Project 1 Final Report

Evaluation of Western Australian Stiff Rope Fishing

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Project Goals and Objectives

During a visit to Maine by lobster fishermen from Western Australian (WA), Maine lobstermen became interested in learning more about the former's fishing methods, especially if an exchange of information might inform the development of fishing techniques for reducing either the incidence or severity of large whale entanglements. Maine lobstermen were particularly interested in examining the tighter lay ropes used in (WA), because discussions within the Atlantic Large Whale Take Reduction Team suggested that increasing the stiffness of ropes might help reduce whale entanglements. This project's aim was to collect information on the Western Australian lobster pot fishery through an on-site study of the ropes used, trap rigging, hauling methods and hauling equipment.

Methodology

In April of 2013, the Bycatch Consortium Director and Maine lobsterman Kristan Porter traveled to Western Australia to observe lobster fishing gear and methods. The Western Rock Lobster Council provided assistance in arranging fishing trips with lobster vessels operating off WA. During active fishing trips, observations were recorded for various gear and techniques used, in particular the hauling/coiling machinery that facilitates the use of hard lay ropes.

A representative sample of hard lay rope used in the fishery was acquired and provided to rope engineer Hank McKenna, who analyzed it to compare its particular properties with similar vertical ropes used in the inshore Maine lobster fishery. These properties included its construction, diameter, material/s, linear density, breaking strength, specific gravity, and stiffness.

Line tension

In addition to the influence of a rope's lay on its stiffness, information on rope tension was also collected. To quantify rope tension, load cells were deployed on lobster trawls in WA and at three fishing locations spanning the coast of Maine in order to capture a geographic range of fishing conditions with inshore lobster trawls. At the Maine locations, load cells were deployed simultaneously with video cameras that recorded groundline behavior as part of Project 2 ("Review of Sinking Groundline Performance in the Maine Lobster Fishery, with Recommendations for Improving its Fishability"). Camera gear was mounted within a lobster trap so load cell measurements were expected to be similar to what they would be even without the cameras.

The load cells were constructed by Blue Water Concepts (BWC) of Elliot, ME, using Monarch Instrument Track-It™ Data Loggers to record line loads (Figure 1). Two different cells were constructed, one with a load range of 0-400lbs, and one 10-3500 lbs. The former load cell has greater precision when measuring lower loads, so is more appropriately used with lighter gear and under less rigorous oceanographic conditions. Although the maximum load recorded in the Gulf of Maine for ropes not being hauled is 535lbs (Salvador and Kenney 2002), Bycatch Consortium studies of "weak" ropes showed that buoy lines on lobster trap trawls can frequently part at 1000 pounds in near-shore Gulf of Maine, and occasionally even at 2000lbs, even when relatively new (Bycatch Consortium, unpublished data). Also, studies supported by the Consortium and MLA of breaking strength of vertical lines used by inshore lobster fishermen show that they can sometimes break between 2000-3000 lbs. Therefore, to be conservative, we decided to have a load cell available with a higher load range for conditions in which higher loads might be anticipated, such as with heavier bottom gear combined with large buoys, or areas with strong currents.

Some additional specifications for the load cells as furnished by BWC are as follows:

Capable of sampling rates between 2 samples per second and one sample per 24 hrs.
A capacity to log up to 64,000 readings
A 5-year battery life, with a replaceable battery
Accurate to within 2%
Stainless steel and aluminum construction, fully submersible
Neutrally, or slightly positively buoyant housing
Eye hooks on each end of unit for attachment to an end line

Load cells were tied on to the vertical line, just below the surface buoy. In WA, this was generally between 1.5-2fm below the buoy. When multiple buoys were used, the load cell was tied to the one nearest to the lobster pots.

Loads were recorded in kilo Pascals (kPa), and later converted to pounds per square foot (lbsf) using the formula: y[lbsf] = .98x[kPa] - 113.32. The initial value of the load cell at rest was substracted from each load measurement so that the resulting values were calibrated to zero. Each output was exported into Excel, and then graphed, with minimum, maximum, and average values calculated.

Figure 1. *Two self-recording load cells designed and built by Blue Water Concepts.*

To examine the influence of tide flows and currents on line tension, a flow meter was used during load cell deployments on lobster trawls. Ocean tides and currents exert a force on the surface buoy or along other portions of the vertical line that can add or reduce rope tension. By including current measures and comparing them with measured line tension we can better understand how the magnitude of tide flows and currents influence line tension. A WinRiver II Acoustic Doppler Current Profiler (ADCP) manufactured by Teledyne was leased from Ocean Leasing in Cambridge, MA to measure current velocity and direction throughout the water column. A catamaran was used to float the ADCP directly beside the boat while the lobster vessel remained on site during the testing (Figure 2). These units can record currents at multiple depths in the water column. A similar unit was not as easily procured during the WA visit, so only load cell recordings were made in Maine.

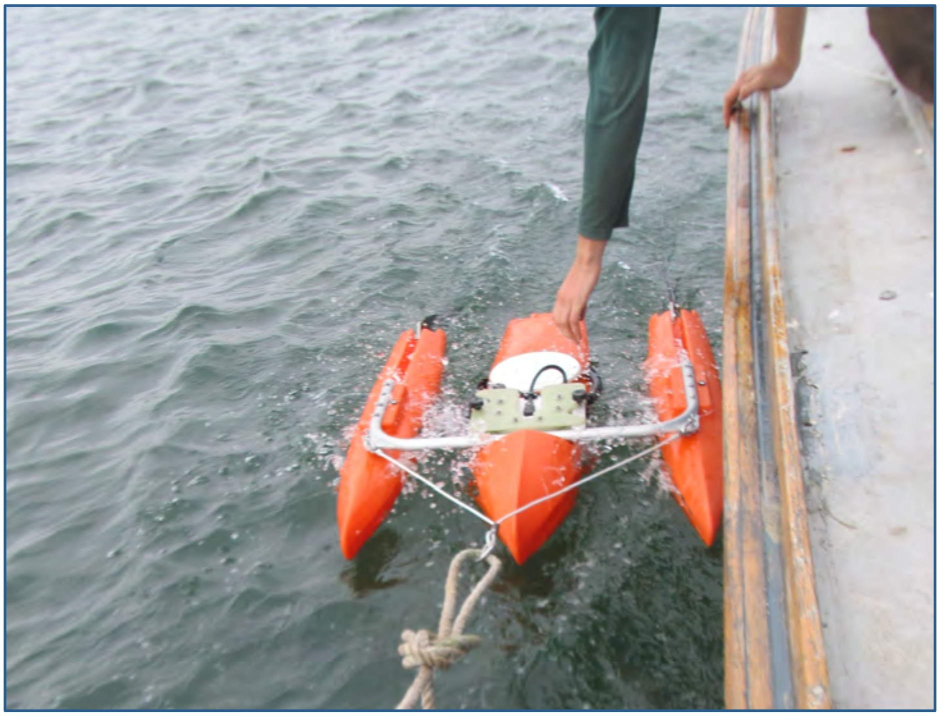


Figure 2. *ADCP with catamaran deployed next to a lobster boat.*

The Whale Project Coordinator, H. Tetreault, employed by Maine Lobstermen's Association, was responsible for recording information as part of each load cell deployment in Maine. The information collected included:

Location
Date, time, sea conditions
Ocean depth
Sea floor habitat
Number of traps
Type of rope (manufacturer, diameter, brand)
Buoy(s)
Length of vertical line
Ocean current at depth and at the surface

Locations for deployments were selected from a geographic range of inshore locations in the Gulf of Maine, from Beals and Mistake Islands in downeast Maine, to Biddeford Pool on the southwestern coast (Figure 3). The objective was not to capture a comprehensive range of line tensions encountered throughout the Gulf but to get some comparative measurements with gear in western Australia.

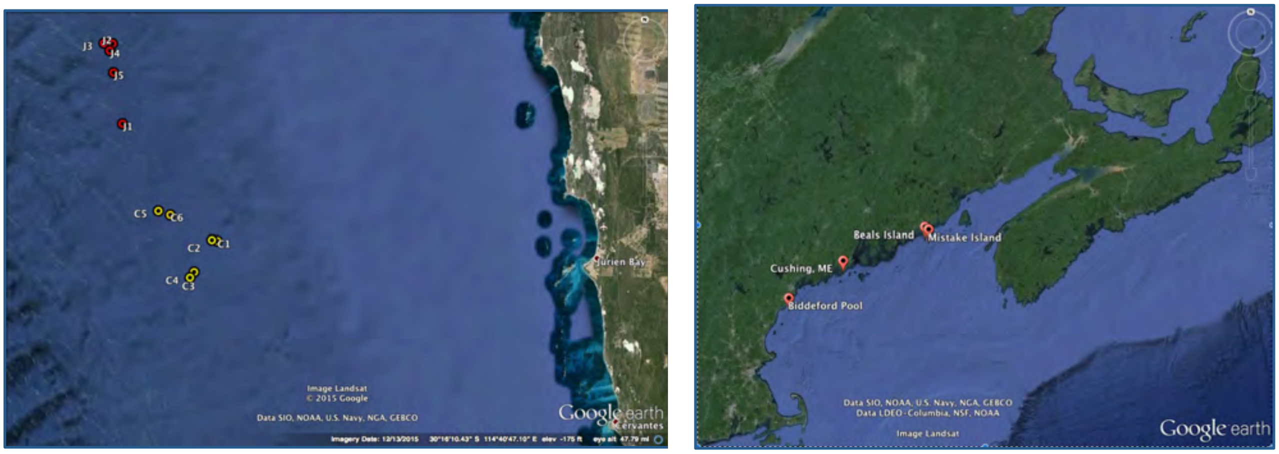


Figure 3. *Locations of load cell deployments locations in Western Australia (left) and Maine. (Maps at different scales).*

Measurements were recorded continuously for approximately four hours at Maine locations so as to capture a range of tidal conditions and include slack tides. In WA, the durations of load cell measurements were shorter, dependent on when fishermen could accommodate load cell deployment as part of their normal fishing activity. This involved deploying the load cell on a pot string, and during its soak time retrieving other pot strings in the vicinity that had been soaking for at least a day. Following these hauls, the vessel would return to the string equipped with the load cell, retrieve it, and then redeploy it at another nearby location.

Results

Observations and load cell measurements in WA were made aboard three lobster fishing vessels: the *F/V San Giuseppe* (Two Rocks); the *F/V Kool Change* (Jurien Bay); and the *F/V Glenley III* (Cervantes).

F/V San Giuseppe (April 17, 2013, Two Rocks)

The vessel is a 60’ fiberglass boat with a 1000hp engine. The pots are top entry, measuring 3.5’ x 2’ x 15”, and constructed of wood (cherry and pine) with a steel base (Figure 4). Welded to the base are three gaps to facilitate the escape of juvenile lobsters. This crew mostly fishes single pots, but sometimes doubles in January, farther offshore. The bait used is mackerel. The groundline is polypropylene, negatively buoyant, and rests on sandy bottom. An annual estimate of pot losses is 10 out of 120-125 total used. The diameter of the three-strand ropes is between 11-14mm (.43 - .55 inches). The thinner diameter ropes are used in the groundline and upper portion of the vertical line. Line scope is typically 2:1 (double the length of line used than the depth fished). Spherical floats are 8-10” in diameter, with 4-5 used per set. Soak time is usually one day, but sometimes two. After four days, lobsters tend to escape from the pots.

Ropes are hauled using a horizontally-oriented hauler, and the rope is deflected down into a metal or plastic bucket where it is self-coiled for redeployment (Figure 4).

Occasionally, WA lobster fishermen will target migrating "white" lobsters, but otherwise tend to target "residential" ones. Similar to Maine, fishermen will follow them as they move offshore. Octopus predate on the catch and need to be removed from hauled pots.

Figure 4. *Emptying a wooden, top entry lobster pot (left), and the rope hauling/coiling mechanism.*

Pots cost AUS$220 new, and $140 if made by hand. The lobster price on this particular day, as quoted by a Co-Op, was $32/kilo, and the price tends to go higher in January (~$50/kilo). An estimated ninety-five percent of WA's produce is exported to China. Unlike in New South Wales (southeastern Australia) where each lobster is tagged individually, in WA only each crate of lobsters is tagged.

Load cells were deployed on five sets during this outing, however the unit did not function properly for an undetermined reason, so no measurements were recorded.

F/V Kool Change (April 19, 2013, Jurien Bay)

Twelve to thirteen boats operate out of Jurien Bay. Before the quota system became implemented in this fishery, there were as many as 90. This vessel generally fishes with some 150 pots in the water at any one time, and tends to fish 15 pots/string. The soak time is generally two days. Pots are equipped with seal excluder devices to prevent seals from preying on the target catch (and bait?) (Figure 5). Pots weigh between 45-50 kilos. Rope diameters used are 12mm at the upper portion of the vertical line, and 14mm for the bridle. Bait is variable, including orange roughy, mackerel, jack, and pig fat. The flotation during our trip consisted of five buoys (Figure 5), but in the deepest waters fished and with stronger tides, 14 floats may be used and all can become submerged. The vessel captain estimated that the pull on the line under these conditions is estimated to be 30X what we could measure using load cells during this outing.

Five load cell measurements were taken aboard this vessel.

Figure 5. *Buoys, with float rope used to connect them (left). A seal excluder device placed in the pot entrance.*

F/V Glenley III (April 21, 2013, Cervantes)

Vessel is a 50-55 ft fiberglass boat with an 850hp engine. Fewer total traps (75) are fished than the other vessels, with sets of similar duration (1-2 days). Only three floats used. Ropes used range between 10mm and 14mm, with a 2:1 scope. Bait consisted of fish and pig fat.

Six load cell measurements were taken.

Analysis of Australian stiff rope (prepared by H. McKenna)

This section provides a description of a representative rope sample acquired from the *F/V San Giuseppe*, and compares it with lobster fishing ropes used in the Gulf of Maine inshore lobster fishery.

In the context of this analysis, stiffness is defined as the resistance to bending when a side force is applied to a rope that has virtually no tension in it. The force may be from the rope's weight, current, or resistance to wrapping around an object such as a whale.

Both rope makers and fishermen refer to ropes as "hard" or "firm" but not "stiff". The "hardness" or "firmness" of a rope is determined by the tightness of the lay, twist in the strands, number of rope yarns in a strand, and the fiber used. Typically, ropes are labeled hard, medium and soft, and in the context of bending stiffness a hard rope will be stiffer than a soft one. Fishermen will assess hardness and, consequently, stiffness by how the rope feels, how it coils on deck, and how easily it can be spliced.

A comparison of an Australian lobster fishing rope and a similar North American rope is shown in Figures 6 and 7. The Australian rope is the yellow line and is shown next to a line of slightly smaller diameter but of the same material and construction for purposes of comparison. Both ropes are 3-strand laid polypropylene, among the most common type found in North American fisheries.

The lay length (one complete revolution around the rope by the same point) is one way to determine determines hardness (Figure 6). Test and measurement results are provided in Table 1, and explained below.

Diameter – The WA rope was identified as 7/16 in. (0.437) but actually is 0.429, slightly undersized for this nominal diameter. 7/16 in. is the midrange of typical fishery rope sizes.

Construction – The WA rope is of three-strand laid construction, the most common type used in fishing. This line has a high degree of lay of the strands and twist in the strands, making it relatively hard.

Linear Density – The linear density of the WA rope is reported along with two similar exemplar ropes. For comparison, the values had to be corrected for variation in diameter. The corrected result is shown in the brackets below each. The higher value of the Australian rope is because of its higher fiber density, due to finer fiber size and a tighter level of lay and twist.

Lay Ratio – Because hardness (stiffness) is dependent on diameter, the lay ratio (lay length / diameter) is more representative. The lower this ratio is, the greater the hardness and stiffness as seen in the data for the WA rope. However, strand twist is also a factor so lay ratio does not tell the whole story.

Material - The fiber material is monofilament polypropylene (PP). The specimen has a smaller average filament diameter than typical monofilament polypropylene, 0.006 versus the typical 0.009 inches. This will provide greater fiber density and increased hardness.

Strength – The tested strength is reported in the data table. One piece of each of the three ropes was tested by grip on a capstan used in lieu of an eye splice. This is common for ropes that either cannot or are difficult to splice. The value is the average and the maximum deviation was 5%. This can be considered a good evaluation of the strength. One piece of the WA rope was tested with eye splices in the ends, and is the most common test method. However, the result was 32% below the average. This may reflect the fact that hard ropes such as the WA rope are difficult to splice. For purposes of comparison an industry survey of similar ropes provides typical values in the "estimated new strength" column. This indicates that this rope was about 10% below what might be expected.

Specific Gravity – The specific gravity of the rope is that of polypropylene fiber, 0.091. All ropes of this fiber will float.

Stiffness – To help quantify stiffness the following test was employed. Two ropes of the same length were groomed so they hung straight down. When gripped together they were then rotated 180 degrees. The result is as shown in Figure 7. The Australian rope is obviously stiffer than the orange one but there is no established method to quantify this.

Table 1. Description and measurements of a typical WA hard lay lobster rope, and two analogous ropes used in the MA inshore lobster fishery. (See text for more information).

Identification	**DIAMETER**		**TYPE**	**LINEAR DENSITY**	**LAY LENGTH**	**LAY RATIO**	**MATERIAL**	**STRENGTH**			**SP GR**
	Inch nominal	Inch actual		lbs/100ft	inch	in/in dia	Polymer type	Test lbsf	Test method	Est New lbsf	
Australian (stiff)	$^{7}/_{16}$ (0,437)	0.429	3-strand	3.84	1.34	3.12	PP	2,818	Capstan	3,150	0.910
				(3.70)				1,921	Splice	3,150	
Exemplar 1 (orange)	$^{3}/_{8}$ (0,375)	0.390	3-strand	2.99	1.30	3.23	PP	2,324	Splice	2,430	0.910
				(3.10)							
Exemplar 2 (typical)	$^{7}/_{16}$ (0,437)	0.448	3-strand	3.38	1.38	3.47	PP	2,620	Splice	3,150	0.910
				(3.55)	← (x.xx) Corrected for dia. variation)						

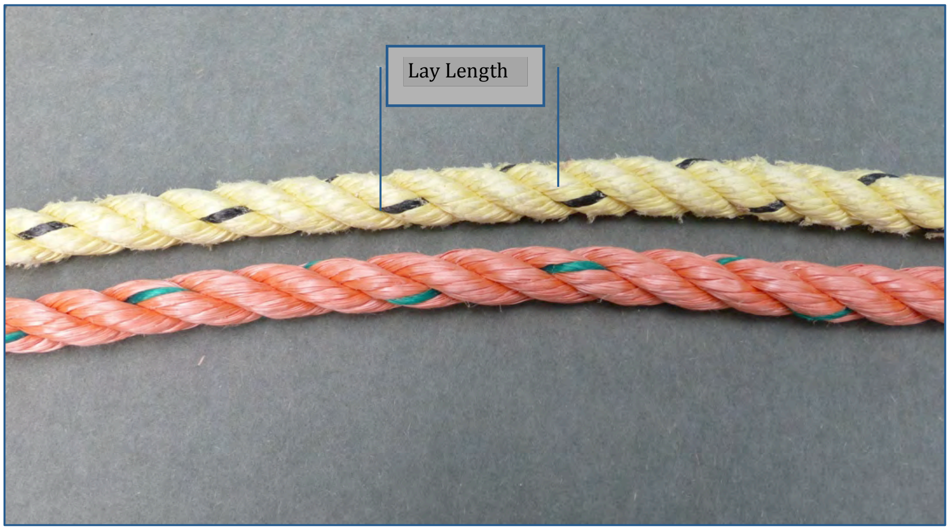


Figure 6. *Marker strand on yellow rope repeats more frequently indicating greater hardness.*

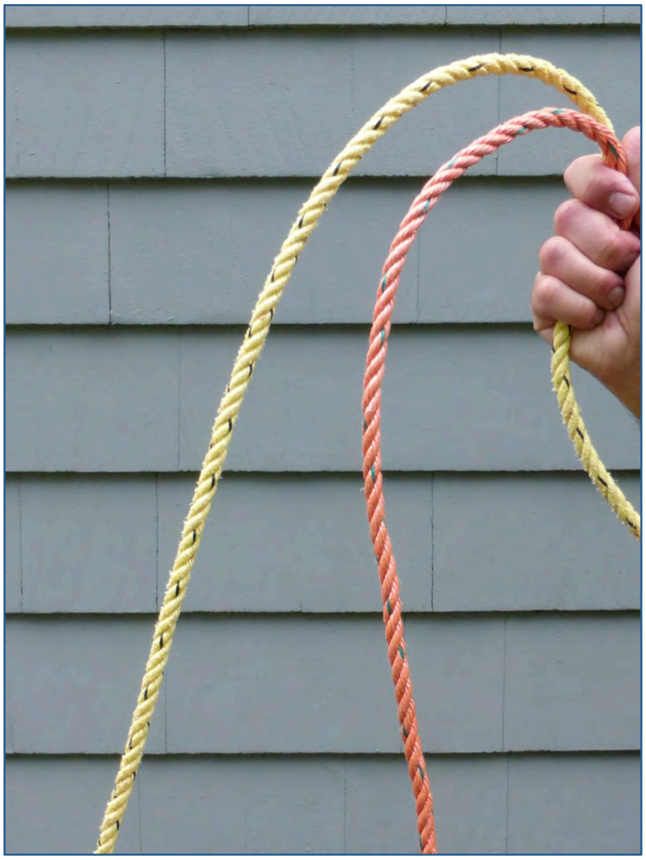


Figure 7. *Bending comparison of the ropes.*

Discussion – Australian Rope Sample

Bending stiffness increases with the hardness of a rope. However, bending stiffness is also highly dependent on diameter. Therefore, tightly laid/twisted ropes that are identified as very "hard" will have considerable different "stiffness" assessments if they are of various diameters. Larger ropes will be stiffer than smaller ones even if all are tightly made and considered to be of similar hardness.

Sink ropes typically are a blend of polypropylene and polyester fibers. Because the polyester component is so fine the hardness or stiffness will not be the same as a 100% polypropylene rope even if the hardness is similar.

As far as known, there is no quantitative standard or test for hardness or stiffness in the range of sizes found in most fishery ropes.

Due to a small lay ratio, tightly twisted strands and smaller fiber size, the WA rope was made harder (thus stiffer) than many comparable lines of the same size that are in common use. In order to make ropes stiffer, rope makers can produced short lay rope with tightly twisted strands if the industry demands them. Ropes of similar harness can be produced. Fishermen usually specify their preference for hardness based on their experience. Current fishery ropes are made to fishermen's preferences but could be made harder.

Load cell measurements – Western Australia

Table 2 has location and gear information for each load cell deployment in WA. Two Rocks information was excluded because the load cell was not functioning. The smaller load cell was used in all cases. Graphic outputs are shown in Figure 8.

For Maine load cell measurements, graphic outputs are shown in Figure 9, and the information recorded as part of each deployment is provided in Table 3.

Table 2. WA load cell deployment information.

Date	Port	F/V	Time in	Time out	Depth (ft)	# traps	# buoys	Rope diameter	Notes
19-Apr-13	Jurien Bay	Kool Change	6:33	7:07	186	~15.string	5	12mm (top); 14mm (at bridle)	
			7:24	8:36	192	~15.string	5	12mm (top); 14mm (at bridle)	
			8:46	9:42	162	~15.string	5	12mm (top); 14mm (at bridle)	
			10:04	11:24	156	~15.string	5	12mm (top); 14mm (at bridle)	
			11:36	13:34	162	~15.string	5	12mm (top); 14mm (at bridle)	
21-Apr-13	Cervantes	Glenley III	6:18	7:42	150	[not recorded; far fewer than Jurien Bay]	2 10mm or 3 8mm polystyrene	combination of 11mmand 14mm, and sometimes 12mm	2m swell
			7:42	8:37		[not recorded; far fewer than Jurien Bay]	2 10mm or 3 8mm polystyrene	combination of 11mmand 14mm, and sometimes 12mm	
			9:05	10:27	168	[not recorded; far fewer than Jurien Bay]	2 10mm or 3 8mm polystyrene	combination of 11mmand 14mm, and sometimes 12mm	
			10:39	11:46	150	[not recorded; far fewer than Jurien Bay]	2 10mm or 3 8mm polystyrene	combination of 11mmand 14mm, and sometimes 12mm	
			12:21	13:19	216	[not recorded; far fewer than Jurien Bay]	2 10mm or 3 8mm polystyrene	combination of 11mmand 14mm, and sometimes 12mm	
			13:31	14:35	174	[not recorded; far fewer than Jurien Bay]	2 10mm or 3 8mm polystyrene	combination of 11mmand 14mm, and sometimes 12mm	

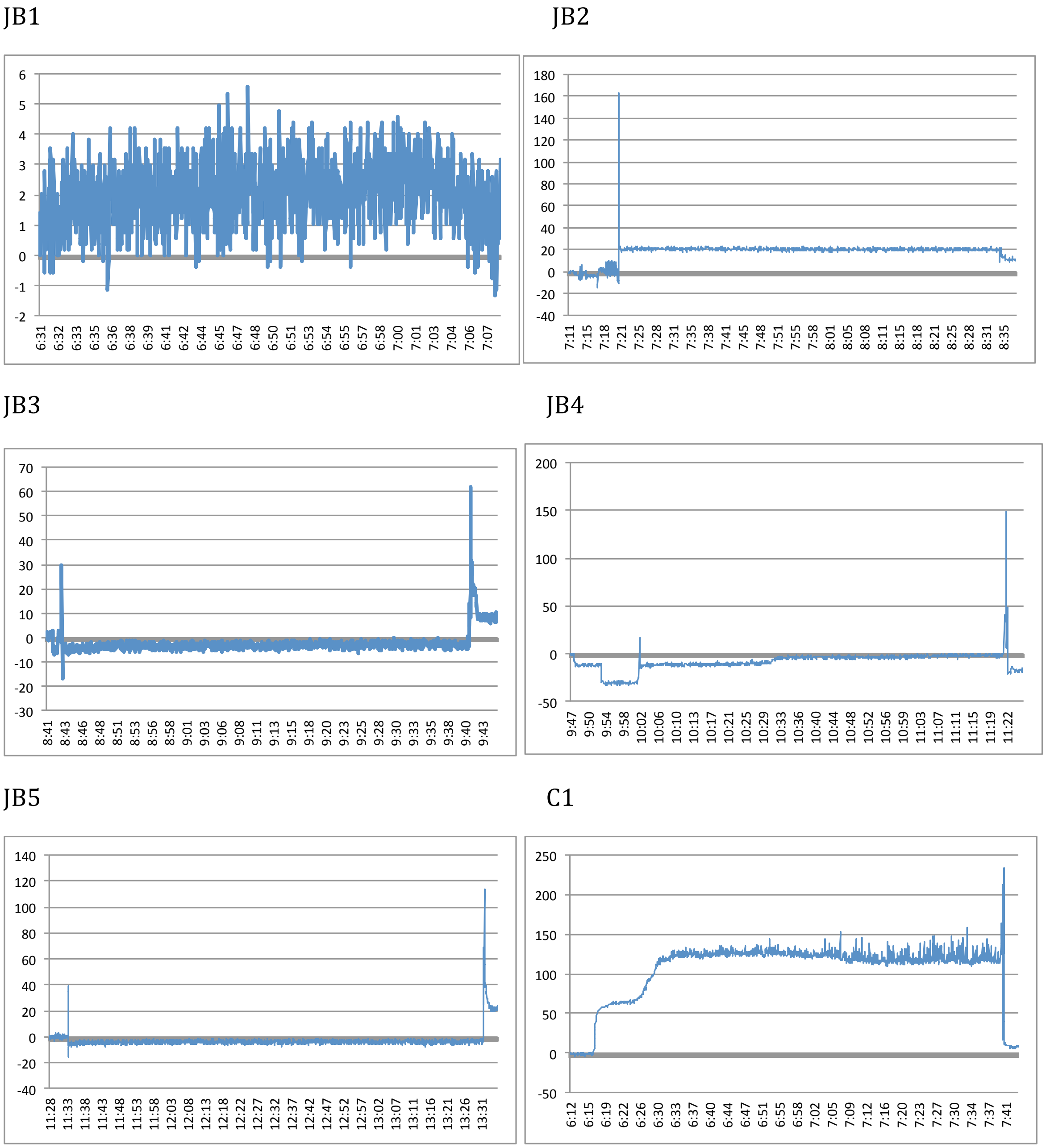
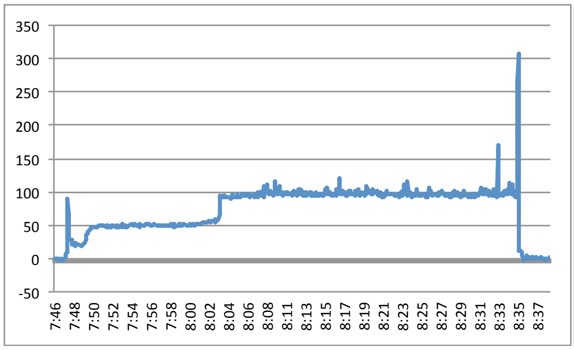
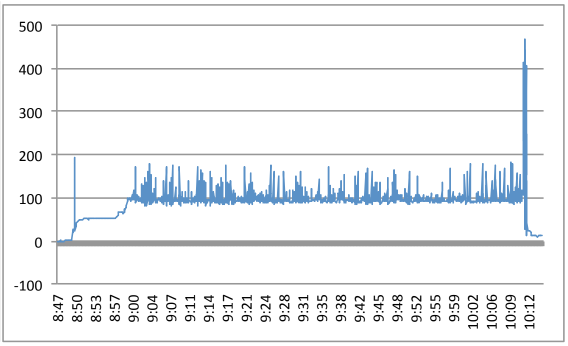


Figure 8. *Load cell outputs in lbsf from WA, with time on the x-axis. Note that the values on the y-axes are at different scales between plots. (JB = Jurien Bay; C = Cervantes).*

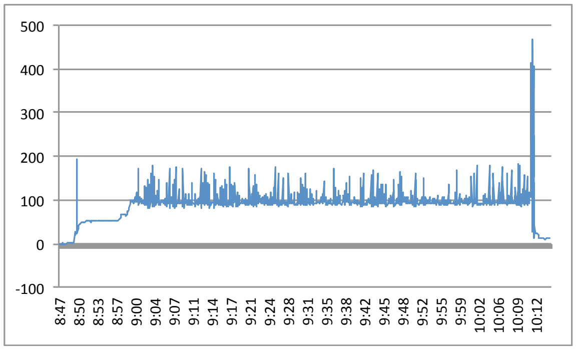
C2



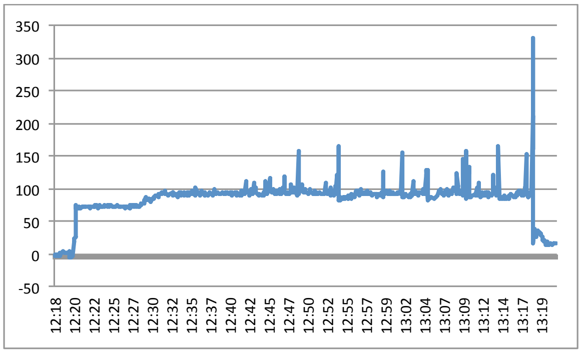
C3



C4



C5



C6

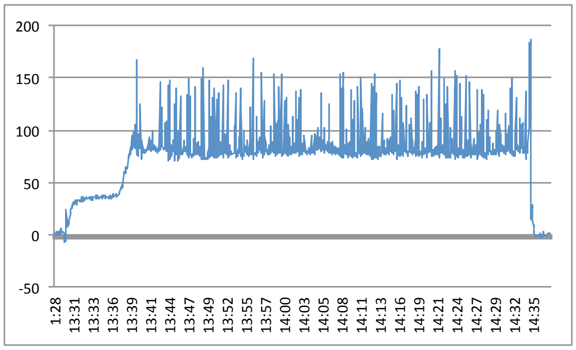


Figure 8. *[continued]*

Table 3. Information recorded by the MLA Whale Projects Coordinator on load cell deployments in Maine.

Date	Location	Vessel	Weather	Wave height (ft)	Depth (ft)	Substrate	Gear in	Gear out	# traps	Weight	Vertical Line diameter (inches)	Line length (ft)	Flotation	Wind velocity
9/27/12	Biddeford Pools	Hard Shel	Sun, light wind	[not recorded]	102	Rocky	12:35	16:30	3	3 bricks	3/8, 7/16	200	1 5/11" bullet	[not recorded]
9/28/12	Biddeford Pools, 2nm east	Hard Shel	Rain. Fog, light wind	3	94	Rocky	8:40	14:30	3	3 bricks	3/8, 7/16	[not recorded]	1 5/11" bullet	[not recorded]
9/29/12	Biddeford Pools	Hard Shel	Light rain	4-6	55	Sand-mud	9:30	13:40	3	3 bricks	3/8, 7/16	100	1 5/11" bullet	20 kt wind
10/3/12	Cushing - St. George River	Shannon Rose	Rain	2-3	108	gravel, rock, cobble	11:54	15:55	2	3 bricks	3/8 (float and sink in equal proportions	132	2 6x14"	5-10 kt wind
10/4/12	Cushing - St. George River	Shannon Rose	Rain	<2	66	Rocky	12:18	16:40	3	3 bricks	3/8 (float and sink in equal proportions	[not recorded]	2 6x14"	5-10 kt
10/5/12	Cushing - St. George River	Shannon Rose	Fog	[not recorded]	60	Mud	7:10	11:30	5	3 bricks	3/8 (float and sink in equal proportions	[not recorded]	2 6x14"	[not recorded]
10/10/12	Moose Peak lighthouse	Whit's End	Rain, fog	sm swells	106	Gravel, some sand and mud	10:50	15:27	3	12 cement wedge, 4 lb ergo/steel	3/8 Esterpro (top); 7/16" Steeliner (bottom)	180	1 9x24" bullet	5-10 kt
10/11/12	Litle Cape Point, Beals Isl.	Whit's End	[not recorded]	[not recorded]	20	Sand	12:13	16:25	5	12 cement wedge, 4 lb ergo/steel	3/8 Esterpro (top); 7/16" Steeliner (bottom)	[not recorded]	1 9x24" bullet	[not recorded]
10/12/12	W. Beals Isd.	Whit's End	Rain, fog	[not recorded]	18	Gravel, sand	13:10	16:55	10	12 cement wedge, 4 lb ergo/steel	3/8 Esterpro (top); 7/16" Steeliner (bottom)	[not recorded]	as above plus one LD2 polyball	25kt
10/16/12	Biddeford Pools	Hard Shel	Partl sunny	[not recorded]	103	Rocky	10:00	14:10	3	3 bricks	3/8, 7/16	200	1 5/11" bullet	20 kt max.

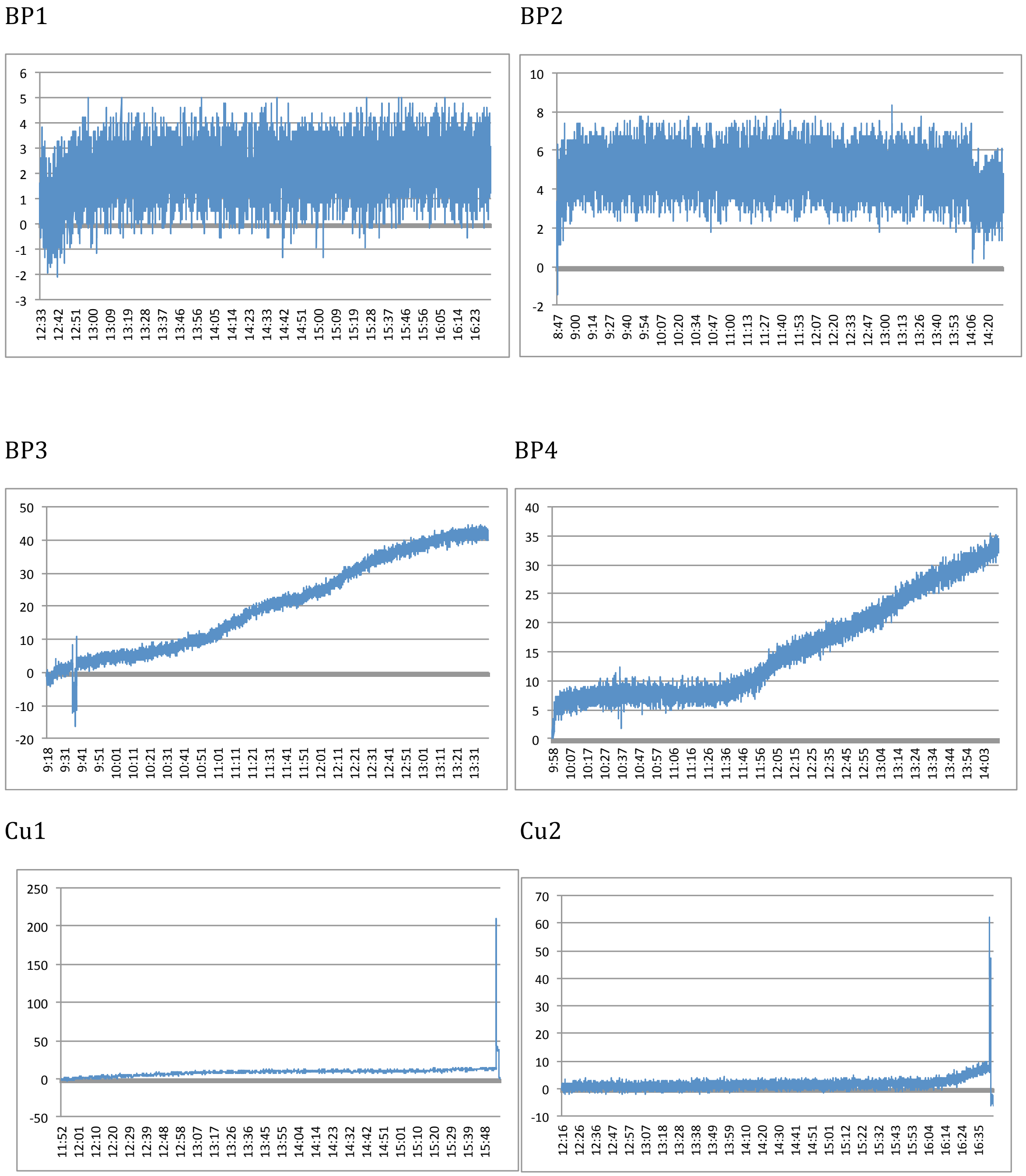
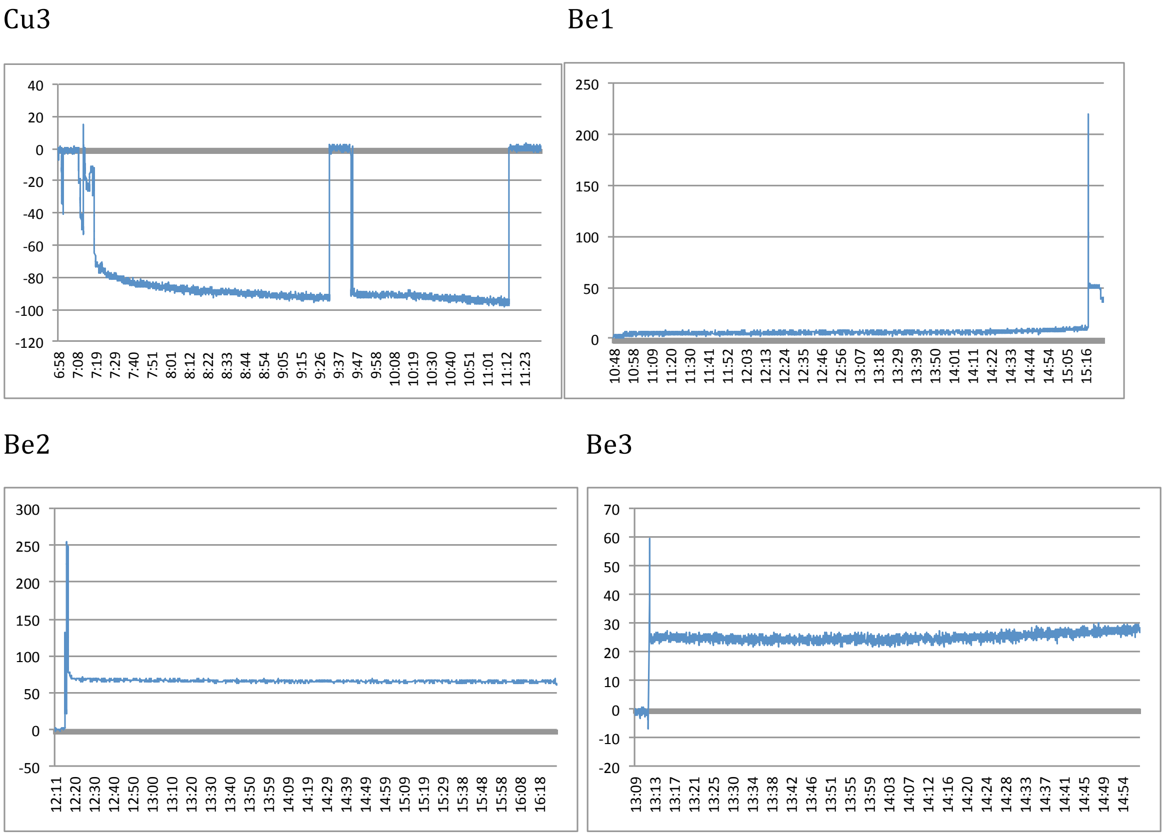


Figure 9. *Load cell outputs in lbsf from Maine, with time on the x-axis. Note that the values on the y-axes are at different scales between plots. (BP = Biddeford Pool; Cu = Cushing; Be = Beal's Island).*


Cu3

Be1

Be2

Be3

Figure 9. *[Continued]*

On October 11th and 12th, both load cells were tied adjacent to each other on the line. A review of load readings showed agreement between the two cells to within 2-5 lbsf, so only the data from the small cell was used.

The plots sometimes show negative values. When these are close to zero, it likely indicates little or no tension on the line, because the accuracy of the load cell is between 1-2% of its maximum output. Nevertheless, other explanations are possible, especially when the values are well below zero. An engineer at Blue Water Concepts provided us with the following explanation for these negative outputs.

> A "negative" tension could indicate the cylinder was actually in compression. This could happen if the load cell was entangled in gear or line, acting to compress the load cell. This could also be explained by the calibration of the instruments. It is also possible that the handling of the instrument could cause a negative reading. A hard shock or compression of the instrument (maybe dropping the load cell on

the deck) on one day could have compressed it, resulting in some hysteresis error the following day.

The most aberrant plot of load cell readings is Cu3 in which the output values are mostly negative, dropping to nearly -100 lbsf for most of the time except for briefly reverting to zero mid-way through the deployment and then again at the end. Clearly something caused this unit to erroneously measure line tension, perhaps owing to a handling issue on deck.

In general, outputs show relatively constant load readings except for minor sustained oscillations, perhaps caused by the force of waves at the ocean surface, adding slight increases or decreases to tension. In many instances, there is also a peak value measured at the point of hauling or, in two instances, at the time that the gear was deployed. It may be that these maxima occurred owing to the tug of the gear once its weight went overboard, or at the instant that hauling began, with the tension abating once the unit--deployed near to the ocean surface--was placed on deck.

Table 4 reports the maximum, minimum, and average loads recorded during deployments in both Maine and WA. In WA, readings during one day at Jurien Bay averaged between 0 (essentially) to 111 lbsf, and at Cervantes between 77-111. In Maine, measurements recorded on different days averaged between 0 to 21 lbsf at Biddeford Pool, from 0 to 9 at Cushing, and 8-65 at Beal's Island.

Table 4. Minimum, maximum, and average measurements of load cells in lbsf. Figures include only the time of deployment and not at rest. Numbers in red were values associated with the initiation of gear hauling, whereas those in green are values at the time of setting overboard. Values between -2 and 2 can be assumed to have recorded little or no tension.

WA	JB1	JB2	JB3	JB4	JB5	C1	C2	C3	C4	C5	C6
Min	-1	8	-7	-21	-8	-1	-2	10	-22	15	-1
Max	6	23	62	149	114	233	306	466	284	331	187
Avg	2	20	-3	-6	-3	111	81	95	73	89	77

MAINE	BP1	BP2	BP3	BP4	Cu1	Cu2	Cu3	Be1	Be2	Be3
Min	-2	-1	-16	0	-3	-6	-98	0	-2	-7
Max	5	8	45	36	210	62	15	219	254	60
Avg	2	5	21	15	9	2	-74	8	65	24

The Gulf of Maine measurements seem consistent with earlier load cell readings reported by Salvador and Kenney (2002) from downeast Maine and the Bay of Fundy. They reported maximum loads in near-shore gear of 105 and 125 pounds, from recordings taken over 68 days. It was not reported if these measurements included load readings while hauling or setting, although another section of their report specifically referred to towed gear outputs. According to the Captain of the *F/V San Giuseppe*, when fishing deeper waters offshore during December-January, line tensions in WA might be expected to reach 30 times what was recorded in this study. If correct, this would put maximum rope tensions up to 3000lbsf or higher.

The MLA Whale Projects Coordinator reported difficulties in operating the ADCP, and the outputs were not analyzed for this report. Readings at multiple depths suggest a relatively consistent range of current velocity measuring between 0 and 1.5 m/s. These data might be re-examined in the future if they would be helpful in informing the design or use of ropes for preventing whale entanglements.

Discussion

The West Coast Rock Lobster Fishery in Australia's state of Western Australia is the largest source of whale entanglements documented in the country, and mainly involves humpback whales (Groom and Coughran 2012). Between 1982-2010, 63 entanglements of baleen whales were recorded, but the number recently has shown dramatic increases, with 32 recorded in 2013 (How, Coughran et al. 2015).

Although the gear used in WA is similar to that of the Gulf of Maine lobster fishery, it is used to target different species: *Panilurus cygnus* versus *Homarus americanus*, respectively. There is also an order of magnitude difference in the number of vessels operating in each area: some 235 in WA according to a 2014 figure from the WA Department of Fisheries[1], and close to 6000 license holders for Maine lobster according to the State's Department of Marine Resources[2]. This difference is huge even though the extent of coastline in Maine is approximately three times as long as the roughly 932 miles in the WA fishery, and includes many more islands.

Lobster fishermen in WA apparently use hard lay rope to reduce the probability of it becoming entangled as they deploy gear (Figure 10). Given the number of entanglements caused by gear in this fishery, there does not appear to be any advantage in using a harder lay rope to reduce whale bycatch. However, increasing rope lay can reduce breaking strength (Klust 1983), and a recent study by Knowlton et al (2015) showed that ropes of reduced breaking strength could help prevent baleen whale entanglements. Increasing the rope lay should therefore be considered as a possible option for producing reduced breaking strength ropes that the Bycatch Consortium, the NEAq, MLA, and fishermen from Massachusetts are currently

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[1] http://www.fish.wa.gov.au/Species/Rock-Lobster/Pages/Lobster-Commercial-Fishing.aspx, accessed on 12-15-15.

[2] http://www.maine.gov/dmr/commercialfishing/historicaldata.htm, accessed on 12-15-15.

examining. Nevertheless, Maine lobstermen generally consider such hard lay ropes less easy to use in their fishery, so this would need to be taken under consideration.

Figure 10. *Tossing a coil of hard lay lobster fishing rope overboard with a set of lobster pots in WA.*

With respect to increasing line tension, we recorded relatively low loads from lobster pot ropes in both WA and Maine when not being deployed or hauled. Assuming that ropes under high tension might be a viable way to prevent whale entanglements, achieving this for the duration of the gear's soak time in both fisheries would require modifications such as increasing substantially both the weight and flotation on these vertical lines. In the absence of other data indicating that high tension ropes of the types used in these fisheries showed promise for preventing whale entanglements, it does not seem justified to examine what would be a relatively impractical adjustment to existing fishing methods. An earlier Bycatch Consortium study (Baldwin et al. 2012) concluded that increased line tension could result in more severe injuries upon contact with a whale flipper, and there may be other unintended consequences from altering pot gear to achieve higher tensions.

Perhaps the more instructive finding from the WA fishery is the regulatory change from controlling fishing effort to issuing quotas. The relatively new quota system has resulted in fewer vessels, gear deployments, and lines in the water column, thereby reducing the density of gear and the degree of exposure to whales. Although there has been a recent increase in entanglement rate following implementation of the quota system, this is most likely due to opening up fishing areas previously closed during the months when whales migrate through the area.

The use of float rope at the surface of the water in WA may also contribute to whale entanglement risk, although there is no evidence from the Gulf of Maine that requiring these ropes to be negatively buoyant has resulted in fewer entanglements. Furthermore, the relative amount of time spent by whales at the ocean surface in both areas is not quantified.

Conclusion

Although the initial interest by Maine lobstermen in examining “stiff rope” fishing in Western Australia for reducing whale entanglements in the Gulf of Maine did not immediately suggest promising ideas for altering fishing techniques, the exchange of information on fishing methods between fishermen from these two parts of the world revealed other insights for advancing research on reducing whale entanglements. Among these is a better appreciation of the relative scale of fishing effort within a lobster fishery, and how effort reduction through quotas can reduce the amount of gear in the water while maintaining a commercially viable fishery. Baseline information on rope loads characteristic in both fisheries can also inform current projects being advanced by fishermen and scientists regarding the prospect of using ropes with reduced breaking strength.

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