portion of the groundline nearest to the trap was slack, but the rest of the line was not observable. The point of connection between the vertical line with the groundline and gangion was observed in the video from the top camera. These lines moved in and out of the video frame throughout the day while the trap rested immobile on the sea floor.

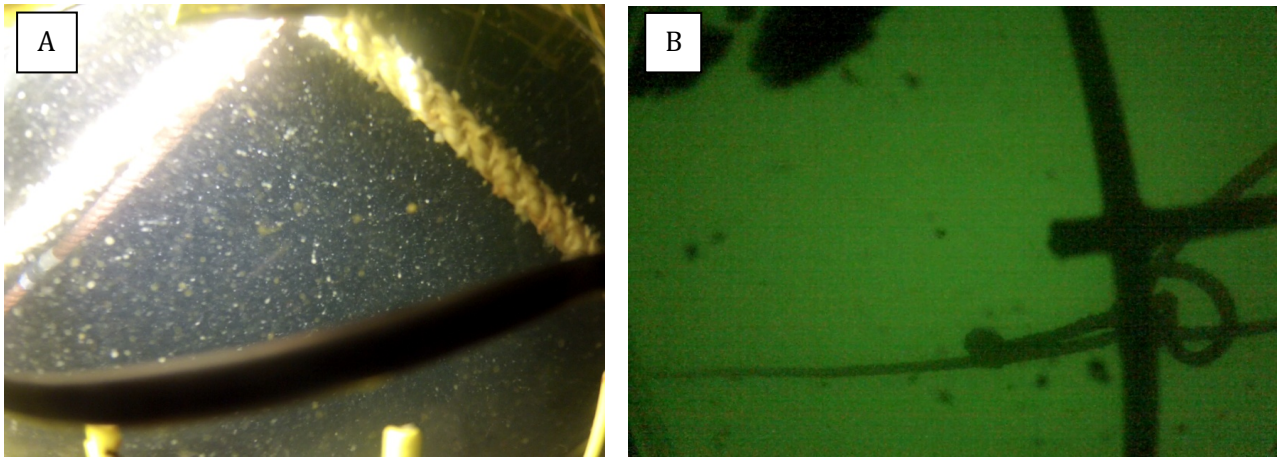


Figure 19. *A) The view from the front camera with one marker visible. B) The view from the top camera with the gangion, vertical line, and groundline all visible.*

October 5

The last day of testing off Cushing occurred in fog, in waters 54 to 60 feet deep and on muddy bottom. The same length vertical line was used as on the previous day, 132 feet. All of the video from this day was of poor quality due to sedimentation and low ambient light. The front video does show the floating portion of the groundline (Figure 20). The second and third groundline markers were visible during portions of the video. The portion of the groundline nearest to the camera trap was slack and moved slightly, but the rest of the line could not be seen.

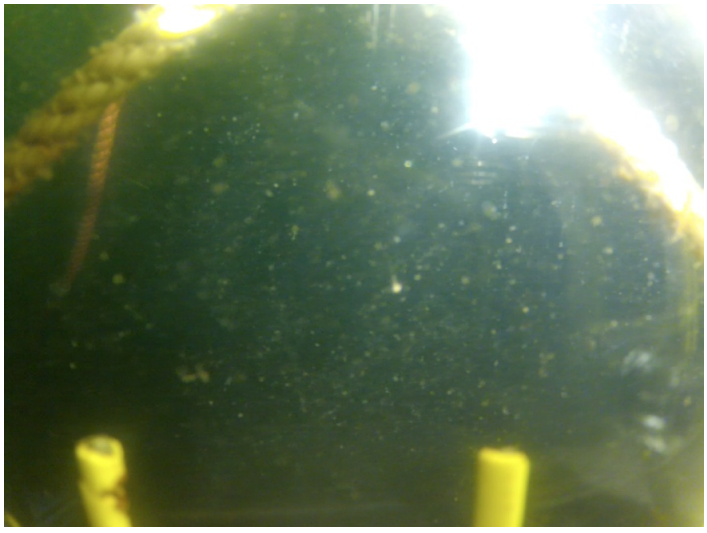


Figure 20. *Groundline observed in the front camera video.*

Jonesport: Downeast Maine

October 10
The experimental trap was deployed in a triple off of Moose Peaks Lighthouse near Jonesport, Maine, in 100 to 106 feet of water on mixed bottom. The weather was rainy with 5- to 10-knot winds and small swells. The length of vertical line was 108', and the groundline 66' between traps. A 9"-by-12" buoy was used in combination with a 12-cement wedge and a 4lb ergo steel weight. The vertical line was tied to the anchor rather than the gangion. The front and top cameras captured video of fair quality, both showing ropes within the frames.

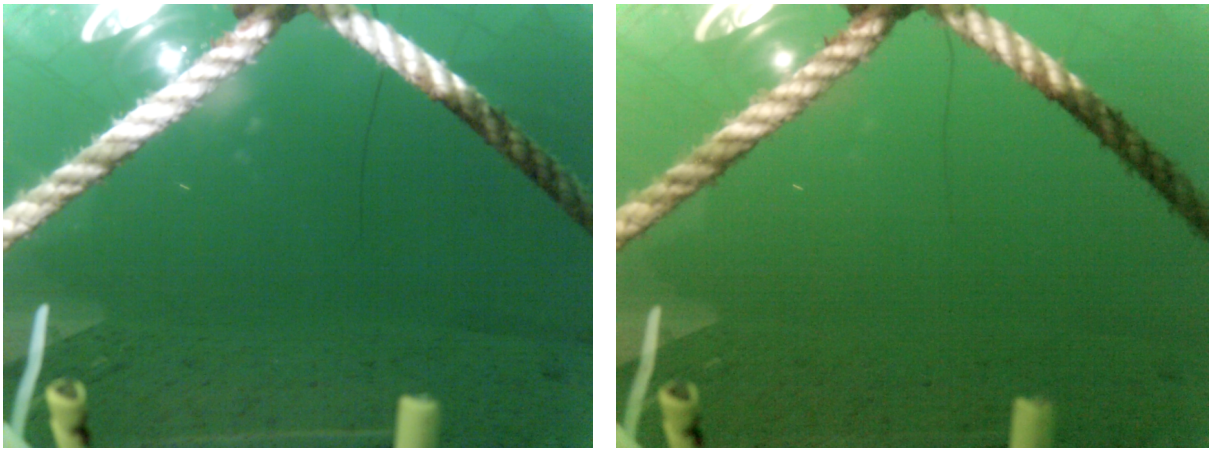


Figure 21. *These two images from the front camera show the degree of movement of the groundline from the Oct. 10 deployment.*

The line visible in the video from the front camera does not appear to reveal any markings (Figure 21). The line seen in the video from the top camera has seven visible markers, so the groundline may have gone up and over the trap (Figure 22). Because of the orientation of the videos, it does appear that the trap did settle on the seabed in the correct orientation, and was not upside-down. Although the markers can be seen, the color pattern of the markers cannot be identified, meaning the section of the line visible cannot be identified. In Figure 20B, a pair of entwined ghost-gear lines can be seen floating by the groundline.

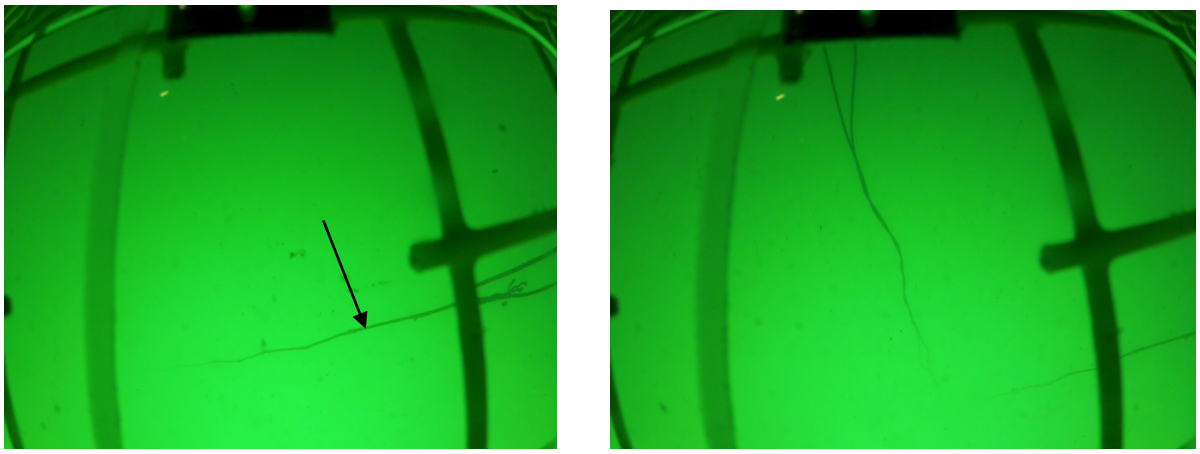


Figure 22. *Two images from the top camera: A) The groundline with at least seven markers visible; B) A pair of entwined floating lines.*

October 11

The second day of trials in Downeast Maine was carried out at Little Cape Point off Beals Island on a sunny day with strong waves and wind. Due to the weather, the traps were deployed in a sheltered area in 20ft of water. The five-trap trawl was placed on sandy bottom, with 180' of vertical line and 66' of line between traps. The front and top cameras produced video of fair quality. The front camera did not record the groundline. This was not due to the image quality; instead, the line was probably looped over or around the trap (Figure 23).

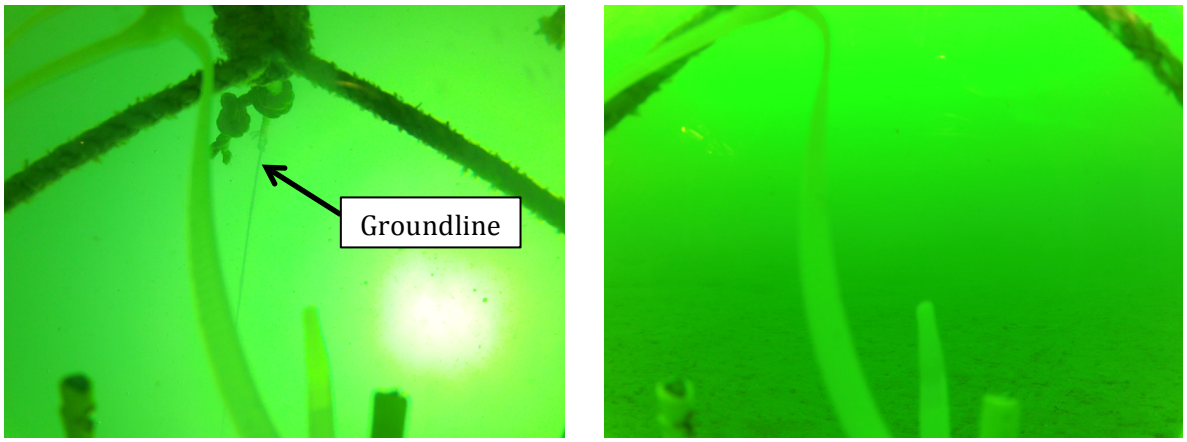


Figure 23. *The image at left was produced by the front-facing camera before the trap landed on the sea floor, and shows the groundline. The second image was taken with the trap resting on the bottom but no groundline is visible for the duration of the video.*

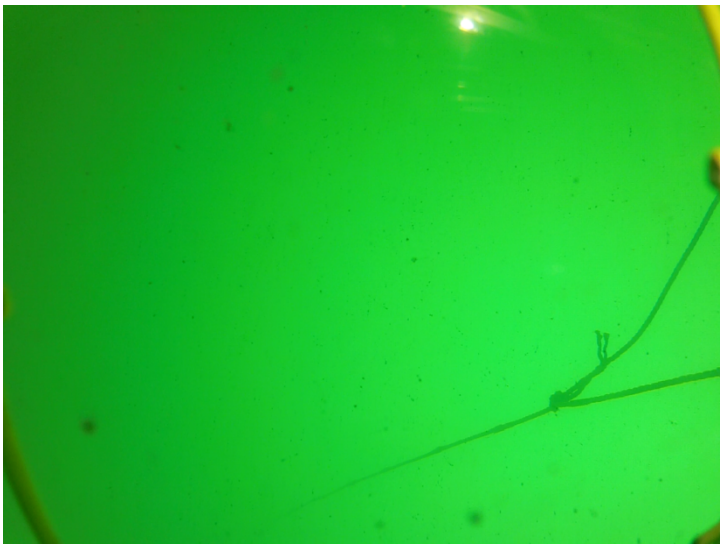


Figure 24. *Top camera view showing the gangion and groundline, with markers. The other line may be the floating vertical line that is not connected to the anchor.*

The images from the top camera were excellent and show the groundline with up to four markers visible (Figure 24) floating above the trap.

October 12

The last day of testing in Downeast Maine took place west of Beals Island Bridge in 18 feet of water. A ten-trap trawl was deployed on a bottom of gravel and sand. A 12lb cement wedge and a LD2 polyball were also used due to the strong currents in this area. The front and side videos were excellent, but the top camera video was poor. The front camera shows between three and four markers at any one time, depending on image visibility or line movement, and the groundline remained taut and did not make contact with the seabed throughout the video (Figure 25). The groundline is connected to an anchor. The movements of the groundline are erratic in the beginning, but then the line stops moving.

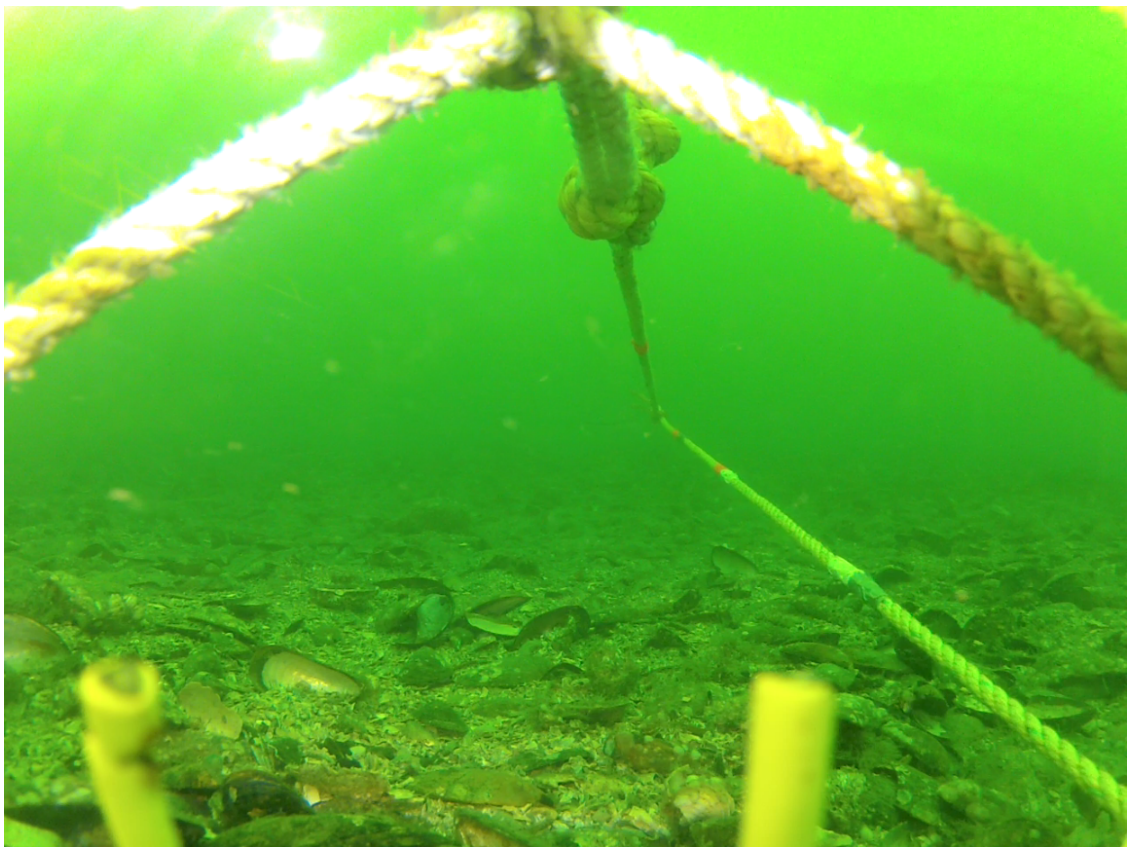


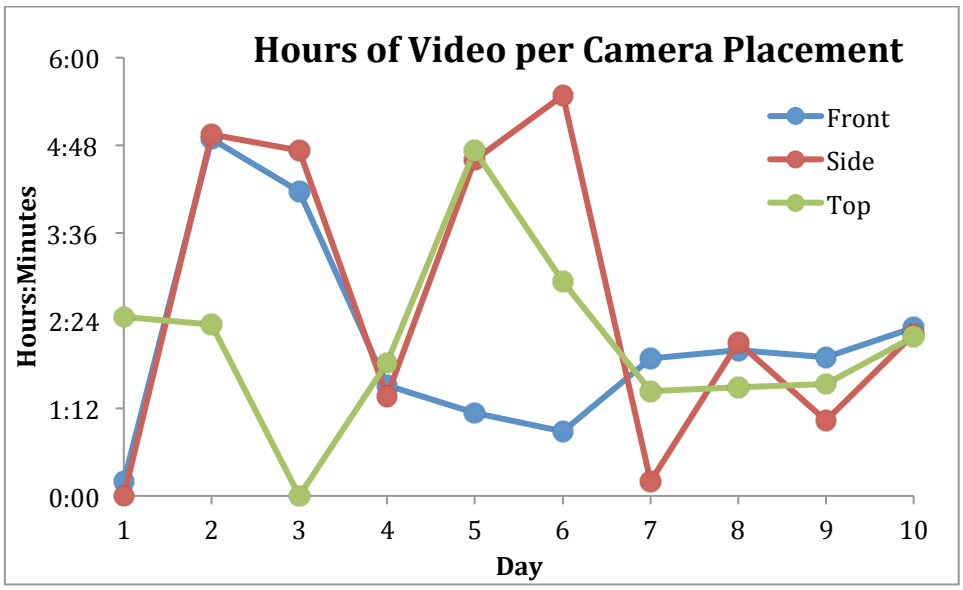
Figure 25. *Groundline and gangion seen from the front camera.*

Summary – Groundline Video Recording

As indicated in Table 4, deployments were made over a diversity of substrates from rocky to mud or sand. The weather ranged from calm and sunny to rain combined with high seas and wind. The gear was set at depths ranging from 13 to 108 feet.

A total of 68 hours and 28 minutes of video was collected over 10 field days. The duration of video collected by each camera on each day varied significantly; the cameras recorded between 0 and 339 minutes of video (Camera 1 mean = 1 hr 57 min; Camera 2 mean = 2 hr 07 min; Camera 3 mean = 2 hr 52 min) (Figure 24 and Table 5). Due to the difference between the expected battery life and the actual battery life, it was not possible to capture video from any single camera from two hours before and after a tide change, except on three of the days with the side camera (Figure 26).

a.



b.

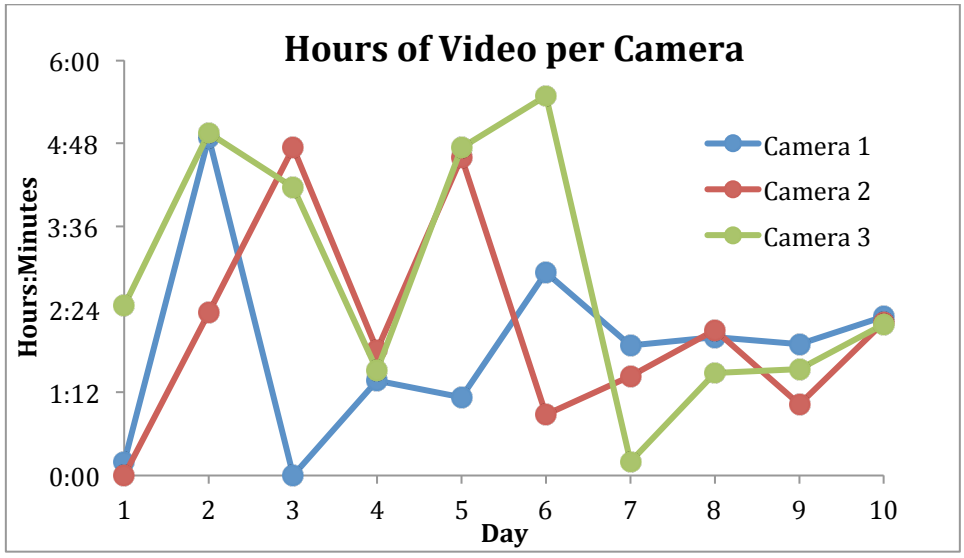


Figure 26. *The amount of video recorded each day based on a) camera placement in the trap (changed daily) and b) camera number (remained the same).*

After reviewing the videos, each was given a quality rating to characterize the clarity of the images: *Poor* (little to nothing is visible for all or most of the video due to light and sediment); *Fair* (some periods of visibility where the line can be seen clearly); or, *Excellent* (clear visibility for most or all of the video). The quality of the videos does not appear to be correlated with the current, weather or substrate type. The groundline was observed only on eight occasions in videos recorded from the front-facing camera (1, Fig. 12). No line of any type was observed in footage produced from the side camera (2, Fig. 12). On six occasions, camera 3 (Fig. 12) captured the vertical line, groundline, and/or gangion.

Table 5. The duration and quality (P=Poor, F=Fair, E=Excellent) of video obtained from each camera, whether or not the groundline was visible, and characterization of groundline behavior when observable.

	9/27	9/28	9/29	10/3	10/4	10/5	10/10	10/11	10/12	10/16
Front Camera										
Duration	12 min	4 hr 53 min	4 hr 10 min	1 hr 31 min	1 hr 8 min	0 hr 53 min	1 hr 53 min	2 hr	1 hr 54 min	2 hr 18 min
Quality	P	F-E	P	P	P	P	F	F	E	E
Grd. line visible?	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Side Camera										
Time	0 min	4 hr 57 min	4 hr 44 min	1 hr 22 min	4 hr 36 min	5 hr 29 min	12 min	2 hr 6 min	1 hr 2 min	2 hr 13 min
Quality	n/a	F	P	P	P	P	P	F	E	E
Line(s) Visible?	n/a	No	No	No	No	No	No	No	No	No
Top Camera										
Time	2 hr 27 min	2 hr 21 min	0 min	1 hr 49 min	4 hr 44 min	2 hr 56 min	1 hr 26 min	1 hr 29 min	1 hr 32 min	2 hr 11 min
Quality	P	P	n/a	P	F	P	F	F	P	F-E
Line(s) visible	No	Yes	n/a	Yes	Yes	No	Yes, GL	Yes, GL	No	Yes
Groundline Behavior										
Minimum visibility (ft)	n/a	6	4	2	1	2	n/a	4	4	2
Contact with seafloor	n/a	Yes	Yes	Not visible	Not visible	Not visible	No	No	No	Yes
Observed tension	n/a	Slack	Slack	Slack	Slack	Slack	Slack	Slack	Taut	Slack
Extent of motility (1 = none; 5 = extensive)	n/a	5	4	3	Not visible	Not visible	5	4	2	4

Discussion

One of the common problems discussed throughout forums, workshops, meetings, and one-on-one conversations with lobstermen was chafing of the sinking groundline, especially between the first and second traps. One interest in filming

groundline performance was to visually study this phenomenon, with an anticipation that it might lead to suggestions for modifying rigging in ways that could reduce the wear and tear on groundlines and thus contribute to increasing their operational life.

Although underwater visibility hampered clear views during some deployments, the videos captured images of the portion of the rope that lobstermen had reported as the most prone to chafing. The videos showed that the groundline encounters the substrate some distance away from the lead trap and not immediately adjacent to it because it is rigged with a bridle and held partially aloft by the vertical line. As waves, wind, and currents change, the vertical line moves up and down in the water column and sweeps along the ocean floor. The point where the groundline first makes contact with the bottom bears the brunt of this vertical and horizontal movement, which abates at a greater distance from that point towards the second trap where there is reduced influence from the vertical line (Figure 27).

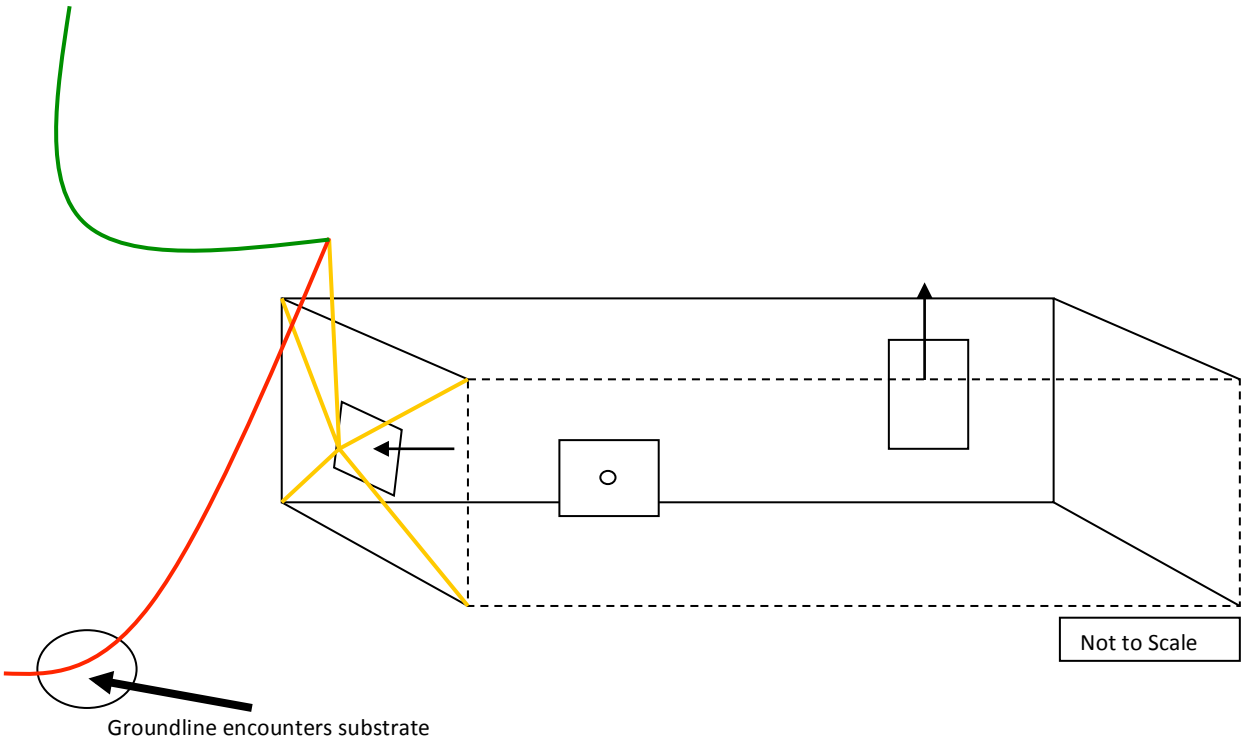


Figure 27. *Illustration of the camera-equipped trap, the typical line positions, and the location of where the greatest chafing was observed.*

None of the videos showed evidence of groundline rubbing against the first trap, which several lobstermen had suggested might be causing the localized chafing pattern. Furthermore, in cases where the upper front edge of the trap was spray-

painted prior to each deployment, no paint rubbed off on groundlines. If any paint removal occurred, it was during deployment and retrieval on board the vessel.

Project Summary

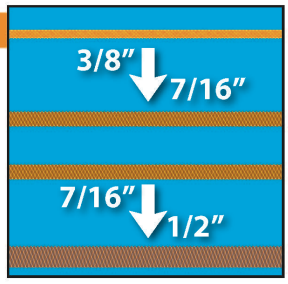
Drawing from the body of work covered under this project, lobster fishermen in New England have come up with several recommendations to mitigate the negative effects of using sinking groundline (Figure 28).

SUCCESSFUL IDEAS

FROM MAINE LOBSTERMEN

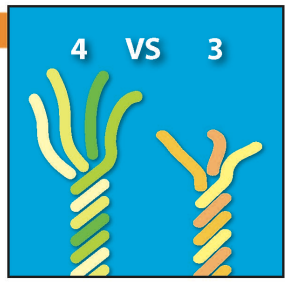
KEY: 1 SINK ROPE MODS. 1 HAULING MODS. 1 OTHER MODS.

1



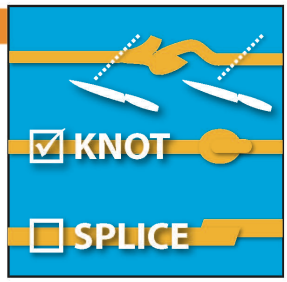
Size up the diameter of sink rope groundline to get more strength (from 3/8 -> 7/16 -> 1/2 inch).

2



Use a 4-strand rope instead of 3-strand.

3

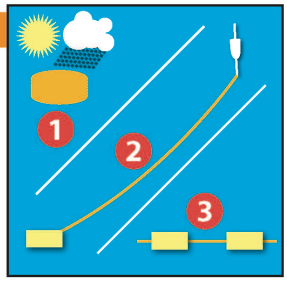


Cut out trouble spots and knot (instead of splice). Knot seems to resist chafe.

4

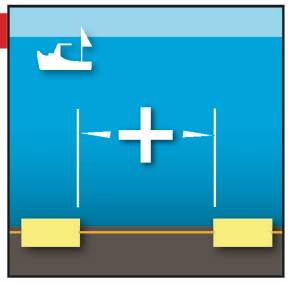
Steady clips are helpful to reduce rope chafing on trap -- bend the tail warp into the clip on top of the trap before setting back. Or, use a "poor man's steady clip" and simply tuck the line into the mesh on the top of the trap.

5



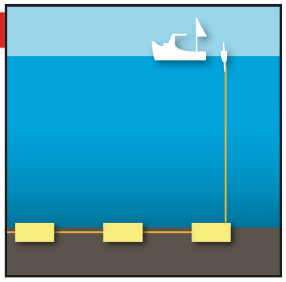
Leave new coils of sink rope outside and fish sinking rope on buoy line for several seasons before rotating to groundline, to increase tightness of lay and harden rope. *(Caution - May make rope more difficult to handle on deck.)*

1



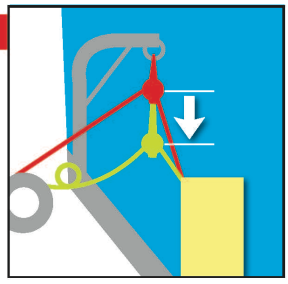
In deep water, lengthen spreaders between traps on 20-trap trawls to reduce strain on rope in hauler.

2



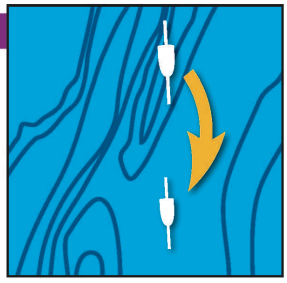
Keep the boat over the gear while hauling; haul slower; use shortest endline and the smallest buoy(s) possible to reduce swing in scope.

3



Consider hauler modifications such as reducing the angle between block and fairlead; or increasing the angle between sheaves.

1



Move gear off hard bottom (onto mud, gravel, sand) to avoid hangdowns.

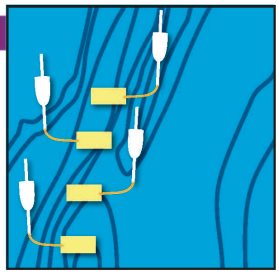
PAGE 1

SUCCESSFUL IDEAS

FROM MAINE LOBSTERMEN

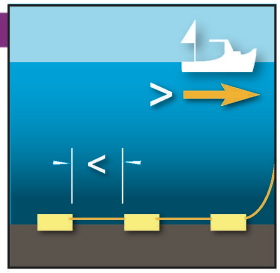
KEY: 1 SINK ROPE MODS. 1 HAULING MODS. 1 OTHER MODS.

2



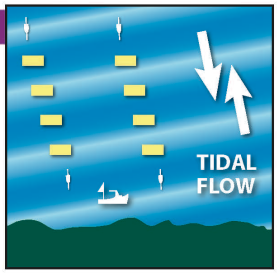
Fish singles on hard bottom that is too productive to move off of.

3



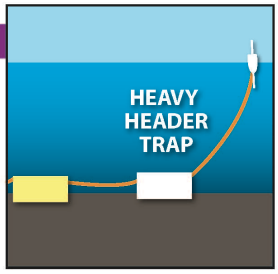
On triples, shorten distance between traps, and increase set speed to keep rope taut.

4



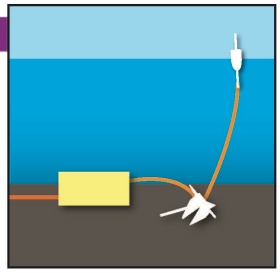
Set parallel to (with) the tide to decrease rope movement on bottom, and reduce hangdowns.

5



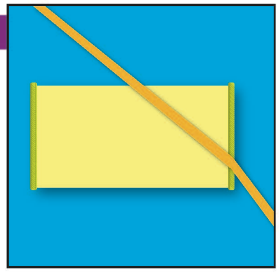
In smaller trawls, weight the first trap to reduce movement on bottom. Using a heavier end trap may reduce wear on rope at first trap by reducing movement caused by the buoy/surface system.

6



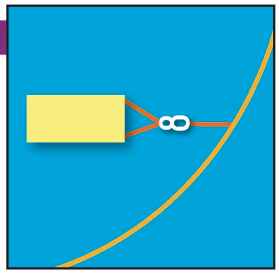
If you use anchors on your trawl, consider using float rope for the line between the anchor and first trap - not considered part of the groundline which is strictly the portion of line between traps.

7



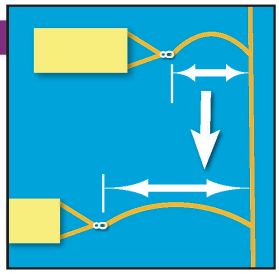
Add a wear plate on the wire to reduce rope wear. Wear plate is a piece of wire *(7 meshes)* which bends over the edge to cover up the corner. Or wire tie a piece of garden hose along top edge of trap to prevent rope and wire coating from chafing.

8



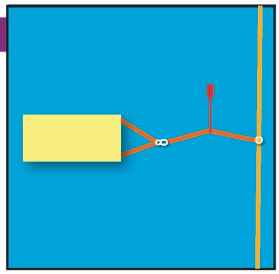
Use dog bones (a white plastic figure-8 piece) on the bridle to prevent spinning and unlaying of rope.

9



Use float rope (polypropylene) bridle and becket or gangion to keep rope away from the trap and reduce wear at the first trap. Increase length of gangion from 1fa to 2fa or more.

10



Use a toggle on a sink rope becket.

PAGE 2

Figure 28. *Ideas from Maine Lobstermen on how best to fish sinking rope.*

Future Directions for Research

Now that sinking groundline has been in use throughout most of the lobster industry for several years, lobstermen have adjusted to fishing with it even given the various challenges reported. Moving forward, it may be productive to investigate aspects of sinking groundline that remain problematic, particularly in light of vertical line regulations that went into effect in 2015, and that require a minimum number of traps on a trawl depending on the area fished and distance from shore. Recommendations for future research are summarized, below.

1) Inferior sink rope – Investigate producing a lower quality sinking rope for less money, which will cost less to replace when it chafes since most rope is replaced on an annual basis.

2) Rope diameter and rope strand – Investigate whether ropes of larger diameter or of different construction (4-strand vs 3-strand rope) are more durable under chafing conditions. Several lobstermen increased diameter (e.g., from 3/8" to 7/16" or 1/2") when they transitioned from floating to sinking groundline. Others have since gone back to smaller diameter ropes. Offshore lobstermen have noted that they have found four-strand rope to be more chafe resistant than the three strand rope used in the inshore fishery. The trade-off between weight and diameter would need assessment.

3) Spreaders – Investigate shortening vs. lengthening rope between traps to reduce chafing. Might shortening the length of groundline between traps (thereby eliminating rope slack) reduce chafing? An underwater camera might be used to compare the variations from setting-out at different speeds with different spreader lengths.

4) Knots vs. splices – Compare chafe resistance and breaking strength of ropes using these two methods.

5) Trawl orientation – Experiment with setting out gear rigged with sinking groundline in different orientations to the tide or prevailing currents—e.g., setting first anchored trap at the SW end, running the rest NE; setting across the tide; setting with the tide slower/faster than it is running to determine whether the speed or direction of the set affects how the rope chafes.

6) Dog bones – Survey fishermen to determine how prevalent the use of a dog bone (spinner or swivel) is, and whether lobstermen not using them are more likely to experience chafing near the traps as a result of line twisting in water current.

7) Trap, bridle and gangion rigging – Investigate the impact of rigging bridles and/or gangions with floating line instead of sinking line; and how the placement of the bridle on the trap (middle versus top) impacts the chafing off the lead trap. Investigate the use of a heavier lead trap to hold the gear in place and minimize any source of movement from the trap.

8) Hauler research – Add to the DMF hauler research to examine issues with the Maine fishery, particularly federal permit holders fishing long trawls in deep water (near the LMA 3 line). Test polyurethane plates for hauler sheaves, smoothness of inshore sheaves and knife angle. Examine varying sink ropes under microscope to discern scope of wear, as materials may respond differently to hauling and/or sediment infiltration.

9) Trap loss/reason reporting – Existing reporting systems could be enhanced or modified to allow researchers and managers to capture information regarding groundline performance with respect to lost traps, such as through the state's affidavit-based trap tag replacement program or the mandatory harvester reports.

Conclusion

Maine lobstermen have been fishing with sinking line since 2009. The rope poses many challenges that lobstermen did not face with floating groundlines.

In 2015, lobstermen also had to adjust to regulatory restrictions on minimum trap numbers per trawl based on the area fished and distance from shore. In Maine, the most aggressive trawling up is required in offshore waters, which are most conducive to fishing sinking groundlines due to the less complex bottom substrate. While minimum trap/trawl numbers fished closer to shore are less aggressive (pairs in non-exempt state waters, triples from 3 to 6 miles and 5's or 10's from 6 to 12 miles), these requirements may pose challenges for lobstermen in areas of complex rocky bottom because they must use sinking groundlines. The cumulative impacts of these regulatory changes on the whole on the lobster fishery should be monitored for operational, safety and economic concerns.

NMFS began a formal monitoring plan to assess the impacts of regulations under the Atlantic Large Whale Take Reduction Plan in 2012, which will provide data on how well the plan is working to protect large whales. In addition, further investigation of the potential negative impacts of the rule should be conducted such as the incidence of derelict gear, rate of injury to lobstermen, and the risk of a whale becoming seriously injured or killed in smaller deployments of gear such as singles, pairs or triples versus larger trawl sets. The impacts on the length of the trawl; size, weight and strength of rope; and size and weight of trap should be examined.

Acknowledgments

The authors extend appreciation to the commercial lobstermen who have collaborated on the experiments, fieldwork, research and assessments discussed in this document. The breadth of involvement by the Maine lobster industry in collaborative research extends beyond the list in the appendices. It includes lobstermen who have not formally been involved in collaborative research, but who have attended meetings, workshops, conferences, and demonstrations; have experimented on their own with gear modifications; and who have paid attention to the path that groundline regulation has taken over the years. The preparers of this document extend gratitude to each individual lobsterman for his or her contribution to the process.

The detailed notes taken by MLA staff at the 2011 Forum were instructional for helping create the modified gear artwork, which was created by the talented Andrew M. Cook of Lobstering Is An Art.

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Glossary of Terms

ALWTRP – Atlantic Large Whale Take Reduction Plan, a plan implemented by NOAA Fisheries to reduce serious injury and mortality to large whales due to incidental entanglement in fishing gear located at http://www.nero.noaa.gov/whaletrp/.

ALWTRT – Atlantic Large Whale Take Reduction Team, established in 1996 to implement the ALWTRP. Consists of 60+ stakeholders in the whale-gear entanglement issue, including fishermen, state and federal managers, scientists, and conservationists. Information is located at http://www.nero.noaa.gov/whaletrp/trt/.

Breakaway – a link or connector installed on the endline at the buoy designed to break under a force of 600 pounds as required by the ALWTRP in nearshore Gulf of Maine; may be achieved by installing an off-the-shelf plastic device or by rigging the line with hogrings. A full description is available under ALWTRP Outreach Supplements at http://www.nero.noaa.gov/whaletrp/links.html.

Bridle – harness, with two or more attachment points, that stretches across face of trap and into which endline is tied.

Buoy line – the length of rope connecting the surface buoy to the head trap (and also to the last trap in a trawl configuration), comprised of all sinking line or a combination of sinking and floating line, by which a trap or trawl is hauled.

Dog bone – a plastic figure-eight-shaped piece often tied between bridle and gangion to prevent rope from twisting in tide and currents; also called a spinner, as it spins with the current and prevents the line from twisting.

Double/Pair – two lobster traps attached to each other by a length of rope (tailer warp) and fished with a single endline.

Endline -- see Buoy Line.

Exemption zone/line – a line established by NOAA Fisheries running along the Maine coast inside the 3-mile line (state waters boundary) beyond which sinking groundlines must be used (Figure 1).

Fathom – six feet (6'); common unit of measurement in the lobster fishery.

Floating line – also called "poly", for polypropylene; rope with a specific gravity of less than 1.03 which floats in sea water; preferred rope for groundlines in many parts of Maine prior to the groundline regulation.

Gangion/Lanyard – short length of line, floating or sinking, connecting the groundline to the trap bridle in a trawl configuration; or used to tie a toggle into a main line.

Ghost gear – fishing gear lost to recovery when a buoy line is cut off, leaving traps at the bottom where they continue to "ghost" fish or passively ensnare marine life.

Groundline – the line linking one trap to the next in a trawl configuration, a term generally used for configurations of four or more traps; typically called a tailer/trailer for smaller configurations.

Head trap – the first trap in a pair, triple, or trawl of traps.

Highflyer – a surface marker used by offshore lobstermen consisting of a tall (6') buoy stick with one or two buoys topped by flags and a radar reflector of aluminum; used to mark one or both ends of a trawl and required in waters outside of 12 miles from shore.

LMA – Lobster Management Area defined by the Atlantic States Marine Fisheries Commission (ASMFC); Maine's lobster fishery is in LMA 1; the offshore lobster fleet fishes in LMA 3.

Main line -- see Buoy line.

Marker buoy – a float typically deployed five or more fathoms from the main buoy in a surface system; also called tide buoy or wash buoy.

Maine Lobster Management Zones (LMZ) – seven regional zones extending from shore out to the EEZ, including state and federal waters; each Maine lobsterman declares a primary and/or secondary zone where all his gear is licensed to be fished.

Poly -- see Floating line.

Set-over days -- see Soak-time.

Single – a trap configuration featuring one trap attached to one endline; commonly deployed by lobstermen fishing in rocky, shoal areas.

Sinking line – as defined by the ALWTRP, rope with a specific gravity greater than 1.03 so that it sinks in sea water; often called sink rope or "whale" rope and manufactured with varying combinations of polyester, nylon, Dacron, polysteel, or lead.

Soak-time – the number of days baited gear is left untended by its owner between setting out and hauling back; usually ranges from 3-7 days; also called set-over days.

Spreader – the length of groundline separating one trap from another in a trawl configuration, usually 10-20 fathoms long.

Tailer/Trailer warp – vernacular for the rope connecting two or three traps together in a pair or triple configuration; the rope connecting the head trap to the tail or trailing traps.

Tide buoy -- see Marker buoy.

Toggle – a smaller buoy or float deployed on a short gangion below the main buoy to help keep the main buoy from being pulled under by tidal action (in deep water) or to provide more flotation to prevent the endline from dragging on the bottom (in shoal water).

Trap runners – two or three courses of wood, concrete or plastic running along the length of the bottom of the trap to allow the trap to be hauled over the rail more readily; protects the claws of lobster that may protrude through the bottom mesh upon hauling; in many cases are used to ballast the trap.

Trawl – a set of multiple traps, from 4 to 40 or more, attached in series by a single line (groundline) and with one, two or three buoy lines.

Triple – three lobster traps linked by a groundline (tailer warp) and typically fished with one buoy line.

Polyball – a large mooring ball (40" – 50") used by certain lobstermen in place of or in conjunction with a buoy and/or highflyer to mark the end of a trawl; used to prevent the line from being pulled under in areas of extreme tidal or current action.

Polysteel©, polysteel – the brand name of rope produced by Polysteel Atlantic Ltd., based in Cape Breton, NS; also any float rope that is constructed with a co-extrusion of polypropylene and polyethylene.

Vertical line -- see Buoy line.

Wash buoy -- see Marker buoy.

Weak link -- see Breakaway.