APPENDIX A

Extending the Life of Sinking Groundline: Observations and Experiments

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Summary

The following observations and ideas for improving the service life of sinking groundlines are explained more fully in the body of this report.

- The fact that most blended-fiber ropes showed more deterioration than straight Polysteel © floating rope, even without sediment in the hauling simulator, points to the need to test sinking ropes made entirely of polyester, or of polypropylene with an added lead strand or other heavy material.
- The surface smoothness of hauler discs is a critical factor in determining rope wear. Hauler sheaves with a smooth surface are less likely to abrade groundline as it wedges between the sheaves.
- Hydroslave stamped steel hauler sheaves resulted in significantly less rope deterioration than did machined steel sheaves. The likely reasons for the improvement are the smooth surface of the Hydroslave sheaves and the variable angle between the sheaves.
- Hauler sheaves should be kept closely spaced, thus keeping the rope as far out as possible, to reduce rope wear.
- Larger diameter haulers, fairleads, and hanging blocks are likely to reduce rope wear compared to smaller diameters that create a smaller "bend radius" for groundlines under strain. Bending ropes under strain causes internal friction and abrasion and is a known cause of rope wear.
- The pressure required for the splitter to force the groundline out of the hauler is a factor in rope wear. Keeping the rope further out toward the rim of the hauler reduces the pressure needed to force the line out.
- The use of a splitter with a reverse curve on the edge that meets the rope can reduce rope wear by reducing the angle at which the rope hits the splitter and lifting the groundline out of the hauler gradually.
- Experiments have shown that rope wear occurs through the wedging action of the standard trap hauler. A different approach to hauling that does not rely on wedging the groundline between sheaves and then forcing it out, may cause less rope wear. A hauler similar to the Crosley net lifter might be an alternative worth testing.

Background

U.S. Atlantic coast lobstermen have been required to use sinking groundlines on lobster trap trawls since April 2009. The change from floating groundlines to sinking groundlines has created a number of problems for lobstermen. Any attempt to solve these problems needs to recognize the different categories of problems. Two broad categories are 1) problems caused by using sinking groundlines on hard bottom and 2) problems using sinking groundlines on soft bottom. The service life of sinking groundlines has proven to be shorter than floating groundlines in both cases, but the reasons for the shorter life can be quite different.

Obviously, sinking groundlines are more prone to hanging down and chafing on hard bottom. Groundlines that get snagged under rocks suffer severe chafing in a localized area, often to the point that they break before they come free. Groundlines also chafe as they move with the tides and currents across hard bottom. Using sinking groundlines in hard bottom creates safety concerns as well as shortened rope life. There isn't much a lobsterman can do to avoid the problem of sinking groundline chafing on rocks when he is fishing on hard bottom, other than keeping the boat over the gear and avoiding dragging the gear over the bottom. There are, however, steps that can be taken to reduce the risk of additional damage to the rope, to the boat, and to the crew when sinking groundline gets hung down. These steps will be discussed further below.

A number of research projects have identified both the causes of shortened groundline life when used on soft bottom and steps that can be taken to increase rope longevity. Research projects have looked at differences in rope construction, the effect of bottom sediment on rope wear, and differences in rope wear depending on hauler adjustments.

Basic Rope Construction

Lobster trap groundlines are typically three or four-strand twisted ropes constructed of either three or four strands of polypropylene fibers, which float, and/or polyester fibers, which sink. Both have been used for years for lobster pot warp. Over the last 10-15 years, a proprietary polypropylene fiber named Polysteel © became popular for its high strength and durability. Polysteel © ropes are manufactured from extruded copolymer (polypropylene and polyethylene) fibers. The introduction of Polysteel © occurred at the same time that concern over whale entanglements in groundlines was growing, leading to regulations requiring the use of sinking groundlines. Whereas straight Polysteel © floats, rope manufacturers have tried various combinations of Polysteel © or other forms of polypropylene and polyester to make sinking ropes. These ropes vary significantly in the way the different yarns are blended to make the rope. Experience from both research and fishermen's reports has shown that even ropes with the same name from the same manufacturer may vary in construction from one batch to another.

Some lobstermen have used sinking ropes for decades while others used nothing but floating rope until regulations required sinking rope. Experience with sinking rope varies from area to area, with many lobstermen finding that sinking rope doesn't last as long as floating rope. Laboratory and field-testing have attempted to pinpoint the factors that determine rope longevity.

Sediment and Rope Construction Are Both Important

Lobstermen and researchers have been testing sinking groundlines for durability since the early 2000's. In 2004 the Massachusetts Division of Marine Fisheries partnered with the Atlantic Offshore Lobstermen's Association to design and build an offshore trap hauling simulator (Lyman et al. 2005). The simulator allowed rope to be subjected to wear that approximated 5 years of field use in four hours of continuous hauling. The simulator allowed the rope to relax in a bed of sand and water between being subjected to hauling loads typical of offshore trap hauling.

The first set of laboratory rope tests that used the hauling simulator were intended to compare rope durability while keeping the hauler and all other conditions as constant as possible. In those tests, the rope used as the standard for comparison (control) was Polysteel© Atlantic floating rope. All of the ropes tested were 5/8" diameter. The control rope averaged 42.6% loss in strength over multiple testing cycles. The top performing sinking rope, which were all blended polyester and polysteel, in those tests was Everson three-strand, which showed less loss of strength for the same hauling cycles as did the control.

When lobstermen initially switched from floating to sinking groundlines, it was generally believed that the reduced service life of sinking groundlines was a result of the rope picking up sediment that chewed the rope up from the inside and as it passed through the hauler. Research using the hauling simulator has demonstrated that most sinking groundlines deteriorate faster than floating ropes even when there is no sediment in the simulator. Sediment in the simulator did increase rope wear, but most sinking rope deteriorated faster than floating rope with or without sediment. The conclusion that sediments inside the rope fibers are not the only cause of the shorter life for sinking rope is also supported by the results of visual and microscopic examination of sinking groundlines examined after field use by lobstermen. Tension Technology International (2007), a rope consulting firm, concluded that surface abrasion, both external and internal, was the dominant cause of rope damage for a selection of used and tested groundlines, but the damage to the internal structure of rope strands due to the abrasive effect of sediment was not a major contributor to damage, although it was seen.

Of particular interest is the observation by TTI that the "center ridge" that forms where the rope strands meet in the center of the rope shows rope damage characterized as "fibrillated debris". This damage within the rope appeared to have been caused by friction between the rope strands themselves, not by sediment between the strands. TTI noted that the center ridge was less prominent with 4-strand rope than with 3-strand rope, which could explain some increase in longevity of the 4-strand rope if deterioration along the center ridge is an important contributor to loss of strength over time.

Machine testing of groundlines showed no discernable difference or correlation between breaking strengths and the specific gravities, or weight, of the lines. Only 5/8" lines were tested. In other words, for the few lines tested, heavier non-buoyant lines did not wear more or have lower breaking strength values than the lighter non-buoyant lines. This would suggest that other factors, such as how the materials are woven, the lay of the line, and material content, may be more a factor for determining endurance to wear, than the "weight" of the line or degree of contact with the substrate.

The fact that sinking groundlines lose strength faster than floating groundlines even when they are tested with no sediment, together with the fact that machine testing did not demonstrate any correlation between rope density and loss of strength, leads to the conclusion that there is something about the construction of blended-fiber ropes (a combination of polyester and polypropylene) that leads to a loss of strength that is caused by the hauling process alone. Perhaps the differences in the size and elasticity of the fibers that are blended together in sinking rope cause internal damage as the fibers strain and then relax when hauled. The hauling process also squeezes the fibers together in the hauler, creating abrasion between the different fibers.

The greater loss of strength of blended fiber groundlines compared to straight Polysteel © contrasts with what was found during the development of mixed filament ropes for vessel moorings, as noted in the TTI report. For mooring lines, the most wear resistant ropes were made with blended yarns of polyester and polypropylene. Mooring lines with outer yarn assemblies of 100% polyester or 100% polypropylene yarns were found to be less wear resistant. Mooring lines, however, do not go through the squeezing action of a trap hauler and are not subject to the sharp bends under strain that groundlines experience. Field experience in the lobster fishery has also found that Polysteel ©, which was not used in the mooring line comparison, is superior to normal polypropylene.

From its inspection of both field-tested and machine-tested groundlines, TTI concluded that ropes where there are both polypropylene and polyester fibers on the outer surface of the strands have a good balance of resistance to abrasion and particle penetration. TTI only examined blended fiber groundlines, so no microscopic comparison was made between blended fiber ropes (Polysteel © and polyester) and straight Polysteel © or straight polyester.

Although no tests of non-blended sinking ropes were done on the hauling machine, one offshore lobsterman reported good results from the heaviest polyester rope that he had used, which was likely constructed almost entirely of polyester, with little or no polypropylene or Polysteel © added. More testing with the hauling machine or in the field is necessary to determine whether sinking ropes made entirely of polyester, or of polypropylene with an added lead strand or other heavy material might last longer than the more common blended ropes.

The evidence showing that sediment is not the only factor in groundline deterioration led researchers to look more closely at the hauling process itself, since groundlines hauled without any sediment in the hauling machine did show significant loss of strength. One research project tested different hauler disc angles, different hauler disc materials, different hauler spacing, and a new splitter (knife) design. Larger rope diameter is an obvious way to increase the strength and longevity of groundlines. The simulation studies did not investigate the longevity gains from increasing rope diameter.

Rope Damage from Trap Haulers (from Burke, et al. 2008)

Lobster trap haulers are so simple that it is easy to assume that they aren't part of the rope wear problem and they can't really be improved much. It may be helpful to think about how they do their magic. The sheaves develop tension in the groundline through friction and the wedging action of the V shape shown in Figure 1. It's important to keep in mind that the squeezing, or wedging action creates considerable sideways pressure on the rope, in addition to the lengthwise strain of the pulling action. Pressure from the hauler and flexing over pulleys caused flattening of the filaments of polyester (PET) yarns, and, splitting, flattening and compression of the polypropylene (PP) yarns as seen under microscopic analysis of used groundlines. The rope also slides across the surface of the sheaves as the rope passes around them, causing fiber abrasion on the surface of the rope.

This “grating” action is especially noticeable with machined-steel sheaves hauling rope with a heavy strain. Contrary to its relatively smooth appearance to the naked eye, a machined steel surface looks like a mountain range under a microscope. Rope dust comparable to sawdust could be seen being scraped off groundlines during machine testing using machined-steel hauler discs.

Figure 1 Lobster trap haulers work by wedging the pot warp between two steel discs. Higher tension in the line causes it to wedge more deeply into the V between the discs.

Smoothness of Hauler Surface

The experiments focused on rope longevity in the offshore lobster trap fishery. For that reason, the “standard” hauler set-up used 16” machined steel hauler discs with a constant four-degree angle on the disc surface, for an eight degree angle between the two discs. The most noteworthy potential for a reduction in rope wear compared to this standard offshore hauler arrangement was demonstrated by the increase in residual breaking strength of sinking groundlines tested with 17” Hydro-Slave hauler sheaves compared to the standard offshore hauler setup. The Hydro-Slave stamped steel sheaves gave the best results of all the hauler tests, producing a 30% increase in residual breaking strength of sinking rope compared to machined-steel hauler discs. Although the Hydro-Slave sheaves were an inch larger in diameter than the machined steel sheaves, the diameter of the wear area was not measured. Whereas a smaller working diameter requires a smaller length of line to take the force of hauling, it seems likely that larger diameter sheaves would spread the load over a longer length of line and reduce the amount of wear.

Those research results lead to the conclusion that the surface smoothness of hauler discs is a critical factor in determining rope wear. This conclusion is supported by a comparison of un-lined Hydro-Slave sheaves with the same sheaves plus a set of the stamped-steel sacrificial galvanized liners sold by Hydro-Slave. Residual rope strength was greater without the liners than it was with the liners for both floating and sinking ropes. The stamped-steel Hydro-Slave galvanized liners have radial grooves that are apparently intended to increase their grip on the rope. The good news is that most inshore lobster boats are already using Hydro-Slave hauler discs; the bad news is that the hauler liners may contribute to rope wear when compared to Hydro-Slave discs without liners.

Angle of Hauler Discs

In addition to having a smoother surface than the typical machined-steel hauler disc, the unlined Hydro-Slave discs have a variable surface angle from the hub out to the rim. This contrasts with machined hauler sheaves, which normally have a constant four-degree angle from the hub to the outer rim of the working area. The hauler experiments indicated that the angle between hauler sheaves and the depth at which the rope rides in the sheaves are important factors in rope wear for variable angle sheaves like the Hydro-Slave stamped-steel sheaves. The test ropes showed less loss of strength when the sheaves were close together, causing the rope to ride further out on the sheaves where the angle between the Hydro-Slave sheaves widens out. The message from those results is that sheaves should be kept as close together as possible while still maintaining an adequate grip to haul the groundline.

The improvement in rope wear seen when the rope was riding further out on the Hydro-Slave sheaves suggests at least two things that could have caused that improvement. First, more rope was in the hauler at any one time, requiring less compression of the rope to achieve the same line pull. Second, squeezing the rope deeper into the sheaves is likely to damage the rope by scuffing it across the surface of the hauler sheaves and by increasing the pressure on the rope that must be exerted by the stripper to force the rope out of the hauler. As discussed below, the force with which the rope pushes against the hauler knife was shown to be a factor in rope deterioration.

Size of Hauler

The demonstrated improvement in rope wear from keeping the rope riding as far out as possible also suggests that the longevity of rope can be improved by using the largest hauler possible. Assuming that larger sheaves also have a larger flat surface at the center hub, larger diameter sheaves cause the line to ride at a larger diameter, thereby putting more rope in contact with the sheave and increasingthe pulling friction without squeezing the line as deeply between the sheaves. Although no experiments have been done to compare rope longevity with different size haulers, it seems likely that bigger is better, both for haulers and for fairleads and hanging blocks. “Bend radius” is a known factor in rope wear, with sharper bends leading to faster rope wear.

Splitter or Knife Factors

The hauling machine was fitted with a pressure sensor (load cell) behind the splitter. The results showed that the hauler configurations with the least rope damage also had the lowest splitter load cell readings. This finding is likely to be even more important in the field than it was in the lab because the force with which the rope pushes against worn splitters is likely to be a significant factor in rope damage caused by the splitters.

In addition to the “routine” rope damage caused by the splitter regardless of the type of bottom, splitter damage likely spikes when the groundline gets hung down. In that case, the groundline is forced deeper into the sheaves and pushes much harder against the splitter before it is forced out. The sharp edges on a worn splitter might not do a lot of harm when the strain on the rope is moderate, but will likely cut the outside fibers when the rope is squeezed hard against the splitter. Keeping the splitter in good condition will reduce this source of damage.

Experiments with the hauling machine also showed an improvement in rope longevity through the use of a splitter with a reverse curve on the edge that meets the rope (Figure 2). The reverse curve reduces the angle at which the rope impinges on the splitter, thus lifting the rope out of the V more easily. Splitter load cell readings with the reverse curve splitter were significantly lower than with the standard splitter. The reverse curve splitter may not be practical on smaller haulers, another reason for using the largest hauler possible.

Figure 2 – A splitter with a reverse curve (top) lifts the groundline out of the hauler gradually in comparison to a straight-sided splitter (bottom).

Could the Crosley Net Lifter Save the Day?

The conclusion that trap haulers cause considerable wear on groundlines through the wedging action of the V-sheaves leads to consideration of alternative rope-hauling methods. One such device is the Crosley net lifter, which uses spring-loaded, cam-actuated fingers to grip the rope during the hauling portion of the hauler revolution, rather than wedging the rope between V-sheaves. The net lifter then releases the rope from the grip of the hauler rather than requiring a knife or splitter to force the rope out. Crosley net lifters are commonly used in the New England gillnet fisheries and might be worth experimenting with as an alternative to the standard trap hauler if they could be shown to significantly increase the service life of sinking rope. Horizontal haulers and rail rollers are commonly used in other trap fisheries. The large diameter of gillnet rail rollers may reduce rope wear compared to small diameter hanging blocks and hauler fairleads.

Hard-Bottom Hauling

The use of sinking groundline on hard bottom will undoubtedly result in more chafing and hang-downs and result in rope damage. Fishermen who specialize in hard-bottom fishing may discover certain tricks to avoid hang-downs and to escape from them, but none seems obvious, other than keeping the boat over the gear and avoiding dragging the gear across the bottom. However, some of the lessons learned about adjustments to the hauling machine are even more important for improving rope wear on hard bottom.

Because hang-downs create higher than normal line strain, it is important to start with the rope riding as far out on the hauler sheaves as possible. That way, when the extra strain comes on the line, it will have more room to squeeze into the hauler without getting as deep as it would if it started deeper. Here again, a larger diameter hauler will provide more working surface with a larger bend radius, which is kinder to the rope. Fairleads and hanging blocks create the tightest bend radius in the hauling system, making it particularly important to use the largest possible diameter for hauling in hard bottom where hang-downs are frequent.

Safety concerns also suggest the need to upgrade davits and their support structures when using sinking rope in hard bottom because hang-downs create large forces on the line and hauling equipment. Another important safety feature that is often over-looked is the relief valve on hydraulic hauler valves. Wise use of the relief valve may also save on rope wear by letting the relief valve pop rather than jamming the groundline deeper into the hauler when the boat goes up on a wave and the groundline is hung down. Winches are commonly designed to exert constant tension on the cable they are hauling. Something like that may prove useful for pot haulers, both for safety and for rope wear.

Conclusions

Experimentation and observations of both field-tested and machine-tested groundlines leads to the conclusion that the service life of groundlines is influenced by a multitude of factors. Comparisons of rope samples used by different lobstermen reveal differences that may result from seemingly small differences in the condition and spacing of hauler sheaves and splitters as well as differences in hanging blocks and fairleads. These unknown differences between boats make it difficult to predict with certainty which ropes will perform well for individual lobstermen. Greater attention to hauler size, block size, hauler sheave spacing, hauler sheave condition, and splitter fitting and condition are clearly important to rope life, particularly when sinking groundlines get hung down and the rope is forced deep into the sheaves.

The fact that blended fiber ropes show more loss of strength than straight Polysteel © in the absence of sediment deserves additional experimentation to test whether some method of weighting Polysteel © other than blending it with polyester might produce a more durable groundline.

Despite the simplicity and functionality of the standard trap hauler, improvements in rope wear may be achieved by finding ways to haul rope without wedging the rope between steel plates and then forcing it out with a narrow steel "knife." The design of the Crosley net lifter offers one possibility.

Lobstermen will be sticking with the standard trap hauler for the foreseeable future, making it important to use the most rope-friendly splitter design. The reverse-curve splitter proved to reduce rope wear in laboratory tests and has been used with success in the field.

No one thing is likely to bring about a major improvement in the service life of sinking groundlines. Rather, attention to detail has the potential to improve rope life incrementally here and there, adding up to considerable cost savings over the years.

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