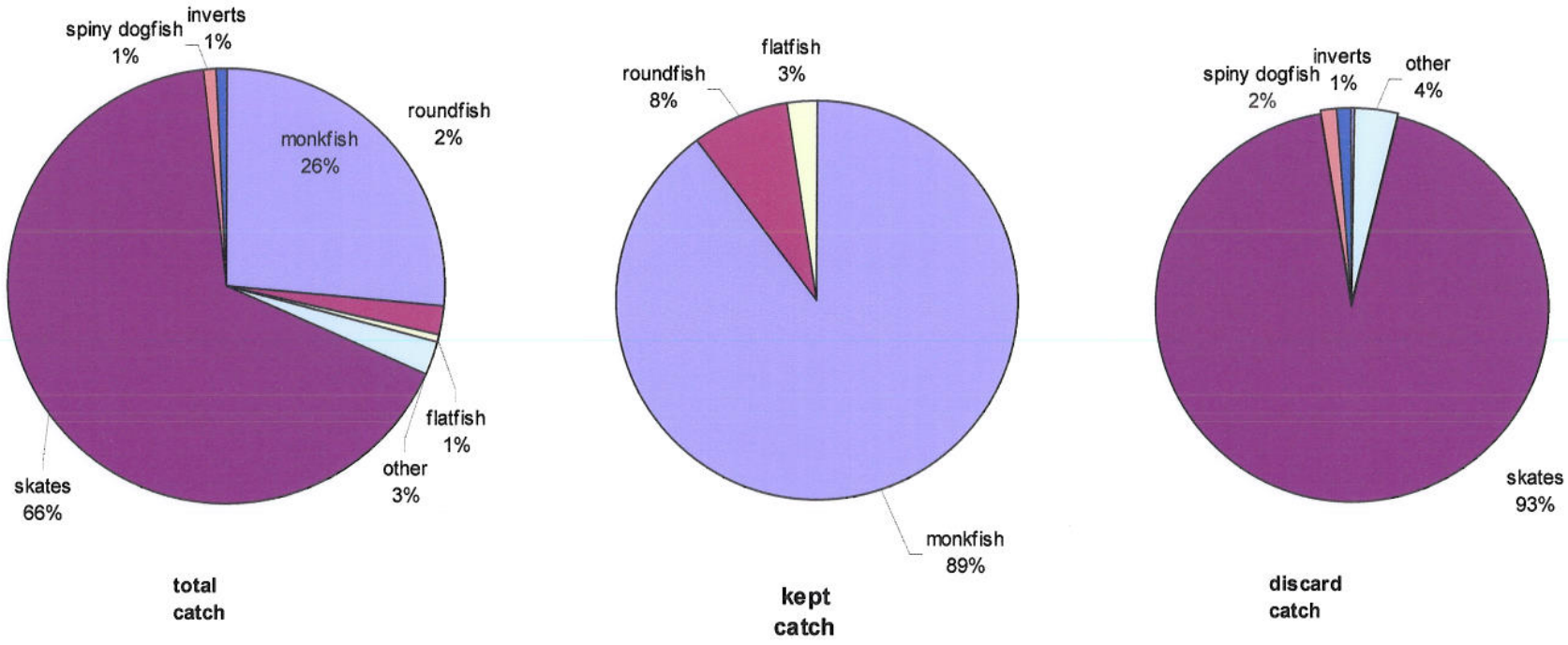


Figure 10b. Pooled catch (weight) showing disposition of total catch, kept catch and discarded catch using the 12" experimental net.

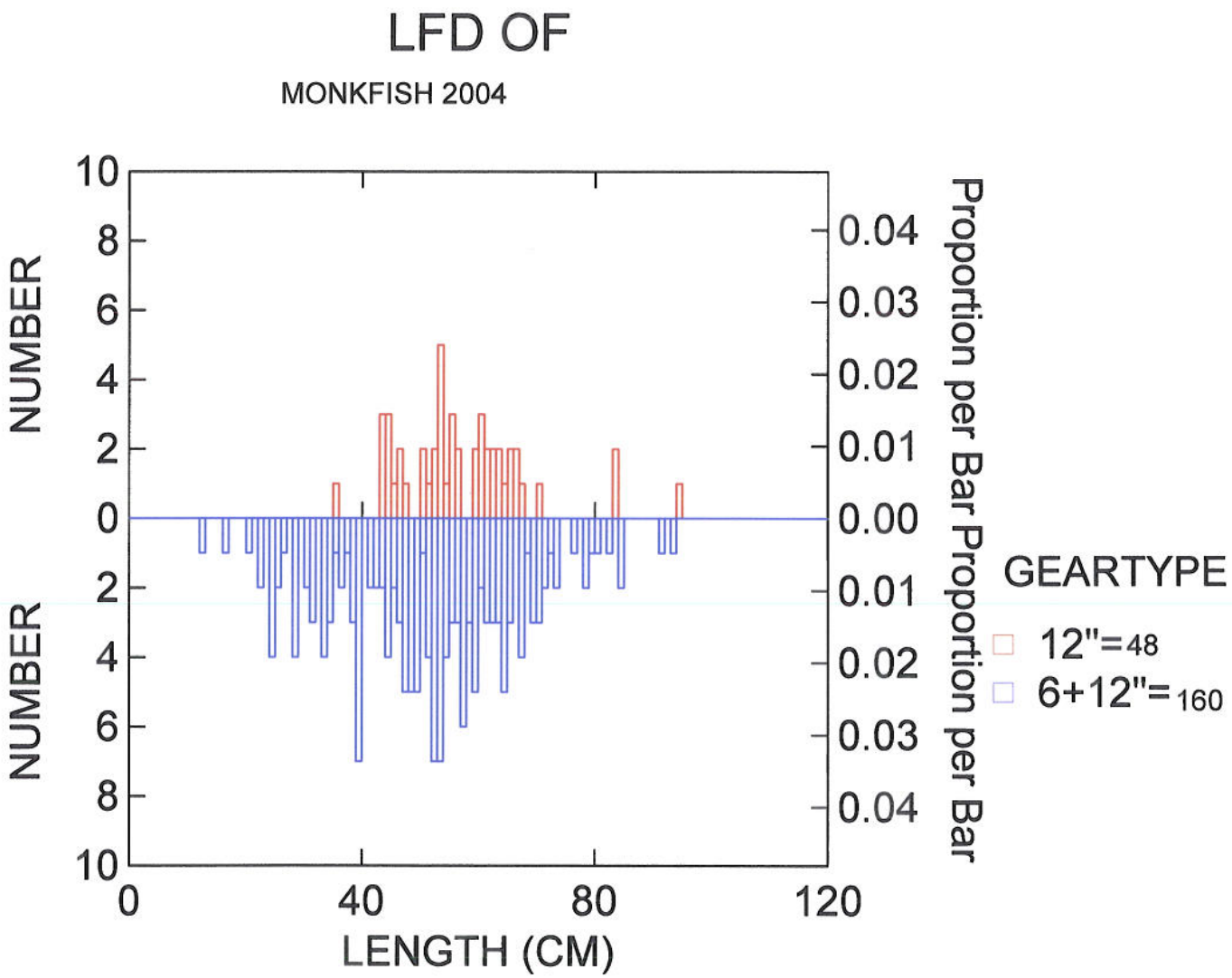


Figure 11. Length frequency distributions of kept and discarded monkfish for the 12" and mixed mesh experimental nets.

Comparison between sampling periods

The F/V North Star towed the net made entirely by 12" square mesh in both years of the study. In 2003, the total catch from the 12" net was consistently higher, across most hauls, than in 2004. Because the total fishing time was also higher in 2003, it makes sense to look at the CPUE, to standardize the efficiency of the net in terms of lbs/hr. In this case also, the CPUE is higher in 2003 and the difference is significant, as shown by table XXIII. In general, the North Star towed in the same general area in 2003 and 2004, area (Figure 6), but the sea trials in 2003 occurred in October-November, while in 2004 they occurred in June. Table XXII shows the catch obtained by the large mesh net in 2003 and in 2004 and associated basic statistics.

Table XXIII shows the results of the t-Tests comparing total catches from between the two years.

Table XXIII

12" net 2003 *vs.* 2004	*p*
Total catch	0.000
CPUE (lbs/hr)	0.000
Kept catch	0.000
Discard catch	0.020

Catch of monkfish was also consistently higher in 2003 than in 2004, as shown in Table XXIV. However the discard of monkfish was very low in both years, so the large mesh net consistently caught virtually no bycatch of undersized monkfish.

Table XXV shows the results of the t-Tests comparing monkfish catches from between the two years. The test compared numbers and weight of monkfish respectively.

Table XXV

12" net 2003 *vs.* 2004	p_{no}	p_w
All monkfish	0.000	0.000
CPUE (lbs/hr)	0.002	0.000
Kept monkfish	0.000	0.000
Discard monkfish	0.195	0.195

The LFDs for monkfish caught in the 12" net were also pooled and compared (Figure 12). Despite the obvious difference in numbers of fish caught, the distributions are not significantly different (Kolmogorov-Smirnov Two-Sample test, p=0.697). This means that the large mesh net sampled consistently the same population of monkfish, in terms of size-range, but the numbers of monkfish available to the net were different from year to year (see table XXIV).

Table XXIV

2003		Monkfish							Monkfish CPUE					
12" square		No. of fish			Weight (Lbs)				No. of fish			Weight (Lbs)		
Trip	Haul	Kept	Discard	total	Kept	Discard	total	hrs	Kept	Discard	total	Kept	Discard	total
D05M01	1	19	0	19	106	0	106	2.05	9.27	0.00	9.27	51.71	0.00	51.71
D05M01	2	27	1	28	196	2	198	3.00	9.00	0.33	9.33	65.33	0.67	66.00
D05M01	3	9	0	9	66	0	66	2.03	4.43	0.00	4.43	32.46	0.00	32.46
D05M02	1	30	0	30	192	0	192	2.40	12.50	0.00	12.50	80.00	0.00	80.00
D05M03	1	39	0	39	308	0	308	2.20	17.73	0.00	17.73	140.00	0.00	140.00
D05M03	2	8	0	8	66	0	66	2.08	3.84	0.00	3.84	31.68	0.00	31.68
D05M03	3	30	0	30	238	0	238	1.07	28.13	0.00	28.13	223.13	0.00	223.13
D05M04	1	13	0	13	87	0	87	2.07	6.29	0.00	6.29	42.10	0.00	42.10
D05M05	1	45	0	45	324	0	324	3.05	14.75	0.00	14.75	106.23	0.00	106.23
D05M05	2	52	0	52	333	0	333	2.62	19.87	0.00	19.87	127.26	0.00	127.26
D05M06	1	42	0	42	261	0	261	4.10	10.24	0.00	10.24	63.66	0.00	63.66
D05M07	1	61	0	61	347	0	347	3.08	19.78	0.00	19.78	112.54	0.00	112.54
D05M07	2	30	0	30	179	0	179	2.85	10.53	0.00	10.53	62.81	0.00	62.81
D05M08	1	53	2	55	263	4	267	5.19	10.20	0.39	10.59	50.64	0.77	51.41
D05M09	1	22	1	23	131	2	133	2.50	8.80	0.40	9.20	52.40	0.80	53.20
D05M09	2	23	0	23	141	0	141	2.67	8.63	0.00	8.63	52.88	0.00	52.88
D05M10	1	10	0	10	66	0	66	2.03	4.92	0.00	4.92	32.46	0.00	32.46
D05M10	2	25	0	25	161	0	161	2.03	12.30	0.00	12.30	79.18	0.00	79.18
D05M10	3	28	0	28	192	0	192	2.05	13.66	0.00	13.66	93.66	0.00	93.66
D05M11	1	57	1	58	382	2	384	3.02	18.90	0.33	19.23	126.63	0.66	127.29
D05M11	2	19	0	19	131	0	131	2.03	9.34	0.00	9.34	64.43	0.00	64.43
	total	642	5	647	4170	10	4180	54	253.10	1		1691	3	
	mean	31	0	31	199	0	199	3	12.05	0		81	0	
	st. deviatio	16	1	16	100	1	100	1	6.06	0		46	0	
	no. of haul	21												

2004	HAUL	Monkfish							Monkfish CPUE					
		No. of fish			Weight (Lbs)				No. of fish			Weight (Lbs)		
12SQ		Kept	Discard	total	Kept	Discard	total	hrs	Kept	Discard	total	Kept	Discard	total
D05M12	1	2	0	2	31	0	31	0.23	8.70	0.00	8.70	134.78	0.00	134.78
D05M12	2	2	1	3	17	2	19	0.42	4.76	2.38	7.14	40.48	4.76	45.24
D05M13	1	1	0	1	5	0	5	0.88	1.14	0.00	1.14	5.68	0.00	5.68
D05M13	2	3	0	3	41	0	41	2.01	1.49	0.00	1.49	20.40	0.00	20.40
D05M14	1	1	0	1	11	0	11	2.05	0.49	0.00	0.49	5.37	0.00	5.37
D05M14	2	8	0	8	73	0	73	1.73	4.62	0.00	4.62	42.20	0.00	42.20
D05M15	1	7	0	7	51	0	51	2.03	3.45	0.00	3.45	25.12	0.00	25.12
D05M16	1	0	0	0	0	0	0	2.00	0.00	0.00	0.00	0.00	0.00	0.00
D05M16	2	5	0	5	22	0	22	2.12	2.36	0.00	2.36	10.38	0.00	10.38
D05M16	3	1	0	1	6	0	6	2.03	0.49	0.00	0.49	2.96	0.00	2.96
D05M17	1	1	0	1	5	0	5	2.03	0.49	0.00	0.49	2.46	0.00	2.46
D05M17	2	3	0	3	22	0	22	1.03	2.91	0.00	2.91	21.36	0.00	21.36
D05M17	3	0	0	0	0	0	0	2.01	0.00	0.00	0.00	0.00	0.00	0.00
D05M18	1	5	0	5	36	0	36	2.01	2.49	0.00	2.49	17.91	0.00	17.91
D05M18	2	5	0	5	32	0	32	1.83	2.73	0.00	2.73	17.49	0.00	17.49
D05M19	1	1	0	1	44	0	44	2.03	0.49	0.00	0.49	21.67	0.00	21.67
D05M19	2	2	0	2	41	0	41	2.05	0.98	0.00	0.98	20.00	0.00	20.00
C16M19	1	NA	NA	NA	NA	NA	NA	2.05						
C16M19	2	NA	NA	NA	NA	NA	NA	1.63						
	total	47	1	48	437	2	439	32.17	37.59	2.38		388.25	4.76	
	mean	2.76	0.06	2.82	25.71	0.12	25.82	1.69	2.21	0.14		22.84	0.28	
	st. deviatio	2.41	0.24	2.40	20.52	0.49	20.48	0.59	2.26	0.58		31.53	1.15	
	no. of haul	17												

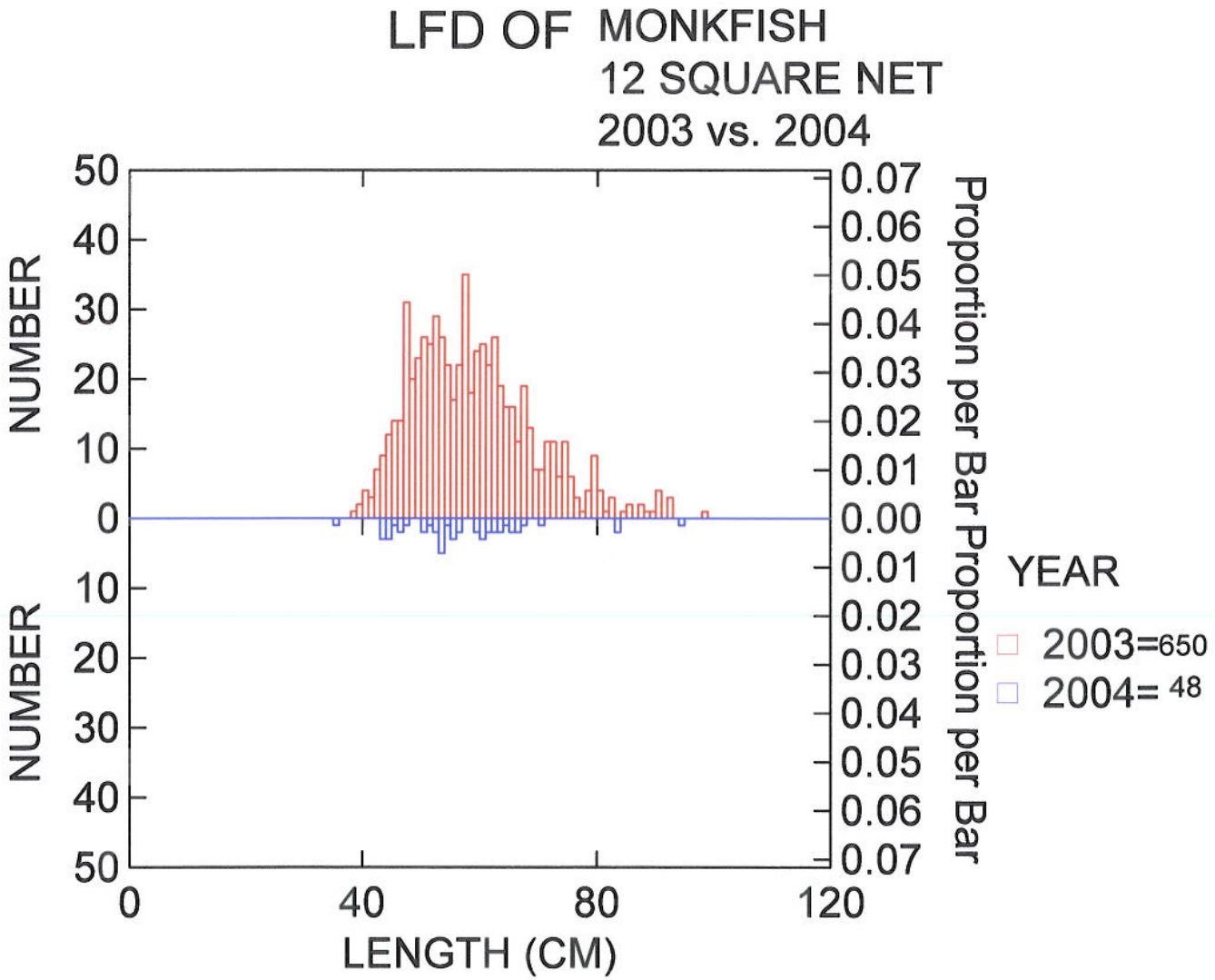


Figure 12. Pooled length frequency distribution for monkfish (kept and discarded) compared between sampling periods using the 12" square mesh net.

Discussion

The purpose of the sea trials in 2003 and 2004 was to test the effectiveness of large mesh trawl gear at reducing bycatch of undersized monkfish. In 2003, a codend made entirely of 12" square mesh was compared to a regular codend, (net body 6 ", codend mesh 6.5" square mesh). The large mesh codend eliminated bycatch of undersize monkfish completely. It was also very effective at catching exclusively monkfish, among the fish of commercial interest. The only other species caught in significant numbers were skates. However, a considerable amount of marketable monkfish was lost, which is of concern to the industry.

The mechanism by which undersized monkfish are not retained by in a large mesh codend is not entirely understood. However, many fish species will only actively attempt to escape from a net when they find themselves crowded in the extension or the codend. In this case, large mesh throughout the body of the net would not further reduce retention of undersized fish, because fish would ignore them. It might, however, facilitate escape of borderline fish just by mechanical sieving. Therefore, in order to reduce escape of borderline monkfish but still not retain undersized ones, a net with a body of 6.5" and a codend with large mesh was built and tested in 2004, and again compared with the large mesh net. This so called "mixed mesh" net was designed to continue to offer the undersized monkfish the possibility of escape, but limited it to the codend of the net.

Overall catches in 2004 were much lower than in 2003, which undermine any attempt to compare results from the two years. However, it is interesting to note that in 2004 the mixed meshes and the large mesh net sampled the same population of monkfish, but the mixed mesh still retained some undersize fish and a considerable amount of borderline fish, albeit less than a regular codend. From field notes, it appears that many of the bycatch, whether undersize monkfish or flatfish, were not actually in the codend, but had to be 'shaken down' from the body of the net. This implies that monkfish and flatfish are not actually actively seeking escape from the net at any point, but they rather filter through the meshes, and if the meshes are not open or large enough, they get stuck in them.

Given the disparity in catches between 2003 and 2004, a direct comparison between the data from the regular net and those from the mixed mesh net has not been attempted. However, it is clear that in 2003 the regular net sampled a different population from the large mesh net, while the large mesh codend sampled a similar population in 2003 and in 2004, which appears to be also the population sampled by the mixed mesh net. Therefore it appears that the mixed mesh net still samples a population of bigger monkfish, even though it does not eliminate bycatch of undersized ones to the extent of a large mesh net.

This highlights one of the biggest challenges in designing a new or more selective fishing gear, namely how to reduce bycatch while retaining all the target catch. Clearly the fishing industry will tend towards solutions that retain all target catch while managers and regulators will tend towards solutions that reduce bycatch to zero. Here we have shown that by designing a net that takes into account the morphometric characteristics of the target species (monkfish) it is possible to achieve zero retention of undersized monkfish and to reduce bycatch of other species to minimal levels. The study therefore was therefore highly successful in its original intent. However, substantial reduction of marketable size monkfish may render this design unacceptable to the fishing industry.

Findings

a) actual accomplishments and findings

This study designed 2 bottom trawl nets to reduce by-catch of groundfish and of undersize monkfish, and tested them at sea on commercial fishing vessels. Based on monkfish measurements collected during 2 dedicated trips, it was established that a mesh opening of 20x10 cm was required to release undersized monkfish. This opening translated into a 12" square mesh net, which was tested at sea in direct comparison with a standard net, in 2003. The results showed that the experimental large mesh net was very effective at releasing undersize monkfish: only 1% of the bycatch was monkfish, compared to 48% in the control net. However, the large mesh net also let a sizable portion (48%) of marketable monkfish escape.

In an attempt to understand this mechanism, a second experimental net was designed with a body of 6.5" square meshes and the codend of 12' square (mixed mesh) and tested at sea, in 2004, comparing it directly to the large mesh codend. Both nets proved effective at limiting bycatch of undersized monkfish to 1-3% of overall bycatch, but 25% of the monkfish catch of the mixed mesh was still undersized, while 36% of overall marketable fish was still lost.

In general, the presence of large 12" mesh greatly reduced bycatch of undersized monkfish, virtually eliminating them when the whole net was made of large mesh. However, a considerable amount of marketable fish was lost through the large meshes. A mixed mesh net still lost a substantial quantity of marketable fish, while retaining more undersized monkfish than the large mesh net, but a direct comparison between a conventional net and the mixed mesh net is undermined by the disparity in overall catches observed in the two field seasons.

b) significant problems and description of need for additional work

The most serious problem encountered during the course of the project was the low catch rate of monkfish during the second experimental period. This could not have been predicted and remains unexplained at this point. It was our intent to conduct a more robust comparison between the two experimental nets but this

was not possible due to very low catch rates in the second experimental period. However, low catch rates aside, the results indicate there is little difference in overall effectiveness between the two experimental nets and this is further emphasized by video observations indicating that capture of monkfish is an inert process compared to the active responses shown by other fish species.

Availability of fish remains one of the biggest challenges in designing an effective research program at sea especially when experimental fishing gear is used and when a finite number of sea days are available. The program reported here would have been more definitive if additional sampling had been possible during the second experimental phase until sufficient catches of monkfish had been encountered.

A second problem centers on the perceived need to retain all target catch while reducing bycatch and discard in the fishery. Our aim here was to design a net that would reduce retention of undersized monkfish to zero. However, in doing so, a proportion of marketable monkfish were also released. Despite the unequivocal nature of the results presented here – it is possible to fish for monkfish with negligible retention of undersized fish – further work on refining the design to retain a greater proportion of marketable sized fish is recommended. Furthermore, it would be of great value to all parties to have a clearer understanding of collective goals for research of this nature. It is almost impossible to design a fishing gear that will release all undersized fish while retaining every marketable fish (knife-edge selection). But in many cases it is possible to reduce catch of undersized fish to zero and it is also possible in other cases to design gears and strategies that retain all marketable fish. Mutually acceptable strategies fall somewhere between these two apparent extremes but there are no clearly articulated guidelines on which to base programs of research. It would be instructional and helpful to all parties to have a regional workshop addressing this issue.

Evaluation

No changes were made to the original goals and objectives and we believe all project goals and objectives were attained. Morphometric characteristics of monkfish were obtained and formed the basis of the design of a towed net configuration capable of releasing undersized monkfish in directed monkfish fisheries. Fishing trials comparing a standard groundfish net and an experimental net (in two similar but separate configurations) were conducted in the Gulf of Maine onboard commercial fishing vessels. Reaction behavior of monkfish to the experimental fishing gear was observed and documented and these results confirmed observations made during other studies. The new fishing gear design has potential to reduce by-catch and discard of undersized monkfish and all groundfish in the New England monkfish fishery but retention of marketable sized monkfish is also reduced.

Preliminary results from the study were presented at a workshop under the auspices of the Maine Fishermens Forum (2004). Results have also been presented to appropriate staff members of the New England Fisheries Management Council and a full presentation of results will be made on request to the New England Fisheries Management Council. It is the intent of the principal investigators to prepare the results as a short communication for peer reviewed scientific publication. The final report will be posted as a PDF file on the world wide web sites of The NOAA Fisheries Cooperative Research Partners Initiative, The Gulf of Maine Research Institute, and Manomet Center for Conservation Sciences. All participants in the program of research will obtain a hard copy of the final report and hard copy can be made available to all interested parties who do not have access to the world wide web.

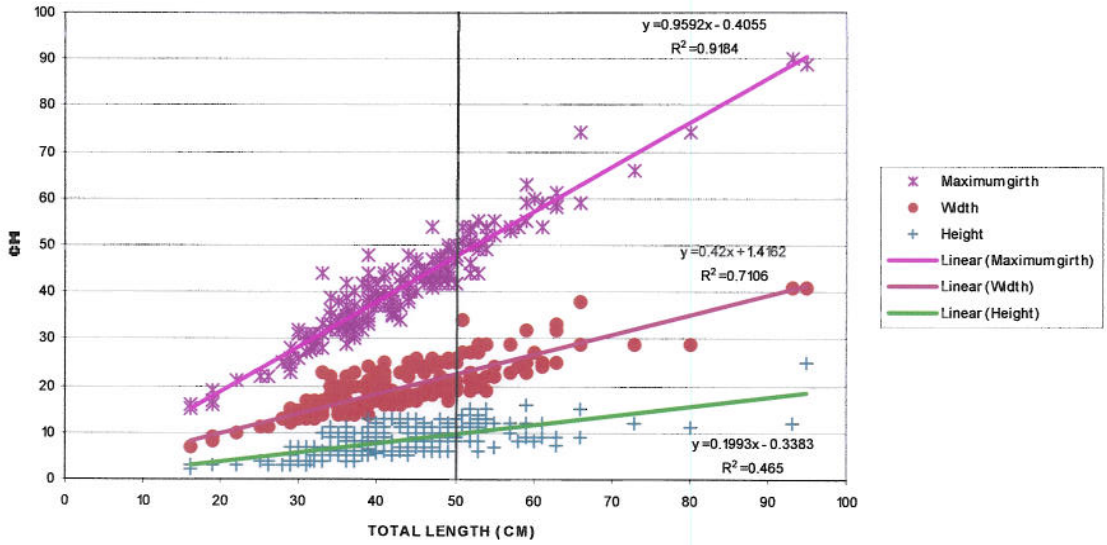
References

Anon. 1997. NEFSC [Northeast Fisheries Science Center]. 1997. [Report of the] 23rd Northeast Regional Stock Assessment Workshop (23rd SAW) Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast. Fish. Sci. Cent. Ref. Doc. 97-05. 191 p.

Anon. 2000NEFSC [Northeast Fisheries Science Center]. 2000. [Report of the] 31st Northeast Regional Stock Assessment Workshop (31st SAW) Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. Northeast Fish. Sci. Cent. Ref. Doc.

APPENDIX 1

MONKFISH 2003 ALL



TOTAL LENGTH		*MAX WIDTH*		*WIDTH*		*HEIGHT*	
Mean	49.66667	Mean	46.96667	Mean	21.9	Mean	10.23333
Standard Error	0.268385	Standard Error	0.635146	Standard Error	0.678657	Standard Error	0.391529
Median	49	Median	47	Median	21	Median	10
Mode	48	Mode	47	Mode	19	Mode	10

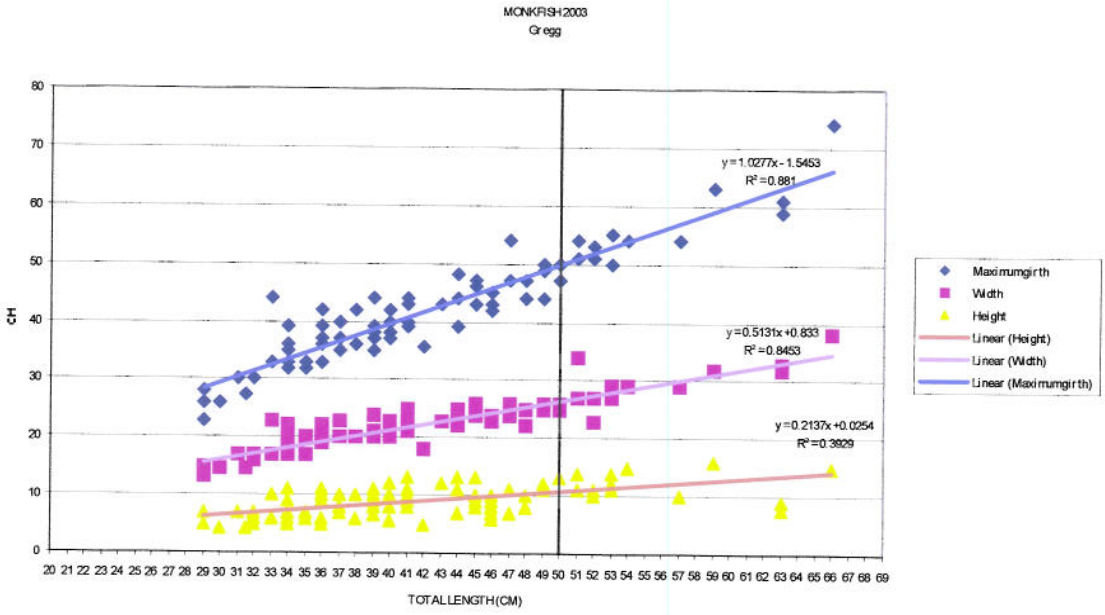
Morphometric measurements of monkfish were taken during 8 selectivity trips in July 2003. The Total Length (TL) Maximum Girth (MG), Width (W) and Height (H) of 233 monkfish were measured to the nearest cm. Data were pooled from 2 sets of observations.

Linear regressions were computed, relating MG, W and H to TL. The above chart shows the regression plots, with the relative regression lines and equations. The R^2 (coefficient of determination) ranges from 0 to 1 and indicates how closely the estimated values of the regression (trend-line) match the actual data. Values close to 1 indicate a good match, as in the case of MG.

For monkfish ranging from 48 to 52 cm TL, the Mean, Standard Error, Median and Mode of MG, W and H were also calculated, as shown in the above table. These descriptive statistics are helpful in visualizing the actual measurements of fish around the minimum landing size (MLS) set at 48 cm, since the overall objective of the project was to design a codend that would release undersize monkfish, while retaining marketable ones.

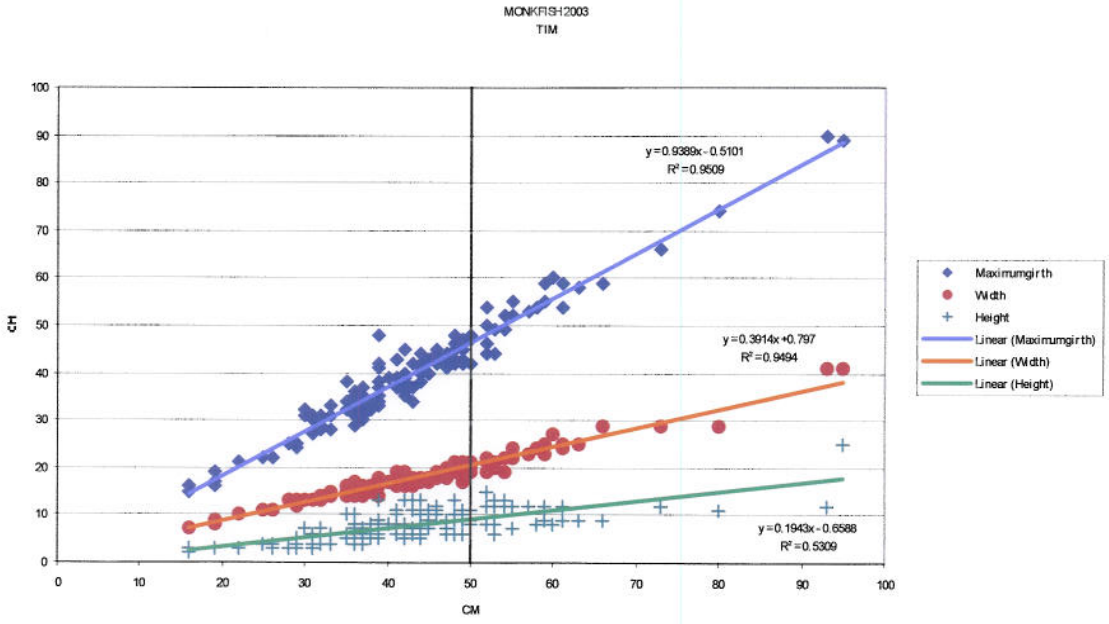
On this basis, it seems reasonable to design a mesh with an opening of 20x10cm, in order to release below MLS monkfish.

While entering and computing the data, a discrepancy in the morphometric measurement taken by different observers was noticed, so the data from these 2 sources was also examined separately. The first set includes measurements from 81 monkfish. The measurements in this set seem to show larger W and H, in relation to TL, than in the pooled data. To accommodate these fish, a mesh with a larger opening might be required. However, it is worth noting that the fish ranging between 48 and 52 cm were few in this set.



TOTAL LENGTH		MAX GIRTH		WIDTH		HEIGHT	
Mean	49.90909	Mean	49.09091	Mean	25.90909	Mean	11.27273
Standard Error	0.435985	Standard Error	0.995029	Standard Error	0.928876	Standard Error	0.50616
Median	50	Median	50	Median	25	Median	11
Mode	49	Mode	44	Mode	25	Mode	11

The second set includes measurements from 151 fish. These seem to represent a sample of fish with smaller W and H, in relation to TL, than the pooled samples. The discrepancy is most likely due to different measuring techniques. The pooled samples probably offer the best set of measurements to use to design the new more selective meshes.



TOTAL LENGTH		*MAX WIDTH*		*WIDTH*		*HEIGHT*	
Mean	49.52632	Mean	45.73684	Mean	19.57895	Mean	9.631579
Standard Error	0.345128	Standard Error	0.691816	Standard Error	0.279052	Standard Error	0.502686
Median	49	Median	45	Median	19	Median	9
Mode	48	Mode	45	Mode	19	Mode	9

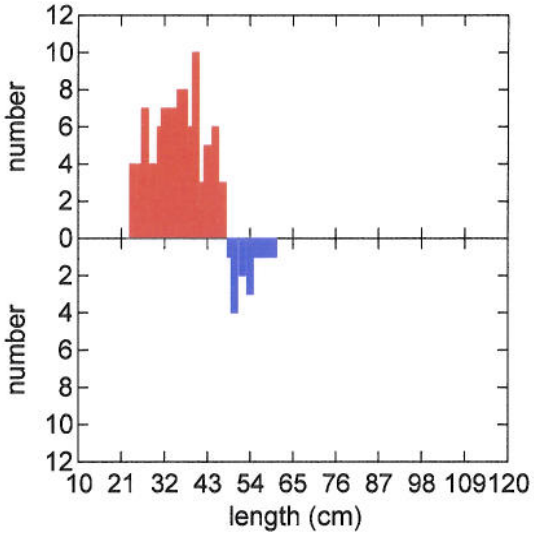
APPENDIX 2

2003

Monkfish

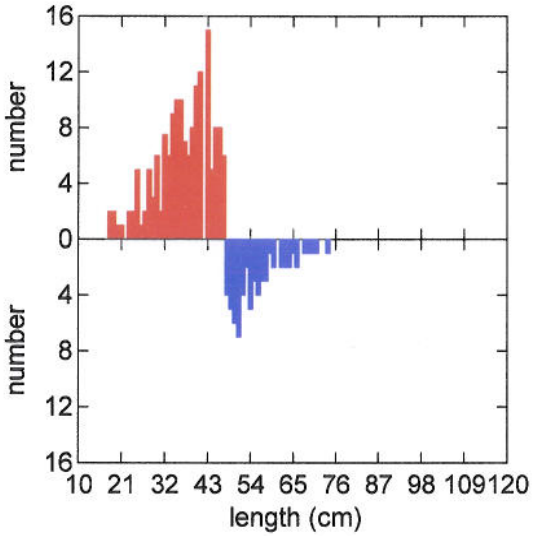
TFM01

Haul 1



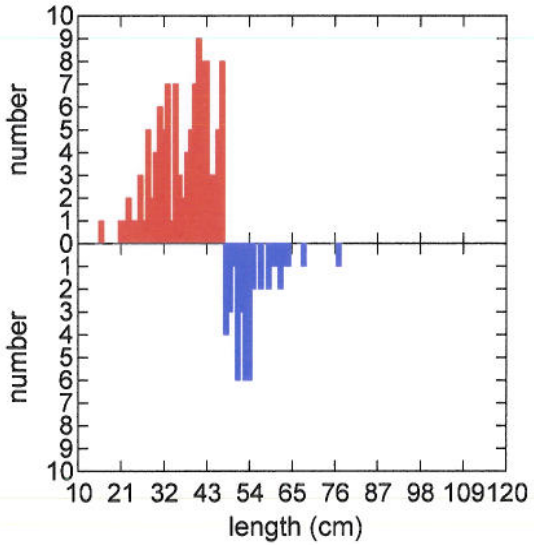
DISPOSITION
- discard
- kept

Haul 2



DISPOSITION
- discard
- kept

Haul 3

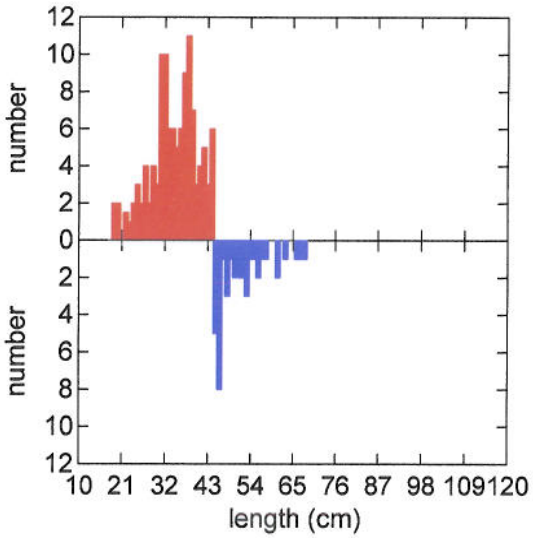


DISPOSITION
- discard
- kept

Monkfish

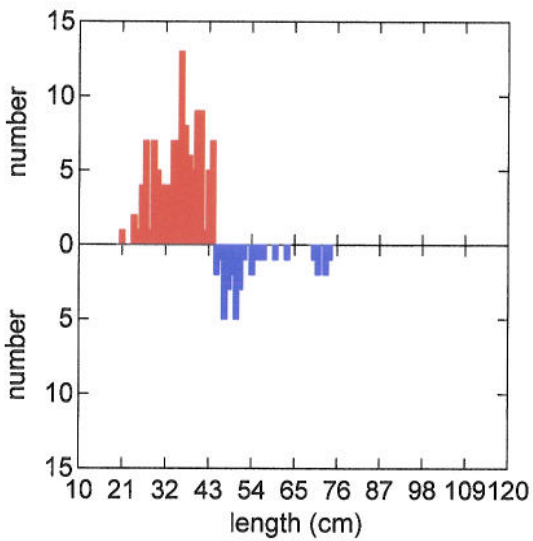
TFM02

Haul 1



DISPOSITION
- discard
- kept

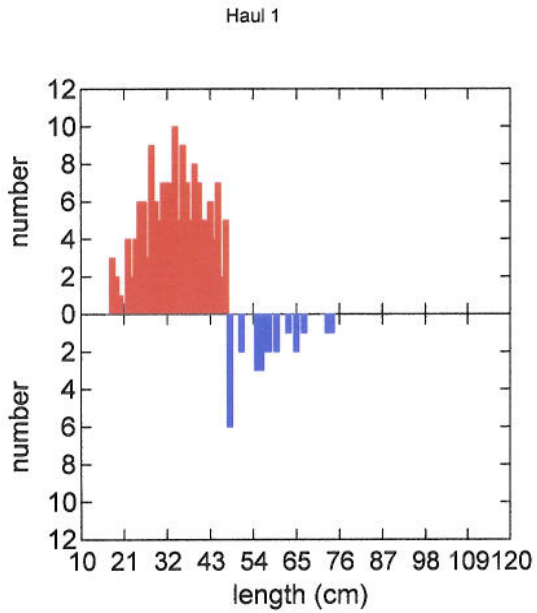
Haul 2

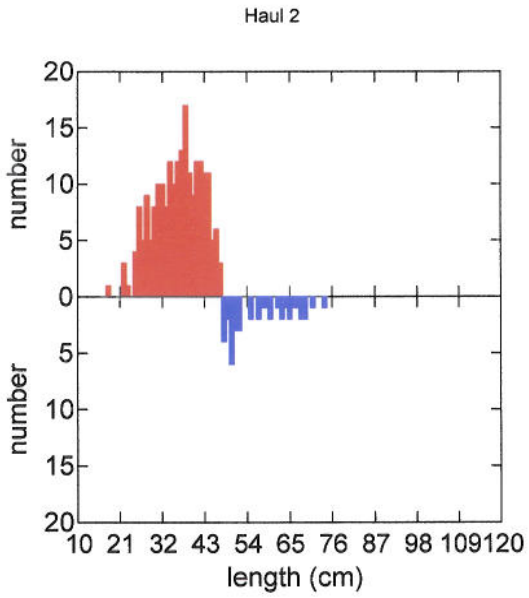


DISPOSITION
- discard
- kept

Monkfish

C16M01

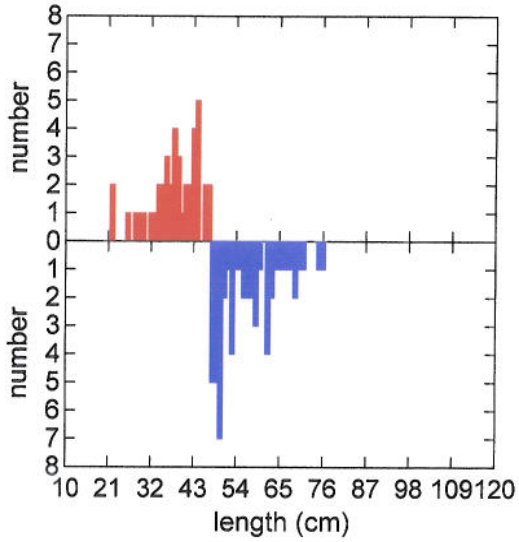




Monkfish

C16M02

Haul 1



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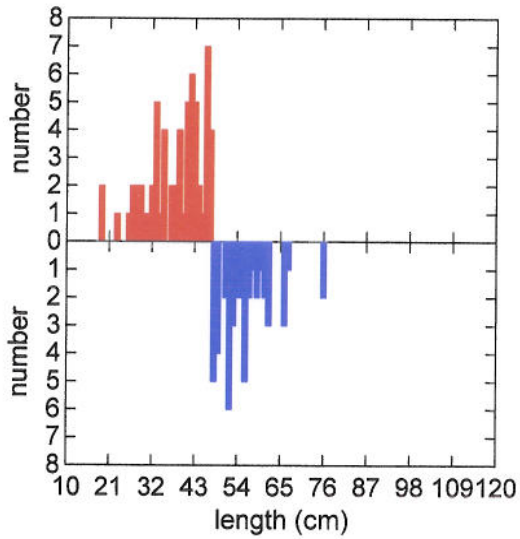
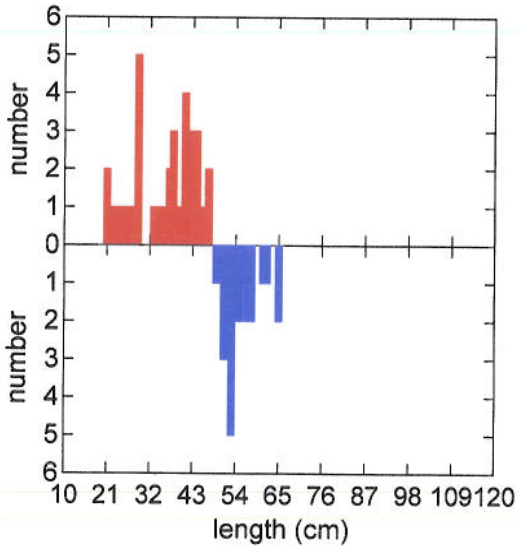


Haul 3

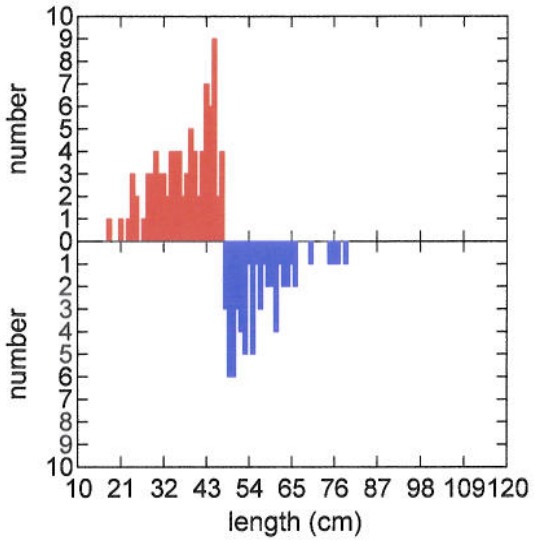


DISPOSITION
- discard
- kept

Monkfish

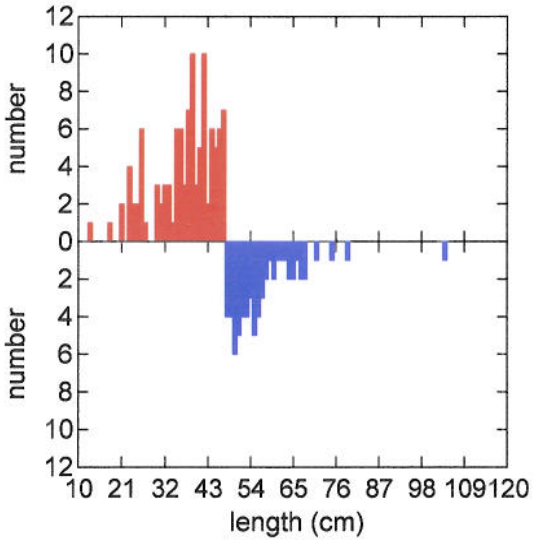
C16M03

Haul 1



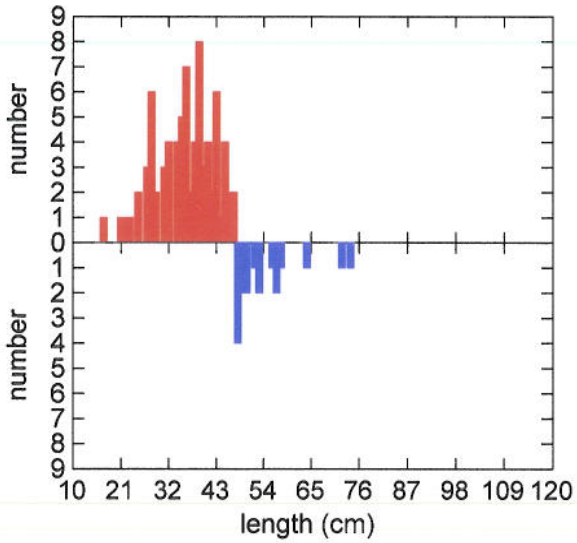
DISPOSITION
discard
kept

Haul 2



DISPOSITION
discard
kept

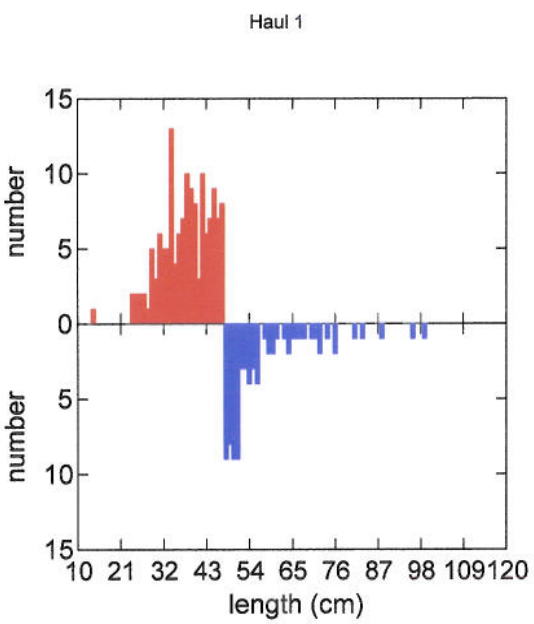
Haul 3

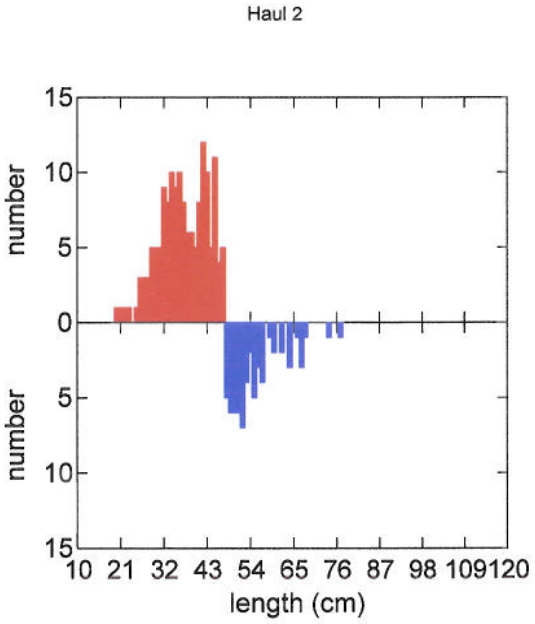


DISPOSITION
discard
kept

Monkfish

C16M04





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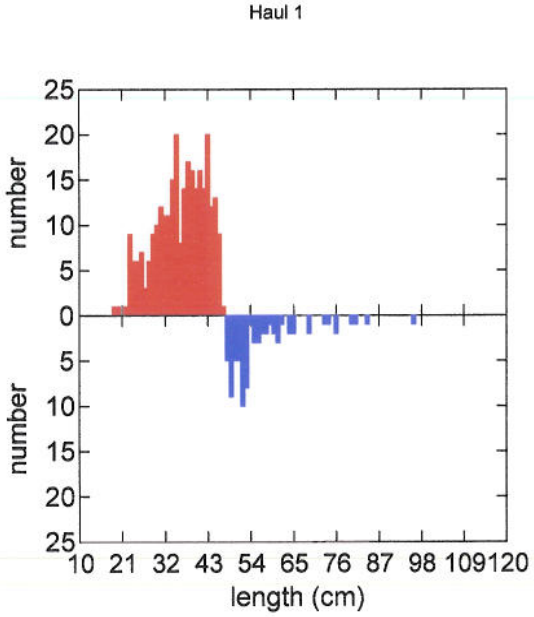
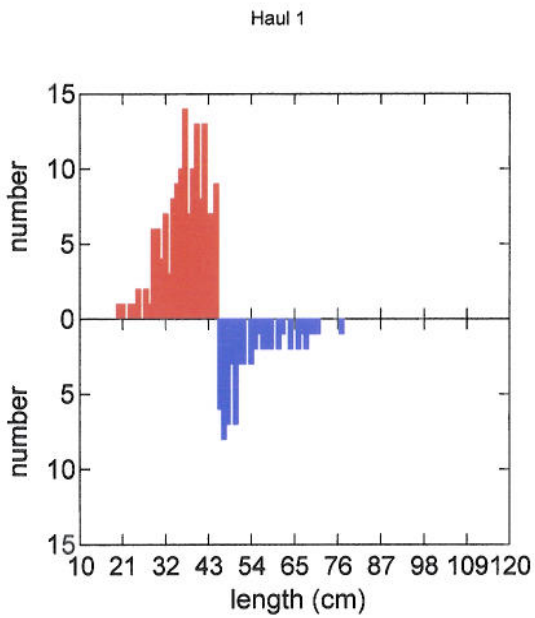
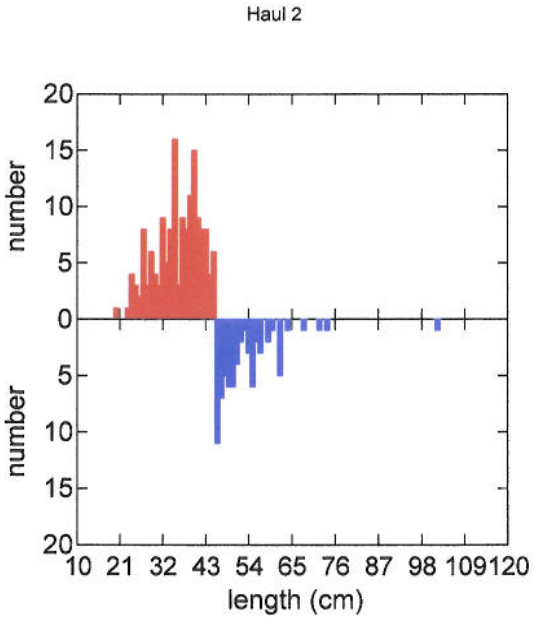


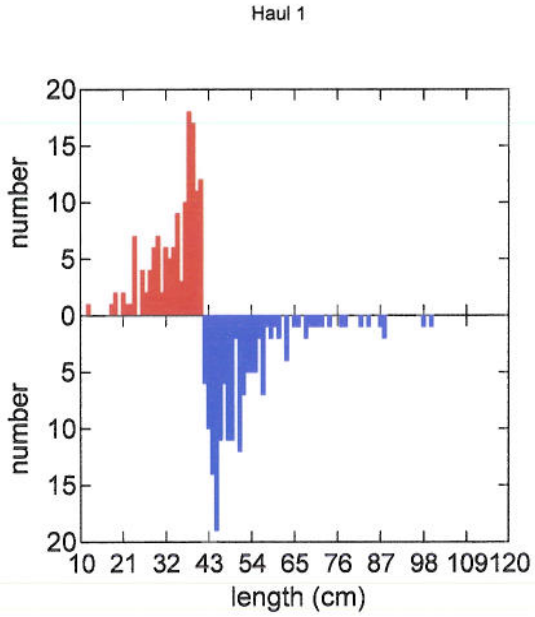
Monkfish

C16M06



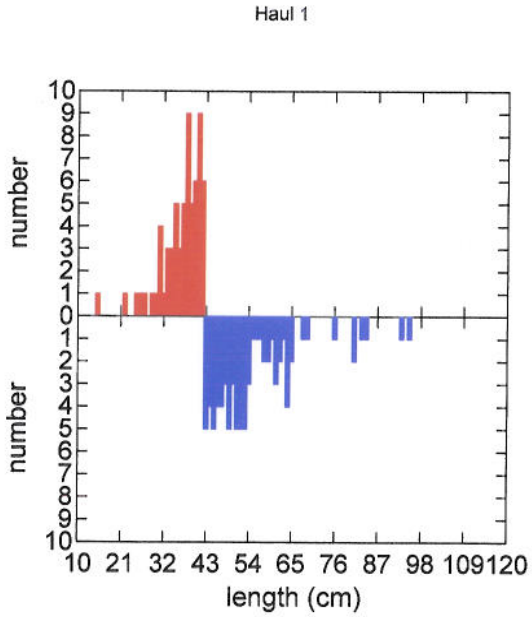


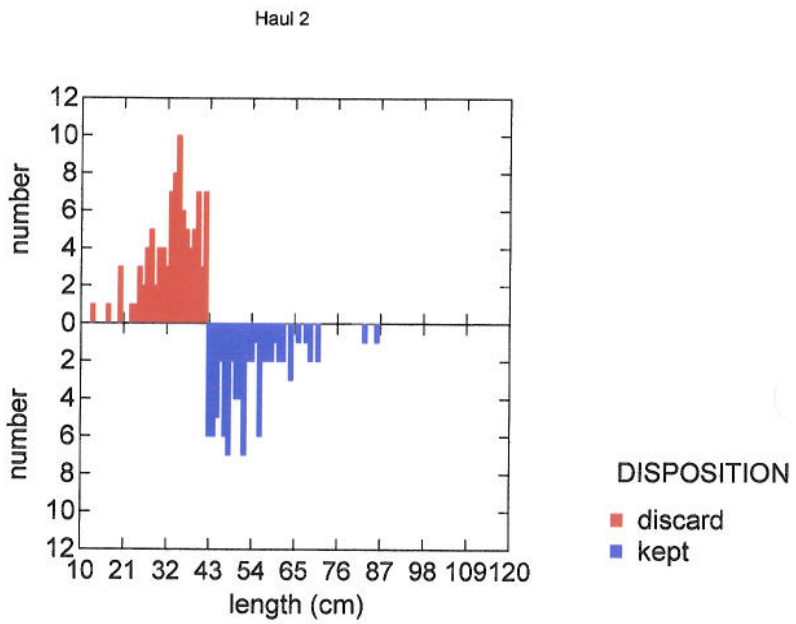
C16M07



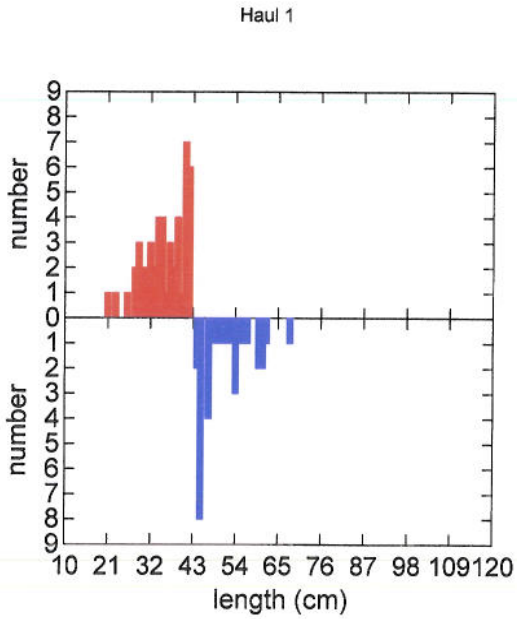
Monkfish

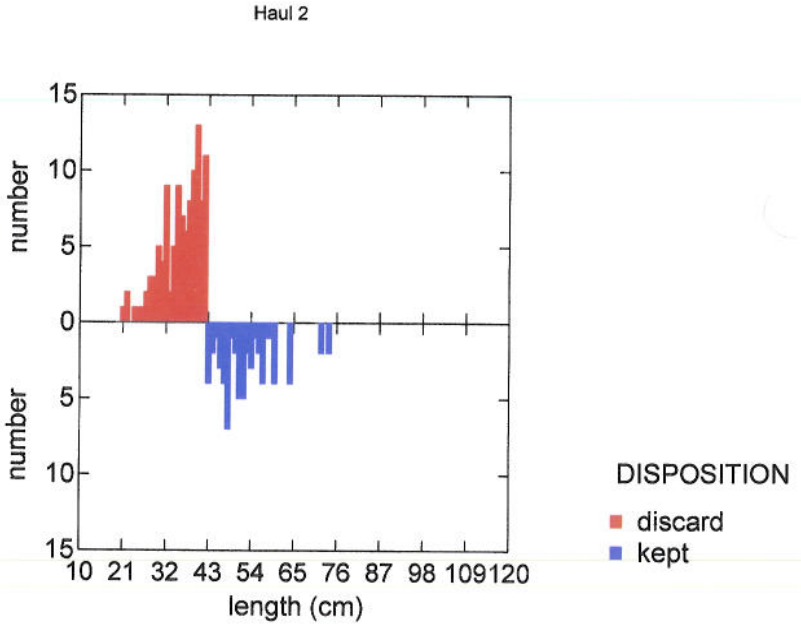
C16M08



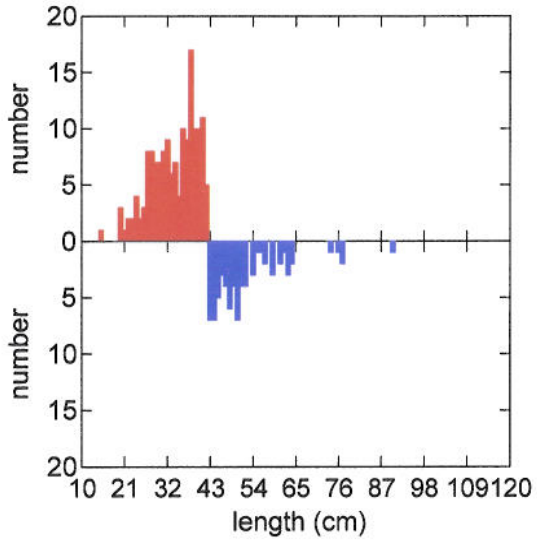


C16M09





Haul 1



Monkfish

C16M10

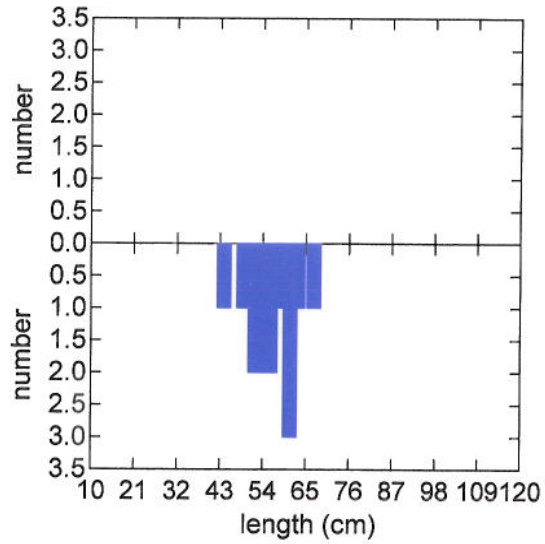
DISPOSITION

- discard
- kept

Monkfish

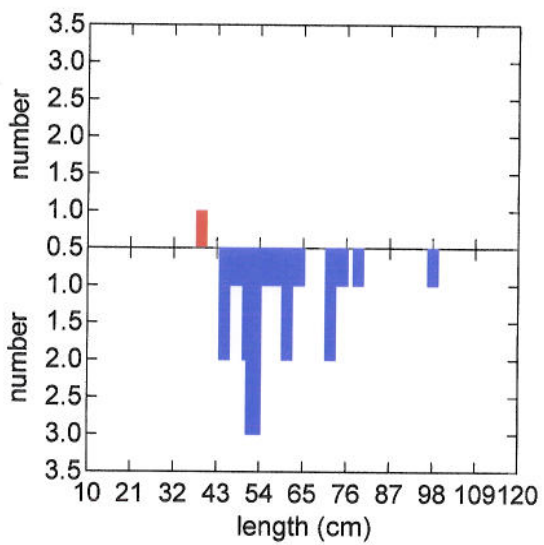
D05M01

Haul 1



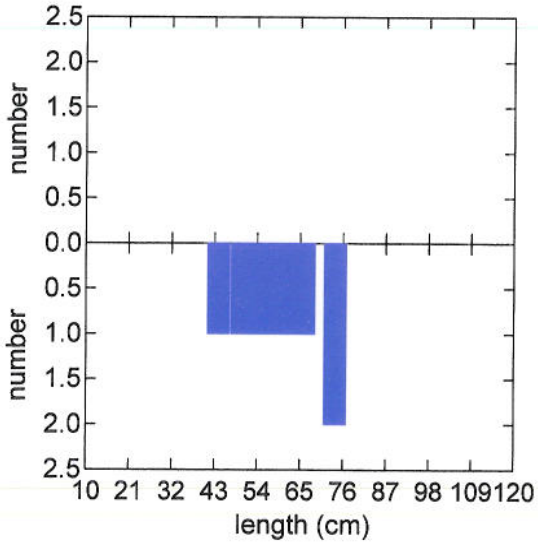
DISPOSITION
- discard
- kept

Haul 2



DISPOSITION
- discard
- kept

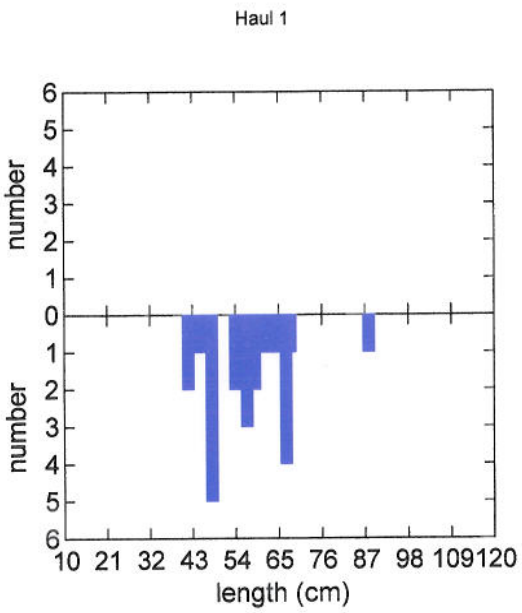
Haul 3



DISPOSITION
- discard
- kept

Monkfish

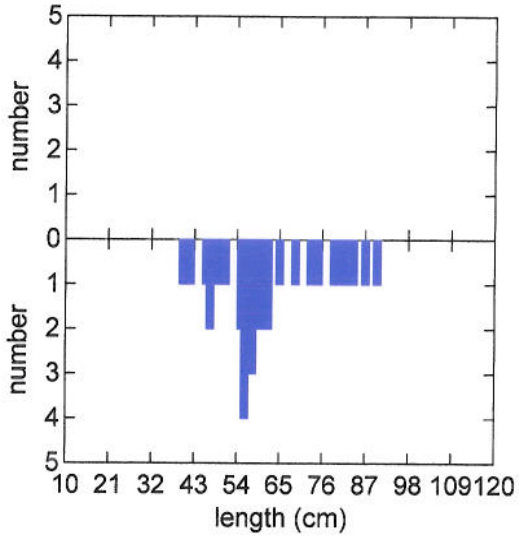
D05M02



Monkfish

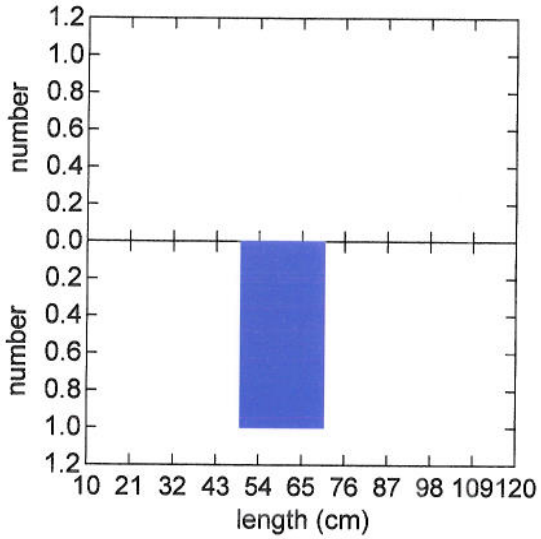
D05M03

Haul 1



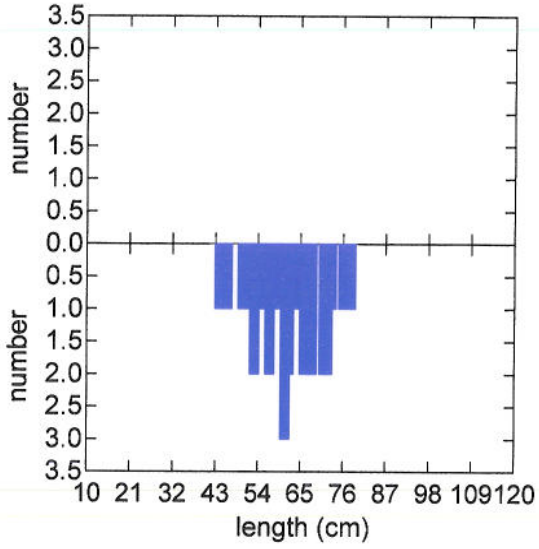
DISPOSITION
- discard
- kept

Haul 2



DISPOSITION
- discard
- kept

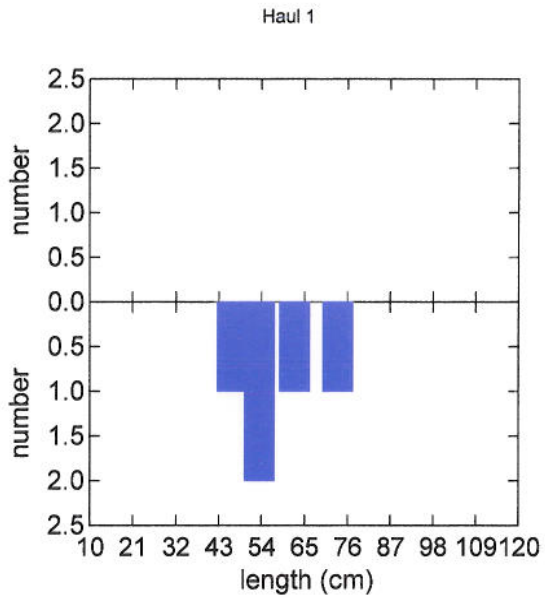
Haul 3



DISPOSITION
- discard
- kept

Monkfish

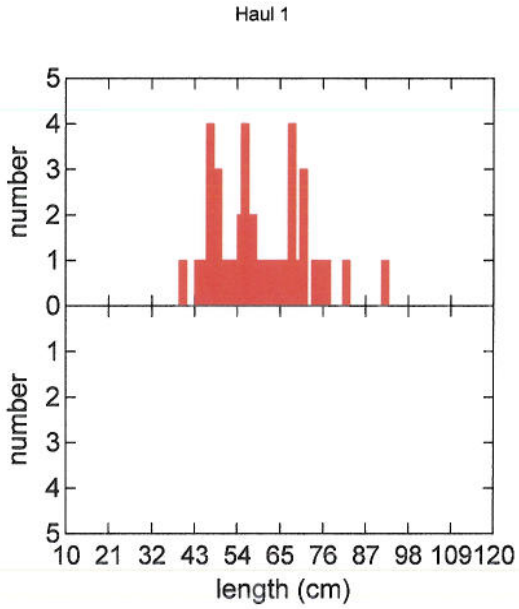
D05M04



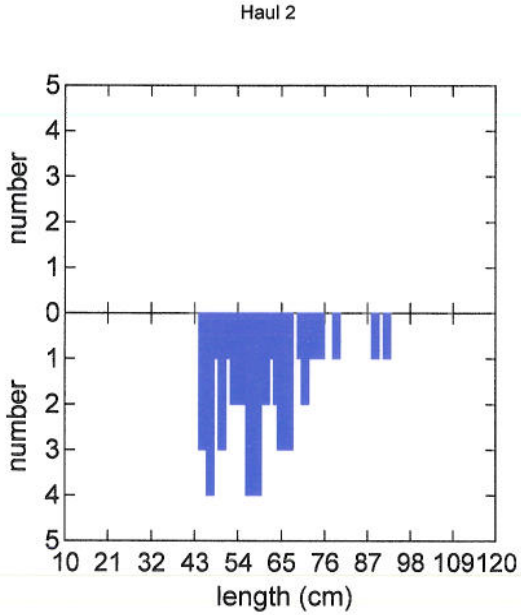
DISPOSITION
- discard
- kept

Monkfish

D05M05



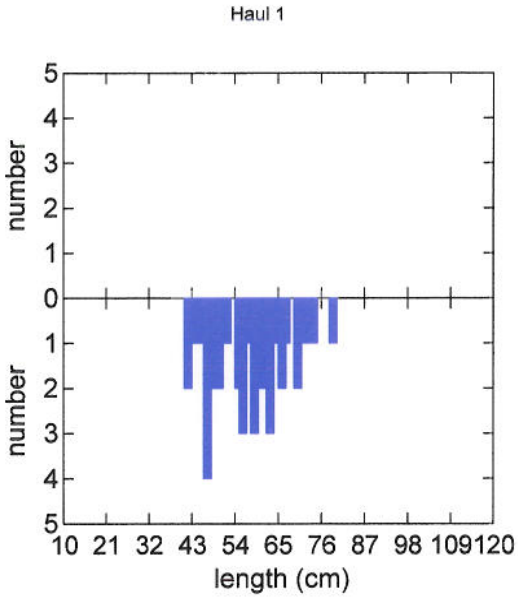
DISPOSITION
- discard
- kept



DISPOSITION
- discard
- kept

Monkfish

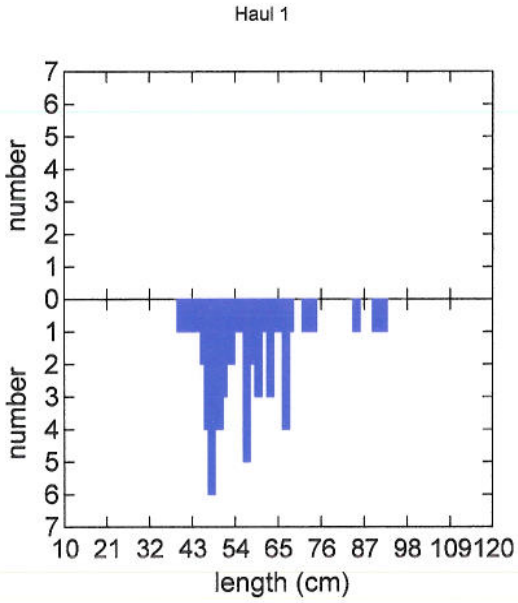
D05M06



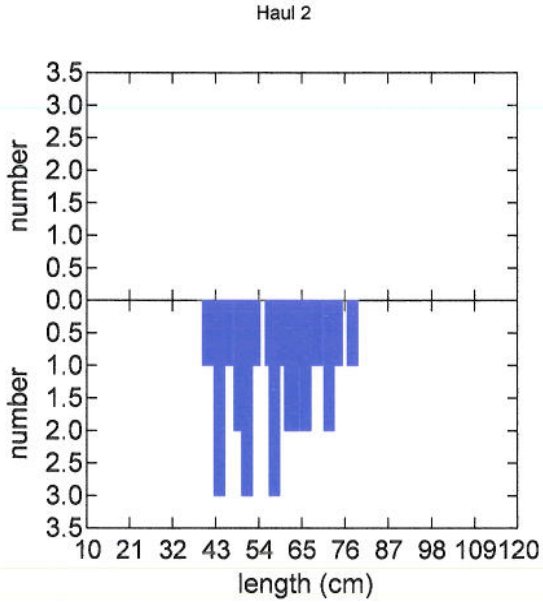
DISPOSITION
- discard
- kept

Monkfish

D05M07



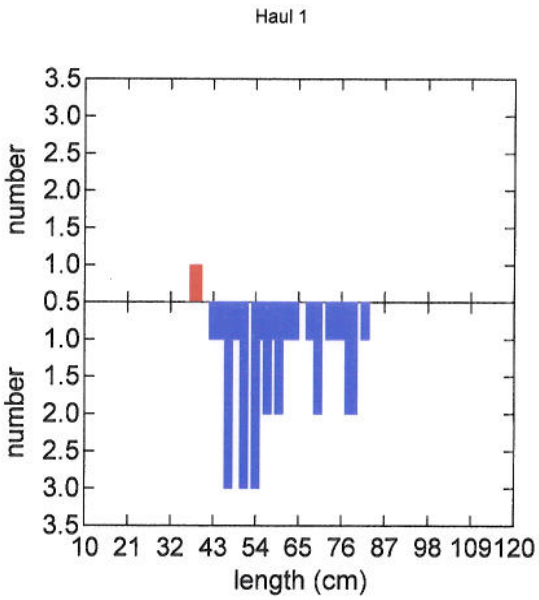
DISPOSITION
- discard
- kept



DISPOSITION
- discard
- kept

Monkfish

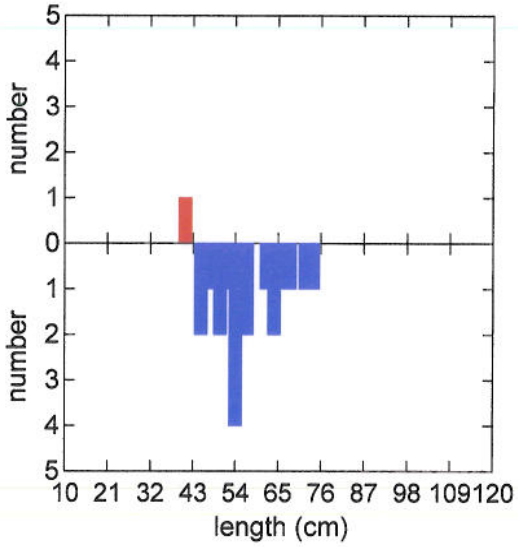
D05M08



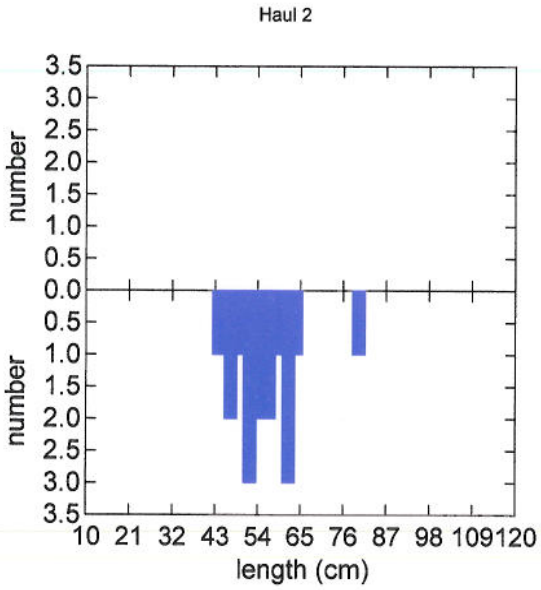
DISPOSITION
- discard
- kept

Monkfish

D05M09



DISPOSITION
- discard
- kept

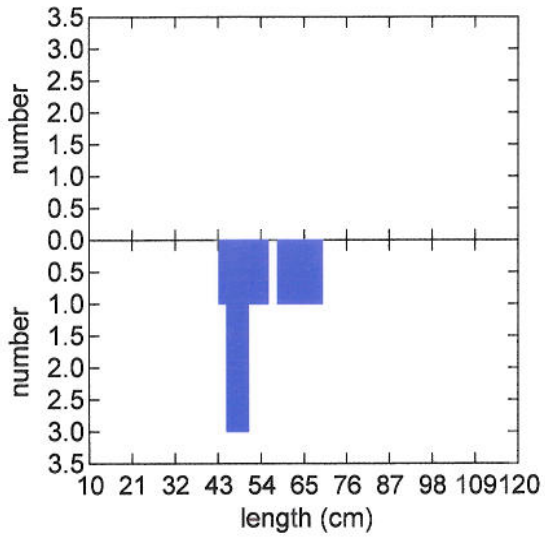


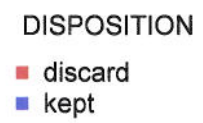
DISPOSITION
- discard
- kept

Monkfish

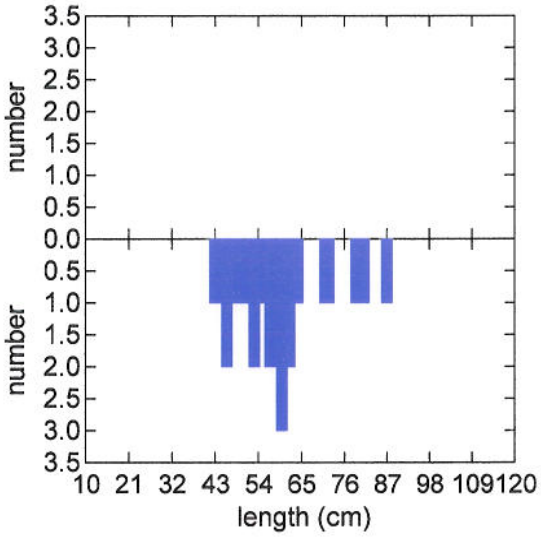
D05M10

Haul 1

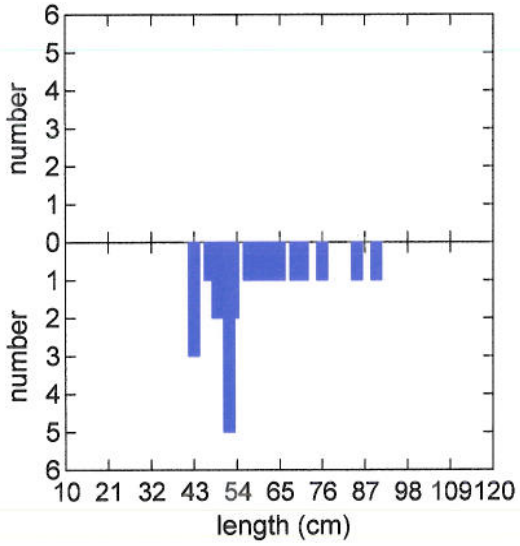




Haul 2

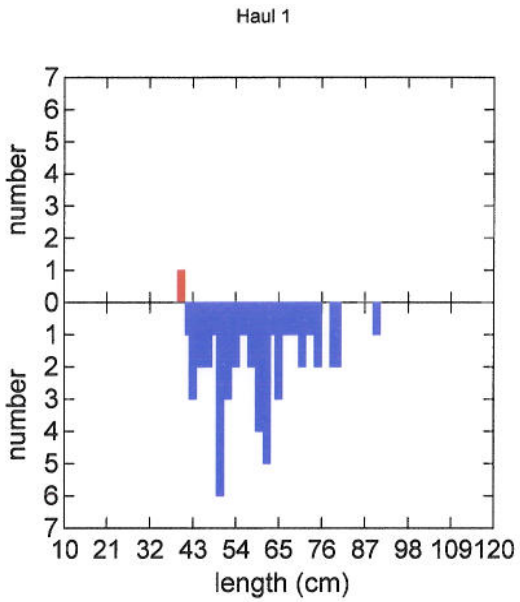


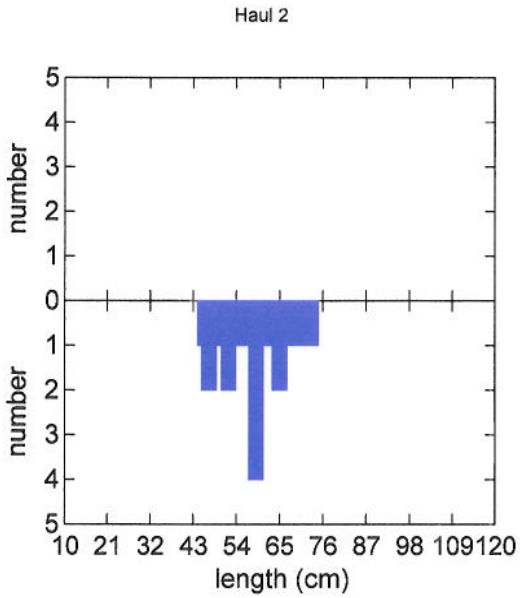
Haul 3



Monkfish

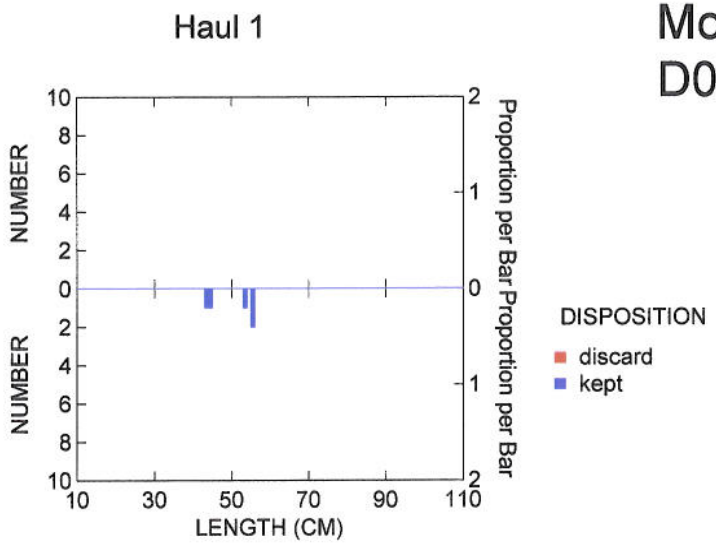
D05M11

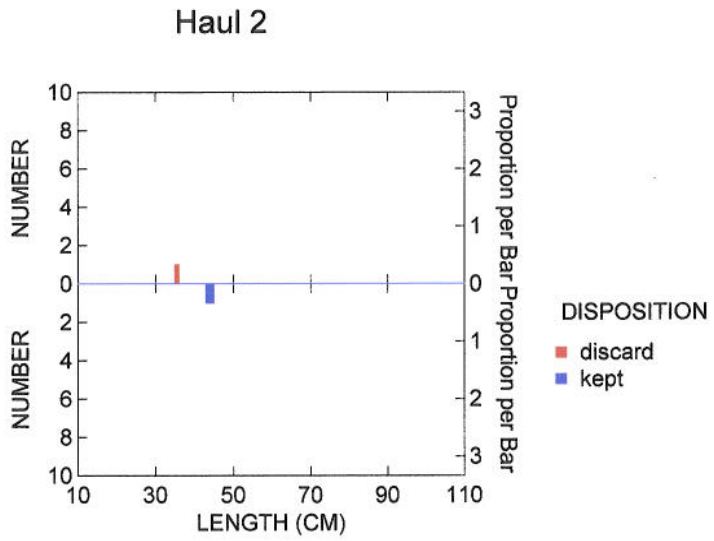




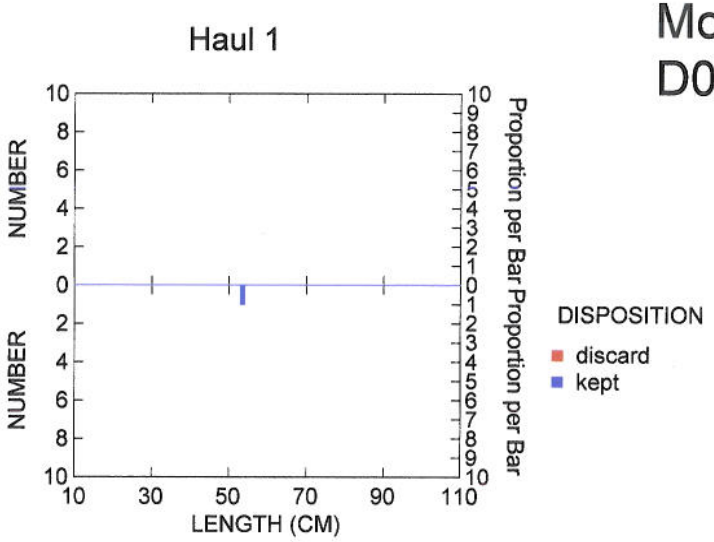
2004

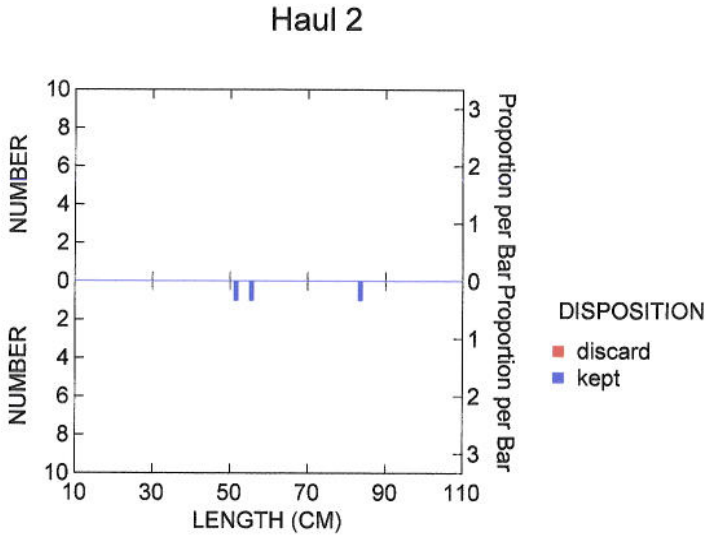
Monkfish
D05M12



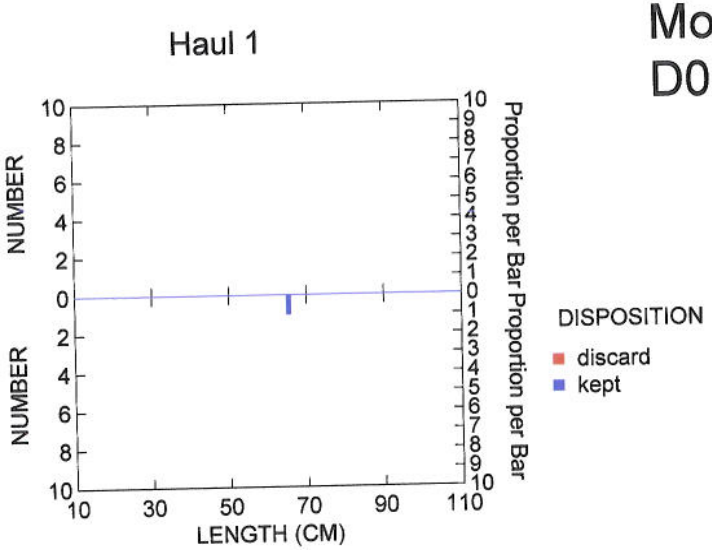


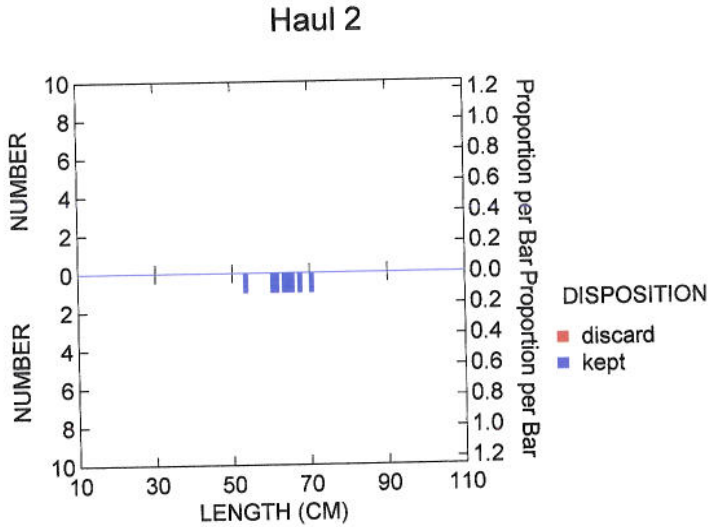
Monkfish
D05M13



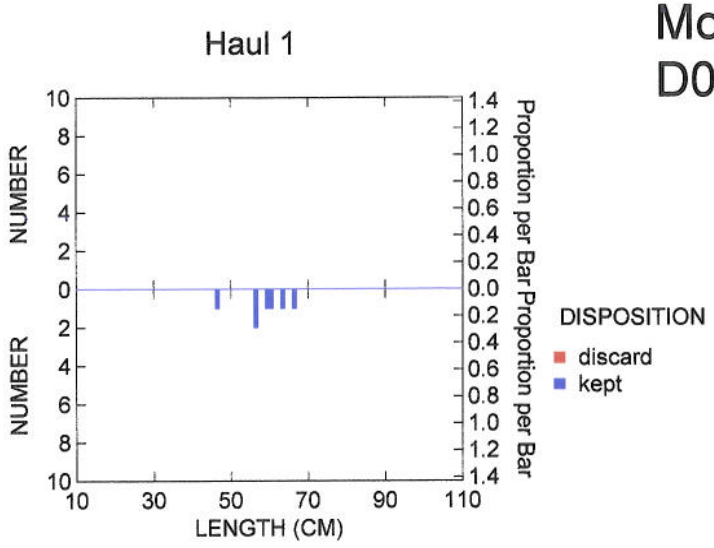


Monkfish
D05M14





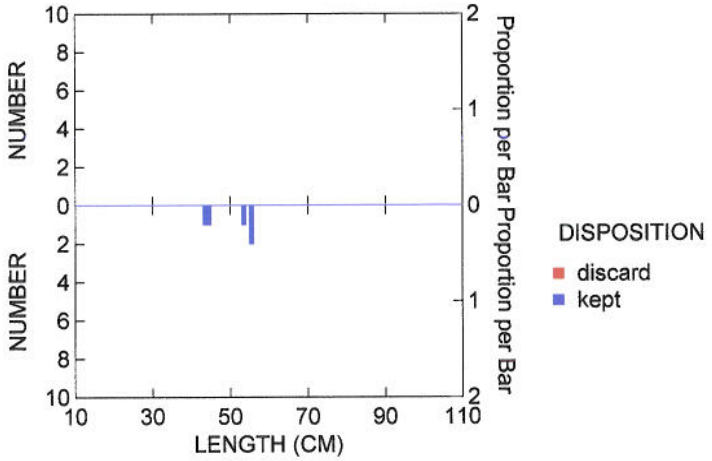
Monkfish
D05M15



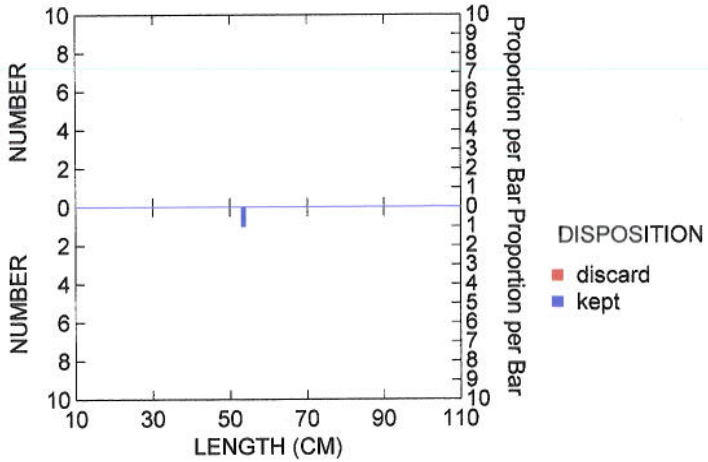
Haul 1
No Monkfish

Monkfish
D05M16

Haul 2

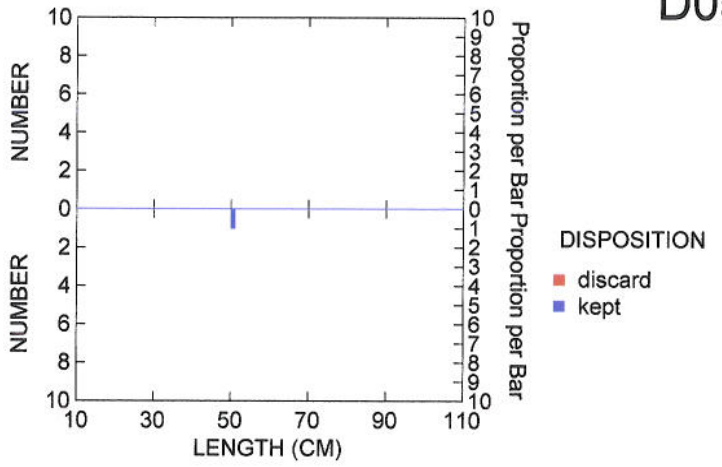


Haul 3

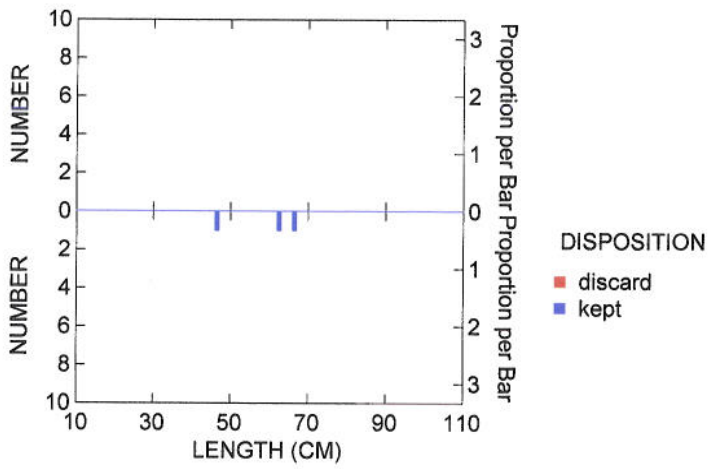


Monkfish
D05M17

Haul 1

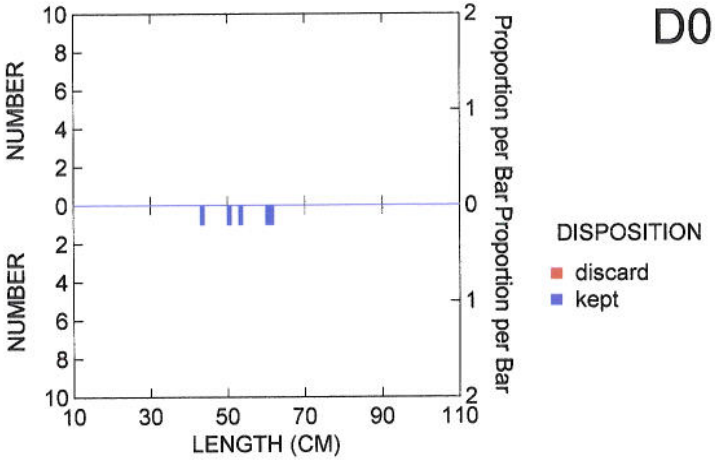


Haul 2

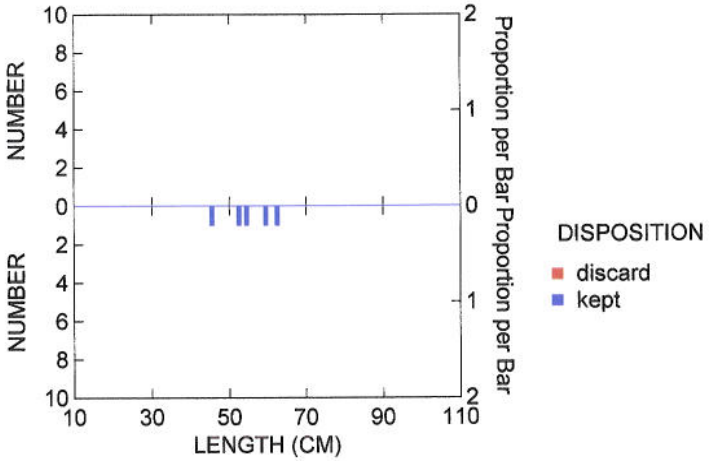


Monkfish
D05M18

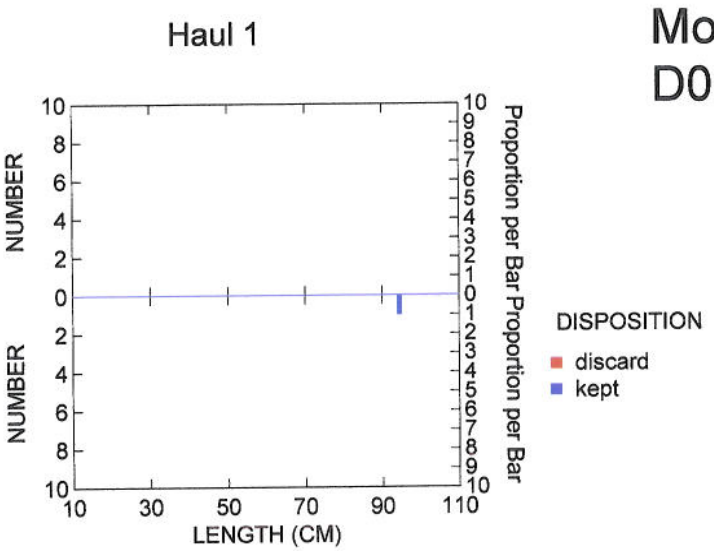
Haul 1

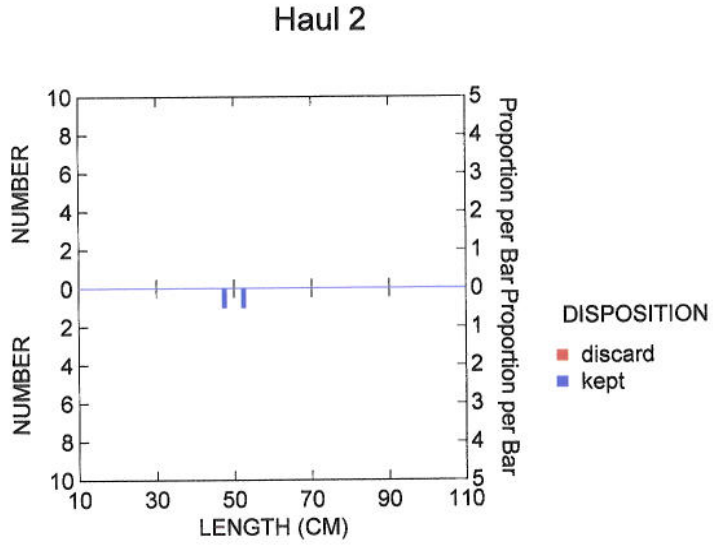


Haul 2



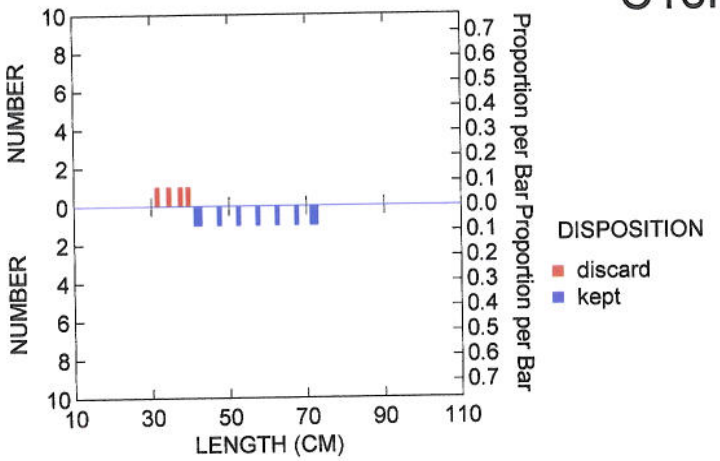
Monkfish
D05M19



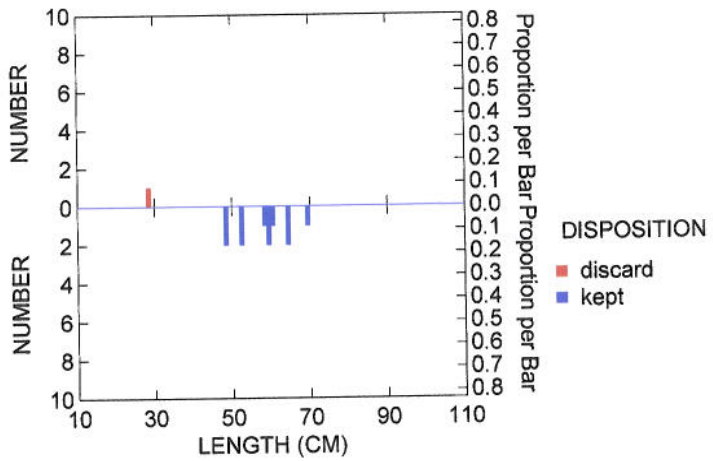


Monkfish
C16M11

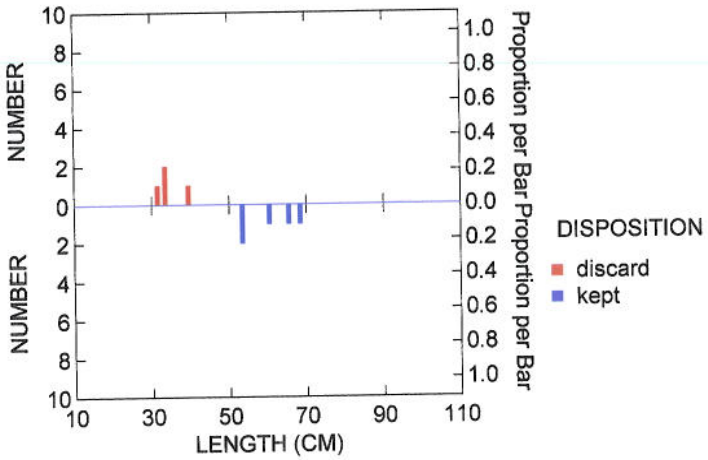
Haul 1



Haul 2

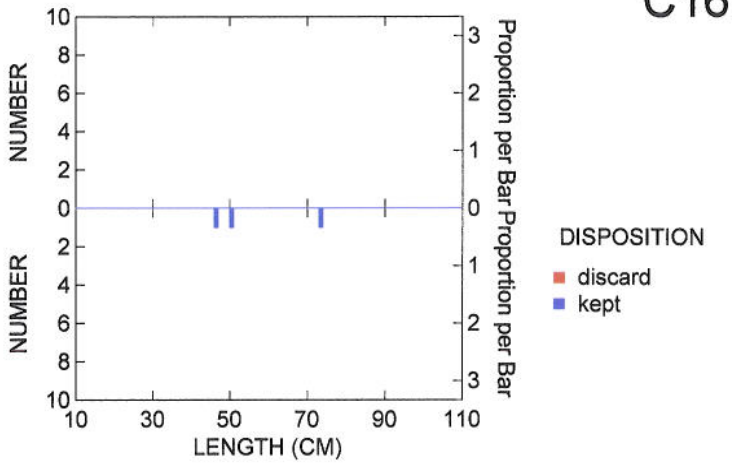


Haul 3

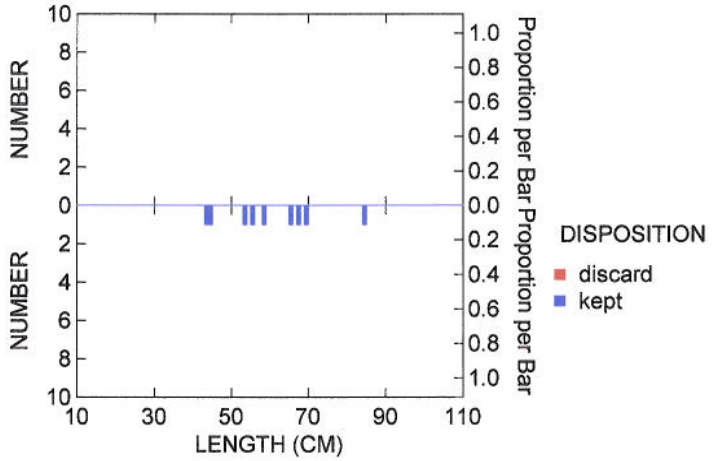


Monkfish
C16M12

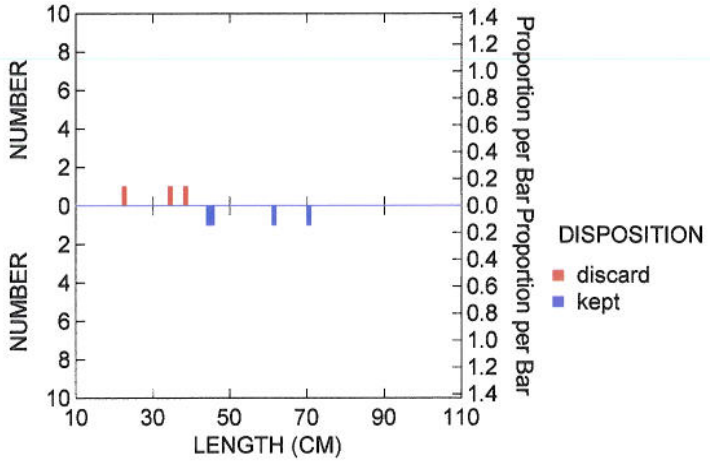
Haul 1



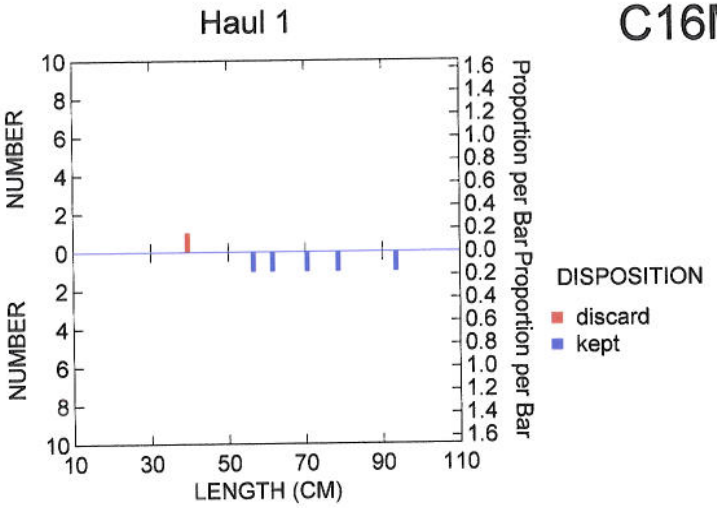
Haul 2

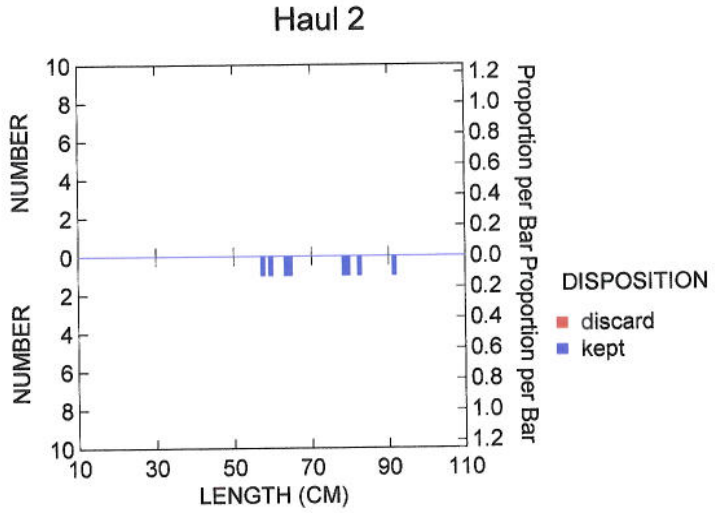


Haul 3

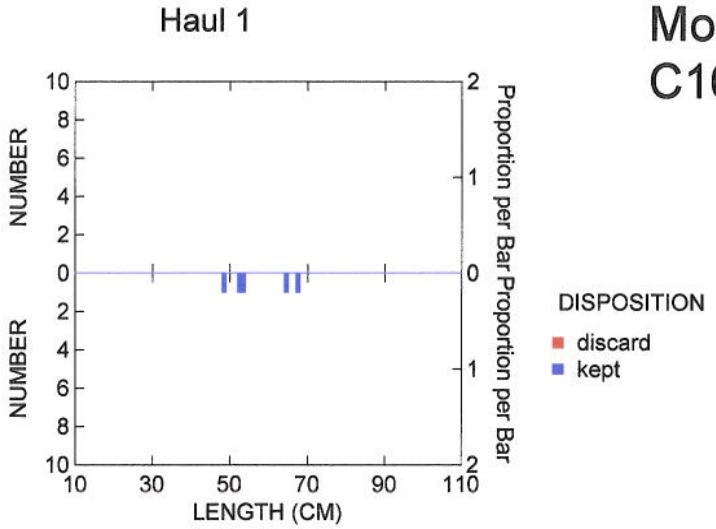


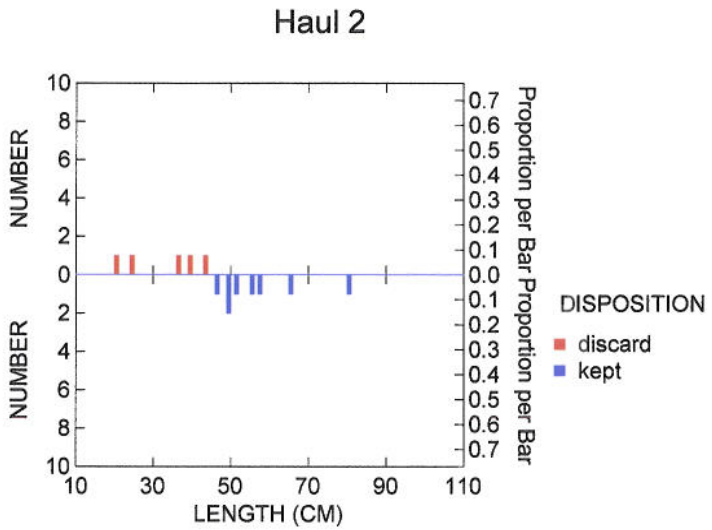
Monkfish
C16M13



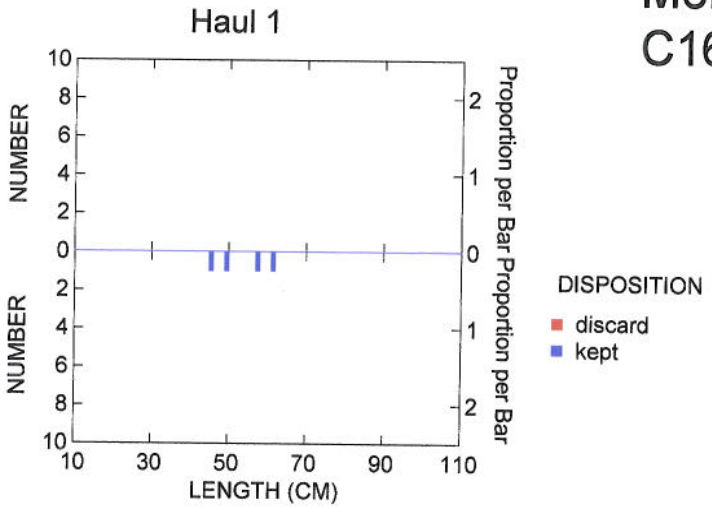


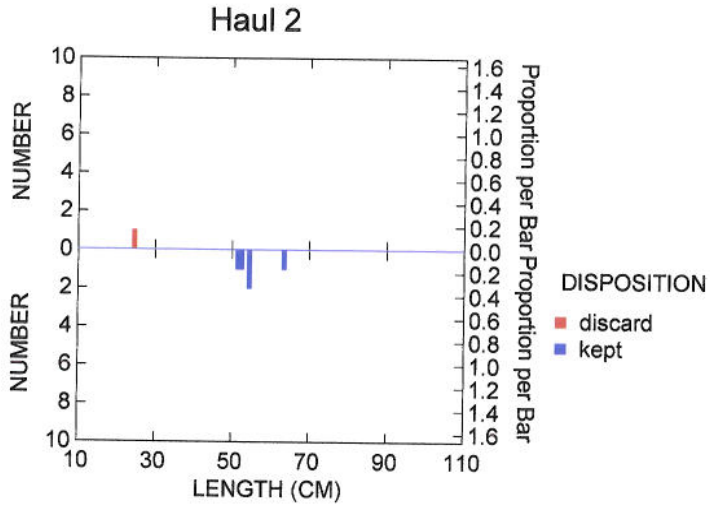
Monkfish
C16M14



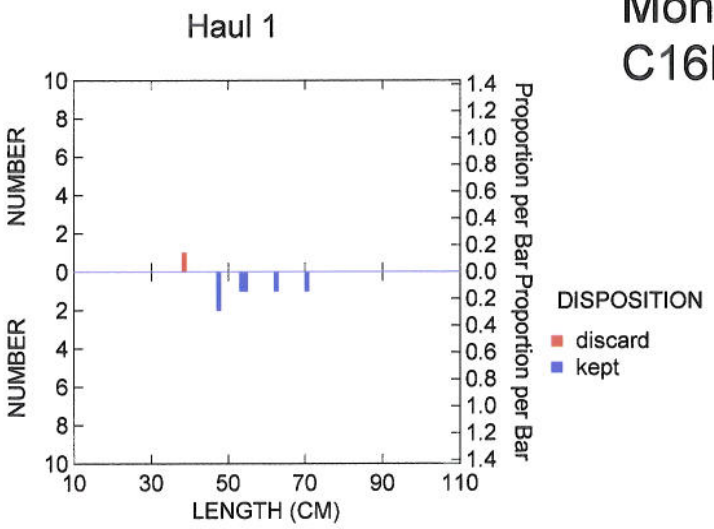


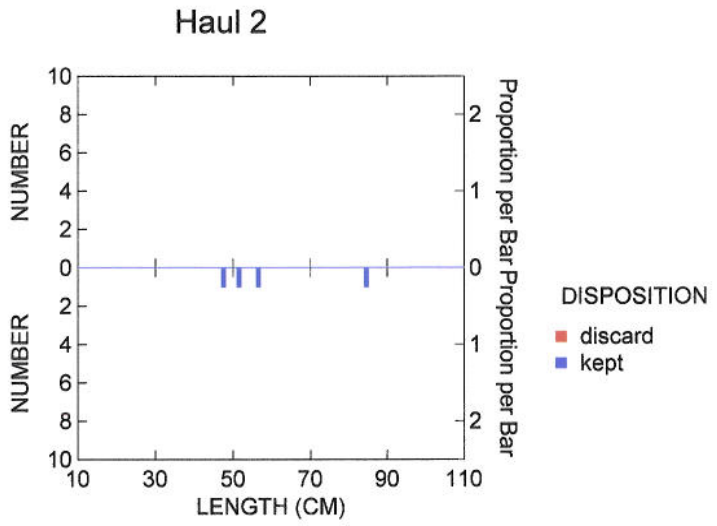
Monkfish
C16M15

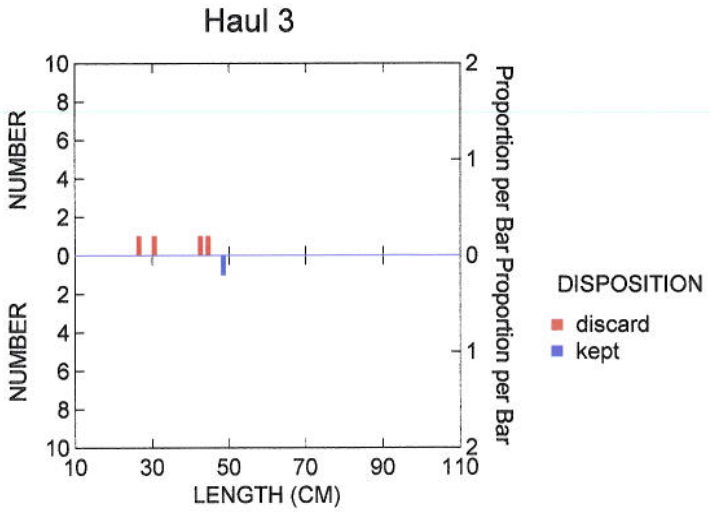




Monkfish
C16M16

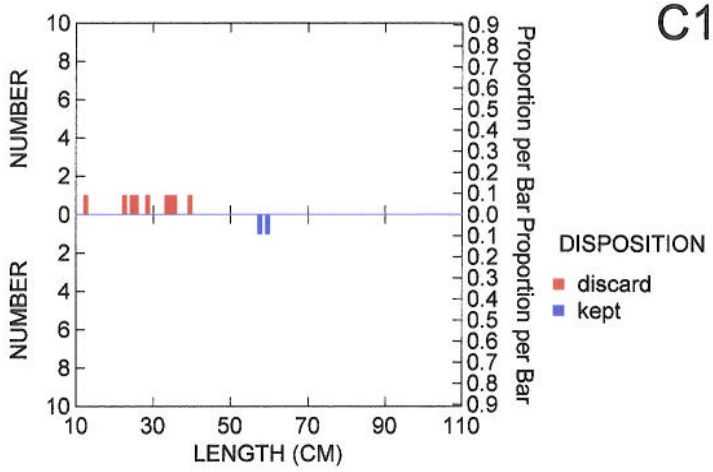




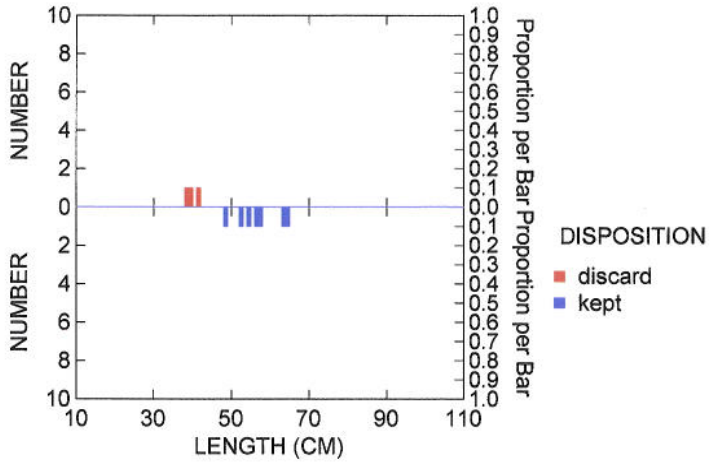


Monkfish C16M17

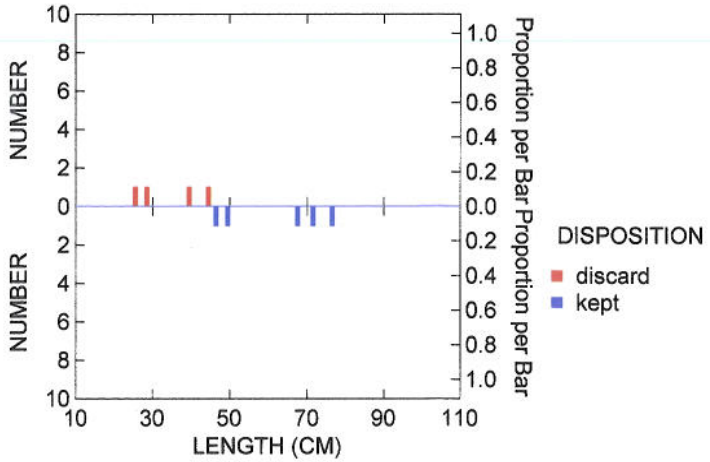
Haul 1



Haul 2



Haul 3



Monkfish
C16M18