UNIVERSITY OF NEW HAMPSHIRE
INSTITUTE FOR THE STUDY OF EARTH, OCEANS AND SPACE
OCEAN PROCESS ANALYSIS LABORATORY
DURHAM, NH 03824

Final Report

Design and Test of a Kite-assisted Shrimp Codend to Reduce Small Shrimps and Juvenile Fish Bycatch

Submitted to:

The Northeast Consortium
142 Morse Hall
University of New Hampshire
Durham, NH 03824

March 2008 **UNH-FISH-REP-2008-044**

Design and Test of a Kite-assisted Shrimp Codend to Reduce Small Shrimps and Juvenile Fish Bycatch

by

Pingguo He
(Principal Investigator)

University of New Hampshire 137 Morse Hall, Durham, NH 03824.
Tel. (603) 862-3154, Fax. (603) 862-7006, Email: pingguo.he@unh.edu

and

Dan Schick
Maine Department of Marine Resource, Boothbay Harbor, ME

In association with
Industry Partners:

Vincent Balzano, F/V "North Star", Saco, ME
Proctor Wells, F/V "Tenacious", Phippsburg, ME

Submitted to

The Northeast Consortium
The University of New Hampshire,
142 Morse Hall, Durham, NH 03824

March 2008

You may cite this report as:
He, P. *et al.* (2008). Design and Test of a Kite-Assisted Shrimp Codend to Reduce Small Shrimps and Juvenile Fish Bycatch. Submitted to the Northeast Consortium. University of New Hampshire, Durham, NH. UNH-FISH-REP-2007-043. 16 p.

UNH-FISH-REP-2008-044

Design and Test of a Kite-Assisted Shrimp Codend to Reduce Small Shrimps and Juvenile Fish Bycatch

Summary. This project was to test an assumption that codend meshes expended by water-borne kite would allow more small shrimps and finfish to escape from the codend. A full scale kite-assisted shrimp trawl codend was tested in a flume tank to determine kite size, number of kites, their position and installation on the codend. The resulting full scale codend was tested at sea for the pink shrimps in Gulf of Maine shrimp trawl fishery through comparative fishing using the two-vessel parallel tow method. Seventy-seven pairs of tows were completed on two rigging designs. The results did not support the assumption that codends expanded by water-borne kites would reduce finfish and small shrimp catch in the fishery. Catch and bycatch data collected throughout sea trials showed that a significant amount of fin fish bycatch still exists in the fishery even with the use of the Nordmore Grid. This is especially true for whiting for which a large amount of catch was discarded late in the season. This result indicates a need for continued effort in research and development for a better shrimp trawl to minimize bycatch in the pink shrimp fishery.

1. INTRODUCTION

Use of the Nordmore Grid in shrimp trawls has reduced finfish bycatch tremendously in shrimp fisheries in the North Atlantic. However, the Nordmore Grid cannot reduce small shrimps and small fish which pass through the 1" space between the bars in the Gulf of Maine pink shrimp fishery. Small shrimps occasionally struck western Gulf of Maine, resulting in reduced average shrimp size (higher counts) and poor prices. Small fish such as whiting, flounders, smelts and herring are also often caught as bycatch in various quantities. In a separate shrimp trawl project carried out by the principal investigator during 2003, an average of 13 lbs of bycatch was caught for every 100 lbs of shrimp (He & Littlefield, 2003). Various projects have been carried out to reduce small shrimps and small fish, but with very limited success. One of the measures employed to reduce small shrimp catch is to install a second narrowly-spaced grid immediately behind the main Nordmore Grid (Valdemarsen *et al.*, 1993). Reduced flow behind the Nordmore Grid seemed to impede passage of small shrimps and small fish through the second grid, reducing its effectiveness (H. Delouche,

pers. comm.). Additional grids on the codend may also add operational difficulties for small vessels operating in Gulf of Maine. Another measure to reduce small shrimp and small fish was to use a square mesh codend or square mesh panels in a shrimp trawl codend. Square meshes stay open even with loads in the codend. Square mesh shrimp codend was reported to reduce small fish bycatch such as capelin in Gulf of St. Lawrence (H. DeLouche, pers. comm.). Square mesh panels installed in part of the codend reduced small fish catch bycatch species in the Australian shrimp fishery (Broadhurst & Kennelly, 1994). Square meshes are difficult to repair and handle. Diamond meshes can be forced open using water-borne kites as did by He and his collegues (He *et al.*, 2005; He, 2007) during a codend mesh selectivity study. This technique might be used to expend shrimp trawl codend to reduce small fish and shrimp discards in a similar fashion. We therefore proposed and were subsequently funded to test a shrimp codend whose mesh would be forced open with the assistance of water-borne kites. Reducing small fish and small shrimps in shrimp fisheries is very important in groundfish and shrimp conservation, and can also improve economic performance as a result of higher prices paid for large shrimps.

Objectives: The overall objective of the proposed project was to reduce discards in the Gulf of Maine pink shrimp fishery. Specific objectives were to:

- Design a shrimp trawl codend using kites to expand mesh opening through flume tank tests of a full scale codend;
- Modify and refine the design with industry participation so that the design can be employed in commercial operations;
- Use commercial fishing vessels to conduct sea trials in the Gulf of Maine pink shrimp fishery;
- Involve state agencies and industry to ensure practicality of devices and wider application of the design upon successful findings.

2. METHODS

Kite and codend design. The kites used in the codend cover were 2'6" by 1'3" and 1'3" high trapezoids made of rubberized canvas (He *et al.*, 2005; He, 2007). The kite was restrained by a 16" twine to form an arc shape to ensure expanding in the correct direction.

The codend used was the same size as the commercial shrimp codend. Shorter gore rope or lastridge ropes, were installed on the gore of the codend to take the strain of the load in the codend during the second half of the sea trials. Eight kites were used in each codend. The number and the position of the kites were determined by flume tank tests as described below.

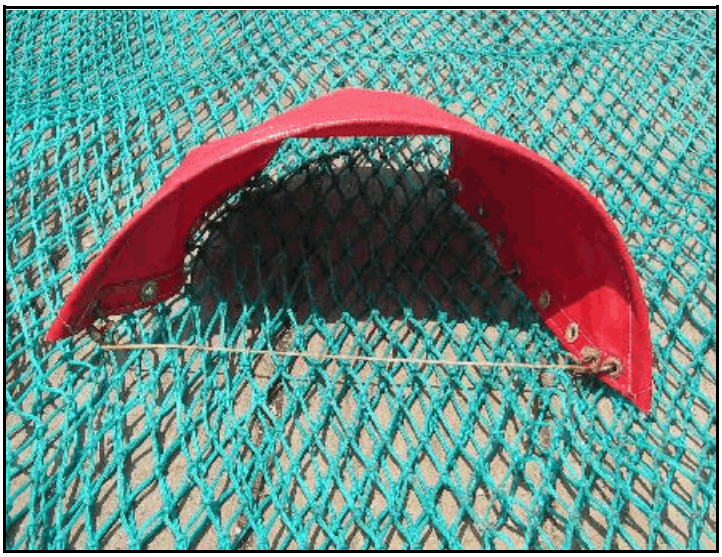

Exhibit 1. Kite used in codend cover project. Similar kites will be used in shrimp codends.

Flume tank tests. A full scale codend with the last belly section of the trawl and the Nordmore Grid was shipped to the Newfoundland flume tank for testing in December 2003. Kites were installed onto the codend by the engineer at the flume tank with assistance from the project team members. Industry partners, the scientific collaborator and the principal investigator participated in flume tank tests. The codend design at the end of flume tank tests is shown below.

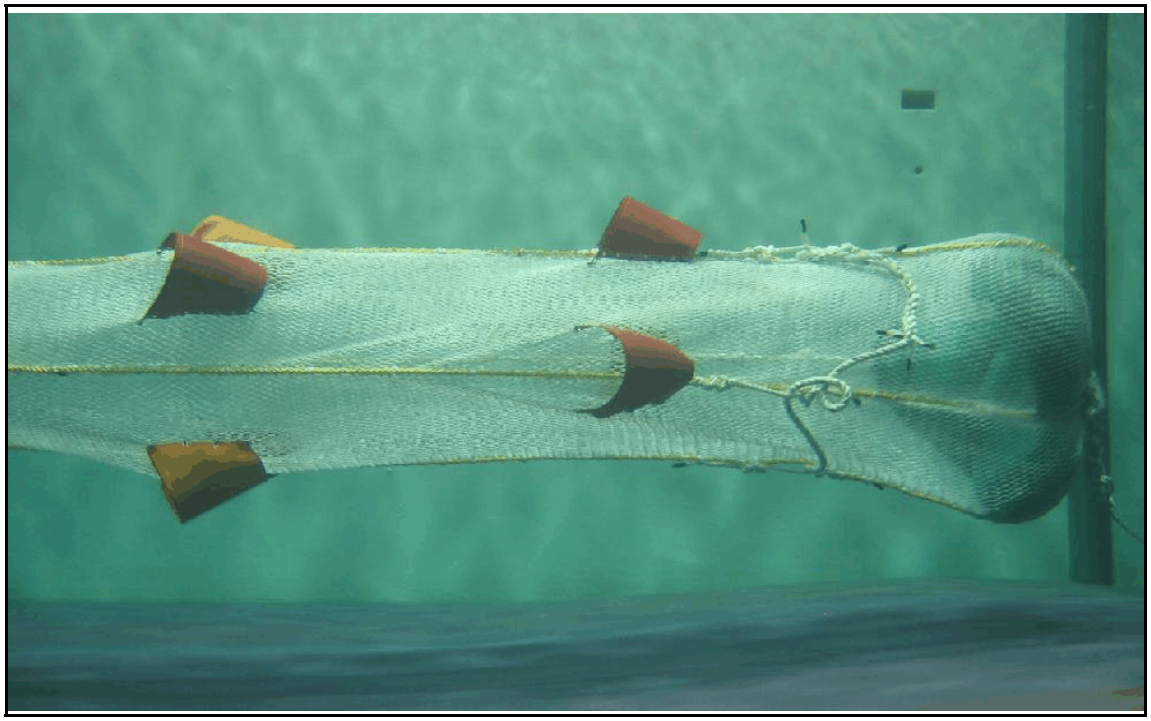

Exhibit 2. Kite-assisted shrimp trawl codend as seen in the flume tank.

Fully-rigged codend with kites and the Nordmore Grid was shipped back to industry partners for sea trials. Another codend identical to the one tested was constructed by a local gear manufacture for the other vessel.

Sea trials. Sea trials were carried out during the 2004 shrimp season between February and May off the coast of Maine. An exempt fishing permit was obtained from the State of Maine to fish out of the shrimp season during the late part of sea trials. Two vessels were involved constituting parallel tows, comparing catch and bycatch of shrimp codends with and without kites. Vessels owned and operated by industry partners were used for the sea trials. F/V "Tenacious" based in Phippsburg (ME) and operated by Proctor Wells, and F/V "North Star" based in Portland (ME) and operated by Vincent Balzano were fishing side by side during sea trials (Exhibit 3).

Exhibit 3. F/V "North Star" (left) and F/V "Tenacious", two fishing vessels used during the comparative fishing trials.

The two vessels had a similar shrimp trawl (880 mesh fishing circle) and compatible trawl doors (Bison #7). The bridles between the door and the wingend were 85'. Similar 12' Rockhopper sweeps were used by both vessels. The two vessels performed comparative fishing using the parallel tow method. While one vessel was towing a codend with kites, the other would be towing a regular codend without kites. The codend was switched after fishing for not more than two days. The tow duration was one hour and the towing speed was 2.4 knots.

The sea trials were divided into two sessions, with modification to the gear made at the start of the second session. During comparative fishing between the two vessels, the vessels stayed within 1/4 nautical miles from each other. The codend was switched from “with kites” to “no kites” in one vessel, while from “no kites” to “with kites” in the other vessel, or *vice versa*. During the second session of the sea trials, starting from Tow 35, modifications to the codend included shortened gore rope which was 7% shorter than the fully stretched codend length.

Six tows were completed with both vessels towing a codend with kites at the same time to examine if there was any difference between the two codends with kites. The “calibration” tows were carried out at the middle of the sea trial period.

An underwater video camera and acoustic measurement devices will be used to monitor the functioning of the shrimp trawl codend with kites. A video camera was installed above the codend in a number of times to monitor the fish/shrimp escaping from the codend (exhibit 4). The NetMind™ trawl measuring device was used to monitor trawl geometry.

Exhibit 4. Underwater camera installed on top of the kite-assisted shrimp trawl codend.

Sampling, measurement and analysis. The total shrimp catch was weighed. A sample of about 1 kg shrimp from each tow from each vessel was sent to the Maine Department of Marine Resources' (DMR) Boothbay Harbor laboratory for further measurement and examination. Catches were divided into four categories during analysis: target species - shrimps, and bycatch species including controlled species, other species, and shellfish (Exhibit 5). All controlled groundfish bycatch was separated and their lengths measured. A sub-sample was measured in cases when large number of bycatch species were retained. Some dominant species in the "other fish" category were also sampled and measured. All catches were weighed according to species.

Target species "shrimp"	*Pandalus borealis*. Other shrimp species caught: *Pandalus montagui*, *Dichelopandalus leptocerus*
Bycatch "controlled species"	Atlantic cod (*Gadus morhua*) haddock (*Melanogrammus aeglefinus*) yellowtail flounders (*Pleuronectes ferruginea*) American plaice (*Hippoglossoides platessoides*) witch flounder (*Glyptocephalus cynoglossus*) winter flounder (*Pleuronectes americanus*) monkfish (*Lophius americanus*) white hake (*Urophycis tenuis*) windowpane (*Scophthalmus aquosus*)
Bycatch "other species"	silver hake (whiting), red hake, ocean pout, four-spot flounder, thorny skate, sea raven, longhorn sculpin, shorthorn sculpin, pipefish, cusk, herring, smelt, alewife, pogy, snake blenny, silveside, wrymouth
Bycatch "shellfish"	American lobster, rock crab, scallops

Exhibit 5. Species caught during sea trials.

Shrimp sizes were evaluated by measuring the carapace length and determining the "count" which is the number of shrimp per pound. Shrimp samples sent to DMR were measured (for carapace length), and examined (sex, sexual stage, and whether egg bearing). Three species of shrimps were identified in the shrimp samples and their were separately recorded.

Paired t-test was used to evaluate differences of shrimp catch, bycatch of controlled and other species, and shrimp size (count) between codends with and without kites.

3. RESULTS

Seventy-seven tows were completed in twenty fishing days for each vessel. Results include size distribution of shrimps retained by the codend with and without kites, catch rates of shrimps (kg/hr), bycatch rates and size of major bycatch species. Analysis was made on changes of composition of male and female shrimps, and stages of female developmental status during the course of sea trials between February and May 2004.

3.1 Operations and gear geometry

Operation of the kite-assisted shrimp trawl codend was almost the same as regular trawl. No special equipment was needed to handle the new codend. The kites were robust and very little damage was sustained during the 20 days of fishing.

The 880 mesh shrimp trawl operated on F/V "Northstar" had a headline opening of 10' with the door spread of around 85' and wingend spread of 39' (Tow 29 on 04/08/2004). The trawl was fishing at 75 fathoms (fm) with 200 fm of warp length towing at 2.4 kt when the gear data were measured. The bridle angle calculated from these numbers was around 16 degrees. These were expected gear geometry data by the skipper under these fishing conditions.

3.2 Calibration tows

Six tows (Tow 29-35) were completed when the two vessels were fishing side-by-side, both using codend with kites. There were no differences in the amount of shrimp catch, controlled species, other species, or shellfish between the two vessels both with kites ($P>0.1$), indicating that we had two similar kite-assisted codends.

3.3 Catch and bycatch

Majority of shrimps caught were pink shrimp (*Pandalus borealis)*. Other shrimp species which were much smaller in size and quantity were *Pandalus montagui*, and

Dichelopandalus leptocerus. When not specified, shrimps refer to the pink shrimp *(Pandalus borealis)* in this report. Shrimp catch rates ranged from a minimum of 20 kg/hr tow to 377 kg/hr tow. Highest catch rates were in late February (Tow 23 by F/V "Northstar"), and were gradually trailed off toward the end of May (Exhibit 6).

The gear was modified at the start of Tow 35. Two gear configurations (Tow 1 - 28 and Tow 35 - 77) were therefore analyzed separately. During Session 1 from Tow 1 to Tow 28, there was a slight increase in shrimp catch with the use of the kites, but the catch of controlled species and other species was very similar between the codend with kites and that without kites (Exhibit 7). During the second session from Tow 35 and Tow 77, there were no differences of shrimp catch, bycatch of controlled species and other species between codends with and without kites. Major controlled bycatch species was juvenile American plaice, while major bycatch of other species was whiting.

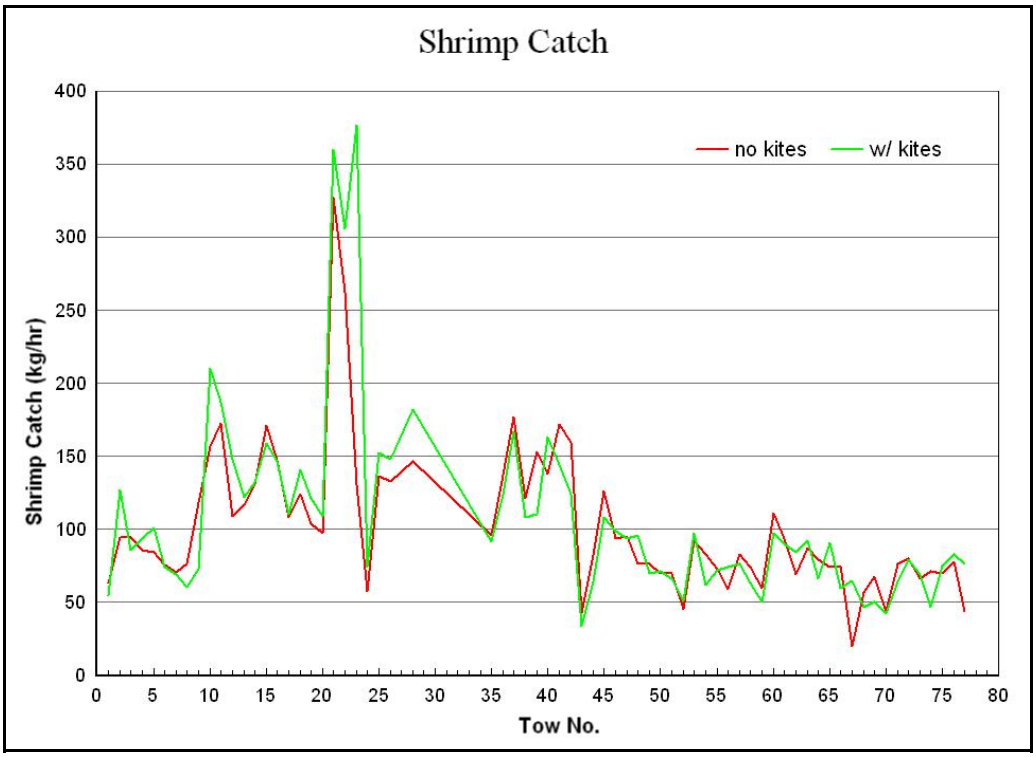

Exhibit 6. Underwater camera installed on top of the kite-assisted shrimp trawl codend.

Session	Codend	Shrimp			Controlled Species			Other Species		
		Mean	SE	Diff.	Mean	SE	Diff.	Mean	SE	Diff.
1 28 tows	with kites	145	15.81	P<0.05 *	2.26	0.23	P>0.05 NS	3.65	0.92	P>0.05 NS
	No kites	126	11.10		2.63	0.36		3.50	0.62	
2 43 tows	with kites	83	4.55	P>0.05 NS	5.02	0.24	P>0.05 NS	91.17	12.05	P>0.05 NS
	No kites	86	5.33		4.54	0.28		103.29	12.59	

Exhibit 7. Comparison of catch of shrimps and bycatch species between codends with kites and without kites. * statistically significant at 95% level, NS - statistically not significant.

Whiting started to show up in large quantities in early May at Tow 43. As much as 402 kg/hr of whiting were caught and discarded from Tow 62 (Exhibit 8), when only 84 kg of shrimp were caught, indicating that the whiting catch was five times the catch of shrimp on that tow. The maximum bycatch of American plaice was 8.5 kg/hr tow, with majority tows being less than 4 kg/hr (Exhibit 8).

3.4 Shrimp Size and size distribution

There are no differences in the size of shrimp caught. The average count of shrimp caught by codends both with and without kites was 55 shrimp per pound. It seems that the kites did not provide extra opening for small shrimps to fall out of the codend.

February shrimps were large in size and were dominated by females with eggs (Exhibit 9). As month passes, more male shrimps showed up in the catch. From the month of April, the shrimps were dominated by Female II and males in the catch.

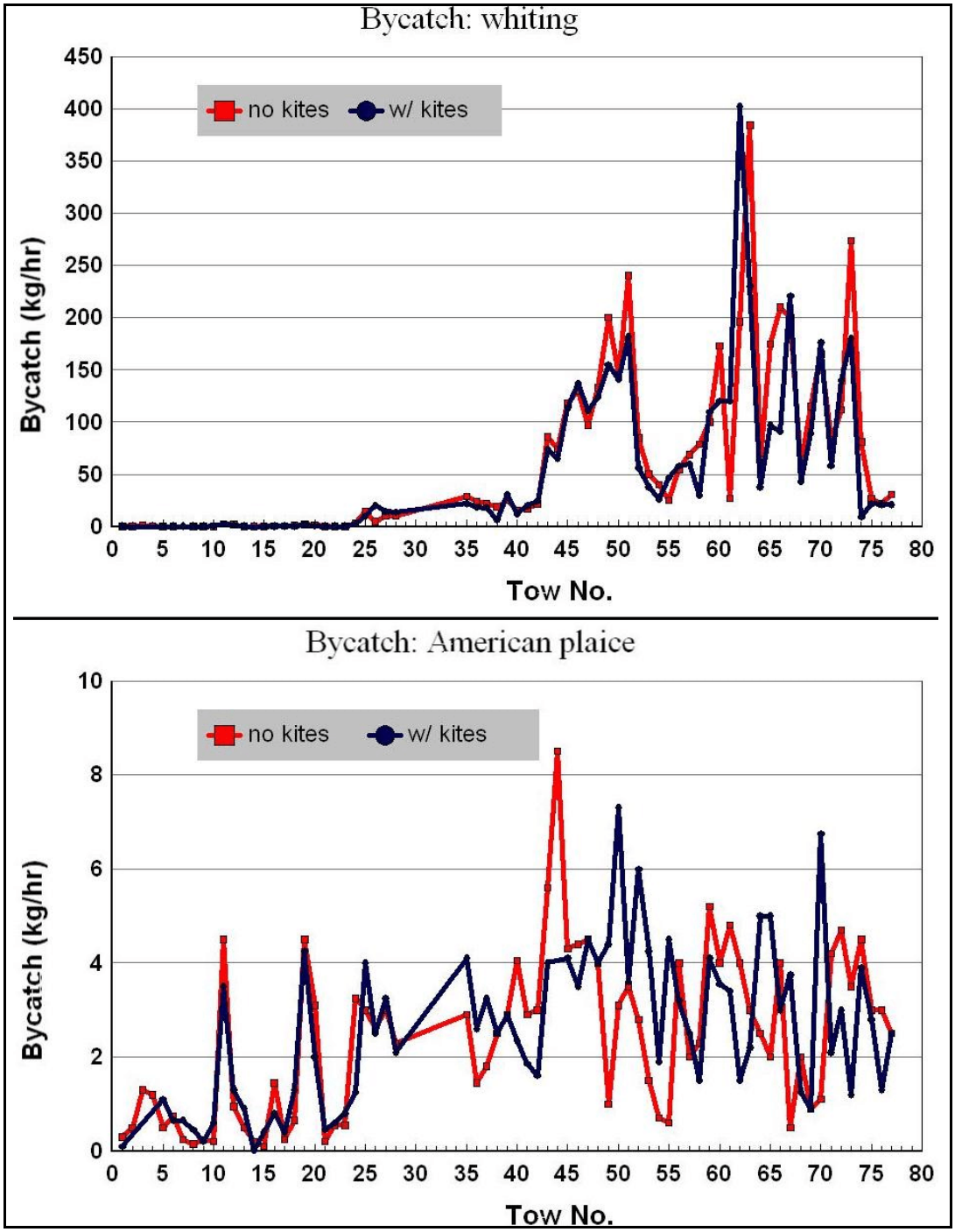

Exhibit 8. Bycatch of whiting (top) and dab (bottom) by codend with and without kites.

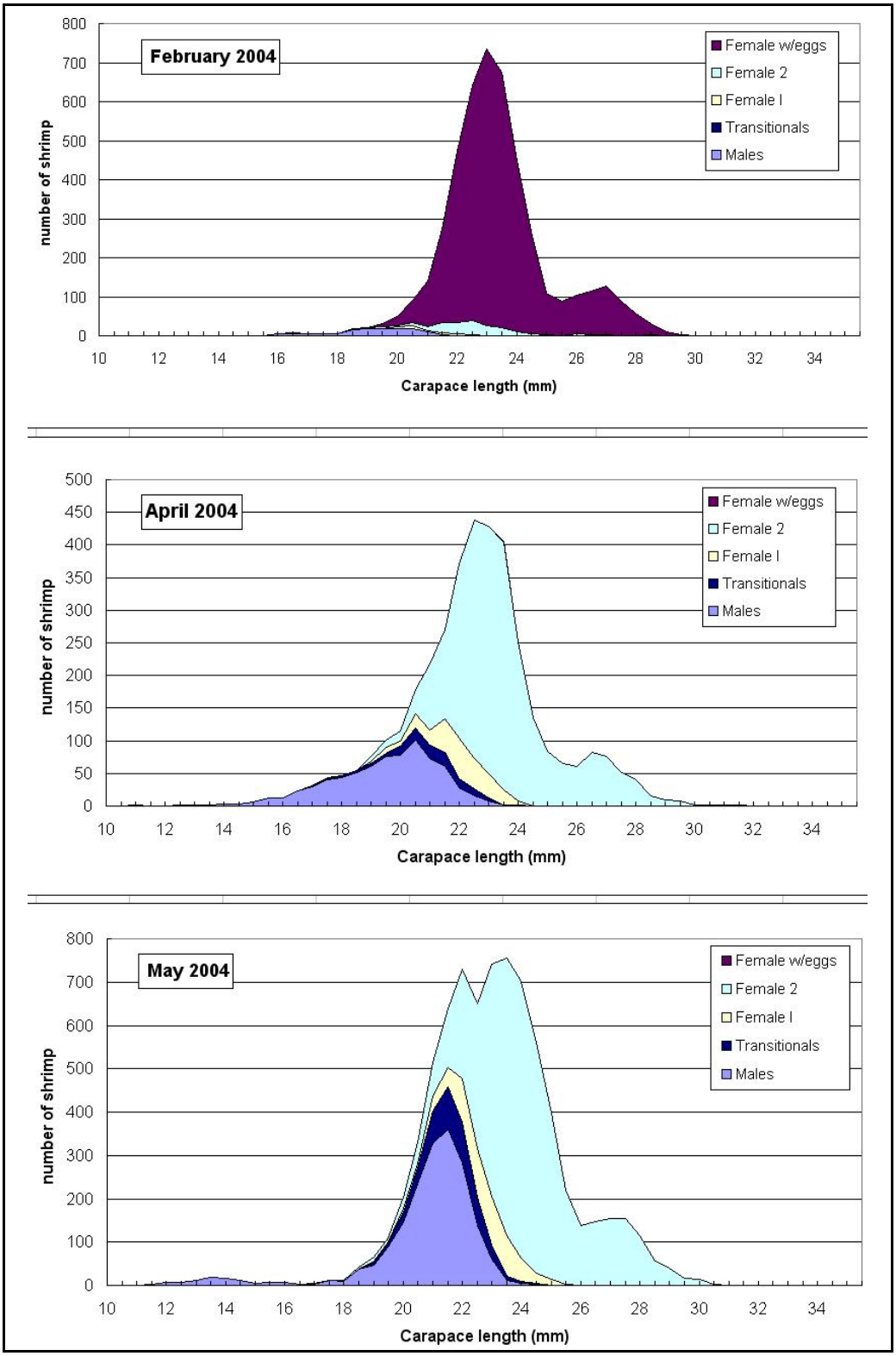

Exhibit 9. Composition and size distribution of pink shrimp (*Pandalus borealis*) during the month of February, April and May, 2004.

4. DISCUSSIONS

4.1 Use of water-borne kites in shrimp trawl codend

The analysis indicated that the use of kites in the codend did not reduce finfish bycatch and small shrimps as one had expected. The extra mesh opening by the kites seen in the flume tank might have not been fully realized under heavy loads of codend catches. Further research through other means should therefore be carried out to solve small shrimp and juvenile fish bycatch problems in the pink shrimp fishery in Gulf of Maine. A size-sorting grid and a topless shrimp trawl have since been successfully developed by He and his colleague (He & Balzano, 2007; He *et al.*, 2007).

4.2 Characteristics of target and bycatch species

As the commercial shrimp fishery closed in the middle of March 2004, biological data of shrimps and bycatch species obtained during April and May 2004 are very useful for resource management. Size distribution, and composition of shrimps of different developmental stages and sexes would complement resource survey data obtained by the Maine Department of Marine Resources's shrimp trawl surveys.

Bycatch amount and species composition obtained during this study will provide useful information on bycatch and discard in this fishery. A large amount of whiting bycatch late in the season is a concern and requires further research and development for finfish bycatch reduction were the shrimp season to be extended to the month of April.

4.3 Partnership between commercial fishermen and researchers

This project is a joint effort of two commercial fishing vessels, the Maine Department of Marine Resources, and the University of New Hampshire. Additionally, a commercial fisherman was also used as at-sea observer for ten fishing days. There were numerous opportunities for cooperation and collaboration among scientists (from DMR & UNH) and

fishermen from the start of the proposal stage, to flume tank testing in Newfoundland, to the sea trials which completed at the end of May. The DMR scientist (Dan Schick) was in charge of sample handling and processing, taking advantage of his years of experience in shrimp biology and shrimp survey. All samples were measured at DMR facility at Boothbay Harbor using DMR's existing equipment and procedure.

4.4 Impacts and Applications

The preliminary results from the project do not suggest that a reduction in small shrimp and finfish bycatch can be realized through the use of kite-assisted codends. However, the project does highlight the need for further research on finfish bycatch reduction in the pink shrimp fishery, especially for whiting. Whiting to shrimp ratios of as much as 5 to 1 were recorded in this study, even with the use of Nordmore Grid bycatch reduction system. A recent study by the principal investigator and one of the industry partners, not directly related to this project, investigating bycatch reduction in shrimp trawls, showed promising results of using a modified Nordmore Grid for reducing finfish bycatch in the fishery (He & Balzano, 2005, 2007; He et al., 2007).

5. ACKNOWLEDGMENT

The project was supported by the Northeast Consortium, a join initiative of the University of New Hampshire, University of Maine, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. Keri Stepanek, Bruce Gadaree, Tim Eddy, and staff at Maine Department of Marine Resources participated data collections during sea trials. George Legge and Harold DeLouche at Fiosheries and Marine Institute of Memorial University assisted in kite design, fabrication and tank testing.

6. LITERATURE CITED

Broadhurst, M. K. & Kennelly, S. J. (1994). Reducing the by-catch of juvenile fish (mulloway *Argyosomus hololepidotus*) using square-mesh panels in codends in the Hawkesbury River prawn-trawl fishery, Australia. Fish. Res., 19, 321-331.

He, P. (2007). Selectivity of large mesh trawl codends in the Gulf of Maine: I. Comparison of square and diamond mesh . Fisheries Research, 83: 44-59.

He, P. & V. Balzano (2005). Preliminary Test of a Modified Nordmore Grid in Reducing Fish Bycatch in Shrimp Trawls. A report submitted to the Northeast Consortium. University of New Hampshire, Durham, NH. UNH-FISH-REP-2005-014. 16 pp.

He, P & V. Balzano. (2007). Reducing small shrimps in the Gulf of Maine pink shrimp fishery with a new size-sorting grid system. ICES Journal of Marine Science. 64: 1551-1557.

He, P., D. Goethel & T. Smith. (2007). Design and test of a topless shrimp trawl to reduce pelagic fish bycatch in the Gulf of Maine pink shrimp fishery. J. Northw. Atl. Fish. Sci. 38: 13-21.

He, P., R. Hamilton, T. Smith, C. Bouchard (2005). The effect of mesh size and shape on codend selectivity in the Gulf of Maine multispecies trawl fisheries. A final report submitted to NOAA Fisheries. University of New Hampshire, Durham, NH. UNH-FISH-REP-2005-023. 173 pp.

He, P. & G. Littlefield. (2003). Reducing seabed contact of trawling: sea trials of a semi-pelagic shrimp trawling system on board F/V "Lady Regena". A report submitted to the Northeast Consortium. University of New Hampshire, Durham, NH. 18 p.

Valdemarsen, J. W., K. Lehmann, F. Riget & J. Boje. (1993). Grid devices to select shrimp size in trawls. ICES CM, 1993/B:35, 1-12.

Appendix

Additional Photographs