Investigation of Practical Aspects of Marking Fixed Fishing Gear With Coded Wire Tags To Better Understand Whale Entanglement

Final Grant Report for the International Fund for Animal Welfare

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Executive Summary

The objective of this project was to investigate the feasibility of utilizing coded wire tags (CWTs) to mark line utilized in commercial fixed gear fisheries to better understand whale entanglement. We investigated the practicality of several methods of placing CWTs into line used for commercial fixed gear fisheries. The project examined the effectiveness, safety, and longevity of marking fixed fishing gear with CWTs and utilizing marked ropes in fixed gear fisheries.

The project had two components: 1) field deployment of rope marked with CWTs; 2) accelerated longevity testing of CWTs in marked ropes using a rope testing device that simulates gear hauling. A total of 1,967 tags were placed into rope for testing. We evaluated the different methods utilized to implant CWTs in rope for each component of the project.

The objectives of the work was to determine if the CWTs would be retained in the gear and remain readable after field use and testing to simulate 5 years of hauling gear used in commercial fishing operations.We also examine safety aspects and potential problems of utilizing rope marked with CWTs. No problems or safety concerns were expressed by any of the fisherment that used marked gear while for fishing operations.

We found that >90% of the CWTs read after testing were readable. The methods of marking developed during this pilot study showed substantial promise but are not currently adequate for large scale industrial deployment to assure retention rates >90%. Placing CWTs into twine that can be woven into rope proved to be the most practical and effective method of marking gear with over 80% of CWTs place in gear subjected to the equivelant of five years of hauling retained.

We project potential costs per tag for industrial use of a CWT based technology and examine options for marking frequency of rope employed in commercial fishing operations.

Background

Whale Entanglement

The bycatch of right, humpback, fin and minke whales in commercial fixed gear fisheries is known to cause serious injury and mortality to these protected species. NOAA's National Marine Fisheries Service (NMFS), in consultation with the Atlantic Large Whale Take Reduction Team (ALWTRT), implemented the Atlantic Large Whale Take Reduction Plan (ALWTRP) in 1997 to reduce the risks of entanglement to large whales through a set of gear modification and other requirements that affect commercial fishing operations along the East Coast. Affected fisheries include gillnet and lobster trap/pot fisheries, as well as more recently other trap/pot fisheries (e.g. Jonah crab, hagfish, red crab). Currently the ALWTRP requires placing one 4" colored mark at the midpoint of buoy line.

In a recent effort to examine gear that entangled right and humpback whales only 45% of the gear entangling right whales could be identified to a given fishery (Johnston et al. 2005). A fuller scientific understanding about the nature of entanglements, specifically the gear components (e.g., buoy line, groundline) and other factors involved, would help to (1) monitor the ALWTRP and (2) develop further management measures to reduce the risk of large whale entanglements due to incidental interactions with fixed gear fisheries.

There is a need for a technological device to mark line in a wet environment that can provide additional information about the nature of the gear involved in an entanglement. NMFS and others have researched alternative marking scheme/systems, but to date none has been deemed satisfactory in meeting the needs of both the fishery and the management data-collection requirements. Ideally, the device will help identify data surrounding the entanglement event such as whether the rope is groundline or vertical, the fisherman (e.g. owner's name, contact information, hail port), type of fishery, the area fished, and date of deployment as well as other data. The device could refer back or link to a database that contains most of the information which can be updated as needed. Data retrieval should be accurate and dependable. The device should be portable for use in more than one fishery.

The device must be durable to withstand the harsh environmental conditions of the commercial fishery. For example, underwater pressures may reach 600 psi in some depths; line may be subject to loads from 1000-5000 lbs.; while under load, hauling equipment subjects the rope to sharp radius turns; and typical hauling equipment functions as a result of the rope wedging itself into a "V"-shaped groove in a rotating disk. The ideal device must also require minimal time and be straightforward to deploy/attach and maintain over the life of the gear. The device needs to be safe to use and technologically feasible to implement. Additionally, the device must be able to be attached to a wide variety of rope types and sizes (e.g. ropes typically range between 5/16" and 3/4" diameter) used in fixed gear fisheries. Costs associated with purchase and maintenance/replacement is an important factor in practical application of the device.

The Potential to Use Coded Wire Tags to Mark Commercial Fixed Fishing Gear

Coded wire tags (CWTs) exhibit many of the characteristics required to mark line in commercial fixed gear fisheries. They are a proven technology with a long history of use in the marine environment. They have an enormous coding capacity to reliably store data. They can be reliably detected with a portable handheld wand. They are tiny and should be able to be placed into line of any diameter so that they will not impact utilization by fishermen in any way. They are relatively inexpensive.

CWTs were developed over 30 years ago for large scale studies on migratory salmonids (Jefferts et al. 1963). CWTs are made of surgical grade stainless steel wire 0.25 mm in diameter and typically measure 1.1 mm long (Figure 1), but they have been deployed at half, one-and-a-half, and double lengths for various purposes. Five different CWT formats are available: Standard, Half-Length, One and a Half-Length, Sequential, and Agency Only.

Figure 1. A standard length CWT measures 1.1 mm long by 0.25 mm diam.

All CWTs are etched with a series of decimal numbers 0.16 mm tall. Standard CWTs have four rows of repeating decimal numbers etched along the wire from which the CWT is cut, at 90^{o} intervals around the wire (Figure 2).

For this project we chose to use Decimal Sequential CWTs which are the same size as the Standard tags, but in addition to the three types of two-digit numbers found on the Standard tag, the Sequential tag also includes a unique number on each tag. Thus Sequential CWTs come in groups of tags that are numbered in sequence.. These tags are designed for use where identification of small groups of tags or individual specimens is desired. The Decimal Sequential tag has three words (Agency, Data 1, Data 2) written along the axis of the tag in two rows, followed by a sequence number written along the circumference. The formatting of the Sequential tag ensures that one entire Sequence number is always available. To resolve the ambiguity created when two complete Sequence numbers are readable, the convention is that the lesser number be used. The marked 1.10 mm example shown below (Figure 3) as a flattened face of the wire that would be read as: Agency = 16, Data 1 = 58, Data 2 = 09, Sequence = 00146. As an example, for use in marking fishing gear the 100 possible numbers for Agency could represent th entity issuing permits, the 100 possible numbers for Data 1 could represent the fishery, the 100 possible numbers for Data 2 could represent the area fished, and the 10,000 possible numbers in the sequence could represent tags issued to a given permit holder that go into specific parts of each of his/her gear. This is only one simplistic possible example of a numbering strategy that could be employed. The use of these sequential tags is somewhat more complex because it requires saving or "archiving" of a CWT before and after the implanted tag or tags.

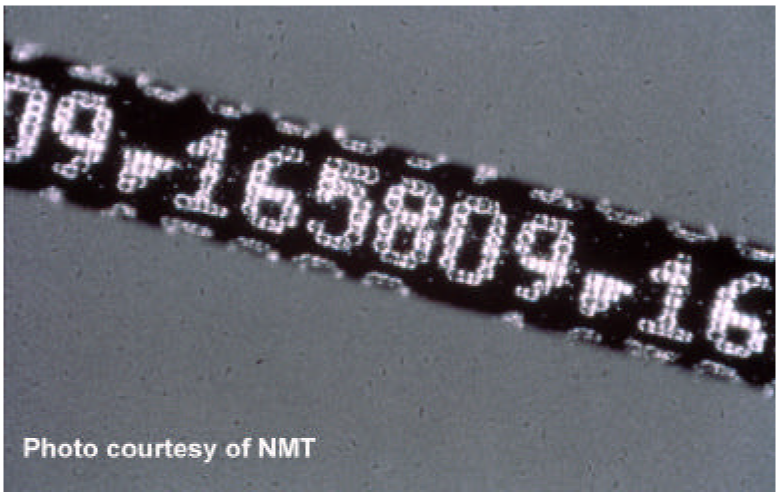


Figure 2. Numbers 0.16 mm tall etched in four ropes along the circumference of Standard CWTs.

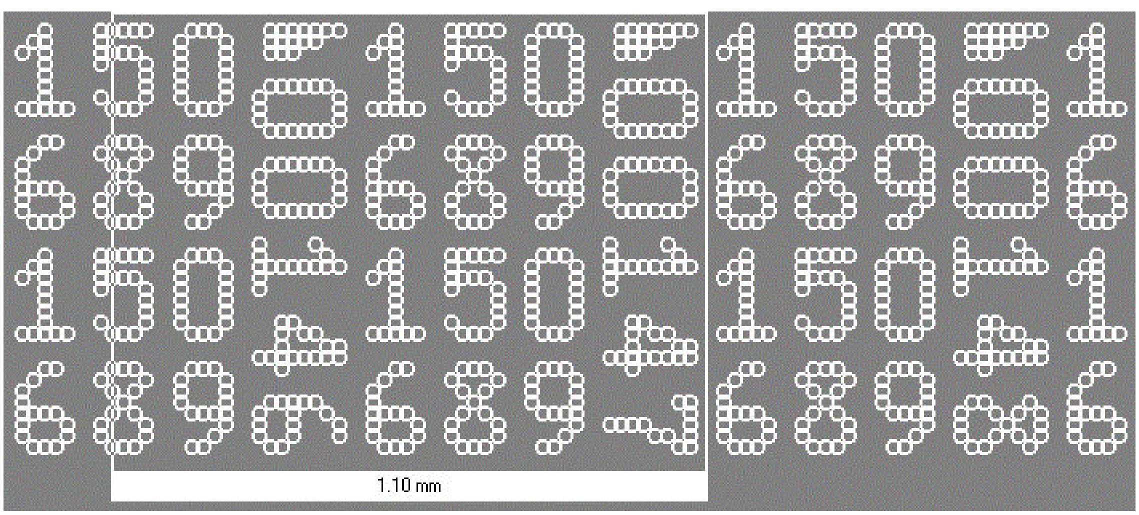


Figure 3. Sequential CWTs have three repeating “words” (Agency, Data1, Data2) followed by a unique 5 digit sequential number..

The coding capacity of CWTs is immense, especially considering the small size of the tags. This coding capacity would allow each set of fixed fishing gear belonging to an individual fisherman/permit holder to be marked and the rope used for groundline to be distinguished from rope used for endlines or surface systems. A database with information about the individual permit holders could contain any additional data desired and collected, such as location or region fished and dates gear was last set or checked.

CWTs are magnetized and can be detected using any of a number of magnetic detection devices including a highly portable Handheld Wand Detector. CWTs must be retrieved to be read. CWTs are read using a low power (20 to 40 x) light microscope. In the case of rope recovered from an entangled whale, CWT(s) would be extracted and read after any other data about the gear recovered is documented.

CWTs are manufactured by Northwest Marine Technology, Inc. (NMT) base in Shaw Island, WA. Much more information about CWTs including history of their development, the wide variety of successful uses of this technology, and a long list of scientific publications featuring the use of CWTs is available on the NMT web site http://www.nmt.us/. The "Coded Wire Tag Project Manual" compiled by D. J. Solomon available on the NMT web site http://www.nmt.us/support/appnotes/apc15.pdf provides basic information on utilizing CWTs and details on all formats as well as background information.

Project Overview

The objective of this project was to investigate the feasibility of utilizing CWTs to mark line utilized in commercial fixed gear fisheries to better understand whale entanglement. We investigated the practicality of several methods of placing CWTs into line used for commercial fixed gear fisheries. The project examined the effectiveness, safety, and longevity of marking fixed fishing gear with CWTs and utilizing marked ropes in fixed gear fisheries.

The project had two components: 1) field deployment of rope marked with CWTs; 2) accelerated longevity testing of CWTs in marked ropes using a rope testing device that simulates gear hauling. We evaluated the different methods utilized to implant CWTs in rope for each component of the project.

Data collected on the lengths of pieces of rope recovered from entangled whales was provided by NMFS gear specialists who analyzed the gear. A length frequency distribution of rope recovered from entangled whales examined. The objective was to utilize the distribution frequency of rope lengths to examine the consequences of marking rope at different intervals. Specifically we looked at the likelihood of recovering marks based on their spacing to help with a cost benefit analysis in being able to identifying rope recovered from an entangled whales.

Finally we examine potential costs for tags developed utilizing CWT technology for an industry wide program to mark rope used in fixed gear fisheris.

Utilizing Pre-cut Sequential CWTs

We utilized pre-cut CWTs for this project because we anticipated needing approximately 3,000 tags. Northwest Marine Technology, Inc. (NMT) provided us with 55 sheets of paper with pre-cut 51 pre-cut tags per sheet. Pre-cut tags were also used to facilitate injection directly into rope with adhesive. To distinguish between methods of placing CWTs and the various ropes they were placed in,we kept or "archived" tags. The archived tags were left in place and taped over with cellophane tape on the sequentially number sheets containing pre-cut sequential CWTs. Notes on the method used to insert tags and the ropes they were inserted into or destined to be utilized in were also recorded on the tag sheets. The archived tags were later read and the tag numbers recorded to bracket the sequence of tags utilized for any given treatment in any given rope. These data were put into a simple database that allowed us to easily look up specifics for any given tag when it was later read after testing was completed.

Methods to Place CWTs into Fixed Fishing Gear Rope

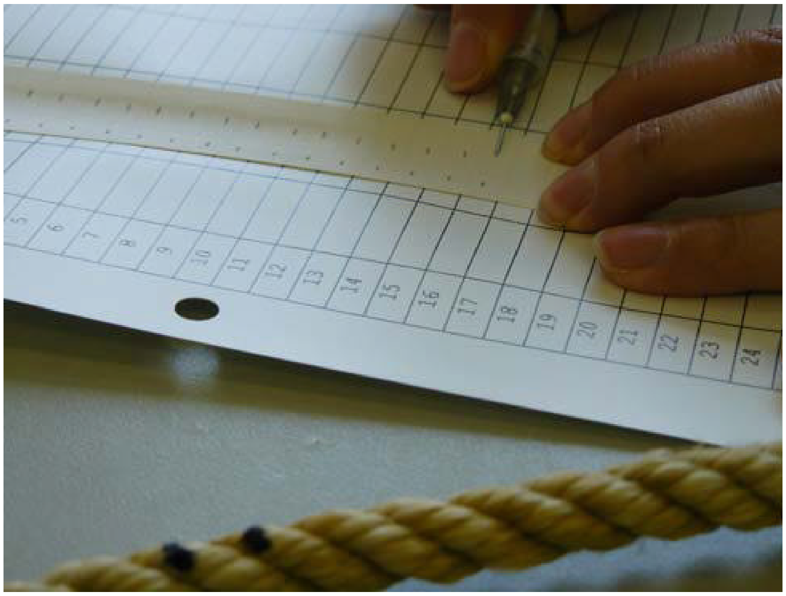
Injection with Adhesive

Several methods of injecting precut coded wire tags (CWTs) into rope were initially explored in the laboratory and a number of adhesive product manufacturers were contacted for their suggestions for products to adhere the stainless steel tags to rope made of synthetic fiber typically used in commercial fisheries in the marine environment. Two adhesive products were selected for use in injecting CWTs into rope for this project:

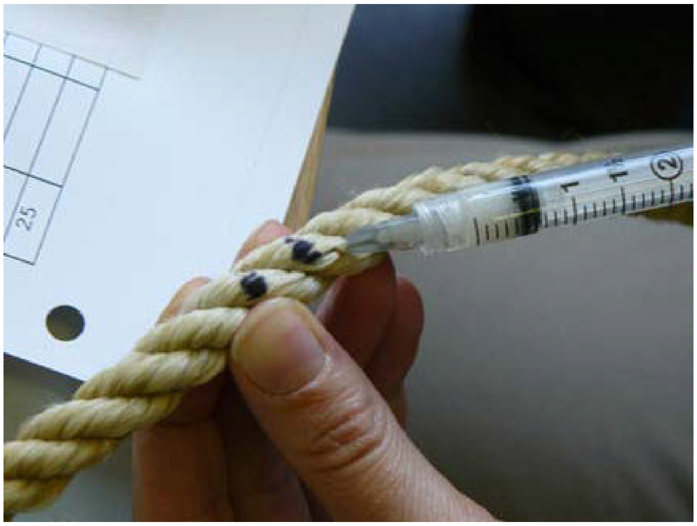
1) 3M Scotch-Weld 2216 translucent epoxy adhesive – see http://multimedia.3m.com/mws/mediawebserver?66666UuZjcFSLXTtlx&X5x&_EVuQEcuZgVs6EVs6E666666-- for product details.
2) Bostik marine grade 920 Urethane Sealant – see http://www.bostik-us.com/TDS/TDSFiles/920.pdf for product details.

We injected CWTs into ropes with adhesive using a 3 ml Luer-Lok tip syringe with 20 gauge ½ inch long needle in the manner described below. The photos below show the injection method and data sheets with pre-cut tags where data was recorded during injection.

- Load the syringe with the glue.
- Wipe glue off the needle before loading each tag.
- With the bevel of the needle pointing down, place the needle over the tags, and push the needle forward so that the tag loads into the needle. Once the tag is loaded, push the needle against the paper to further push the tag into the needle.
- The tag does not have to disappear completely into the needle, but it should be mostly inside.



- Insert the needle into one of the strands of the rope more or less parallel to the rope fibers. Start expelling the glue to eject the tag, and slowly pull out the needle once some glue oozes out. Gently twist the needle as it is pulled out to make sure the tag does not stick on the needle.



- Use the handheld detector to verify that the tag was injected

The same method was used for all CWT injected directly into rope with adhesives.

<u>CWTs Placed in Seine Twine</u>

Additional methods for placing CWTs in rope were also explored. Placing CWTs in braided nylon #18 seine twine produced promising results in initial laboratory work. This method was expanded for this project.

We used a a standard single shot tag injector from NMT to inject Cwts into the pieces of colored twine cut to approximately 10 inch lengths. The single shot tag injector is designed for utilization with pre-cut CWTs rather than the continuous wire form of CWTs utilized with the handheld multi-shot tag injector and the Mark IV automatic tag injector. The single shot injector is similar to a hypodermic needle, but has a metal pushrod that goes thru the barrel of the needle to push the tag into place. One single shot injector was utilized to insert all CWTs into twine for this study.

Two methods were tested: 1) coating the twine a clear liquid rope whipping compound; 2) not coating the twine. The commercially available liquid rope whipping compound is available at marine hardware stores and it typically used to prevent rope end from fraying after it is cut. The method of inserting the CWTs into the twine was the same for coated and uncoated twine. The CWT was put into the injector and injected into the twine so that it is parallel with the length of the twine and is completely enclosed. The liquid rope whipping coating was applied after the CWTs were inserted. The twine was dipped in the liquid and allowed to dry. We prepared an equal number of pieces of coated and uncoated twine in an effort to compare tag retention and readability. The 10 inch pieces of twine were woven into rope in a manner similar to splicing (Figure 4). Twine were tested both in the field by commercial fishermen and in rope machine accelerated longevity experiments. All twine were prepared in the same manner.

Figure 4. A piece of black seine twine with an embedded CWT woven into rope.

Field Testing of CWT Marked Gear

<u>CWTs Injected with Adhesives</u>

Field testing of CWTs injected into rope with adhesives was piggybacked on the ongoing Coastwide Ventless Trap Survey for American Lobster (CVTSAL)research project conducted by the Massachusetts Division of Marine Fisheries (MADMF). This study uses 6 trap trawls with 60 feet of sinking groundline between traps. Endlines, also made of sinking line, vary in length depending on the depth where the gear is set. Rope diameter is typical of inshore lobster fisheries. Gear was deployed in state waters designated by the National Marine Fisheries Service (NMFS) as statistical area 514 off of the state of Massachusetts. The large area encompassed by NMFS 514, was divided into five zones based roughly on the locations of active lobstering ports along the coast. In each of these zones, four stations in each of three depth ranges (0 – 20 meters, 21 – 40 meters, and 41 – 60 meters) were selected. There are a total of 60 stations in Area 514 for the CVTSAL study.

A total of 24 trawls marked with CWTs were utilized for field testing - 6 trawls marked by injecting tags with each of the 2 different adhesive products were utilized at stations in two selected zones with two participating vessels, F/V Stanley Thomas out of Gloucester, MA and F/V International Harvester out of Marblehead, MA (Figure 5). Rope was marked with CWTs at approximately 10 ft. (3 m) intervals. Unmarked gear was utilized in the remaining three zones to the south of our study area. All the commercial fishermen participating in the CVTSAL study were asked to report any problems or safety issues utilizing gear.

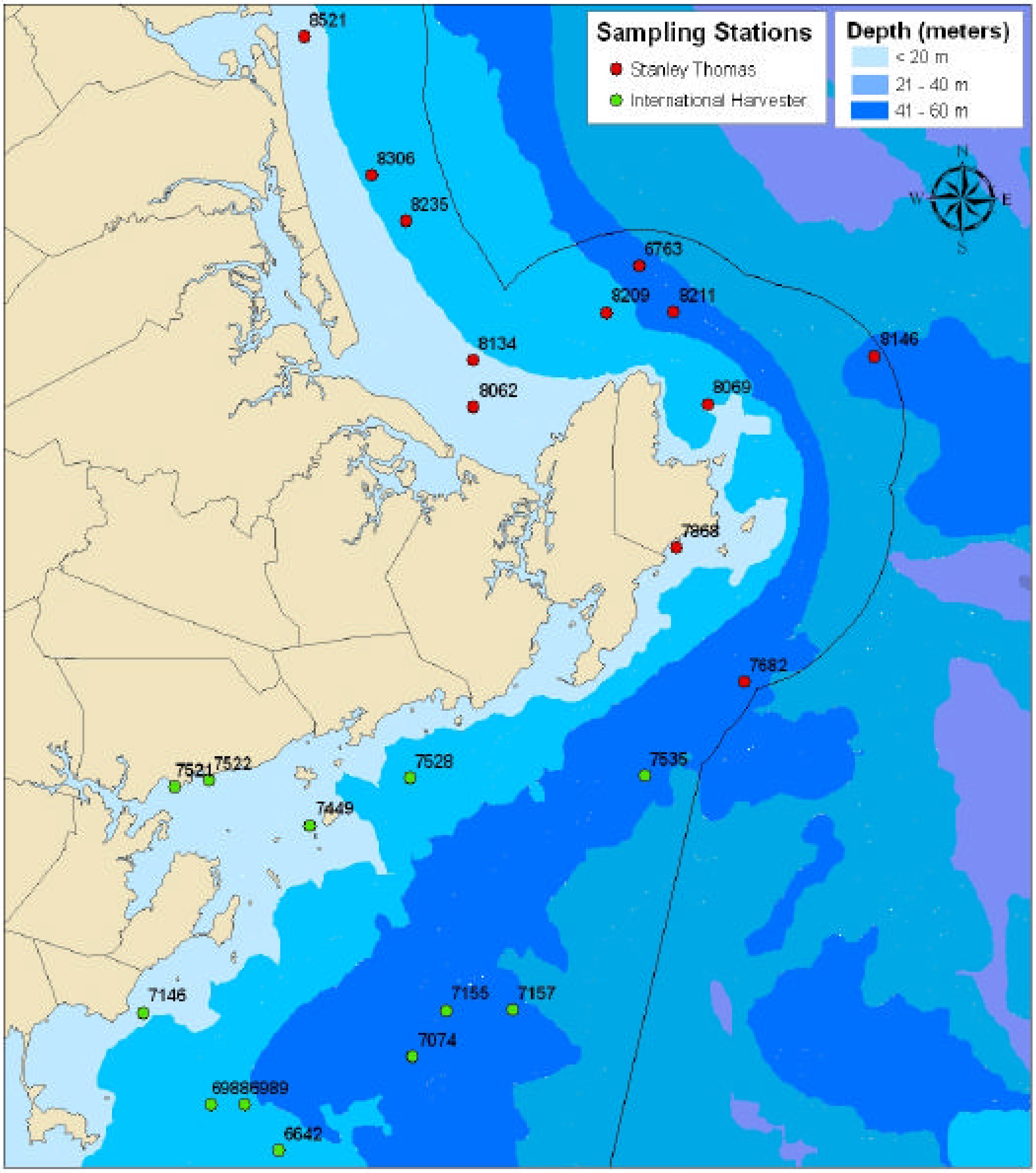


Figure 5. Station locations and depth range fished by vessels utilizing gear marked with Coded Wire Tags injected into rope with adhesive.

Tags were injected into both groundlines and endlines utilized by the F/V International Harvester, and the groundlines utilized by the F/V Stanley Thomas. Both vessel captains agreed to test the marked gear during their work on the CVTSAL. The gear utilized in the CVTSAL was provided to the fishermen and had already been used for at least one season. Dried marine growth was on the surface of some lines and bottom sediments were embedded in others. The gear was in totes when we received it for tagging and the tote number was recorded while tagging the gear. In an effort to field test similar numbers of tags injected with each type of adhesive, the 12 trawls fished by the F/V International

Harvester that included endlines were paired by similar endline lengths. One trawl from each pair was tagged with each type of adhesive. We were not made aware of the station location where any given trawl was fished by either vessel. Fishermen were not aware of which type of adhesive was used on any given trawl. This created a double blind experiment. We were needed to match rope from trawls returned to us with the tote number that was recorded during marking in order to determine CWT retention rates for each trawl. This could only be done by reading tags when the gear was retrieved and returned to us. The situation was similar to what would be experienced retrieving marked gear from an entangled whale.

A total of 1,267 CWTs were injected into gear for this phase of field testing, 678 with epoxy and 589 with urethane. The difference was in part due to double tagging one of the sets of gear from Marblehead with epoxy injected tags by mistake. In the Glouchester gear the number of CWTs injected with each adhesive type was almost equal: 188 with epoxy, 192 with urethane.

Field deployment of rope marked with CWTs took place from June through October, 2008 and hauls were conducted several times per month (Table 1). Marked gear fished in an identical manner as unmarked gear and no problems or safety issues were reported. One set of gear fished by the F/V International Harvester was lost at sea and not recovered. The station number was recorded on each set of gear returned to us by the F/V International Harvester. Gear returned by the F/V Stanley Tomas did not include information on where it was deployed. The vessels did not provide records of any modifications made to the gear during the fishing season. Rope was returned to PCCS for CWT detection, extraction and reading.

Table 1. Deployment and hauls of marked gear. Gear from station 7074 was missing on 10/8/2008. International Harvester brought in gear from stations 7157, 7535, 7528, 7449, 7522, 7521 on 10/11/2008 and remaining gear on 10/12/2008.

Haul dates	
Glouchester F/V Stanley Thomas	**Marblehead F/V International Harvester**
6/1/08 set out	6/9/08 and 6/10/08 set out
6/4/2008	6/13/2008
6/7/2008	6/16/2008
6/28/2008	7/13/2008
7/2/2008	7/17/2008
7/5/2008	7/22/2008
8/8/2008	8/19/2008
8/11/2008	8/22/2008
8/14/2008	8/25/2008
9/13/2008	10/5/2008
9/18/2008	10/8/2008
9/22/2008	10/11/2008
	10/12/2008

CWTs Placed in Seine Twine

NMFS gear specialists identified fishermen who agreed to test the gear marking methods during commercial fishing operations. Marked twine was sent to Glenn Salvadore in the mid-Atlantic region and to John Higgins in Maine. The marked twine sent to each of them was of the color specified for marking gear specified by the Atlantic Large Whale Take Reduction Plan (ALWTRP) for the area being fished. Glenn Salvador was given 100 pieces of marked orange twine. John Higgins was given 100 pieces of marked black twine, and 100 pieces of marked red twine. Half the twine of each color was coated with liquid rope whipping compound. Thus a total of 300 CWTs in seine twine were field tested in commercial fishery operations. The objective was to determine any differences in retention or readability of coated vs. uncoated twine.

The orange marked twine was placed into two trawls utilized by the F/V Skilligalle while at sea during fishing operations on September 30, 2008. The vessel fishes for black sea bass and lobster. Glenn Salvador or the vessel captain placed the CWT marked twine into the rope by hand without any tools. Two trawls were marked. Coated CWT marked twine was placed in one trawl - 25 in endline spaced approximately 1 fathom apart and 25 in groundline spaced approximately 6 to 8 fathoms apart. Uncoated CWT marked twine was placed in the other trawl - 25 in endline and 25 in groundline with the same spacing. Glenn reported that the center section of the marked twine was placed under 2-3 strands of rope and the remaining twine was tucked through the rope at varying intervals. These trawls were deployed approximately 20 miles off the Maryland coast. The photos provided by Glenn below (Figures 6, 7, 8) show the marked rope during fishing operations in December 2008. The twine appears to cross on the outside of 3-4 strands of rope between tucks through the rope.

Figure 6. Orange seine twine marked with Coded Wire Tags deployed in fishing gear off the Maryland coast. Photo courtesy of Glenn Salvador, NMFS.

Figure 7. Rope marked with CWTs in orange seine twine being hauled off the Maryland coast in December 2008. Photo courtesy of Glenn Salvador, NMFS.

Figure 8. Captain and crewman of the F/V Skilligalle fish with gear marked with CWTs off the Maryland coast in December 2008. Photo courtesy of Glenn Salvador, NMFS.

Glenn was able to go to sea several times with the vessel to check the condition of the marked twine and ask fishermen if they experienced any problems with the marked gear. In February Glenn reported that "the untreated twine is falling apart and gets snagged in hauler and is getting pulled out of line. The treated twine is holding up ok ." Gear marked with CWTs worked exactly like unmarked gear. It was fished without incident and no safety or practical issues were reported by fishers utilizing marked gear. No details of trawl locations and hauling dates were provided. Glenn retrieved marked twine from the fishermen during the first week of May 2009. Twine were returned to PCCS for CWT detection, extraction and reading.

The black twine given John Higgins was placed into one 40 trap trawl utilized by an 85 foot Shaftmaster vessel employed in the offshore lobster fishery. The CWT marked twine was placed into the rope on November 18, 2008 while the trawl was ashore. Twenty-five coated and twenty-five uncoated CWT marked twine were alternately placed in both groundline and endline of the trawl spaced approximately 10 fathoms apart (~18.3 m) for a total of 100 tags in the trawl. A fid was used when placing twine into the rope. John Higgins placed all marked twine into the endline, a crew member assisted in placing the twine in the groundline because of the hard lay of the line. He reported that twine was woven under and over each strand in the rope and that it took approximately 2 hours to put all 100 pieces of marked twine into the rope. No details of deployment locations and hauling dates were provided.

The red twine sent to John Higgins was given to captains of two vessels engaged in the inshore lobster fishery with instructions to place alternating coated and uncoated CWT marked twine into both endline and groundline. Twine was woven into the rope with a series of over and under tucks. A 38 foot vessel out of Stonington, ME was given 13 pairs of coated and uncoated CWT marked twine. A 32 foot vessel out of Pemequid, ME was given 12 pairs of coated and uncoated CWT marked twine. John reported that the twine was deployed on October 26th 2008. The vessel out of Stonington, ME fishes out to ~30 nautical miles (nm) offshore. The vessel out of Pemequid, ME fishes out to ~20 nm offshore. No photos or further details of the method used to put the twine into the rope, deployment locations or hauling dates were provided.

On May 13, 2009 John reported that he had retrieved marked twine from all the Maine fishermen. Twine was returned to PCCS for CWT detection, extraction and reading.

Accelerated Longevity Testing with Rope Machine

Ropes of 5/8 inch diameter were prepared for accelerated longevity testing using a rope machine designed to simulate hauling gear during commercial fishing operations. CWTs were placed in these ropes with both the adhesive njection method and the CWT marked twine method. Two types of rope were utilized, a floating rope called Polysteel made by POLYSTEEL Atlantic Limited, Edwardsville, NS, Canada and a sinking rope called Ever Haul Blue made by Orion Ropeworks in Winslow, ME. Four ropes, 2 float ropes and 2 sink ropes, were injected with 100 CWTs each, 50 CWTs using epoxy and 50 CWTs using urethane, in alternating order. Eight ropes, 4 float ropes and 4 sink ropes, were marked with 50 CWT marked twine each, 25 coated and 25 uncoated, in alternating order. A label specifying the CWT treatment and rope type was affixed to each rope. All ropes were run on the rope testing machine to simulate 5 years of hauling utilizing the methods described in Lyman et al. 2005 (report available from MADMF). Runs were conducted in December, 2008 and January 2009 in New Beford, MA. Labels for each rope were removed for testing and replaced after testing. The photo below (Figure 9) shows the accelerated longevity test for CWTs in progress on the rope machine.

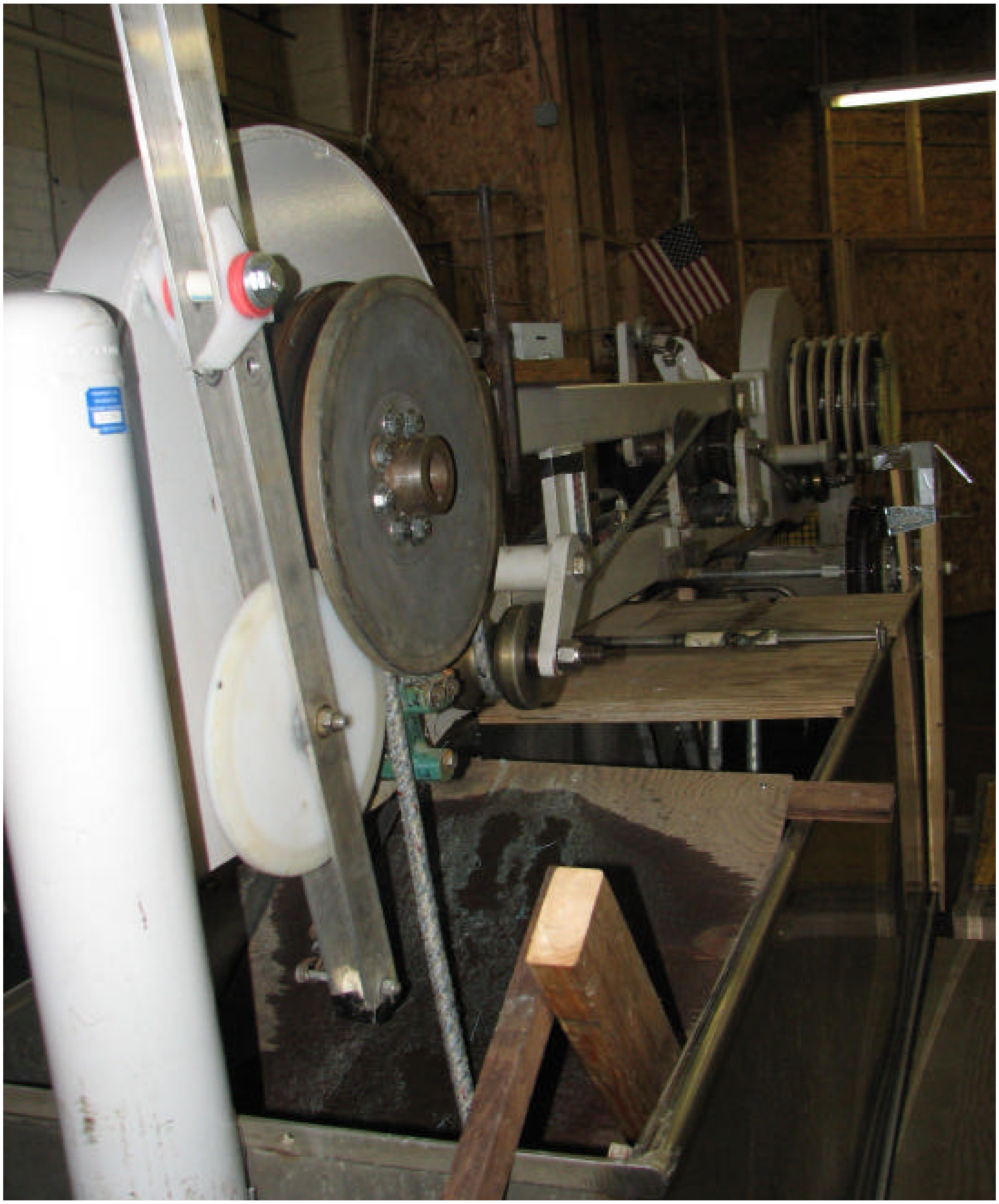


Figure 9. Accelerated longevity testing of CWTs with rope machine. The test was designed to simulate 5 years of hauling with commercial fishing gear. Photo courtesy PCCS.

Rope run through the machine was returned to PCCS for CWT detection, extraction and reading. Extensive wear on the rope and twine was evident (Figure 10). Some of the twine was completely worn away where it was exposed on the outside of the rope, leaving several separate pieces of twine where it was tucked into the rope.

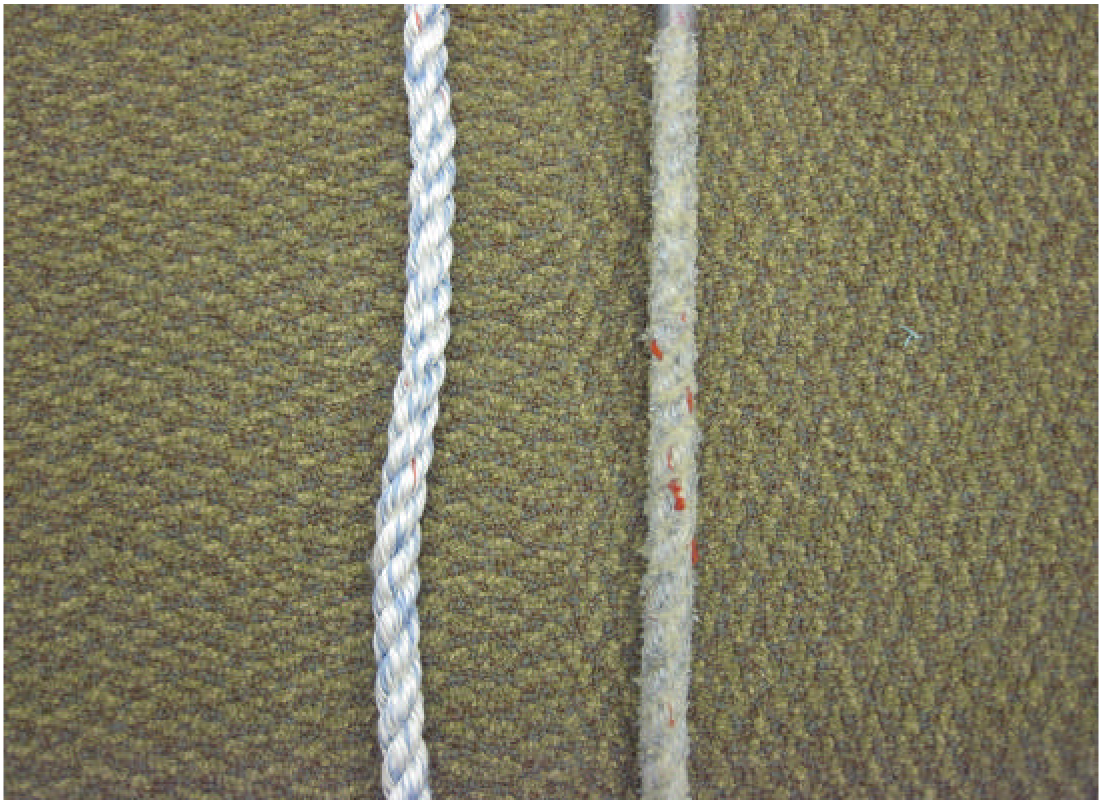


Figure 10. Comparison of sink line used for accelerated longevity testing of CWTs. Rope on left is new, the rope on the right was run in the machine to simulate 5 years of hauling in offshore commercial fishing operations with CWTs in red twine.

Detection, Extraction and Reading

We used a handheld wand type tag detector manufactured by NMT to detect CWTs in rope or twine returned to PCCS afte testing. The Wand is designed to operate by passing it or rubbing it over the location of the tag. Its detection range is approximately 3 cm for standard length CWTs. The number of CWTs detected in a rope was tallied multiple times to assure that all CWTs were detected and the count was accurate. Pieces of marked twin used on commercial fishing vessels in Maine and Maryland were removed from the gear by the fishermen and placed in zip lock bags that denoted the part of gear it was deployed in, endline or groundline, and whether or not the twine was coated (eg. endline). Each piece of twine returned from use on the commercial fishing vessels was subjected to detection. Detection counts were compared with the number of tags placed in each rope to determine minimum retention rates. Retention rates were a minimum for rope from CVSTAL because it is possible that a fishermen may have modified the gear during the season. For example, a marked enline may have been shortened because it was deployed at a shallower location than in previous years. A random selection of at least 10% of tags detected in each treatment based on extraction notes were selected for reading by subjecting the tag count to a random sequence generator.

We extracted CWTs from ropes by cutting the section with the CWT out of the rope. CWTs injected into the rope with adhesive the section of the rope with the CWT was progressively separated into smaller sections for detection until the CWT could be found and extracted with a scalpel. Again the magnetized tags often stuck to the scalpel upon final extraction. The process of extraction for tags injected directly into rope is documented in the photos below (Figure 11). For rope with CWTs in twine it was easy to pull the twine freed from the rope after the rope was cut. CWTs were cut out of twine with a scalpel. The CWT usually stuck to the scalpel making it easy to find. We did not find a systematic difference in the time required to extract CWTs for coated vs. uncoated twine. For We did not find a systematic difference in the time required to extract CWTs injected with urethane vs. epoxy. We did however find that it took almost twice as long to extract CWTs injected directly into rope than those placed in twine and woven into the rope.

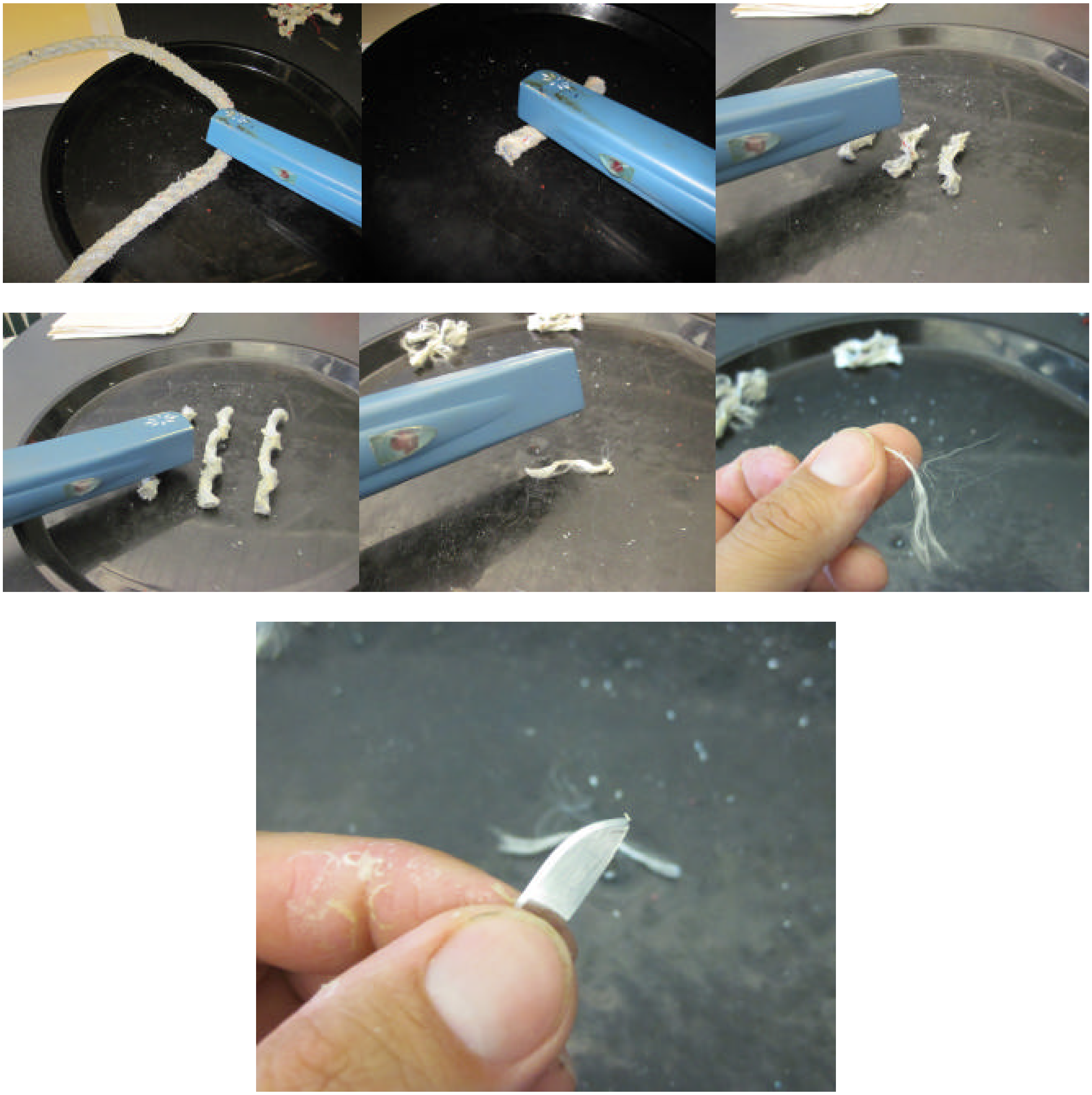


Figure 11. Progression of steps to extract CWTs injected directly into rope ending with CWT stuck to the scalpel. Photos courtesy of PCCS.

We read tags with a Leica S60 dissecting microscope (Figure 12). CWTs were placed on a reading jig that allowed the magnetized tag to extend lengthwise its point and be rotated to read the digits around the circumference of the tag. Extracted CWTs were taped in place on paper with extraction notes and reading results recorded next to the tag. We compared extraction notes with insertion notes for all tags that were successfully read.

Figure 12. Reading a CWT on the jig under a dissecting microscope. Photo courtesy PCCS.

Tags injected directly into rope with adhesive required removing as much adhesive residue as possible to be read. Tags were cleaned by rolling tags back and forth on clean paper under finger pressure. Even after cleaning tags with adhesive were sometimes more difficult to read because left over residue.

Results and Discussion

<u>Tag Extraction and Reading</u>

Overall we were able to read 248 of the 275 the randomly selected tags (90.4 %) that we extracted and attempted to read. The percentage of readable tags was similar for tags injected directly into rope with adhesive (90.6 %) and those placed in twine and woven into rope (88.9 %).

A number of tags were lost during the process of extracting and reading. Ten of 285 tags extracted were lost before they could be read and 1 was lost after being read for a total loss rate of 3.9 %. To determine if this rate of tag loss was normal we contacted the supervisor of a laboratory that specializes in CWT extraction and reading. Between 20,000 and 60,000 CWTs are processed annually at this lab run by the Oregon Department of Fish and Wildlife. That lab experiences a tag loss rate of approximately 0.01 % (Bill Haugen, pers, com.). Our tag loss rate was two orders of magnitude higher. Handling CWTs was a new experience for personnel involved in this project. We attribute the difference in tag loss rate to their relative lack of training and inexperience handling CWTs.

We noted earlier that the CWTs injected into the CVTSAL ropes presented us with a double blind experiment to match tags extracted to the gear into which they were injected. We successfully identified all eleven of the ropes (100%) returned by the fishermen participated in this work.

When injecting CWTs into ropes with both urethane and epoxy adhesives to be run on the rope machine each rope was first marked with black permanent marker at 1 ft intervals, then tags were injecting with urethane at each mark, finally tags were injected with epoxy between each mark. Thus, tags were spaced approximately 6 inches apart. By the end of a run on the rope machine the black marks were no longer visible. We re-marked the rope with permanent marker at the first tag found near the splice. Counts were then tallied for tags at marks and those between marks. We determined which type of adhesive was used to inject CWTs extracted at marks and those extracted from between marks after reading tags from each group. Again this presented us with a double blind experiment to match CWTs with the injection adhesive. Although we were able to correctly assign the proper adhesive to tags in most cases 7 of the randomly selected tags read from these ropes extraction notes did not match insertion notes. We believe that these seven mismatches are likely the result of assigning the the adhesive incorrectly during marking and extraction. With the close spacing of approximately six inches separating tags and need to re-measure and re-mark the rope, minor measuring mistake could quickly add up to place tags out of sink. This mismatch made calculating definitive retention rates for some of these ropes impossible.

We found that for 7 of the 275 tags read (2.5 %) extraction notes did not match insertion notes. No plausible explanation other than errors in recording information at some stage of the process

CWT Retention and Methods of Placing Tags in Rope

<u>Comparisons Between Epoxy and Urethane</u>

Neither adhesive exhibited a significant advantage in retaining CWTs in the ropes fished in the CVTSAL. We compared minimum tag retention in 10 ropes fished with epoxy injected CWTs and 12 ropes fished with urethane injected CWTs. Two of the ropes with tags injected with epoxy could not be utilized in this comparison. One because it was lost at sea. The other rope was double tagged as noted earlier. Over all 73.6% of 484 tags injected with epoxy were retained in these 10 ropes. Individual ropes ranged from 33.3 % retention to 100% retention. The results for 12 ropes with urethane injected tags ranged 41.2 % to 93.0 % retention. Overall, 76.9 % of the 589 urethane injected tags were retained in these 12 ropes. The wide variation in retention for both adhesives suggest that factors other than adhesive played a role in tag retention.

Retention rate for one of the four ropes with CWTs injected with both adhesives types that were run on the rope machine was possible. Neither adhesive proved satisfactory in this float rope with 25 of the 50 tags (50 %) injected with epoxy retained and 29 of the 50 tags (58 %) injected with urethane retained.

<u>Comparisons Between Coated and Uncoated Twine</u>

No clear pattern emerged from the paired test design for coated and uncoated twine placed into the 8 ropes run on the rope machine. (Table 2).

Table 2. Percentage CWT retention for paired trials of coated and uncoated twine after a simulation of 5 years of hauling gear in a commercial pot fishery. N = 25 CWTs for both coated and uncoated twine in each trail.

92	76	16
92	88	4
88	76	12
88	96	-8
72	60	12
60	84	-24
80	80	0
92	80	12

Results of coated and uncoated twine tested in commercial fisheriesoff the coast of Maine suggest that coated twine stood up better to the rigors of industry use and had higher retention rates for CWTs than in uncoated twine. Twenty- four out of 25 pieces of coated twine place in groundline and 20 out of 25 pieces of coated twine placed in endline were retrieved from the two trawls and returned for CWT detection. In total (88 %) of the red coated twine deployed was retrieved and all of it retained CWTs. The problem was in loosing twine from the gear rather than loosing tags from the twine. All randomly selected tags that we extracted from theses twine were readable and matched. The retention rate in the uncoated twine was lower, with 80 % of CWTs retained. All of the randomly selected tags extracted and read from this group also were readable and matched.

The black coated twine placed in gear fished by the offshore vessel off Maine also stood up better to industry use than uncoated twine although not as well as it did in the inshore gear. Fifteen of the 25 pieces of coated twine placed in groundline and 13 of the 25 pieces place in endline were retrieved and returned for CWT detection. All 28 pieces of coated twine retained CWTs and all randomly selected CWTs that were extracted were readable. Seventeen of 25 uncoated twines from endline, but none of the 25 uncoated twines from groundline were retrieved for CWT detection. Thirteen of the 17 uncoated twine (76 %) retained CWTs, a similar percentage to the red uncoated twine from the inshore gear.

The coated twine placed in gear fished off the Maryland coast also seemed to fair better than uncoated twine. As noted earlier Glenn Salvador commented on the shortcomings of the uncoated twine that he observed. Seventy-six percent of the 50 CWTs deployed in coated twine were retained, whereas 54 % of CWTs deployed in uncoated twine were retained. It is worth noting that because coated and uncoated gear were not deployed in the same trawls, the differences noted could be trawl effects rather than coating effects.

<u>Comparison of Retention of CWTs Injected with Adhesives vs. Woven into Rope in Twine</u>

A Chi-Square analysis was performed to determine if the number of CWTs retained was independent of whether the treatment for the rope testing machine work. For this test we ignored the type of adhesive used and whether or not the the twine was coated and concentrated on whether twine and injection with adhesive were independent of retention. A two by two frequency table was constructed.

Frequency Table

	retained	lost	Row Total
injected	276	124	400
	34.50%	15.50%	50.00%
twine	326	74	400
	40.75%	9.25%	50.00%
Column Total	602	198	800
	75.25%	24.75%	100.00%

We determined that treatment was significantly related to retention (Chi-Square = 16.11, df = 1, p = 0.001 with the Yate's correction). Indeed the proportion of CWTs retained for ropes with twine was 81.5 % whereas the proportion for ropes with injected CWTs was 68.5 %. Clearly the placing CWTs in twine and weaving them into ropes worked better than injecting them with adhesive in the accelerated longevity testing with rope the rope machine.

Practical Considerations

The tests conducted in this project demonstrated that CWTs are able to withstand the rigors of use in the commercial fishing industry. Over 90 % of the tags randomly selected for reading after tests proved to be readable. This rate could likely be improved if CWTs cold be better protected in the gear. While the use of CWTs in twine holds promise there is still room for improvement. The # 18 braided nylon seine twine utilized in this pilot project was less than ideal. A better method of keeping CWTs in rope than was demonstrated in this pilot project is needed and more development and testing is necessary to approach 100 % retention. Heavier guage twine made from a variety of different material fibers is one of several avenues to explore, but there may be other better ways of protecting CWTs and placing them in rope so that they will stay put.

The method of placing CWTs in twine and weaving them into ropes used in commercial fisheries has a number of clear practical advantages. This method would allow twine marked with CWTs to be mass produced in one location and then distributed as needed to mark commercial fishing gear. Fishermen are used to working with twine and are adept at splicing techniques utilized to place twine into fishing gear. We also found that it was quicker and easier to extract CWTs for reading from twine woven into ropes than it was to extract them if they injected into rope with adhesive. Twine has the added advantage that color coding would be possible to help facilitate visual identification of the type of gear entangling a whale or at least narrow down the possibilities. The twine method would also likely be more cost effective because the technology for automated injection of CWTs without the use of adhesives already exists. Live fish are tagged with CWTs at rates of several hundred per hour with existing technology. Use of an automated methodology to scale up for industrial use would be essential. CWTs in a continuous role of wire is the obvious way to go for larger scale use as it is more cost and time effective than using pre-cut tags as was done in this pilot project.

Utilizing sequential CWTs is more complex that using standard CWTs. As we found in this pilot study extreme care must be used to assure that information is recorded accurately. Standard CWTs would be far easier to use. The database technology to match CWTs already exists because these tags are used extensively for marking animals, particularly salmon. Standard CWTs are produced in batches of tags that all have the same code. The appraoch to coding between these two types of CWTs would neccesarily be different.

A ballpark projection for cost of individual tags once a reliable method for deploying CWTs in fishing gear is developed for industrial use. Continuous rolls of tags for use with an automated injector of multi-shot handheld injector sell for between $87/1000 and $164/1000 depending on the quantity ordered and the time frame in which delivery is required. Braided #18 nylon seine twine that was utilized in this pilot project retails for ~$105 for 12 rolls of 480 foot/roll. That is enough twine for roughly 7,000 pieces of twine of similar lengths used inour pilot study. An order of seven thousand tags would at the current price of $147/1000 for continuous rolls of CWTs comes to $1029. Add the cost of the twine and that comes to under $0.17 per tag in material costs. Tags produced to be sold for somewhere between $0.25 to $0.50 per tag seems feasible.

How frequency should marks be spaced in commercial fishing gear? John Kenney a gear specialist with the NMFS provided us with the lengths of rope removed and recovered from entangled whales over a 7 year period from 1997 to 2003. There were 61 pieces of rope that ranged for 5 to 1,200 feet in length. Some simple summary statistics are given below:

Average = 181.8
Median = 102
Mode = 50
Minimum = 5
Maximum = 1200
Lower quartile = 60
Upper quartile = 222

Perhaps a more interesting way to look at these data is to consider the percentage of rope that falls below a given length:

1.0% = 5
5.0% = 12
10.0% = 40
25.0% = 60
50.0% = 102
75.0% = 222
90.0% = 378
95.0% = 480
99.0% = 1200

These data were the best that were readily available and are thought by NMFS gear specialists to be a representative selection of rope lengths retrieved from entangled whales. Thus, if rope were marked every 12 feet, on average we could expect get the information contained in the mark 95% of the time rope was removed from an entangled whale. Alternatively, if rope were marked every 40 feet we could expect get the information provided by the mark 90 % of the time, because at least 40 feet of rope is likely to be recoverd. Acquiring these ropes is not a trivial matter, as disentanglement operations are

quite dangerous and can require substantial resources be dedicated to the operation.
It shoud be noted that each of these 61 pieces of rope rope removed from entangled whale over this 7 year period could have provided significant information if they were marked so that detaile information about the fishery they were used in, where they were deployed, and when they were last checked could be determined. Information gathered from any given piece of rope is potentially quite valuable if were to provide sufficient information.

In the end it is a cost benefit analysis and a societal value judgment that will determine the spacing of marks on commercial fishing gear. So what would it cost to mark substantial lengths of rope to assure that information contained in the tags when gear is recovered from an entangled whale? If the cost of a tag is $0.25 and tags are placed at 40 ft intervals so that we could expect that 90 % of the time rope is recovered from a whale one ore more tags would be recoverd from the rope it would cost $33/ mile of rope placed in the ocean. If the cost of a tag were doubled, marking a mile of rope deployed in the ocean at 40 foot intervals would cost $66. Table 3 shows the cost of marking one mile of rope deployed in the ocean as a function of tag cost and certainty of acquiring the the tag when rope is recovered from an entangled whale.

Table 3. Cost per mile of tagged rope placed in the ocean as a function of tag cost and certainty of data acquisition when rope is removed from an entangled whale.

Tag Cost	**Certainty of data Acquisition**		
	95.00%	90.00%	75.00%
$0.25	$264.00	$33.00	$12.94
$0.50	$528.00	$66.00	$25.88
$0.75	$792.00	$99.00	$38.82

Marking rope at 40 foot intervals seems like a bargain even at $0.75 per tag.

Budget summary for Project Expenses Funded by IFAW Grant

Materials and Equipment		$1,871.00
Shipping		$188.00
Labor		$18,980.00
Travel		$1,047.00
Total		**$22,086.00**

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