COONAMESSETT FARM
277 Hatchville Road
East Falmouth, Massachusetts, USA 02536
508-564-5516 FAX 508-564-5073
cfarm@capecod.net

Final Report

Project: Gill Net Survey (RFR#: 9836)

August 10, 1998

Executive Summary

The intent of this project was to continue to collect and analyze information in support of the Commonwealth's program to reduce the risk of entanglement of right whales in bottom set gill nets. The project was divided into a number of tasks as follows: 1) Survey the type of bottom set gill net gear currently in use along the coast of Massachusetts including mesh size, twine size, float and lead line configurations, material, and age; 2) Collect a minimum of twenty samples representative of actively fished gill net float line and conduct loading tests on these samples to determine breaking strengths; 3) Acquire and test weak link configurations on commercially fished gill nets on a minimum of three vessels representative of the Massachusetts gill net fleet; 4) Perform a minimum of ten sea trials consisting of 2 sea days, one day to set the MDMF logger and the following day to retrieve the logger, on commercial bottom set gill net boats operating off Massachusetts; and 5) Complete a written report presenting the results of the survey, testing, and sampling.

Information on gill net design and rigging was collected from the F/V Miss Fitz (Chatham), the F/V Chrissy (New Bedford), the F/V Hostile (Gloucester), the F/V Lady Irene (Scituate) and several other vessels. A sink gill net data sheet was designed and utilized for these interviews. In addition, the NMFS sea sampling data base was accessed and data assembled on gill net rigging for 1995 and 1996.

Twenty-five samples of float line from four geographic areas were acquired from gill nets. The samples consist of ten foot sections of float line cut out of the net and replaced with a new sections. The samples were cut into specimen sections and tested for breaking strength at the Massachusetts Maritime Academy and/or the Woods Hole Oceanographic Institution utilizing existing tensile testing apparatus. Some of the sections were tested both wet and dry. An additional nine samples of new float line material were acquired and similarly tested for comparison purposes.

Weak link sections were placed into the gill net float lines of three vessels that provided float line samples for the tests outlined above. The weak links consist of 1/4" manila line, 3 mm braided twine, the MacKinnon Whale Safe, and engineered plastic links. The participating vessels maintained a fishing record of the modified nets.

Introduction

The northern right whale (*Eubalanea glacialis*) is the most critically endangered large whale in the world, and is protected under the Endangered Species Act (ESA). The western North Atlantic population is estimated to be approximately 300 animals. In 1995, the re-authorized Marine Mammal Protection Act (MMPA) mandated that the kill of northern right whales from interaction with commercial fishing gear be reduced to zero. In September 1996, a Federal District Court in Massachusetts issued an injunction which ordered the Massachusetts Division of Marine Fisheries (MDMF) to develop a proposal to restrict, modify, or eliminate the use of fixed fishing gear in waters of Massachusetts considered right whale critical habitat, including most of Cape Cod Bay.

Coonamessett Farm has been working over the past decade on means to reduce the rate of serious injury and mortality of marine mammals in commercial fishing gear. In January, 1997 the International Wildlife Coalition (IWC) received a grant from the Massachusetts Environmental Trust to develop and test snag-free fishing gear for use in reducing right whale entanglement and mortality. The IWC research team consisted of members from the IWC (whale biologists), Coonamessett Farm (gear technologists), and the Massachusetts Lobstermen's and Massachusetts Bay Area Gill Netters Associations (fishermen).

One aspect of the research program was the development of a means of surface buoy attachment that would break free without snagging a whale that came into contact with the buoy. After considerable research, a method was devised using hog rings to attach the buoy line to the buoy (Wiley et al, 1997). With a satisfactory working solution to this aspect of the entanglement problem, the research project began to focus on the gill net itself.

Bottom sink gill nets used in the New England groundfishery are typically 300 feet (91 m) in length, 8 feet (2.4 m) to 12 feet (3.7 m) in height, and are set end to end in strings of nets up to 6000 feet (1,828 m) in length. Each net consists of a float line and a lead line to which monofilament webbing is attached or "hung". The webbing in the groundfishery typically ranges from 6 to 8 inches in mesh size and is mostly 14 gage thickness. At the end of each net the float line attaches to the lead line forming bridles to which the next net in the string is attached. The end nets of the string are anchored and attached to the surface buoy line. When targeting certain species, such as flounders, the float line is sometimes "tied-down" to the lead line reducing the vertical height of the net to 2-3 feet.

In October, 1997, the National Marine Fisheries Service funded Coonamessett Farm to examine the possibility of using weak links on the float line of gill nets. Three days of largely empirical land testing of gill net modifications were conducted to examine potential means to reduce whale entanglement using weak links. More than two dozen trials were conducted in which loads were recorded on each end of the float line and lead line as well as the simulated whale loading. Weak link devices tested included knotted line, light line, plastic links, and "Chinese fingers". The breaking strength of 6.5 and 7.0 inch, 14 gage, monofilament webbing was also tested.

The land testing indicated that a weak link in the float line could theoretically reduce the risk of a whale being entangled in a gill net after striking that net. The concept is that the float line would part before the whale gets concerned enough to thrash and rotate thus becoming enmeshed in the gear. A fundamental question though is to what design load should the weak link be constructed. The stronger the link the more likely a whale encountering the net will be entangled. On the other hand, if the link is too weak the fisherman may have trouble in retrieving the fishing gear.

To determine what the required working strength of a float line can be accomplished in several ways. One approach would be to find out what type and size float line fishermen currently use and and get the breaking strengths from the manufacturers. Another approach would be to go out and haul gill nets and measure the loads under a range of conditions. There are difficulties with each approach. Float lines used in the fleet can be many years old and thus suffer a significant loss in working strength. If this is the case, fishermen are in fact accepting breaking loads much lower than published values before retiring the float line from service. The difficulty in measuring actual loads is that the gill net is hauled as a unit with the load being distributed between the lead line, float line, and twine in a highly variable fashion. To measure that part of the load placed on the float line would be difficult if not impossible.

The approach chosen for this project was to conduct an initial phone survey of fishermen that set gill nets off the coast of Massachusetts to determine what degree of variation existed in the gear. In addition, we made site visits to four of the main gill net gear suppliers and two leading gill net gear hangers in Massachusetts. The results of this initial effort indicated that there was very little variation in gill net gear design that would be significant from the perspective of reducing whale entanglement risk. The few variations that we considered important were as follows:

a) Gear fished offshore in areas of greater depth and/or strong currents, used stronger float lines. However, the range of material and size was still very limited.

b) The anchoring weight used was also a function of tides and depth, ranging from 10 to 160 lbs each end. Total string anchor weight of 240 lbs was reported.

c) The float lines were virtually all either braided foam core or twisted polypropylene with attached floats.

d) Float line condition ranged from new to very used. Eighty to ninety percent of the nets in use have been re-hung. Ten year old float lines are not uncommon.

We then confirmed what we found in our initial survey by examining the NMFS Observer program data base. The primary source of information in this data base relevant to this project was the Sink Gill Net Gear Characteristics Log (**Appendix One**). The review of this data base confirmed the results of our interviews.

Our next step was to collect samples of float lines representative of the gear actually being fished (as identified by our preliminary survey). A Sink Gill Net Float Line Data Sheet was completed for each sample collected (**Appendix Two**). The data sheets were completed by the fishermen and contain their understanding of the characteristics of their float line. There is probably a range of accuracy on issues of age and times re-hung. Some fishermen reported net height as their estimate of the location of the float line in the water column as the gear fishes. Fishermen typically refer to all twisted line as “poly”. In a number of cases this line might not be pure polypropylene but a blend of fibers. Also, similar line (size and color) might in fact be produced by different manufacturers and thus have more subtle variations associated with construction. We made an attempt to acquire new line to match the float line samples.

Another portion of this project was to field test some weak link designs to get a preliminary understanding of some of the operational problems that may exist. Our primary concern was whether or not the weak links were strong enough to hold up under actual fishing conditions. Secondly, we wanted to see if the plastic weak links, designed for lobster buoy lines, would cause problems by snagging the monofilament twine mesh during hauling and setting. We did not continue this part of the project to the extent we planned because it was becoming apparent that the float line strength required to safely haul gill net gear may exceed that needed to reduce risk to whales. This point will be covered in more detail in the discussion section of this report.

One final aspect of the project was to test a prototype gill net data logger supplied by the Division of Marine Fisheries. The logger was designed to measure tilt and current speed. The concept was to determine how high the gill net float line is located off-bottom under different tidal conditions. Initial field trials with the data logger identified a number of problems with its deployment that need to be resolved before data collection could begin.

Float line survey

The NMFS observer data base for 1996 was examined to describe the gill net fishery in relation to its use of float lines (Appendix One). Float lines can be fished in a "tied-down" manner, in which the float line is tied to the lead line, or in a "stand-up" manner, in which the float line is not constrained. The float line itself can be made of foam core, twisted poly, or less frequently, other materials.

Tie-down Method:

The data base included 64 vessels that used tied-down gear. A total of 11,734 observed nets (nets) were fished in this manner. Of those nets, 8% (n=957) used foam core for the float line, 90% (n=10,306) used twisted poly, 1% (n=58) used "other" material, and 1% (n=91) did not have the float line material recorded. Anchor weights used in association with tie-down nets ranged from 0 lbs to 240 lbs in weight. These anchor weights probably are the combined total for a string.

Stand-up Method:

The data base contained 112 vessels that fished nets without tying the float line to the lead line. A total 30,024 nets were fished in this manner. Of those nets, 7% (n=2,059) used foam core for the float line, 89% (n=26,842) used twisted poly, and 4% (n= 1,111) did not have the float line material recorded. A single vessel dominated the use of foam core float line in the stand-up gear type. This vessel accounted for 752 of the nets recorded as using foam core for a float line. Anchor weights for this gear ranged from 0 lbs to 240 lbs.

Data was collected by Coonamessett Farm during this project on twenty-five sink gill nets representative of the gear fished by six vessels out of various Massachusetts ports as follows:

F/V Miss Fitz	Chatham, MA
F/V Chrissy	New Bedford, MA
F/V Hostile	Gloucester, MA
F/V Dawn T	Chatham, MA
F/V Danny Boy	Boothbay Harbor, ME (fishing off MA)
F/V Lady Irene	Scituate, MA

The results of this survey were, in part, documented on the Sink Gill Net Float Line Data Sheets (Appendix Two).

Float Line Size:

Most float line is made out of 3-strand twisted polypropylene fiber rope. The diameter is virtually always 5/16". We could not find any vessel fishing 1/4" diameter line. We did find several that operate offshore using 3/8" diameter and heard of a few that might be using 7/16" diameter but this was not confirmed. A percentage of the fleet, at times, uses polypropylene foam core line of 1/2" nominal diameter. We could not find any consistent reason why this choice is made other than the belief the gear fishes better under certain conditions.

Float Line Material:

Most of the float line samples we received seem to be made of polypropylene fibers. There are a number of blended fiber ropes on the market, containing polyester, but these are usually more expensive thus apparently not commonly used for float line. The gear suppliers are receiving inexpensive polypropylene line from China but do not have any specification sheets on the product.

Float Line Age:

Fishermen estimate that between 80-90 % of their gear is re-hung. This means that new monofilament mesh is attached to the used rope frame (float line and lead line). Re-hanging is reported to be at least an annual event but may easily occur 3-4 times annually depending on where the individual fisherman operates. We found samples of gill net rope frames that the owners thought were at least ten years old. This is quite common because most fishermen have several sets of nets; some of which they only fish for a limited season then store. Storage is almost always covered ut commonly outside.

Lead Line:

The only lead line we found in use was 50# and 65# woven fiber rope lead line. We did not find an example of a fisherman using attached line weights historically used for the gear.

Anchoring:

Anchor weights can range from a 10 pound weight on one end of a string to weights at both ends; some as heavy as 160 lbs. The offshore gear fished in high tidal conditions use the higher weights on the uptide end. Anchors commonly are made of sections of railroad rail. Danforth anchors are commonly used and cement blocks have also been reported. In many cases there are no anchors used on one end of the string.

Float line testing

Fifteen samples of float line, ten feet in length, were acquired during February and March 1998 for breaking strength tests (Sample #'s 1-15) from five vessels. Sample # 13 of this group was brand new line never used. In April and May 1998 an additional ten samples of similar length (Sample #'s 16-25) were acquired from the collection of nets fished by the F/V Lady Irene out of Scituate, MA. Information on the gill nets these samples were taken from can be found in Appendix Two.

The initial fifteen samples were cut into sections and tested at Massachusetts Maritime Academy (MMA) on April 30, 1998. The sections were tested using a Tinius Olsen Universal Testing Machine calibrated on 3/15/98. Two sections, two feet in length, were cut from each of the ten foot samples. One section of each sample was soaked in fresh water for 48 hours before the test.

The purpose of this exercise was to get an idea of the actual breaking strength of float lines in the fishing fleet. There was no attempt to do replicate samples for the purposes of establishing confidence limits at this time as these tests were exploratory in nature. There was a significant problem in using the MMA machine relative to standard testing procedures (Cordage Institute). The first aspect of the problem was the testing machine did not have an adequate throw (distance between crossheads) to test lengths required to meet testing standards. Secondly, the only way to hold the samples consisted of wedge grips which may of impacted the strength of the samples. The distance between wedge grips during the tests was about six inches.

The tests were conducted and the results are displayed in Table One. There seems to be no significant difference between wet and dry samples. In fact, the wet and dry samples failed within 10% of their total breaking strengths.

In order to better approximate standard testing procedures, a second series of tests were conducted at the Woods Hole Oceanographic Institution using their Baldwin Materials Tester. This machine had ample throw range. Our samples were prepared in two foot sections overall with eye splices at each end. The samples were attached to the crossheads by shackles through the eye splices. Some of the braided samples had the eye splices made by three straight tucks through the braid. The results of these tests can be found in Table Two.

Before discussing the results of these tests a number of points need to be brought to the readers attention. Even when testing new fiber rope their can be major differences in breaking strength due to the testing procedure. For example, The American Group, a rope maker, gives the tensile strength of their 5/16" 3-strand SSR-100 as 2300 lbs using their test procedures and as 1870 lbs using the Cordage Institute Standards (CIS); a difference of 18.7%.

Once fiber rope is placed into service it is continuously deteriorating, and most likely, non-uniformly. A gill net float line can have weak spots develop due to abrasion (a snag on a rock), a sharp bend under tension during hauling, a section exposed to sunlight during long-term storage, etc. The low breaking strength of sample #22, away from the knot being tested, may of been due to a weak spot.

Cordage Institute Standards (CIS) require a set testing procedure. We will now review two of the key procedures in reference to our two test series. First, regarding the test machine, the CIS requires a minimal distance between grips of 1 ft (300 mm) for ropes less than 5/8" diameter. MMA tests did not meet this requirement; the WHOI tests did meet this standard. The CIS standards require measuring the rope diameter under a reference tension equal to 50 times the diameter squared. For 5/16" rope the reference tension would be about five lbs. The MMA measurements were not made under tension; the WHOI measurements were made under a tension of 20 lbs which is within the calibration accuracy of the testing machine (1% of the estimated breaking force of the test specimen). We could not conduct tests for linear density or elongation because of the used condition of the rope.

Given the above information, we believe the WHOI Test Series is a close match to standard test procedures for determining breaking force. Table Three summarizes these results by rope category. For comparison purposes we gathered rope specification tables from various sources and found the range of listed breaking strength of 5/16" polypropylene fiber rope to be 1710 lbs to 1850 lbs; 3/8" polypropylene fiber rope to be 2440 lbs to 2600 lbs. Our tests of five samples of new 5/16" polypropylene fiber rope gave an average breaking strength of 1757 lbs which is within the published range. The one sample of new 3/8" polypropylene fiber rope we tested failed at 2196 lbs; about 10% below the published numbers for this diameter rope. However, two of the three used samples failed close to the published values.

What is most interestingly observed from the results in Table Three is the deterioration in breaking strength of 5/16" twisted polypropylene from an average strength of 1757 lbs new to an average strength of 1231 lbs used; a loss of 30% of the original strength.

Float line weak link field trials

This portion of the project entailed the placing of weak links in the float lines of commercially fished gill net gear. We began the testing by using 1/4" 3-strand twisted manila fiber rope spliced into the 5/16' twisted polypropylene float line. The published minimal tensile strength for manila is 540 lbs. However, we found that the manila line we were using failed at about 700 lbs during our land trials. The first series of tests were conducted by the F/V Miss Fitz out of Chatham, MA. The tests were conducted offshore in the lower reaches of the Great South Channel in water depths of 35-38 fathoms. The following are some results:

5/28/98	Set gear; 14' tide (current about 3 knots)
5/29/98	Retrieved gear OK, 14' tide; re-set
5/31/98	Retrieved gear; broke link due to hang, trashed net, 13' tide; re-set
6/1/98	Retrieved gear; link failed at splice, 11' tide; re-set
6/2/98	Retrieved gear OK; re-set
6/4/98	Retrieved gear OK; re-set
6/6/98	Retrieved gear; link failed at splice; re-set
6/7/98	Retrieved gear OK; re-set
6/8/98	Retrieved gear OK; re-set
6/10/98	Retrieved gear OK; re-set
6/11/98	Retrieved gear OK; re-set

In summary of this test, the links failed in three out of ten retrievals; an unacceptable 30% failure rate. The vessel captain, John Our, reported that he was almost injured during one failure. The link tended to break at the roller during a sea surge. A second series of tests were conducted closer inshore near the USCG BB buoy. This is in the Great South Channel in 38-42 fathoms. The tidal current runs about two knots. During 17 retrievals in June, 1998 there were no failures of the weak link. Attempts were made to use a plastic link designed for lobster trap buoy lines but they became entangled in the twine mesh.

Gill net data logger

The gill net data logger consists of a cylinder containing a tilt sensor and a pressure (depth) sensor and supporting power and recording components. Attach to the cylinder is a velocity sensor consisting of a vane and rotor.

The unit was deployed twice during a test and in both deployments the velocity sensor components fouled in the gill net twine. Work is underway by MDMF to modify the sensor and deployment strategy to eliminate these start-up problems.

<u>Discussion</u>

The primary purpose of this project was to try to establish what the required breaking strength of a gill net float line should be to safely work the gear. If a float line parts under tension on deck during gear retrieval it can kill or maim the fisherman. It is interesting to note at this time that fishermen fish their gear very close to the breaking strength; not to the recommended working strength. For 5/16" twisted polypropylene fiber rope the recommended maximum working load is 171 lbs.

If OSHA entered the picture, the required diameter of float line would probably be at least 3/4" twisted polypropylene (maximum working load of 1090 lbs; breaking strength of 7650 lbs). Working loads are based on new, unused rope in excellent condition and should be reduced if possible injury to people exist. This is an extremely important point from the perspective of regulation. If a government entity specifies a **minimum** strength (a weak link) for a gear component (such as the float line) it would probably be specifying an unsafe condition by all conventional standards; an act lawyers would most likely resist.

We did not find any fisherman using 1/4" twisted polypropylene fiber rope for their float line. The published breaking strength for 1/4" twisted polypropylene is 1130 lbs. Fishermen for the most part choose 5/16" twisted polypropylene with a breaking strength of about 1750 lbs. Our tests of used float line would indicate that most of the float line is retired from service before its strength is reduced below 1000 lbs. The above facts would indicate that fishermen need a minimum float line strength of 1000 lbs to safely work their gear in the traditional manner. In certain offshore waters, hard bottom with high current conditions (exceeding 2 knots), the strength required may be closer to 2000 lbs based on the fact that 3/8" twisted polypropylene is in common use. Our field testing of 1/4" twisted manila fiber rope (breaking strength of about 700 lbs) as a weak link demonstrated that this strength is unacceptable offshore.

Now we need to examine this issue from the whale perspective. Our land testing of gill nets indicated that if a whale, swimming along at several knots, encountered gill net webbing, the whale would most likely be able to swim right through the mesh (a force of about 200 lbs would be needed to break through). If the whale during the encounter snagged the float line the gill net string would drag behind the whale until it either slipped off or enough force was generated to break the float line. The higher the force needed to break the float line the more likely the whale will take some action that might further exasperate the situation resulting in an entanglement. We can only guess at what point a whale will react.

The goal is to reduce risk of entanglement. On a simple level of analysis, any reduction in the breaking strength of the float line should be in the direction of reducing risk. The results of this project would indicate that fishermen are now working very close to the minimum strength required to safely work their gear. Fishermen traditional take risks to keep their costs down, especially when fishing is marginal economically as is currently the case.

One possible solution would be to eliminate the need to put any strain on the float line during gear retrieval. In current practice both the lead line and float line are placed in the hauler. The strain during retrieval is usually on the lead line but is also shared by the mesh and the float line. Under some conditions (caused by tide, snags, etc) during the hauling process the load is fully transferred to the float line. There are possible changes that can be made to the gear and to the hauler to greatly reduce and possibly eliminate loading the float line.

It is recommended that means to haul gill net gear using only the lead line should be investigated. In addition, fishing tests should be conducted on gill net gear rigged with a minimal float line (either a light foam core or floats only) to examine the feasibility of eliminating the float line completely.