Preliminary Results of the 2009 NMFS – BSFRF Snow Crab Net Efficiency Study (Jointly Released by NMFS Alaska Fisheries Science Center and Bering Sea Fisheries Research Foundation)

September 4, 2009

The NMFS Alaska Fisheries Science Center Resource Assessment and Conservation Engineering Division's Groundfish Assessment Program, in partnership with the Bering Sea Fisheries Research Foundation, conducted a field experiment to estimate the net efficiency (i.e. proportion of the animals in the trawl swept area that are captured) of the NMFS standard Bering Sea 83/112 survey trawl for snow crab *Chionoecetes opilio*. Similar field work by NMFS to address *opilio* catchability was done previously (Somerton and Otto, 1999. Net efficiency of a survey trawl for snow crab and Tanner crab. Fish. Bull. 97:617-625), however, the underbag methodology used in that previous study did not work well in the muddy areas inhabited by snow crab, so sampling could not be done randomly over the entire species distribution. Because of concerns about the potential bias of the net efficiency estimates produced by using an underbag, a new approach was tried at the end of the 2009 annual eastern Bering Sea bottom trawl survey, using a modified version of the survey trawl that initially included a tickler chain in front of the footrope, 37 kg of additional chain (7.9 m) strung along the center of the footrope, and a fine-mesh liner to capture all of the crabs in the trawl path. The modified trawl was not intended to be a replacement for the standard 83/112 trawl but to provide absolute density estimates of snow crab that could be used as the basis to compute the net efficiency of the standard trawl. Before beginning the experiment, the modified NMFS trawl was tested in the experimental area using a 15 minute tow, but the catch rate was so high that the weight tore the netting away from the head and foot ropes. Since the vessel carried only one additional modified trawl, the decision was made to remove the tickler chain, and shorten the length of the tow from 15 to 5 minutes.

The 2009 field experiment was designed and conducted as a three vessel trawl comparison consisting of: the NMFS chartered *F/V Arcturus* towing the standard 83/112 survey trawl, the NMFS chartered *F/V Aldebaran* towing the NMFS modified survey trawl and the BSFRF chartered *F/V American Eagle* towing a trawl designed for the European *nephrops* fishery. The NMFS modified trawl, with the ad hoc changes in design and fishing protocols, was used in the 24 triplicate side-by-side tows of the experiment involving the three gear types to determine

snow crab net efficiency. Exhibit 1 shows the location of the comparative tow work on Bering Sea snow crab grounds.

The first question considered was whether the modified survey trawl and the *nephrops* trawl estimated the same density of snow crab in each category. This question is important because the most unbiased estimate of density is needed to calculate the net efficiency of the standard 83/112 survey trawl. Thus, if the *nephrops* trawl produced a higher density, then its CPUE should be used as the basis for this calculation. For each of the categories, we therefore tested the hypotheses of equality in the CPUE (thousands of crabs per unit swept area) between the modified survey trawl and the *nephrops* trawl (Exhibit 2). Positive values of the test statistic (BSFRF CPUE – NMFS CPUE) and probability levels <0.05 indicate that the BSFRF net efficiency was higher. Crab catch data were divided into five size-sex categories, matching those used in the NMFS Annual Crab Report to Industry, in the following analysis of the experimental data. For all categories, the *nephrops* trawl caught significantly more crabs than the modified survey trawl. Exhibits 3-4 demonstrate the size frequencies of the captured crab by sex taken by each vessel.

The net efficiency of the standard 83/112 survey trawl was then estimated for each category assuming that the *nephrops* trawl caught everything in the tow path (i.e. CPUE of the standard 83/112 trawl divided by the CPUE of the BSFRF trawl averaged over all 24 tows). These values are substantially lower than those found in the previous snow crab net efficiency study. For the large males, for example, the previous estimate is approximately 0.80 while the new estimate is 0.35. This indicates that the standard 83/112 survey trawl has substantial escapement under the footrope of even the largest sizes of snow crab. Exhibits 5-9 provide tabular catch results in numbers of crab caught per square nautical mile by vessel/gear type and net efficiency estimates for each of the five size/sex categories. Exhibits 10-14 provide a graphic presentation of snow crab densities from each of the 24 triplicate tows by the same five size/sex categories and Exhibit 15 provides a summary of snow crab densities derived across the 24 triplicate tows by the same five size/sex categories. Exhibit 16 provides a summary of the NMFS standard 83/112 trawl net efficiency by size and sex category compared to the BSFRF *nephrops* trawl.

The results of this study as described above will be released to the public and to the North Pacific Fishery Management Council's Crab Plan Team meeting on September 14, 2009. Results will also be provided to the snow crab assessment authors for evaluation of the results on the snow crab assessment model during the next crab assessment cycle.

Exhibit 1. Chart showing locations of comparative tows for net efficiency experiment.

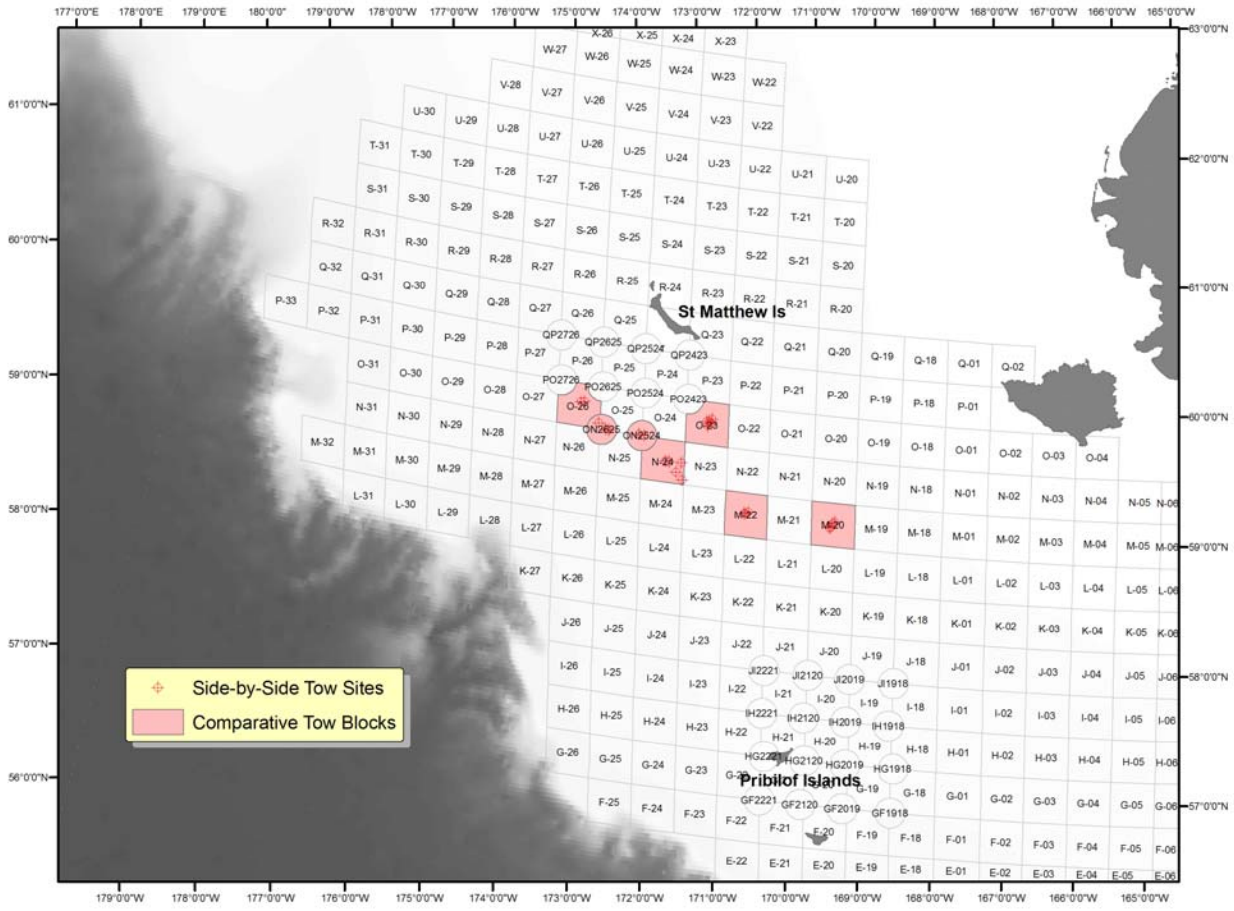


Exhibit 2. One-sample t-Test statistics for comparison of the snow crab CPUEs obtained by the NMFS modified trawl and the BSFRF trawl (BSFRF CPUE - NMFS CPUE). A positive *t*-value and a *p*-value less than 0.05, indicates that the BSFRF trawl was more efficient.

Snow crab length class (chelae width)	t	df	*p*-value
Large male (≥102 mm)	3.2323	23	0.0037
Medium male (78-101 mm)	5.1537	23	0.0000
Small male (<78 mm)	4.3412	23	0.0002
Large female (≥50mm)	2.4048	23	0.0246
Small female (<50mm)	3.5874	23	0.0016

Exhibit 3. Length frequencies of male *opilio* crab binned into 5 mm groups.

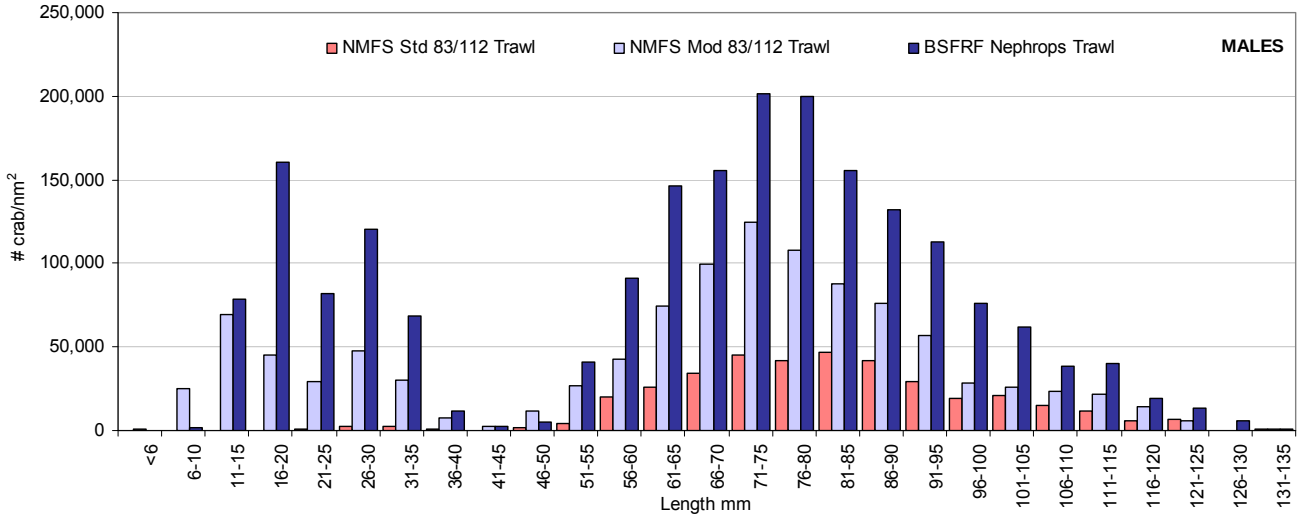


Exhibit 4. Length frequencies of female *opilio* crab binned into 5 mm groups.

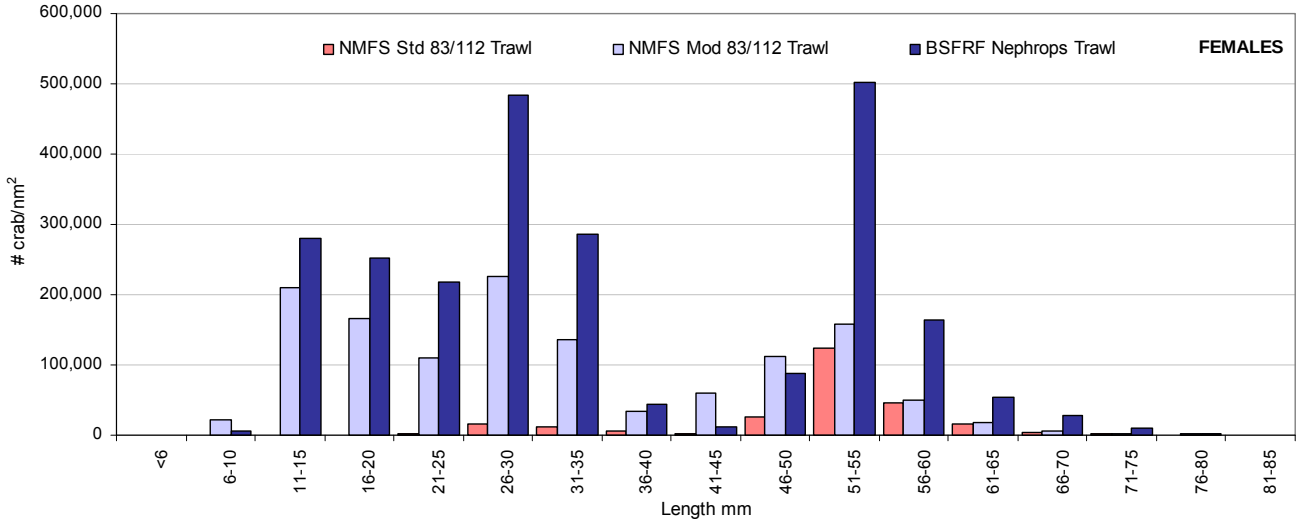


Exhibit 5. Comparison of densities for large male *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment. Net efficiency is defined as the proportion captured within the path of the trawl, which for the NMFS survey trawl for large *opilio* males was 0.35.

LGM	ARC	ALD	AME	Comp Magnitude			Net Efficiency
Tow	A	B	C	B÷A	C÷B	C÷A	A÷C
1	1,684	4,622	9,638	2.7	2.1	5.7	0.17
2	3,959	2,792	3,724	0.7	1.3	0.9	1.06
3	1,962	3,769	2,205	1.9	0.6	1.1	0.89
4	1,831	4,291	5,352	2.3	1.2	2.9	0.34
5	2,917	2,831	4,363	1.0	1.5	1.5	0.67
6	2,977	3,985	18,707	1.3	4.7	6.3	0.16
7	10,867	18,596	33,245	1.7	1.8	3.1	0.33
8	904	1,709	0	1.9	NA	NA	NA
9	284	277	662	1.0	2.4	2.3	0.43
10	0	278	0	NA	NA	NA	NA
11	648	0	1,254	NA	NA	1.9	0.52
12	0	271	589	NA	2.2	NA	0.00
13	2,825	3,946	5,731	1.4	1.5	2.0	0.49
14	8,506	8,786	19,213	1.0	2.2	2.3	0.44
15	4,796	8,302	20,233	1.7	2.4	4.2	0.24
16	7,622	11,915	19,878	1.6	1.7	2.6	0.38
17	1,749	5,969	9,839	3.4	1.6	5.6	0.18
18	1,219	1,070	3,159	0.9	3.0	2.6	0.39
19	1,614	831	1,869	0.5	2.3	1.2	0.86
20	298	1,377	1,370	4.6	1.0	4.6	0.22
21	0	0	0	NA	NA	NA	NA
22	0	663	0	NA	NA	NA	NA
23	0	0	1,659	NA	NA	NA	0.00
24	1,403	676	2,282	0.5	3.4	1.6	0.62
TTL	58,065	86,954	164,973	1.5	1.9	2.8	0.35
AVG	2,419	3,623	6,874				

LGM = large opilio males (≥ 102 mm CW)
ARC = F/V *Arcturus* using NMFS 83/112 std survey trawl
ALD = F/V *Aldebaran* using modified NMFS 83/112 std survey trawl
AME = F/V *American Eagle* using BSFRF *nephrops* survey trawl

Exhibit 6. Comparison of densities for medium male *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment. Net efficiency is defined as the proportion captured within the path of the trawl, which for the NMFS survey trawl for medium *opilio* males was 0.27.

MDM	ARC	ALD	AME	Comp Magnitude			Net Efficiency
Tow	A	B	C	B÷A	C÷B	C÷A	A÷C
1	3,367	7,541	16,233	2.2	2.2	4.8	0.21
2	3,959	5,816	14,897	1.5	2.6	3.8	0.27
3	6,130	20,731	20,950	3.4	1.0	3.4	0.29
4	5,798	18,235	34,253	3.1	1.9	5.9	0.17
5	8,166	21,802	43,626	2.7	2.0	5.3	0.19
6	1,786	1,860	11,107	1.0	6.0	6.2	0.16
7	10,867	18,870	66,491	1.7	3.5	6.1	0.16
8	1,808	2,849	6,000	1.6	2.1	3.3	0.30
9	1,419	2,489	7,948	1.8	3.2	5.6	0.18
10	625	1,668	8,634	2.7	5.2	13.8	0.07
11	1,619	2,149	10,657	1.3	5.0	6.6	0.15
12	2,156	2,439	8,243	1.1	3.4	3.8	0.26
13	5,337	5,637	14,327	1.1	2.5	2.7	0.37
14	2,734	7,936	15,058	2.9	1.9	5.5	0.18
15	3,083	5,634	12,718	1.8	2.3	4.1	0.24
16	6,533	7,830	7,178	1.2	0.9	1.1	0.91
17	4,198	9,129	11,684	2.2	1.3	2.8	0.36
18	11,278	11,497	23,375	1.0	2.0	2.1	0.48
19	10,005	12,181	31,152	1.2	2.6	3.1	0.32
20	10,134	12,117	21,242	1.2	1.8	2.1	0.48
21	20,877	20,969	42,508	1.0	2.0	2.0	0.49
22	11,720	17,889	25,086	1.5	1.4	2.1	0.47
23	20,773	32,309	74,104	1.6	2.3	3.6	0.28
24	12,281	66,201	82,912	5.4	1.3	6.8	0.15
TTL	166,654	315,777	610,382	1.9	1.9	3.7	0.27
AVG	6,944	13,157	25,433				

MDM = medium opilio males (78-101 mm CW)
ARC = F/V *Arcturus* using NMFS 83/112 std survey trawl
ALD = F/V *Aldebaran* using modified NMFS 83/112 std survey trawl
AME = F/V *American Eagle* using BSFRF *nephrops* survey trawl

Exhibit 7. Comparison of densities for small male *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment. Net efficiency is defined as the proportion captured within the path of the trawl, which for the NMFS survey trawl for small *opilio* males was 0.13.

SMM	ARC	ALD	AME	Comp Magnitude			Net Efficiency
Tow	A	B	C	B÷A	C÷B	C÷A	A÷C
1	962	8,270	31,958	8.6	3.9	33.2	0.03
2	2,969	19,077	36,178	6.4	1.9	12.2	0.08
3	1,226	20,312	20,399	16.6	1.0	16.6	0.06
4	1,221	7,509	20,337	6.2	2.7	16.7	0.06
5	2,042	2,831	22,436	1.4	7.9	11.0	0.09
6	0	3,985	10,523	NA	2.6	NA	NA
7	1,863	18,596	36,570	10.0	2.0	19.6	0.05
8	9,946	27,919	70,365	2.8	2.5	7.1	0.14
9	15,889	40,107	84,116	2.5	2.1	5.3	0.19
10	9,370	48,939	88,802	5.2	1.8	9.5	0.11
11	10,365	39,292	99,675	3.8	2.5	9.6	0.10
12	15,707	37,131	88,321	2.4	2.4	5.6	0.18
13	5,337	57,211	31,996	10.7	0.6	6.0	0.17
14	3,038	5,385	14,020	1.8	2.6	4.6	0.22
15	1,370	9,192	8,671	6.7	0.9	6.3	0.16
16	1,089	14,298	11,596	13.1	0.8	10.6	0.09
17	2,099	19,310	41,202	9.2	2.1	19.6	0.05
18	5,182	19,786	41,064	3.8	2.1	7.9	0.13
19	3,873	18,549	39,252	4.8	2.1	10.1	0.10
20	5,067	12,944	24,668	2.6	1.9	4.9	0.21
21	18,680	57,822	87,897	3.1	1.5	4.7	0.21
22	9,376	50,685	112,506	5.4	2.2	12.0	0.08
23	21,747	63,996	166,457	2.9	2.6	7.7	0.13
24	8,421	67,552	59,331	8.0	0.9	7.0	0.14
TTL	156,837	670,699	1,248,341	4.3	1.9	8.0	0.13
AVG	6,535	27,946	52,014				

SMM = small opilio males (<78 mm CW)
ARC = F/V *Arcturus* using NMFS 83/112 std survey trawl
ALD = F/V *Aldebaran* using modified NMFS 83/112 std survey trawl
AME = F/V *American Eagle* using BSFRF *nephrops* survey trawl

Exhibit 8. Comparison of densities for large female *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment. Net efficiency is defined as the proportion captured within the path of the trawl, which for the NMFS survey trawl for large *opilio* females was 0.25.

LGF	ARC	ALD	AME	Comp Magnitude			Net Efficiency
Tow	A	B	C	B÷A	C÷B	C÷A	A÷C
1	2,886	7,784	2,536	2.7	0.3	0.9	1.14
2	742	1,396	4,788	1.9	3.4	6.5	0.16
3	736	4,188	3,308	5.7	0.8	4.5	0.22
4	610	1,073	8,028	1.8	7.5	13.2	0.08
5	875	21,802	3,116	24.9	0.1	3.6	0.28
6	595	1,860	585	3.1	0.3	1.0	1.02
7	1,863	18,870	4,433	10.1	0.2	2.4	0.42
8	39,481	45,335	152,184	1.1	3.4	3.9	0.26
9	34,332	44,064	162,934	1.3	3.7	4.7	0.21
10	46,226	35,109	138,754	0.8	4.0	3.0	0.33
11	36,276	68,084	178,035	1.9	2.6	4.9	0.20
12	23,714	30,084	93,031	1.3	3.1	3.9	0.25
13	1,256	845	1,433	0.7	1.7	1.1	0.88
14	911	283	1,039	0.3	3.7	1.1	0.88
15	0	297	1,734	NA	5.8	NA	NA
16	726	681	1,104	0.9	1.6	1.5	0.66
17	350	702	1,845	2.0	2.6	5.3	0.19
18	3,048	802	4,422	0.3	5.5	1.5	0.69
19	645	1,938	10,592	3.0	5.5	16.4	0.06
20	2,086	6,059	9,593	2.9	1.6	4.6	0.22
21	366	953	3,602	2.6	3.8	9.8	0.10
22	670	2,650	6,842	4.0	2.6	10.2	0.10
23	1,298	1,864	3,871	1.4	2.1	3.0	0.34
24	0	1,689	6,846	NA	4.1	NA	0.00
TTL	199,695	298,412	804,654	1.5	2.7	4.0	0.25
AVG	8,321	12,434	33,527				

LGF = large opilio females (≥ 50 mm CW)
ARC = F/V *Arcturus* using NMFS 83/112 std survey trawl
ALD = F/V *Aldebaran* using modified NMFS 83/112 std survey trawl
AME = F/V *American Eagle* using BSFRF *nephrops* survey trawl

Exhibit 9. Comparison of densities for small female *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment. Net efficiency is defined as the proportion captured within the path of the trawl, which for the NMFS survey trawl for small *opilio* females was 0.03.

SMF	ARC	ALD	AME	Comp Magnitude			Net Efficiency
Tow	A	B	C	B÷A	C÷B	C÷A	A÷C
1	4,810	13,622	56,307	2.8	4.1	11.7	0.09
2	2,227	55,490	76,080	24.9	1.4	34.2	0.03
3	1,716	34,800	29,220	20.3	0.8	17.0	0.06
4	916	19,844	25,154	21.7	1.3	27.5	0.04
5	1,167	10,193	75,411	8.7	7.4	64.6	0.02
6	893	3,985	9,354	4.5	2.3	10.5	0.10
7	3,105	22,425	29,921	7.2	1.3	9.6	0.10
8	6,329	64,327	102,547	10.2	1.6	16.2	0.06
9	4,540	59,268	96,038	13.1	1.6	21.2	0.05
10	7,184	121,098	138,754	16.9	1.1	19.3	0.05
11	8,097	97,003	160,482	12.0	1.7	19.8	0.05
12	3,080	58,814	87,732	19.1	1.5	28.5	0.04
13	1,884	139,405	94,079	74.0	0.7	49.9	0.02
14	1,823	14,171	20,251	7.8	1.4	11.1	0.09
15	685	19,866	17,343	29.0	0.9	25.3	0.04
16	726	24,510	11,596	33.8	0.5	16.0	0.06
17	1,749	62,847	105,158	35.9	1.7	60.1	0.02
18	305	16,043	30,956	52.6	1.9	101.6	0.01
19	323	20,487	29,283	63.5	1.4	90.7	0.01
20	298	14,871	9,593	49.9	0.6	32.2	0.03
21	366	18,109	116,716	49.4	6.4	318.7	0.00
22	335	69,529	145,194	207.6	2.1	433.6	0.00
23	0	2,175	103,967	NA	47.8	NA	0.00
24	0	38,008	52,485	NA	1.4	NA	0.00
TTL	52,557	1,000,889	1,623,619	19.0	1.6	30.9	0.03
AVG	2,190	41,704	67,651				

SMF = small opilio females (< 50 mm CW)
ARC = F/V *Arcturus* using NMFS 83/112 std survey trawl
ALD = F/V *Aldebaran* using modified NMFS 83/112 std survey trawl
AME = F/V *American Eagle* using BSFRF *nephrops* survey trawl

Exhibit 10. Chart of densities by tow for large male *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment.

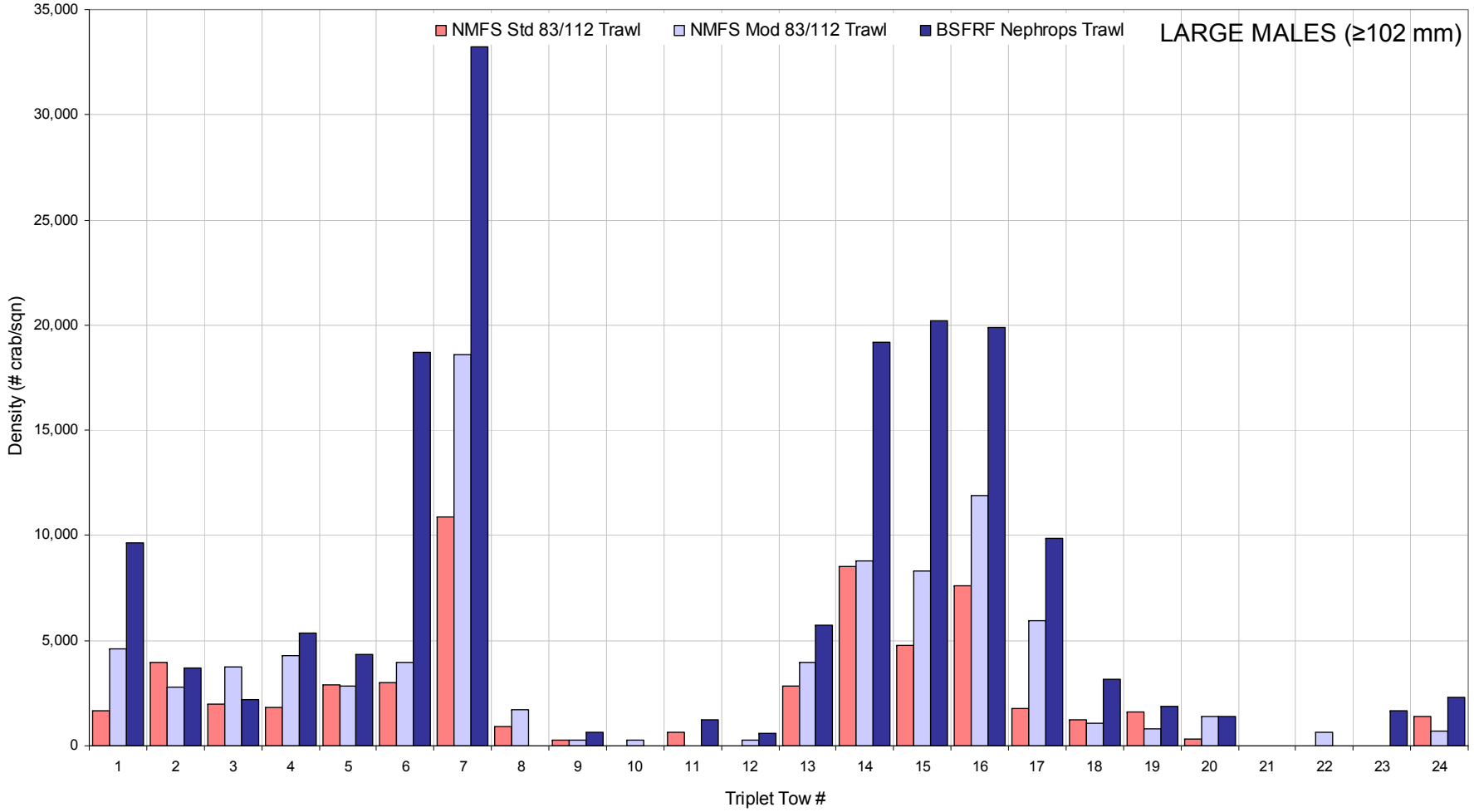


Exhibit 11. Chart of densities by tow for medium male *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment.

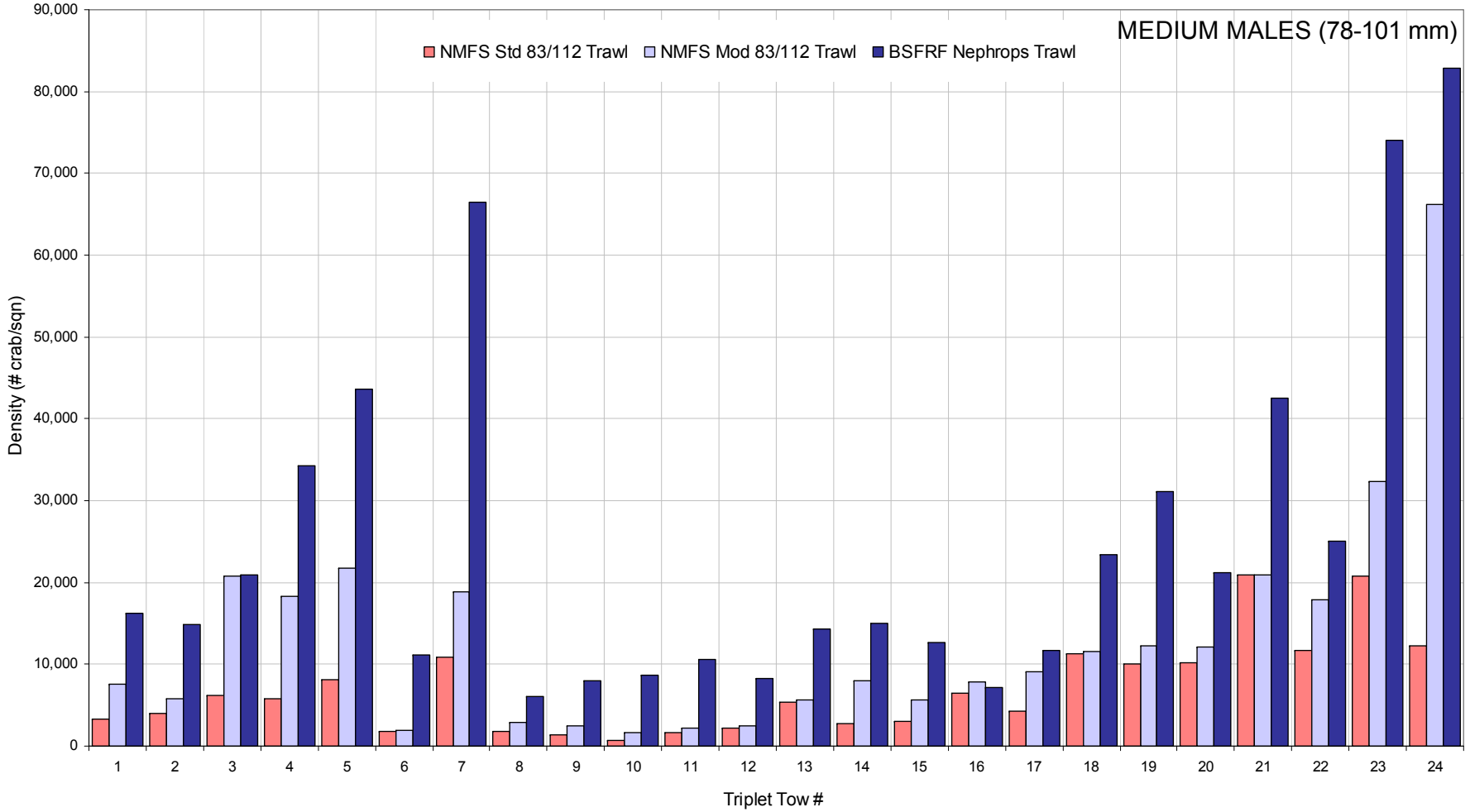


Exhibit 12. Chart of densities by tow for small male *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment.

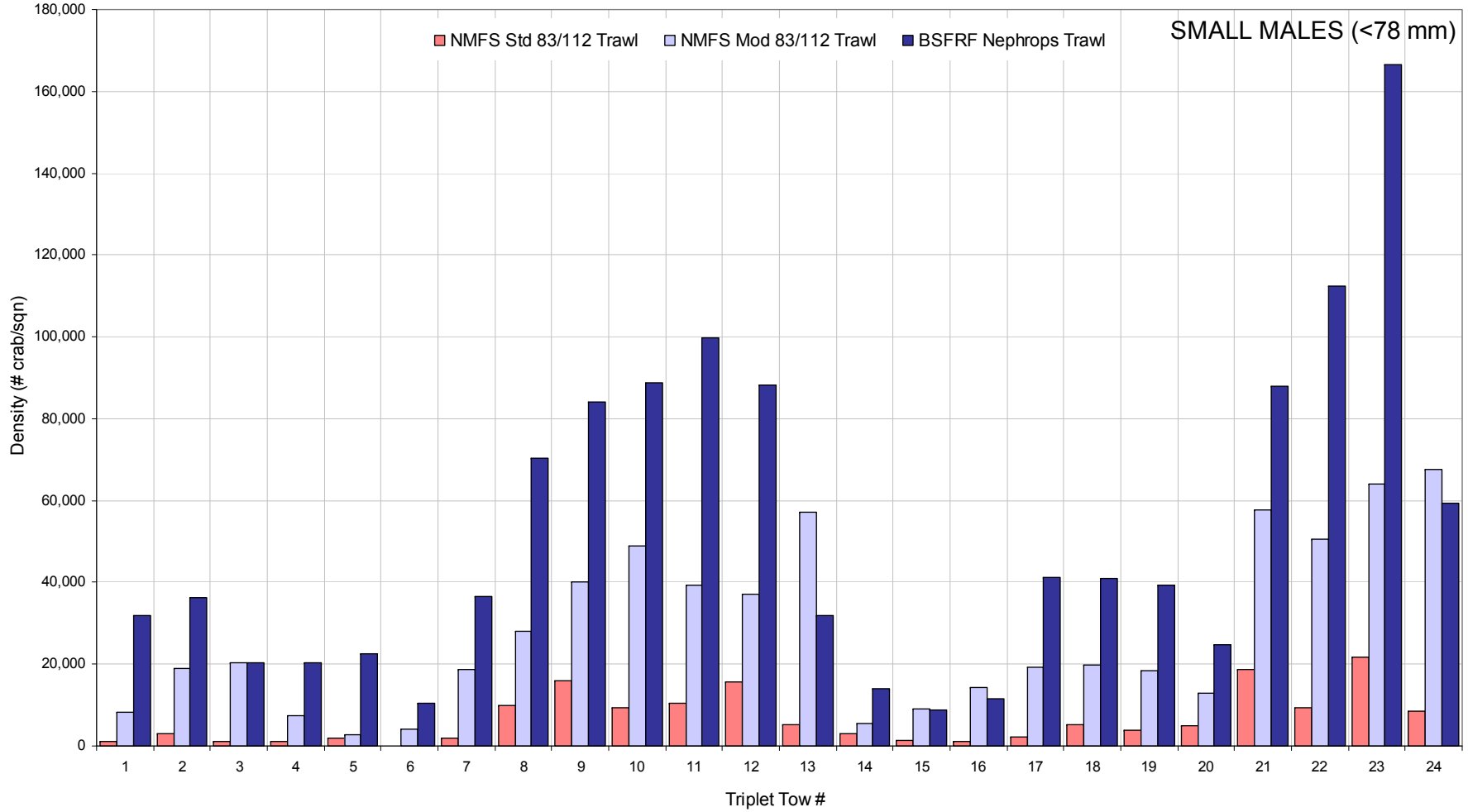


Exhibit 13. Chart of densities by tow for large female *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment.

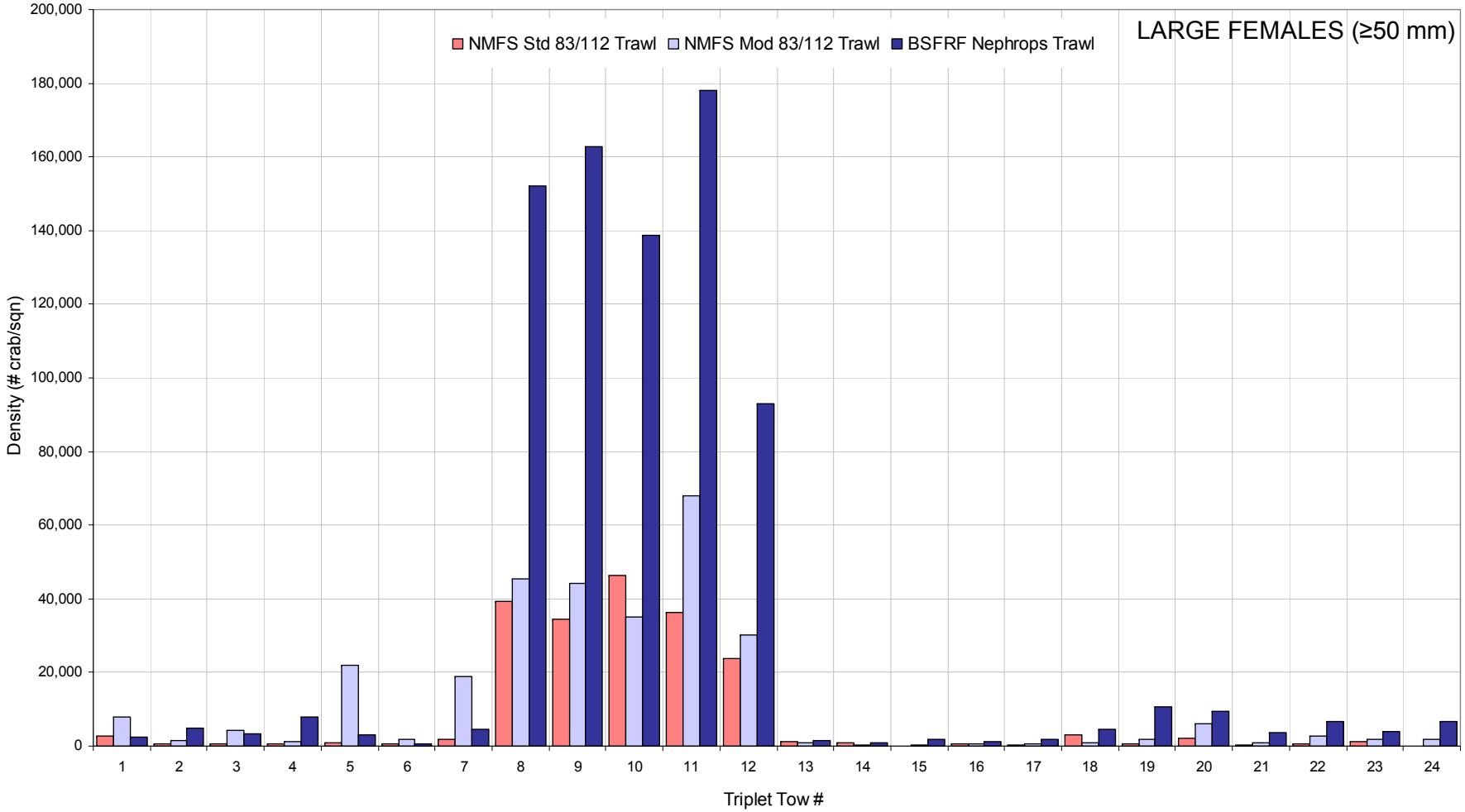


Exhibit 14. Chart of densities by tow for small female *opilio* (#crab/nm2) during 2009 *opilio* net efficiency experiment.

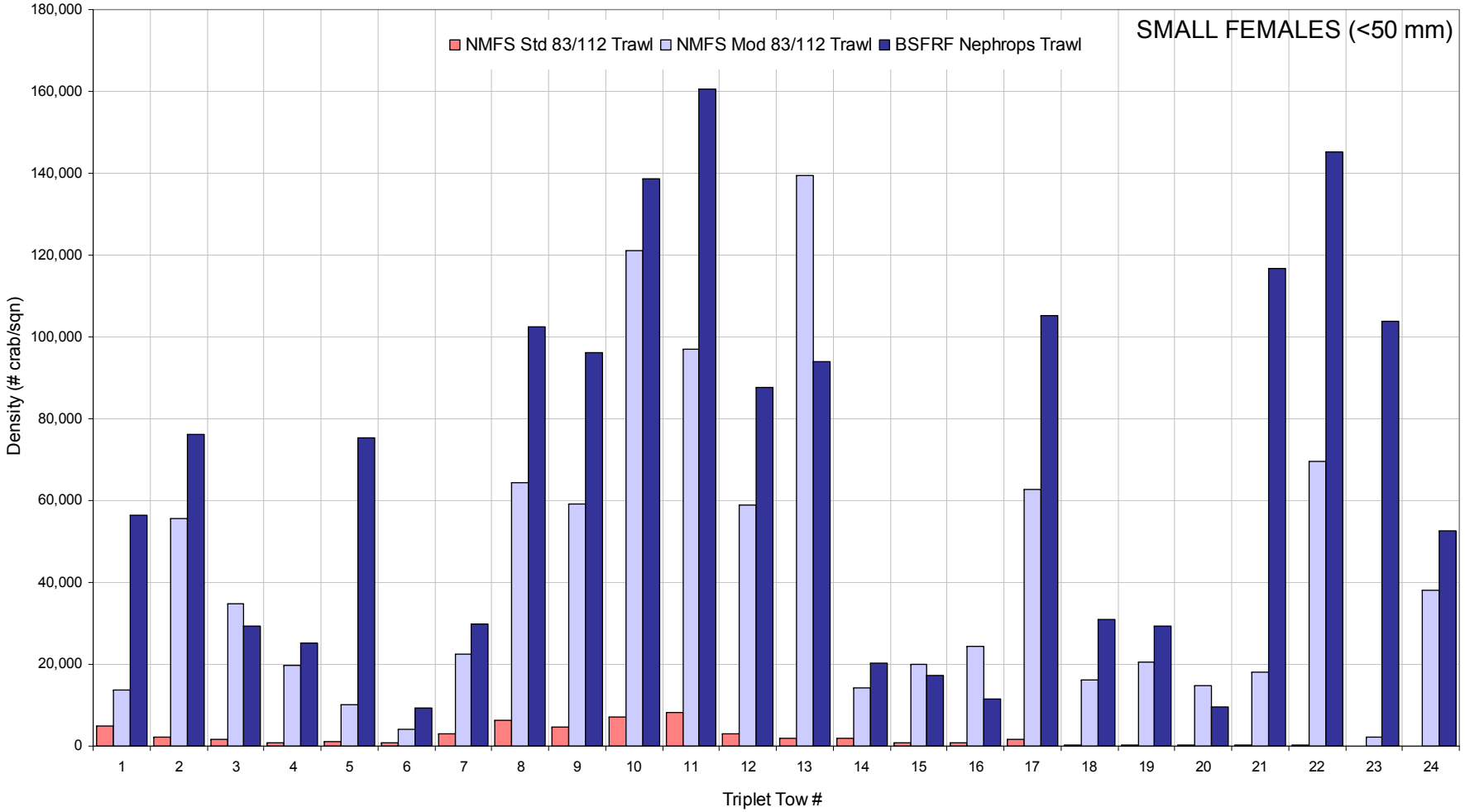
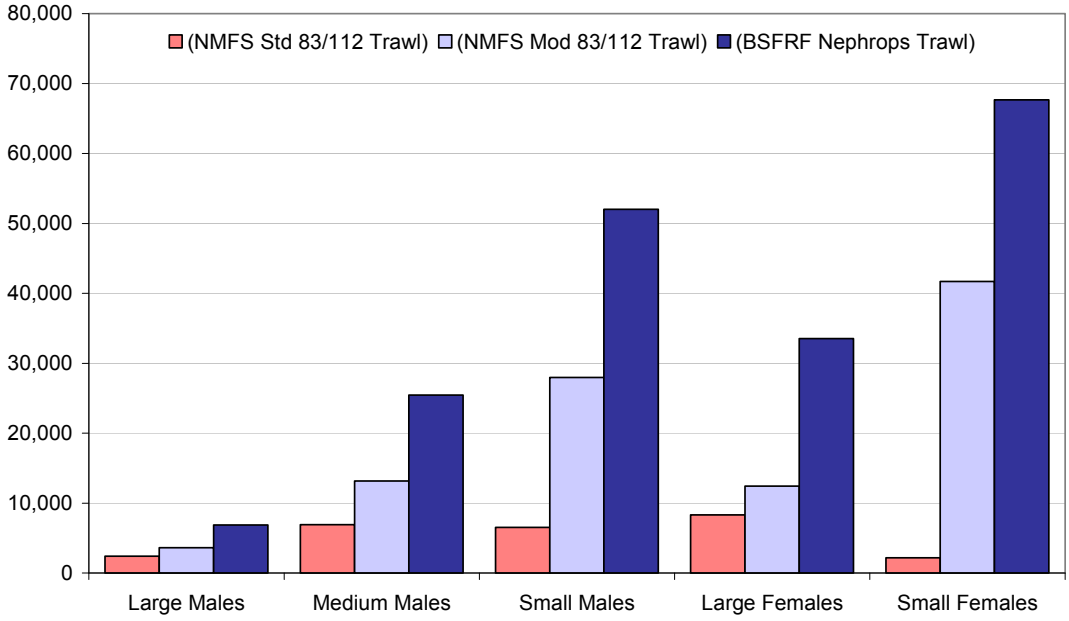
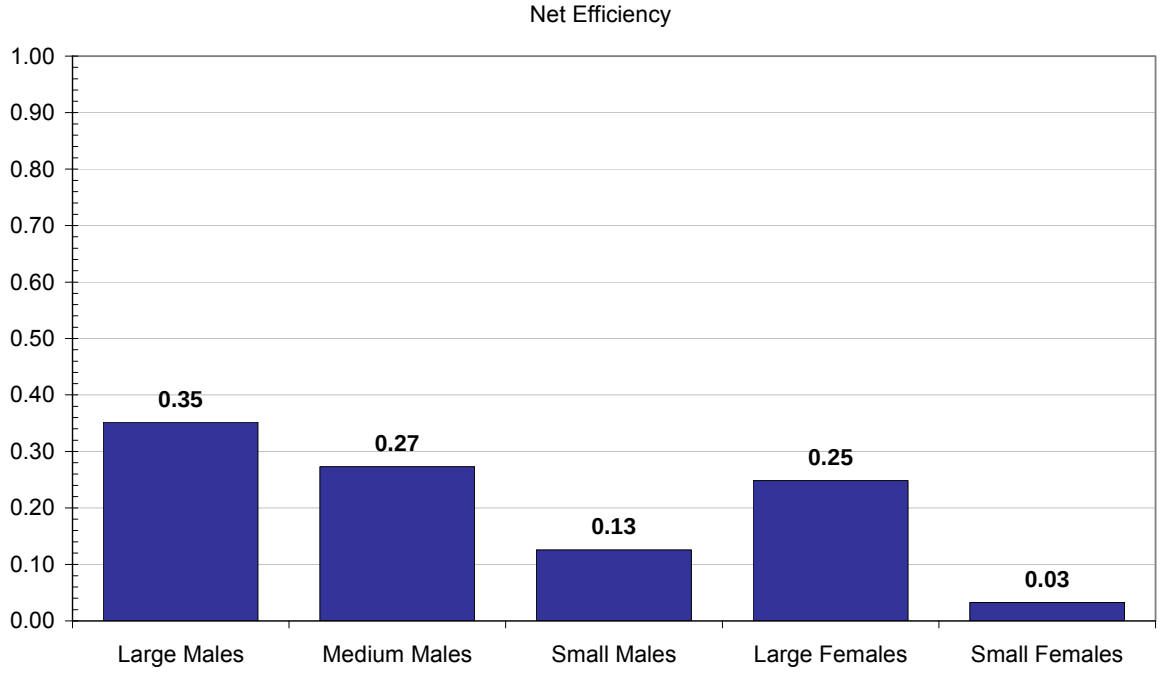


Exhibit 15. Chart and table of average densities for all tows (#crab/nm2) by size and sex category during 2009 *opilio* net efficiency experiment.



Opilio Size Sex Category	Density Averages from 24 Side by Side Tows (crab/nm^2) *F/V Arcturus* (NMFS Std 83/112 Trawl)	*F/V Aldebaran* (NMFS Mod 83/112 Trawl)	*F/V American Eagle* (BSFRF *Nephrops* Trawl)
Large Males (≥ 102 mm)	2,419	3,623	6,874
Medium Males (78-101 mm)	6,944	13,157	25,433
Small Males (< 78 mm)	6,535	27,946	52,014
Large Females (≥ 50 mm)	8,321	12,434	33,527
Small Females (< 50 mm)	2,190	41,704	67,651
Total Opilio (All Sizes)	26,409	98,864	185,499

Exhibit 16. Net efficiency by size and sex category for NMFS standard trawl based on results of 2009 *opilio* net efficiency experiment.



Opilio Size Sex Category	Density Averages from 24 Side by Side Tows (crab/nm^2) *F/V Arcturus* (NMFS Std 83/112 Trawl)	*F/V American Eagle* (BSFRF *Nephrops* Trawl)	Net Efficiency *F/V Arcturus : F/V American Eagle*
Large Males (≥ 102 mm)	2,419	6,874	0.35
Medium Males (78-101 mm)	6,944	25,433	0.27
Small Males (< 78 mm)	6,535	52,014	0.13
Large Females (≥ 50 mm)	8,321	33,527	0.25
Small Females (< 50 mm)	2,190	67,651	0.03