Development of Bottom Weak Links and Buoy Line Messenger System

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INTRODUCTION

The intent of this project is to test and refine prototype systems for the retrieval of lobster pot trawls and gill net strings. The retrieval systems are for hauling fishing gear designed with lower breaking strength connections located at or near the sea floor. These low breaking strength connections are part of a program to reduce the risk of entanglement of right whales in bottom set fishing gear. The project set-out to accomplish the following tasks:

1. To re-design, test and refine a prototype system that uses a messenger type device to descend down a low strength buoy line to a fixed gear trawl or string and retrieve that string.

2. To re-design, test and refine a prototype system that uses a timed release device located on the fixed gear that will provide for a delay after a predetermined load is applied. The timed delay would allow time for a fisherman to retrieve gear that might require higher than normal hauling loads (fetched-up on bottom) before the release parts, but allow for an entangled whale to break free of the gear at the end of the timed interval.

3. To complete a written report presenting the results of the testing and engineering drawings of the devices.

Background

The northern right whale is the worlds rarest species of large whale. During over a half_century of protection, the species exhibited slow, but identifiable population growth (Knowlton et al 1994). However, recent analysis suggest that within the last decade the population has begun to decline and, if current trends continue, may be extinct in less than 200 years (Caswell et al. 1999). Evidence suggest that the recent decline is concurrent with an increase in serious injury and mortality attributable to ship strikes and entanglement in commercial fishing gear (Knowlton 1998, Hamilton 1998). The Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA) require that actions be taken to reduce the factors responsible for these mortalities. Conflicts arise because commercial shipping and commercial fishing constitute the dominant human activities that take place in the marine environment. Each activity is widespread, and each is of major economic and social importance.

Efforts to mitigate negative anthropogenic impacts are complex undertakings. The right whales use of waters of great economic importance to humans, combined with the difficulty of identifying where whales are likely to be found, can confound protection based on straight forward measures such as excluding human activity from areas used by whales. An alternative to separating whales and high_risk human activities is to modify the human activity to reduce the element of risk to whales. Ideally, this approach protects whales and allows human activity to continue. In this report, we provide a brief summary of some of our previous work to develop modifications to sink gill nets and lobster gear. These modifications are designed to reduce the risk of right whale entanglement and the effects of such entanglement should it occur. More detailed descriptions can be found in Wiley et al. (1997) and Smolowitz and Wiley (1998).

Sink gill nets, lobster traps and their associated lines are the gear types most often implicated in right whale/fishery interactions. However, the actual number of interactions for each gear type is quite low (i.e., a few each year). This low rate of interaction, combined with the legal, financial, and practical difficulties of designing controlled experiments involving wild, endangered whales, precluded normal types of hypothesis testing. Instead, our investigations rely upon empirical (observational) studies. The studies are designed to gain insight into the potential behavior of fishing gear relative to whale entanglement. We then use such insights as an aid to problem solving. Our research approach uses an inclusive model with participants and observers from the conservation, fishing and regulatory communities. Procedures involve making predictions about how the gear would respond to whale_like encounters, simulate such encounters, and then observe the outcome of the experimental trials. Confidence in our results is established by repeating and modifying trials until the questions and concerns of all observers are satisfied. While the trials do not, nor were they intended to, result in statistically significant results, they do provide insights important to problem framing and solution.

Lines associated with lobster traps and gill nets

Lines associated with lobster traps and gill nets are known to entangle whales. Lines of concern include the vertical buoy line that extends from surface buoys to traps or nets on the sea floor. This line is used to connect the buoy, which marks the position of the gear on the sea surface, to the actual fishing components of the gear (traps or nets). The buoy line is also used to set and haul the gear. In sets of multiple traps or nets, the gear may have a buoy line at each end in order to mark the location of the string more accurately and to allow the gear to be hauled from either end as conditions warrant. There are also lines that run on or above the sea floor joining multiple lobster traps into trawls or strings **(Figure 1)**. These lines are sometimes referred to as ground lines. Gill net strings usually have the individual nets tied together with short connecting bridles forming long, semi-continuous walls of netting **(Figure 2)**. The top portion of this wall is supported by a float line and the lower portion is held in place by a lead line. Both float lines and lead lines are potential entanglement risks.

Modification to vertical lines

A whale can become entangled in the vertical line when it strikes the line and an obstruction, such as the surface buoy, becomes snagged on the animal **(Figure 3)**. Under this scenario, a modification that would allow the surface buoy to release from the line might eliminate or reduce the threat of entanglement **(Figure 3a)** . To investigate the "pop-off" buoy concept in a previous project, we arranged to meet with groups of fishermen at the Massachusetts Maritime Academy’s Strength of Materials Laboratory (Buzzards Bay, MA) and at the Strength of Materials Laboratory at the Woods Hole Oceanographic Institute (Woods Hole, MA). Fishermen, the conservation representative and the fisheries engineer presented a number of possible solutions for testing and acceptance by the group. Gear configurations were tested for breaking strength, and then considered for ease of use, rigging expense, and enforcement. Considerable discussion occurred during these sessions, with fishermen supporting breaking strengths as high as possible and the conservation biologist wanting breaking strengths as low as possible. The iterative nature of the process, with all interest groups observing the tests, participating in design discussions, and observing re-tests, was key to the final acceptance of the results.

We ultimately devised a weak connection that parted at about 400 lbs. The connection consisted of five, 3/4 inch stainless steel "hog rings" clamped to join the buoy line to itself. When pressure is applied to the buoy, the rings fail and the line runs free, theoretically releasing the obstruction and whale. This is an operationally simple device using low cost materials the fishermen already possess. Its use seems relatively easy to observe and enforce, and it seems capable of reducing the risk of whale entanglement. Subsequent at sea operational testing by fishermen indicated that they could use the 400 lb breakaway device without losing gear under some conditions. Whether this is weak enough to satisfy the needs of whales is less clear.

Bottom breakaways

Our next attempts involved the creation of a release point located at the bottom of the vertical line. Whereas a weak link located at the surface buoy might prevent or minimize the effect of entanglement involving animals contacting the buoy, entanglements also occur when an animal collides with the vertical line and becomes entrapped before contacting the surface buoy. In this situation, a surface buoy breakaway would provide no benefit.

To alleviate this hazard, the breakaway or release point must be located near the bottom, where the vertical line attaches to the trap(s) or net(s), or else the entire line would have to be made of a weak material. However, either of these scenarios is practically and theoretically difficult because a link or line weak enough for whales to break free of would also break when a fisherman attempted to haul the gear. To investigate these concepts, we worked to devise a messenger system to use with an entirely weak vertical line and a delayed release system to function as a bottom release device **(Figure 4)**.

Messenger System

The messenger system is patterned after the common oceanographic practice of sending a weighted device down a line to perform a function at the ocean bottom. In the case of a "whale messenger", the devise would provide a way to send a heavy hauling line down a light, easily broken "tag" line that is attached to the trap(s) or net(s). Once the messenger is attached to the traps, the heavy hauling line is used to retrieve the fishing gear.

A prototype whale messenger was built by Jeffery Goodyear of the Ecology Research Group (Sunderland, MA). As a part of the project reported here, the "Goodyear Grabber" was successfully tested in field trials with a Maine lobster fisherman, and Glenn Salvador of the National Marine Fisheries Service and Maine Department of Natural Resources. A second-generation device was then produced to deal with operational handling issues (e.g., quick attachment and removal of the device from the tag line). In addition to Dr. Goodyear, we are working with several machine shops to produce different versions of the messenger system. The messenger system seems to represent the best immediate solution to the current vertical line dilemma. While substantial operational issues need to be resolved, all are technical in nature and achievable.

Delayed release system

We are working with Frank Torngren of Neptune Inc. (Attleboro, MA) to develop a breakaway device that is time (as opposed to force) sensitive. This delayed release device would permit gear to be hauled for a pre-specified period of time. Once the time limit is exceeded, the line releases from the gear. Similarly, an entangled whale would be released from the gear, although not necessarily the line, after the time limit had been exceeded. The delayed-release component is not activated until an initial force of about 400 lbs has been exceeded. The 400 lbs represents a presumed maximum loading threshold that might be exerted by natural environmental forces. Previous to this project, a prototype of the device had been built but not tested.

We believe that the modification of fishing gear represents the best solution to the vexing problems involving the entanglement, serious injury, and death of right whales. However, both the fishing and conservation communities have cause to view gear modification with caution. Fishermen have concerns as to whether modified gear will be as productive, safe, and operationally viable as traditional gear. In addition, many fishermen have philosophical difficulties with being forced to change their style of fishing. Even relatively simple operational changes might be rejected, not because they are overly intrusive, but because they strike at the heart of who a fisherman is and why he or she fishes. Therefore, gear modifications are likely to be embraced only when alternative measures are more onerous (e.g., extensive time and area closures).

Conservationists have other concerns. Because it is impractical to test gear modifications on actual whales, it is difficult to quantify or predict their success in reducing whale mortality. Additionally, fishermen can easily circumvent unwanted modifications at sea, where regulations are seldom enforced. Therefore, even when modifications are developed and required, their effectiveness can be suspect. Because the effectiveness of gear modifications can not be demonstrated prior to use, management recommendations involving them must be continuously evaluated. Ideally, its products should be incorporated into an adaptive management approach as described by Lee (1993) and Walters (1997).

Buoy Line Messenger System

Coonamessett Farm, in conjunction with the International Wildlife Coalition, was funded by the Massachusetts Environmental Trust in 1997 to examine the issue of right whale entanglement in fishing gear. As a part of that project a prototype model buoy line messenger was built, to illustrate the concept, but never field tested. We will refer to this prototype as a jam cleat style messenger **(Figure 5)**.

The Goodyear Grabber is the original prototype jam cleat style messenger. It basically consists of a heavy steel cylinder with a large diameter slot running the full length. The slot has means to enclose up to a 1/2-inch diameter line. At the top end of the slot is a jam cleat. The concept is that fishing gear would be set with a small diameter low breaking strength buoy line attached to the gear at the bottom with a higher strength hauling line pennant. The messenger is designed to slide down the small diameter tag line with a hauling line attached. Upon reaching the bottom set fishing gear the hauling pennant would pass through the jam cleat allowing for the gear to be retrieved.

The prototype Goodyear Grabber messenger had a number of potential problems associated with the conceptual operation. Two key questions have to do with line fouling and determining when the hauling pennant has been captured. In this project we conducted a field test of the existing prototype, re-designed the messenger based on these initial tests, built several second generation prototypes, and conducted limited field testing of the new units.

Field tests of Goodyear grabber messenger

The initial concept of using the messenger was that the buoy line would be of small diameter, with a breaking strength of about 500 pounds. This would terminate down at the gear into a larger diameter pendant. Some difficulty was encountered joining the two lines together. The twisted nature of the 3/8 poly pendant did not "meet" with the braided nature of the 5mm small diameter line commercially available. Therefore, a traditional splice was not possible. To join the two lines together, we wove the braided poly through about 2_ft of the twisted poly. Test pulls indicated that this arrangement could withstand substantial force, at least sufficient for hauling the cinder block in initial land trials. Initial land tests with the grabber resulted in the grabber becoming stuck at the juncture between the two lines. To alleviate this problem, we used electrical tape to wrap the joined area. This provided a smoother transition area between the two lines. Subsequent land tests demonstrated that the Goodyear Grabber could easily pass down the entire line, with the area joining the two lines presenting no inhibitory affect.

To test the apparatus, we chose a dock with approximately 10 _ 20 feet of water below it. This site was chosen because the water was deep enough to provide some degree of reality to the test. However, the water was shallow and clear enough to allow us to observe the process, and allow us to dive and retrieve the grabber if difficulties arose.

To test the device, we tied a 6 foot length of 3/8 poly to the cinder block. The 5 mm "tag line" was woven into this piece and acted as the surface line for the block. The block was than lowered into the water. In the initial tests, we took up on the tag line until it was taught, and then carefully lowered the grabber down the tag line. Once we could see that the device was next to the block we hauled back. In each instance (n=10), the grabber successfully retrieved the block. We then simulated more natural conditions by throwing the grabber off the pier. We then tightened up on the tag line until the grabber met the block and hauled back. Each time the grabber successfully engaged the heavy hauling line attached to the block and retrieved it. It should be noted, however, that in each instance, the block was directly or nearly directly below the pier. We do not know how well the grabber would work if there were a less than perpendicular angle between the hauler and the object to be hauled.

September 20 _ 24 _ Trip to Maine to field_test the Goodyear Grabber with NMFS representative Glenn Salvador and Maine lobster fisherman Steven Biot.

Initial success in the semi_field trails led us to contact Glenn Salvador of the NMFS to conduct trials with fishermen under actual fishing conditions. Trials were conducted with lobsterman Steven Biot of Kittery Maine aboard his fishing vessel; a 35-foot lobster boat equipped with standard lobster hauling equipment. Tests were made over a two_day period in water depths of approximately 100 feet.

Day 1 _ Tests were conducted by attaching the 5mm tag line with 6 ft of 3/8 poly to one of Mr. Biot's trawls. The trawl was set in approximately 100 feet of water and consisted of 5 traps. The messenger was sent down the tag line, attached itself to the heavy haul line and retrieved the traps. As with our pier tests, the first attempt was made by keeping the tag line taut, and carefully sliding the grabber down the line. After successfully repeating this process several times, we let the grabber "free_fall" down the taught tag line. This method also resulted in successful attachments to the haul line and trap retrieval. We then allowed the tag line to be slack and the grabber to free fall. We then hauled on the tag line to send the grabber to the haul line. This method worked several times. We then tried a quick jerking of tag line assuming that action might be the one most likely to be used by fishermen actually engaged in fishing. This put too much strain on the tag line, and it parted where the two lines were joined. It should be noted that the two lines were joined only by weaving the 5 mm line through about two feet of the twisted poly and was not considered a particularly appropriate or strong joining configuration.

The repeated hauling of the traps also allowed us to observe how the traps behaved in relation to being hauled and problems that would be encountered attempting to get traps on board the fishing vessel. A problem to be overcome consists of getting traps aboard the vessel. Once the messenger becomes lodged against the snatch block, the traps can no longer be hauled because the messenger blocks the snatch block. The messenger must be removed. However, an additional problem exists because the trap is on the haul line. Under normal circumstances, the trap is on a line that leads to the haul line, allowing the traps to be brought aboard in a continuous motion. Under the present messenger configuration, the trap would have to be brought through the snatch block and hauler, an impossible situation.

Upon reaching the dock, we concentrated on making improvements to the system. We gathered at Steven Biot's barn and he spliced a new line tag line into a stronger, short 3/8 inch line to be attached to the traps. He also spliced a short 15 foot line into the short line to be attached to the trap. This line had a cork float attached to the bitter end. Also spliced into this line was a line that would lead to the next trap. This line was to be used to haul the traps once the messenger had become lodged against the snatch block. A new line would have to be tied to the davit from which the snatch block is hung. This would have a clip. When the messenger came lodged against the snatch block, the fishermen would use the line leading from the davit to clip to the pot and hold it in place. The messenger would then be removed, the short floating line gaffed and used to haul the next trap.

Day 2 - We used this system to haul a trawl of two traps. The traps were arranged so that both traps would be in the water column during hauling, therefore assuring that the strength or holding capacity of the grabber could withstand the weight of two traps. We repeated our pattern of first slowly lowering the messenger down the taught trap line, then "tossing" the messenger down the taught tag line. Both of these methods met with 100% success. We then tossed the messenger down a slack tag line and hauled on the tag line to send the messenger from the spot on the tag line it occupied when the messenger contacted bottom to the trap. This method worked some of the time, but on several occasions the messenger grabbed a portion of the tag line before it reached the traps. With a lighter tag line, this would have resulted in the tag line being broken during hauling and the traps lost. We concluded that the tag line should be kept taut when deploying the messenger.

Discussion of results

One user friendly problem consisted of too many lines on the bottom of the boat, as both the tag line and the messenger haul line end up on the deck. One possible solution is that a crew person coil the tag line into a bucket or container as it is retrieved. A more technically sophisticated approach is that the messenger system may require an extra take-up reel or pot hauler for the extra line.

The choice of the tag line also involves some major considerations. Our initial concept was that the tag line would be a small diameter line with a breaking strength of about 500 pounds. The only commonly available commercial line with this low breaking strength are 3-5 mm in diameter synthetic braids. The small diameter creates handling difficulties on deck and also may pose a risk of whale injuries since it is more likely to cut the whale's skin. Also, the small diameter is more susceptible to abrasion failure especially with a messenger routinely sliding down. Pot haulers are not currently designed to handle small diameter line. This approach also leaves the issue of connecting a small diameter line to a larger diameter line.

These problems associated with the small diameter line led us to re-think the concept of the entire buoy line being weak versus the concept of a bottom weak link. We initially considered that a weak line may be more enforceable than a bottom link. However, there are a number of bottom weak link design-options. With the jam cleat style of messenger, the messenger needs to pass over the weak link connection. In addition, with the jam cleat messenger the trap hauling pennant should be braided polyester or other soft construction; not hard twisted poly. The hard twisted poly, especially when wet, is not held tightly by the jam cleat. The weak link would be inserted between the braided hauling pennant and the twisted poly buoy line. One concept would be to hog ring the two lines together in a manner so that the jam cleat messenger can slide pass the joint **(Figure 5**).

Most large jam cleats, used mostly for securing running lines on sailing vessels, are rated for 500 pound working loads. We did not have the opportunity under this project to test the actual loads required for the line to slip through the jam cleats. We did search for other jam cleat type devices that were rated for higher loads and came upon the “Chicago Grip” built by Klein Tool Company **(Figures 6 & 7)**. These grips are made to haul steel wire and many are rated above the expected loads for hauling fishing gear. However, these devices are only rated for steel wire, not synthetic line. We did test a Chicago Grip on synthetic line and found that it worked quite well. To meet the manufacturer’s recommendation for safe use the hauling pennant would have to be constructed out of wire rope. Connecting wire rope to synthetic line is common practice on sailboat halyards. In our application we would require a weak link at this juncture.

We did explore another possible approach to messenger design using the concept of a gate latch. The latch style messenger uses a latch to connect to metal ring or similar device on end of hauling pennant **(Figures 8 & 9)**. The latch style messenger can be designed so that it does not need to have the gripping mechanism slide over the weak link connection as in the jam cleat, it just grabs beyond the weak link connection. The buoy line can either be weak or a weak link needs to connect the buoy line to the ring. Our initial prototype of this style messenger consisted of an inexpensive gate latch attached to the end of a messenger weight held to the buoy line by two snap clips. Upon sliding down the buoy line the latch mechanism contacted a scallop ring attached to the hauling pennant. This contact depressed the latch which then overlapped the ring and closed securing the gear. The prototype was tested on dry land and worked most of the time but not often enough to justify in water tests. The main problem was that the single latch mechanism has to contact the ring in the proper orientation to open.

A second prototype, the “squid”, was constructed with a latching mechanism that can function regardless of the orientation upon contact. The squid consists of a hollow cylinder with four evenly spaced tentacle-like pivoting latches located around the bottom. Each latch is shaped like a door latch. A machined plastic striker plug is located on the lobster pot pendant. The squid’s tentacles slide over the tapered section of the striker plug then hook onto a machined shoulder on the plug. The weak link would be located where the buoy line attaches to the striker plug. The prototype squid was designed so that it hinges open for east attachment to the buoy line. However, this is not necessary. A simple pair of G-hooks, sometimes referred to as sister clips, just below the buoy, can allow the squid to be inserted over the buoy line. The squid can be cast with four holes along the bottom rim into which the tentacles can be pinned.

The prototype squid works but can be improved. The pivoting freedom of the tentacles needs to be restricted. This design change, in combination with small spring mechanisms to provide positive seating pressure, would ensure that the tentacles are properly oriented even at extreme approach angles. In addition, a method for quick release upon retrieval is needed.

There are several aspects to the messenger approach that are common to all styles. The first is that there is still an unknown messenger weight requirement for different depths; sea states. The second issue is that weak buoy line or bottom weak link may require a low drag buoy system to minimize loss due to weather. On the plus side, costs are kept low because the fisherman only needs one messenger plus a spare. There has been some thought given to a messenger design that does not need to have a hauling line attached. The messenger would simply slide down the line and in some manner negate the weak link. The design problem is how to relay the success of this action to the fisherman so he knows it is safe to haul.

Timed Whale Release

As part of the Massachusetts Environmental Trust project mentioned previously, a prototype of a timed bottom release was designed and built under a sub-contract with Neptune Inc of Addleboro, MA. Neptune has been in the business of designing and selling plastic molded devices to the fishing industry which include buoy sticks and traps.

The Neptune design is an all plastic device that functions as a dash pot **(Figures 10 - 12)**. The buoy line is attached to the bottom set gear by means of a sleeve that tightly fits into a cylinder. When force is applied to the buoy/hauling line the sleeve expands against the cylinder and begins to slip at a predetermined load . The rate of slippage is a function of sea water passing through an orifice between sleeve and cylinder. After a designed time period the sleeve leaves the cylinder and the line is released from the sleeve.

The initial prototype was laboratory tested and several conceptual problems surfaced. The binding between the sleeve and the cylinder surface was not consistent. The cylinder and sleeve were also larger than needed. In addition, the flow rate through the orifice may be subject to a number of variables such as water depth, sediment, and fouling. In this project we re-designed the bottom timed release based on the initial tests, built a second generation prototype (Neptune, Inc.), and tested the new unit.

Design objectives

The critical design objectives of the Whale Release with a focus on its designed intent are:

1. The design is a bottom release, to have a 400-lb. pre-load for normal drag on the static line from wind, waves, and currents that pull the buoy marker.

2. When hauling gear the release would take a heavy strain of approximately 1000 lb. for a period of time to allow gear to be hauled aboard.

3. If a mammal were entangled in the static line the line would have no knots or attached components when released from the Whale Release
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4. If a mammal were entangled the release would function after a timed interval.

5. The Whale release would stay attached in its entirety to the traps or bottom gear.

The release consists of four parts: the cylinder, piston, tapered grip split sleeve, and valve.

The Whale Release can be reset to the closed position with a fixture that pushes the tapered grip split sleeve and piston to a closed position allowing any water between piston and cylinder to escape via a valve.

Description of operation

The Whale Release functions by encapsulating the end of static line nearest the lobster pot. The tapered grip split sleeve is allowed to move 1 1/4 inch when a pull force is applied. A 2-degree included taper inside the piston compresses and grips the static line. When the tapered grip split sleeve end butts against the front end of the piston it causes a vacuum between piston and cylinder. This causes water to be pulled slowly through a valve, at a metered rate, giving the piston a timed forward movement. At a given point, the static line releases from the Whale Release.

Test set-up/apparatus

Two trees, a block and tackle, and a 200 lb spring scale were used to determine what load the Whale Release could hold and how much time it took to function through its cycle. The cylinder was attached to the base of one tree via rope. The block & tackle and a static line sample were tied five feet high in the second tree approximately twenty feet apart. The static line was placed into the piston and then the piston into the cylinder. The 200-lb scale was tied to the pull end of the block and tackle, then a rope was tied to the other end of the scale. In this arrangement the scale reads one fifth of the pull force applied to the Whale Release.

Test results Phase One

The first test was a dry run. The rope grips functioned to perfection by sliding the 1¼ inch stroke to tighten around the static line sample. The gripping occurred with about a 100-pound pull load. As the pull load increased to about 80 pounds on the scale (400 pounds on the Whale Release) the piston, 2 grips, and the static line sample were released instantaneously. This indicated that the piston and cylinder timing did not work without water in the system. The test was run several additional times using water in cylinder, to get hydraulic pull, with the same results.

It was decided to tighten up on clearance of the wall between cylinder, piston and o-rings. So, we installed a small sleeve at the far end of cylinder to achieve the reduction in clearance. The results were the same; an instantaneous release between 300 - 400 pounds pull force. It was then decided that the check/metering valve might not be sealing properly due to insufficient sealing spring pressure against the valve seat. Varying shims were made and placed under the finger spring to increase the spring force holding valve in position. Results were the same; instantaneous release between 300 - 400 pounds pull force.

It was next decided to remove the check/metering valve and replace it with a solid press fit plug to allow no water flow. This would demonstrate the piston to cylinder sealing capability only. The results were that you could not push piston in due to water in front of piston. When water was left out, the trapped air had a shock absorber effect. You could push in the piston but, when released, the compressed air pushed the piston out. The assembly testing was then carried out totally under water, with the valve removed to allow the water to escape from the front of the cylinder, then plugged to create the vacuum chamber. This pull trial produced a similar instantaneous release at around 400 pounds pull force. This was slightly better than past performance.

It was then decided to simulate the proper sized piston and cylinder clearances and o-ring groove geometry with a short piston in the existing cylinder. This new piston style contained a tapered valve seat and a wire spring to ensure proper seating. This piston had to be pounded into the existing cylinder with a mallet. This pull trial produced a similar instantaneous release at around 400 pounds pull force. Next, a new cylinder was built with a threaded plughole to vent the water / air pressure during assembly. This cylinder had o-ring manufacturer specified clearances. The plug was installed after the piston assembly was complete. The short piston with the tapered valve was again used for this trial. The results were a pull force of less than 100 pounds.

Discussion of results Phase One

In general, the results show that the strength of the components is satisfactory for the forces experienced. The cylinder did not crack and the piston survived any of the tests conducted. The gripping power of the taper static line holder was exceptional. All line attachment points were very strong. However, there are problems with the piston to cylinder sealing capabilities of the system. The critical feature of a timed release was not satisfied. The primary holding power appears to be generated in friction between the piston and cylinder alone. The testing does not point to a discernable cause for this failure mode. However, piston-in-cylinder sealing arrangements are widespread in other industrial applications. There is no reason to expect that this problem is not solvable. Some thoughts on why the sealing may be malfunctioning are: 1) the sealing surfaces are not smooth enough in the prototypes to enable sealing. 2.) The o-ring manufacturer did not understand the application completely when the geometry specifications were provided, etc. This testing was concluded, at this point, due to a lack of funds to pursue alternate hardware configurations.

In summary, after exceeding a certain threshold strain, about 500 lbs, the whale release rapidly slips until failure. We have solved the problems related to rope gripping and the initial threshold. Cost will be around $5.00 and the device is reusable. We have encountered design problems with the timing component of the release. This component is an o-ring equipped plastic piston with a check valve inserted into a plastic cylinder housing. More testing is needed on cylinder diameter, valve design, o-ring design, and surface preparation to adjust slippage.

Test Results Phase Two

Additional funding was acquired to continue the development of the whale release. The first problem was to find out why the cylinder seals were not holding. It was determined that the vacuum that was pulling on the assembly would not generate the force required to hold the piston. Too simply look at it, the maximum vacuum pressure that can be achieved is a perfect vacuum, which is 14.696 psi below gage pressure of zero (at sea level). With a piston diameter of 1.5", the maximum achievable force due to the vacuum is:

$$F = P \times A = P \times BR^2 = 14.696 \times 3.1416 \times 0.75^2 = 25.97 \text{ lbs}$$

In order to achieve a force of 1000 lbs by the vacuum the diameter of the piston would need to be increased. Using the above equation and solving for R we can determine the radius of the piston required:

$$R = (F \div [P \times B])^{1/2} = (1000 \div [14.696 \times 3.1416]^{1/2} = 4.654 \quad D = 2 \times R = 9.3"$$

The piston diameter required would be 9.3" in order to create a force of 1000 lbs.

These calculations led to a major redesign of the whale release. The vacuum chamber concept was changed to a fluid filled compression chamber. This would be totally sealed to prevent outside dirt from clogging the small valve. The custom built valve was changed to an off-the-shelf Vernay rubber flapper-type check valve. These changes required the whale release to grow from 9 inches to twelve inches long due to the added rod on the piston. The cylinder o-rings were replaced with Parker U-pack rod and piston seals; an other off-the-shelf proven technology. Calculated holding force of this unit is well above 2000 lbs.

A test cylinder and piston were constructed to test the u-packing and the rubber check valve. The first compression test was run at about 500 pounds pull applied to the piston. The test failed and the cause was found to be u-packings that were cut during assembly. The rubber flapper valve, or umbrella valve, leaked as well. The cylinder was re-machined with a lead to eliminate any sharp corners and new u-packings installed. The next test, under similar conditions, found the u-packing to work but the umbrella valve continued to leak under pressure. The umbrella valve was removed and a solid plug inserted. A load of 850 lbs was applied and the unit held the load without creeping for the 12 hour test period. However, the cylinder did deform at the end where the load was applied. This was corrected by machining a disk insert to prevent the cylinder distortion.

We next worked on the valve problem with Mr. Jim Bailey at Vernay Laboratories. We decided to stay with the umbrella type valve but increase the diameter of the rubber flapper. We also brought the hole pattern closer to the center of the valve assembly and decreased the hole size to 0.015" diameter. With these changes the valve works well for sealing under high pressure and in returning fluid to reset the whale release.

The key remaining task is to design and size the orifice that will provide the time delay for the whale release. A series of plugs with different size holes will be fabricated for these tests. The hole size will be very small which may require significant problem solving both from an operational and fabrication perspective. Fluid viscosity, which is temperature dependent, may create large variations in the flow rate through the piston orifice. Once the lab testing of this stage is complete an assembled working model will need to be constructed for extensive lab and field tests.

The whale release as envisioned now would be sold as a single unit, assembled out of molded and machined pieces, with no loose components. The whale release unit would be assembled at the point of manufacture. First, the check valve is inserted into a plastic set screw which is then assembled to the piston front. The piston front and cylinder insert are screwed to the cylinder. The rope gripper washer and screw are next inserted into the piston rear and then fastened to the piston front with a 5/8-18 UNF thread. A washer and screw are fastened to the front piston to seal the bleeder line. The fisherman just needs to insert the end of the line into the release. When the release lets go the unit stays with the lobster trap; there is no component or knots on the released line.

Recommendations For Future Work

1. Field test the Chicago grip type messenger: Preliminary test indicate that this type messenger is ready for more extensive field trials in order to further explore the messenger concept. Design issues relate to the type and location of the bottom weak link. There are also operational questions regarding expected loads placed on a buoy line and weak link upon approach and retrieval. On-deck handling of the hook-up and second (hauling) line needs further development.

2. Squid messenger development: A refined and improved version of the squid messenger needs to be fabricated and tested based on what we have learned from the previous prototype. This will require some engineering design work using CAD software as there are many possible permutations of the tentacle/plug hook-up mechanism.

3. Timed whale release: This unit will now require development and testing of the timing orifice. Calculations have been performed to give a theoretical hole size but actual testing of this component will begin shortly. If all works according to plan, another complete prototype should be fabricated by machining for testing. If this prototype proves successful then a tough economic decision needs to be made. This unit is only affordable as a molded plastic construct. The cost of designing and tooling the molds can exceed $40,000. This project may be a good candidate for an SBIR type grant. NMFS should explore this and other possible funding mechanisms.