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Trap Design and Ghost Fishing: Discussion

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ABSTRACT—This paper presents an assessment of ghost fishing in the New England lobster fishery by reviewing trends in trap design, loss rates, lost-trap catch rates, and related factors. Preventative solutions are discussed.

The studies presented in this issue of *Marine Fisheries Review* (40:5-6) are ultimately concerned with developing preventive measures to avoid a ghost-fishing problem. In researching preventive measures, information has been obtained which enables us to make a preliminary assessment of the ghost-fishing situation as it exists today and what may occur in the future. This discussion presents this assessment and reviews preventive measures.

NUMBER OF POTS LOST

By 1973, the number of lobster (*Homarus americanus*) pots being fished along the Atlantic seacoast exceeded 2 million. The annual inshore loss rate is claimed by many fishermen to be between 20 and 30 percent; one published estimate is 33 percent (Prudden, 1962:43). Most of these pots are all wood or wood framed and were effective fishing units when lost.

There are many reasons why pots are lost in the inshore fishery. Gear failure includes the pot warp parting, the buoy separating from the pot warp, and the buoy breaking up. This gear failure can be caused by normal wear and tear, powerboat propellers, pot "wars" among lobstermen, sea gulls chewing up buoys, fish biting the warp, and many other causes. Losses are also caused by operational mistakes such as setting too deep and improper ballasting. Storm surge can cause the pot to roll on the bottom, wrapping up its buoy line, and becoming unrecoverable.

In the offshore fishery in 1976, there were about 72,000 pots being fished by 150 vessels. Roughly two-thirds of these pots were of wood-frame construction, the remaining third were all metal with nylon heads (NMFS, unpubl. data[1]). The loss rate offshore has varied considerably from year to year and vessel to vessel. Annual loss rates of 100 percent were common in 1971-72 but decreased to 20-30 percent by 1974. Based on confidential information gathered from logbooks and other sources, there may be as many as 40,000 all-metal pots lost on the offshore grounds since 1971. Approximately 180,000 wood-frame pots were lost offshore during the same period.

Offshore losses are mostly caused by vessel propellers, dragged gear, gear mechanical failure, and storms. Experience gained by fishermen has cut these losses to where, in many cases, they are equal to inshore loss rates.

Loss rates, both inshore and offshore, will probably remain in the 20-30 percent range. However, the number of pots in both fisheries is increasing, thus the absolute number of pots lost will probably increase also.

POT TYPE

Pot type, as specified by design and materials, is one of the key indicators of whether a ghost-fishing situation will be created. The pot-design problem, as defined by history, can be simply stated as: To build the most durable pot, for the lowest cost, that catches and retains the greatest amount of legal-sized lobsters in good condition. The design parameters are interrelated with the overall economics of the fishing operation as well ea with each other. This section will focus on the various design factors in order to predict which way trap design may go.

Size

The size of the pot is usually dictated by handling problems, deck space, and expected catch rate. In the inshore fishery, where the availability of legal-sized lobsters is low and the boats are small, the pots are small. A lobsterman who hauls his pots every other day instead of daily might use a slightly larger pot if he expects a larger catch.

In the offshore fishery the pots are larger due to the larger vessels, longer soak periods, and higher availability of legal-sized lobsters.

Both inshore and offshore, larger pots are claimed by many fishermen to catch more lobsters. This may occur because lobsters have a more difficult time finding their way out of the pot due to the increased area to be searched. Another reason may be a lobster-density limitation, which we will cover later on in this discussion.

The deck space limiting factor of large pots can be dealt with by using collapsible or stackable pots (Munro, 1973).

Shape

The shape of the pot is important in determining its resistance to storm damage. Improper shape can cause pots to turn over and roll along the ocean bottom when subject to wave action. Prudden (1962:44) makes the following suggestions to reduce pot losses: 1) Any reduction in the height of a pot from the present 18 inches would reduce the leverage tending to overturn a pot; and 2) The construction of a pot with inclined sides like a pyramid would change the side pressure of a wave from an overturning effect into a force pressing the pot down on the ocean floor.

Proper settling of the pot on the bottom is also a function of shape. Drag

[1]Interview sheets on file at the Woods Hole Laboratory, Northeast Fisheries Center, National Marine Fisheries Service, NOAA, Woods Hole, MA 02543.

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forces acting on the pot as it settles through the water column determine how the pot is going to land. Stability, a function of weight and shape, determines how the pot will remain on the bottom (Burgess, 1969). If the pot does not assume the correct position on the bottom, the entrance heads can become obstructed or ineffective (Fig. 1).

Pot shape also determines what shape the heads will take. The reason that most pots are high and long as they are is to allow for a more effective head design.

Head Design

As the catch rates fell in the inshore fishery, the soak periods increased in order to maintain an economically viable catch. The 15-minute soaks of hoop nets gave way to the full-day soaks of the single-compartment pot. The parlor pot became necessary when soaks exceeded 1 day.

The key problem with longer soak times is how to prevent escapement once the lobster enters the pot. The answer, for the past century, has been better head design. Rathbun (1887) describes variations in head design based on reorienting the position of the head ring, e.g., the opening facing slightly up instead of straight into the pot. He also describes pots with tandem heads made of wood laths, two types that are still seen today.

Thomas (1959) has conducted numerous experiments to improve the efficiency of pots. He has shown that: 1) Lobsters enter a pot more readily if the lower half of the head is lined with fine-mesh netting, 2) high-rigged heads inhibit escape better, and 3) head-opening size affects the number and size of lobsters caught, as does the fitting of nonescapement devices. He further states that the effects of pot variations differ with the size and composition of the population being fished and other fishing conditions.

Leakey (1965) feels parlor pots are a waste of space and materials. His solution to the retention problem is an escape inhibitor that he has patented. This inhibitor, as with many similar devices known generally as triggers, allows the lobster to enter through the head but prevents its escape back out. Triggers have been tried or are in use in many

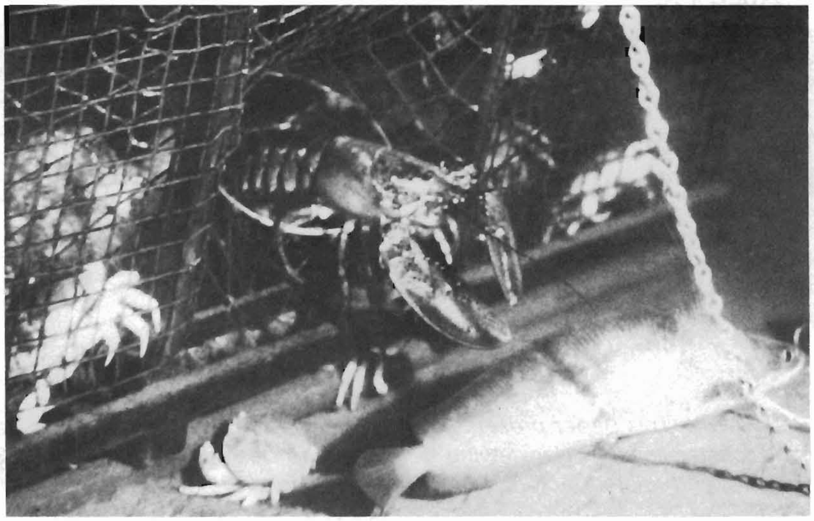

Figure 1.—Lobster escaping from an offshore trap that landed upside down.

areas but there is still quite a bit of controversy as to their effectiveness.

Spurr[2], after comparison fishing five different types of pots, believes that the principal factor affecting pot efficiency is not pot shape but parlor-head design. He believes that the parlor head should have a long steep slope terminating in a small opening very close to the end of the pot and near the top. This agrees with Thomas' (1959) findings that high-rigged heads deterred escape. Our field data confirms Spurr's and Thomas' observations and further demonstrates the degree of sensitivity parlor head design parameters have that affects ingress and retention.

Moody (1965), from a pot-escapement experiment, obtained results that showed 90 percent of the lobsters caught in unbaited pots escaping within 3 days. In baited pots, the escapement rate was 90 percent in 8 days. While it is difficult to make a direct comparison of Moody's work with our field experiments, it seems he had a higher escapement rate. We hypothesize that this is due to the fact that he used wood-lath parlor heads which may be less efficient in retaining lobsters than our nylon-twine skate-mouthed heads. On the other hand, wood-lath heads may allow more lobsters into the parlor in that they provide better footing than nylon netting (Prudden, 1962:41).

The way the entrance head is attached to the bottom of the pot may also be important. Wilder[3] (p. 5) found that wide spaces along the lower sides of the pot made it difficult for the lobster to find the head and thus enter the pot.

Materials

For the purposes of this discussion we have grouped pots into three categories: wood and wood-framed, metal, and plastic.

Degradation

Wood borers are probably the primary degrading force acting on wood pots. Borer damage can destroy a wood pot as an effective fishing unit in as little time as 4 weeks. On the other hand, a treated wood pot may last upwards of 2 years on the bottom in areas with low borer activity. Wood borers do not affect metal or plastic pots.

Corrosion affects metal fastenings on wood pots, wire mesh on wood and metal pots, and wire mesh and structural frames on metal pots. There are many ways to cut down the corrosion rates, such as plastic coatings, designing against galvanic corrosion, anodizing aluminum, etc. Leakey (1965) reports zinc-coated metal-framed pots

[2]Spurr, E. 1972. Lobster research project: Final report of 3-105-R, July 1969-June 1971. Unpubl. manuscr., 22 p. Fish. Div., New Hampshire Fish Game Dep.

[3]Wilder, D. G. 1956. Experiments to improve lobster traps. Unpubl. manuscr. Fish. Res. Board Can., Biol. Stn., St. Andrews, New Brunswick.

lasting over 5 years and some lasting 7 years. Proper anticorrosion design can probably extend a metal pot's life beyond 10 years. Plastic pots do not corrode.

Weight

Metal pots have weight advantages far exceeding wood pots. They are lighter out of water and heavier in water. In tests conducted at the Northeast Fisheries Center (New England Marine Resources Information Program, 1972: 2), one metal and one wood pot were weighed in and out of water. The waterlogged wood pot weighed 22 pounds in water and 115 pounds out of water. The wire-mesh metal pot weighed 33 pounds in water and 53 pounds out of water. Metal pots are thus easier to handle on deck and have better anchoring qualities on the bottom.

Plastic pots vary, in regard to weight and buoyancy, with the type of plastic used and the construction method.

Storm Damage

Metal pots are probably more resistant to storm damage than wooden pots of the same size and shape because of their greater weight on the bottom and less surface area exposed to storm forces.

In a series of comparison-fishing experiments, Wilder (footnote 3, p. 23) reports that during a severe storm he lost 14 out of 19 wood pots with the remaining 5 damaged almost beyond repair. Only 1 out of 19 metal pots was lost during the storm. Similar results occurred during several other storms throughout his experiments. Metal-pot losses that did occur were attributed to buoy line failures.

Experiments by Spurr (footnote 2) provide the same results: wire-mesh pots moved less in current and storm action than wood-lath pots.

Costs

The material to build an inshore wood pot costs from $4 to $6. To buy a pot already constructed costs from $8 to $14. Inshore metal pots cost about $20.

Offshore double-parlor wood pots cost $18 in 1972. In 1974 the cost was $27. Metal pots of the same design were $24 in 1972, $35 in 1974, and close to $40 in 1977.

Efficiency

There is a traditional belief among lobstermen that metal pots are not as efficient as wood pots. Some of the reasons why lobsters are said to be repelled by metal pots are: 1) Metal wire vibrates in the water frightening the lobsters away, 2) lobsters do not like the feel of bare metal, 3) lobsters are sensitive to sharp metal edges, 4) lobsters sense an electric field set up by galvanic action, and 5) lobsters sense chemicals produced by galvanic action.

There are many variables that affect a pot's efficiency, though little is known about how or why. Very little comparison fishing has been performed and documented. Experiments that have been done have not had ample controls to determine if metal construction alone affected pot efficiency. We can say that the five objections to metal pots stated above have been overcome by proper construction and plastic dipping. Many fishermen have reported plastic coated and aluminized metal pots fished well.

Adaptability

Metal and plastic are more adaptable than wood in pot designs that are either collapsible or stackable.

Handling

Wood and wood-framed pots can take a lot more abuse in handling than wire pots. This can be compensated for by building the wire pots stronger and more rigid by addition of a structural metal frame. Shipboard handling systems can also be modified to be less abusive to the pots as they come aboard.

Wire pots have a handling advantage over wood in that they offer less resistance when being hauled up through the water.

Catch Condition

The catch suffers a significant degree of claw damage and loss in wood pots due to claws protruding between the laths and being hit when hauled aboard. This problem is eliminated in wire-mesh metal pots.

Pot-Type Summary

Researchers generally agree that lobster-pot design has not been optimized. The preceding discussion on pot design and materials demonstrates the fact that pots can now be designed that are more durable and efficient than the ones being fished commonly today. The probability of a long-term ghost-fishing situation being created will only increase.

LOCATION WHERE LOST

Biological Deterioration

Since most lobstermen use synthetic twine in pot construction, the main form of biological deterioration of concern is wood-destroying organisms. In the lobstering areas the organisms are usually *Teredo navalis* in the shallow depths and *Xylophaga atlantica* in the deeper part of the range.

Teredo navalis spawns about July. The larvae settle onto the wood traps and can destroy a trap in less than 2 months. Offshore *Xylophaga atlantica* spawns about October and can destroy a trap just as fast.

It is generally thought that most lobster areas are subject to wood-borer activity, though not of the same magnitude. In most inshore and offshore areas an untreated wood trap would probably not make it through the winter.

Corrosion

Location-dependent factors that influence corrosion are temperature, dissolved oxygen, and current velocities. Our trap-release study demonstrated the significant difference in failure rates that occurred with test samples in different areas. Corrosion rates are probably higher inshore than offshore.

Storm Surge

Storm surge and wave action are known to destroy many pots in shallow inshore waters. Though pots without buoy lines are less susceptible to storm action, they too probably move on the bottom in depths less than 20 m. It is generally believed by lobstermen that pots moved by storms tend to break up against rocks on the bottom.

Summer fishing is usually in shallow depths. As fall and winter approach, pots are usually moved farther offshore into deeper water to follow the lobsters and also to reduce storm losses. Pots that were lost during the summer in the shallow water probably do not survive the winter storms on exposed coasts.

Substrate Burial

Pots sometimes become buried in the substrate by the action of storms and currents. This is commonly referred to as "sanding down" or "mudding up." Sanding down is quite common, in depths shallower than 16 m, in the west coast Dungeness crab fishery (Hipkins, 1972:9). In this fishery a pump is carried on board with a special hose arrangement that can be lowered to the pot and water pressure applied to free the pot, sometimes buried to a depth of 4 m.

To what degree this problem exists in the lobster fishery is unknown. We can assume that a pot only needs to be buried about 15 cm in the substrate before its heads become relatively ineffective. There are many areas, inshore and offshore, where the bottom conditions of substrate and current are right for partial burial to occur (Fig. 2).

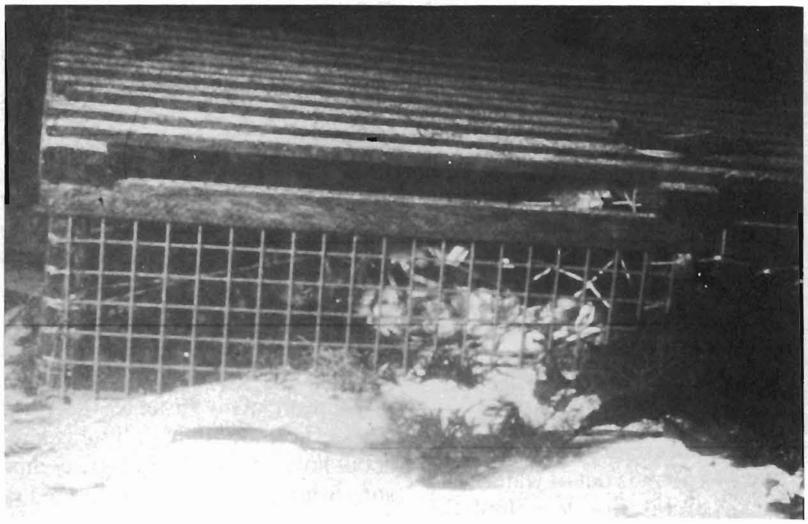

Figure 2.—Lobster trap partially buried in sand after several weeks on the bottom.

Destruction by Dragged Gear

Offshore lobstermen set their pots following the migrations of lobsters from the deep canyons in winter up onto the shallow shelf in summer. Many pots are lost in areas that are not continuously pot-fished. When the pot fishermen move out, the draggers move in, fishing the bottomfish in the area. These draggers haul back many lost pots and quite possibly destroy many others on the bottom. Only pots in the canyons themselves probably escape being destroyed by draggers.

CATCH RATES

Ingress minus escapement and trap mortality equals retention or, in other words, the catch. Catch rate is a time function; in trap fishing the time is defined in set-over days.

Set-Over Days

Set-over days are probably very important in determining rates of trap-related injury and mortality, in addition to their importance in catch/effort relationships. Unfortunately our data is not sufficient to perform a statistical analysis because we cannot isolate the effects of temperature, fishing pressure, and moulting from those of set-over days. (Our surface-hauled traps had set-over periods varying from 1 to 13 days).

We divided set-over days into three basic periods. The first is the baited period, in which some of the initial bait is still in the trap and is effective. The second is the transition period, in which the bait is recently gone and the lobsters caught are highly active in attempts to escape. The third period is the ghost-fishing period. The limits of the transition period cannot be exactly described, but in most cases the trap probably entered the ghost-fishing period by the end of the second week.

There may be times of increased ingress to the trap during the ghost-fishing period. This may be caused by the trap self-baiting, a lobster migration, or some seasonal event. This makes it very difficult to relate ghost-catch rate to set-over days. This is further compounded by the low ghost-fishing period catch rates, in our experiment equal to 10 percent of the surface-hauled catch rate.

Availability and Catchability

Ingress is a function of availability and catchability. A good example of the variation in availability of lobsters to a possible ghost trap can be found in the fishing strategy used offshore. As the bottom water temperature changes, the lobster population migrates and the fishermen correspondingly move their traps. A trap lost in a location where there were good catches one week may not have lobsters available to it for weeks or months afterwards.

Many factors affect catchability but probably the most important are temperature and other seasonal variations. Since ghost traps are on the bottom for long periods, the lobsters available to them will have a wide range of catchability coefficients varying with time.

In summation, availability and catchability cannot readily be used for an assessment of ghost-fishing period catch rates due to their variability. However, during the initial baited period these factors can be used for estimating the initial catch, which during our experiment was more than 50 percent of the overall ghost catch.

Escapement

In our Phase III experiment, 81 lobsters were classified as missing from the ghost traps, this being 33 percent of the known ingress. Two-thirds of this number were missing by the 30th day. Only six of these lobsters were recaptured. We conclude that the escapement rate from ghost traps, after the initial baited and transition periods, is less than 30 percent. This rate decreases with time. This figure is in basic agreement with that of Sheldon and Dow (1975).

Bait

There are a number of artificial lobster baits on the market; they have been used by fishermen with varying degrees of success. One of the goals of the artificial bait manufacturers is to produce a product that is long-lasting in the trap. Accomplishment of this goal would improve the trapping efficiency for longer set-over periods. Correspondingly this would increase ghost-fishing catch rates.

Behavior

The most interesting question about trap-related lobster behavior is why do lobsters enter traps? We must address this question to fully understand trapping efficiency and thus normal and ghost-fishing catch rates.

We know that lobsters primarily enter traps to get food (bait). We also know that lobsters enter unbaited traps, and this is usually thought to be shelter-seeking behavior. In the natural environment inshore lobsters are considered solitary, rarely sharing the same shelter. Offshore, on relatively flat featureless bottom, two or more lobsters have been observed to share the same shelter, usually a depression in the bottom. This observation is the exception though.

This natural solitary behavior is opposite what is observed in trapping. Our field experiment catch data shows many instances, especially in Phase III, where 15 or more lobsters were found in a trap, sometimes after 8 set-over days. Many of those lobsters entered the trap after the bait was gone. The same observation is demonstrated by our "lost" trap inventories. There is ingress to unbaited traps with large numbers of others lobsters present. This is in an area with plenty of available shelters.

We assume that a lobster entering a trap with 10 other individuals already there is aware of their presence before entering. Lobsters possess visual, chemical, and possibly sonic means of communication. The lobster may be entering for some social interaction with its conspecifics.

To determine the effects of social behavior on catchability, Edward Leger, a Boston University Marine Program graduate student, conducted a preliminary experiment at the Northeast Fisheries Center in 1973. Sixteen inshore lobsters (70 mm $\pm$2 mm carapace) and 16 offshore lobsters (74 mm$\pm$2 mm) were tested in 2-m diameter circular tanks under three different conditions. Capture time was recorded for each lobster placed in the tank with: 1) Trap and bait alone, 2) trap with bait and one lobster, and 3) trap and bait and two lobsters. During 1-hour test periods, 14 of 16 lobsters tested entered the trap with bait alone; 26 of 32 lobsters entered the trap containing bait and 1 lobster; none of 6 tested entered the trap with bait and 2 lobsters. This experiment indicated a possible density limitation factor in trap behavior.

Evidence exists that some form of social behavior, other than feeding and shelter related, is affecting catchability of lobsters. Leger's experiment seems to conflict with the field data, indicating the need for more closely controlled experiments to validate the social behavior hypothesis.

Another hypothesis is that lobsters enter unbaited traps because they have been conditioned to do so. Every week lobstermen place millions of pounds of bait into the water via lobster traps. This may constitute the major food source of lobsters who thus relate feeding with traps. Upon seeing a trap a lobster enters expecting a food source. Probably small (sublegal) lobsters have been repeatedly caught and disgarded by fishermen as they became conditioned to traps being effectively a feeding station. Lobsters repeatedly return to the trap as a food source, much as birds return to window feeders. Lobsters may enter unbaited pots simply to "check-it-out" for food.

Injury and Mortality

Emmel (1905) reported that 7 to 25 percent of lobsters caught in Rhode Island were missing one or both claws. Scarratt (1973) found incidence of claw loss from 5 to 19 percent in Canadian waters. Other wounds ranged from 1 to 11 percent in the lobsters sampled. Krouse (1977) analyzed Maine catch data which indicated 6.5 percent of lobsters caught were missing at least one claw and 21 percent had missing and/or regenerate claws.

Our field data for all three phases combined (surface hauled) shows 11.2 percent of the lobsters caught missing one or both claws. The overall incidence of lobsters with one or more types of damage is 27.6 percent. This field data may not truly reflect what is occurring in the actual fishery due to our longer set-over periods. Our data does show that the number of injuries might increase with longer set-over periods, increases in water temperature, increases in fishing pressure, and possibly be related to moulting. More controlled experiments are needed to determine the effects of each of the above factors.

Incidence of newly damaged lobsters during a portion of the Phase III study was similar for vented and nonvented pots. Due to the larger number of lobsters caught in the nonvented traps, more lobsters were injured than in vented traps. Total new damage amounted to 9 percent of the lobsters caught; 42 percent had old damage.

There were 101 instances of major damage to lobsters in our ghost pots, 25 percent occurring within the first 15 days and 69 percent occurring before the 30th day of entrapment. Mortalities amounted to 24.6 percent of the total ghost catch, 30 percent of the mortalities having major injuries prior to their deaths.

There is considerable evidence that the greater part of major damage to lobsters is trap-related. Despite the reputation of lobsters being aggressive, it seems aggression-related injuries in nature may be rare. Scrivener (1971) conducted behavior experiments with 700 pairs of lobsters and never once observed damaging aggression. Writing about decapods, and then his lobsters specifically, he states: "Infrequently fighting leads to physical damage of one individual. This may be rarer under natural conditions for some species, because many of the studies have been done under crowded laboratory conditions. Damaging aggression has occurred among the lobsters in the small holding tanks when the divider has been pushed over but has never been observed in the 6-foot diameter observation tanks."

Stein et al.[4] conclude that the lobster is much less aggressive than previously thought as long as the lobsters have adequate space and shelter. During their experiments, observing lobster behavior in seminatural habitats in large aquaria, there may have been one or two damage-inducing interactions between lobsters.

We have data showing that many injuries are sustained by lobsters in traps. These injuries are mostly induced by conspecifics in the stress conditions caused by the entrapment. There is also evidence from many sources that onboard handling of traps and lobsters induces injuries. Lobsters roughly handled, such as being dumped into a checker, will open their claws and bite down on the first thing contacted, usually another lobster.

The causes of trap-related mortality are harder to define. Many lobsters probably die directly from the injuries sustained in the traps, i.e., they are cannibalized by healthier lobsters or bleed to death. Lobsters that moult in a trap probably don't stand much of a chance for survival. McLeese (1956) reported that lobsters near moult are less able to withstand stress, thus they may also be subject to mortality in the trap even before moulting.

Toward the end of our Phase III study there were mass mortalities in the ghost traps. One possible cause would have been gaffkemia, a lobster disease. Rabin (1965) found that it is endemic in the natural lobster populations in the Woods Hole area. He also states that virulence may be a condition of the holding impoundment. There are no obvious signs of the disease though it is known to be transmitted through wounds. Higher temperatures speed the progress of the disease (Stewart et al., 1969). It can be shown that when our mass mortalities occurred, conditions were ideal for a gaffkemia epidemic.

Another cause of trap mortality may be predation by other species, especially if the lobsters were recent moults or weakened by injuries. It is generally considered that healthy hard-shelled lobsters of trapable sizes are not commonly preyed upon. The predator would have to get into the trap and that limits the possibilities further. Scarratt's (1965) work indicates that weakened lobsters confined in traps may be subject to predation by amphipods.

Lobsters probably do not starve to death in traps but may be weakened and stressed by starvation. Morgulis (1916) found that lobsters starved for 56 days showed no outward signs of emaciation and the greatest weight loss was 2.89 percent. The lobsters absorbed water making up for the loss of organic and mineral matter; the weight loss would have exceeded 34 percent otherwise. Stewart et al. (1967) held starved lobsters for 140 days that suffered physiological changes but showed no outward signs of stress or increased cannibalism. McLeese (1956) reported that the lethal limits established for temperature, salinity, and oxygen did not change after 57 days of starvation.

ASSESSMENT OF LOSSES

In this section we will make an assessment of ghost-pot mortality and claw loss for 1976; 1973 through 1975 are similar. The number of traps and lobster landings are preliminary figures gathered by NMFS.

The inshore fishery landed 25,812,000 pounds (11,615,400 kg) using 2,100,000 traps; an annual landings per trap of 12.3 pounds (5.53 kg). The offshore trap fishery landed 4,220,000 pounds (1,899,000 kg) using 72,000 traps; an annual landings per trap of 58.6 pounds (26.4 kg). The annual landings per trap is a rough figure as many traps are only in the fishery for a few months. Another point is that the landings, especially from inshore, represent only a small part of the actual catch, i.e., 20 percent where the throwback ratio is 4 to 1.

Twenty-five percent is presently the most accepted average figure for annual inshore trap loss rate. To see if we could use this figure for the offshore fishery, the port interview data from offshore lobster boats were analyzed.

Port interviews are conducted by NMFS port agents when a fishing vessel returns from a trip. We surveyed the 1976 interviews from Massachusetts and Rhode Island ports; these two states account for 53,000 of the 72,000 traps being fished offshore. The average vessel fished 400 traps having 25 to 50 traps per trawl. The soak times averaged 4-7 days.

Twenty-nine vessels were listed as fishing 13,040 wood traps. (Many of these vessels fish some wire traps.) One hundred and forty-nine interviews were conducted and a loss of 1,025 pots was reported; a 7.8 percent loss rate.

Eleven vessels fished 4,920 all-metal or plastic pots. During 40 interviews a loss of 121 traps was reported; a 2.4 percent loss rate.

These loss rates at first appear very low but this is due to the fact that many vessels were only interviewed once or twice. We next grouped all vessels that were interviewed six or more times. In this group there were 16 vessels, fishing a total of 7,290 traps, that were interviewed 134 times for an average of 8.3 interviews each. They lost 908 traps for a loss rate of 12.4 percent. From the port weigh-out sheets we determined that these vessels were averaging 20 trips annually so the annual average loss rate was 29 percent. We will use 25 percent for the purposes of this assessment.

Annual inshore trap losses: 525,000 ghost traps.

Annual offshore trap losses: 18,000 ghost traps.

Another category of ghost traps is the cumulative trap losses. From the interview data we found that about one-third of the traps offshore are all-metal or plastic. If we give these traps a 3-year ghost fishing life span, there will be 12,000 additional traps ghost fishing offshore each year. Due to lack of data on inshore trap types lost, we will not evaluate inshore cumulative ghost fishing, but it may be significant.

To determine what the inshore mortality per ghost trap should be, we assumed that half the lobsters in the missing category in our experiments died in the traps. This gives us 0.5 pounds (0.23 kg) per trap in Phase I, 1.3 pounds (0.58 kg) per trap in Phase II, 4.2 pounds (1.9 kg) per trap in Phase III nonvented, and 1.0 pounds (0.45 kg)

[4]Stein, L., S. Jacobson, and J. Atema. 1975. Behavior of lobsters (*Homarus americanus*) in a semi-natural environment at ambient temperatures and under thermal stress. Unpubl. manuscr., 49 p. Woods Hole Oceanogr. Inst. Tech. Rep. 75-48.

per trap in Phase III vented. Annual ghost-trap mortality would be higher for the following reasons: 1) There were lobsters still entrapped at the end of each phase of the experiments. 2) Many of the lobsters were released from our traps when catch escape panels opened and when our traps were raided. 3) Our experiments did not continue into the fall when greater mortality was probable.

We conclude that a conservative figure for the inshore annual ghost-fishing mortality rate would be 2.5 pounds (1.12 kg) per nonvented trap and 1.5 pounds (0.67 kg) per vented (45 mm) trap. (For this assessment we are neglecting legal size differences between states.) We can derive similar figures by taking landings per inshore trap, assume a throwback ratio of 4 to 1 for nonvented traps, and arrive at a catch of 61.5 pounds (27.7 kg) per trap. A ghost trap fishes at 10 percent of this rate (our field experiments) for a ghost catch of 6 pounds (2.7 kg) per trap. Using a 40 percent mortality rate (known mortality plus one-half the missing category) gives us 2.4 pounds (1.1 kg) per nonvented trap.

By an intuitive process we assumed a mortality rate of 6 pounds (2.7 kg) per offshore nonvented trap based on offshore catch rates.

Anuual inshore ghost trap mortality: $525{,}000 \times 2.5 = 1{,}312{,}500$ pounds (590,625 kg).

Landed value: $2,179,000.00 (1976 average price: $1.66 per pound).

Annual offshore ghost trap mortality: $(18{,}000 + 12{,}000) \times 6.0 = 180{,}000$ pounds (81,000 kg).

Landed value: $299,000.00.

To assess claw loss we used 10 percent for the number of lobsters with one or more missing or small regenerate claws. We used 15 percent as the weight reduction per cull lobster. Using 30,000,000 pounds (13,500,000 kg) as the annual trap caught landings, we get 450,000 pounds (202,000 kg), for a value of $747,000.00, lost due to missing and/or regenerate claws.

There are additional losses that cannot be evaluated here. These are the possible decrease in moult frequency and growth increments due to injuries and claw loss sustained in the traps by sublegals.

PREVENTIVE SOLUTIONS

Reduced Effort

It becomes obvious that the best way to reduce trap-related injury and mortality is to reduce the number of traps. Any reduction in the number of traps will cause a corresponding reduction in trap losses and thus in ghost-fishing mortality. If the same landings can be sustained with a 50 percent reduction in traps inshore, then close to 700,000 pounds (315,000 kg) of lobsters will be saved from unprofitable deaths; over $1.1 million in landed value.

Cutting Losses

It may be possible to decrease pot losses both inshore and offshore substantially below levels of 20-30 percent. To do this the first step needed to be undertaken is a survey to identify quantitatively the causes of pot losses and the methods developed by lobstermen to reduce losses.

As mentioned previously, there are many areas in the lobstering operation that can be improved upon to reduce losses. Trapezoidal pots may be less susceptible to loss than half-round pots. Many lobstermen may be using insufficient ballast or an inferior pot warp. There are indications that some types of buoys are better than others (Spurr, footnote 2, p. 19). Multipot trawls may suffer fewer losses than single pots inshore.

Degradable Sections

To prevent a long-term cumulative ghost fishing problem, the solution might be to have all virtually nondegradable pots contain a section that would rot out in about a year's time. When this section fails it should leave an opening with a minimum dimension at least equal to the diameter of the head opening. The degradable section could consist of wood, natural fiber, or untreated iron wire. As mentioned in the introductory paper (Smolowitz, 1978), this approach has been taken in several fisheries already.

To solve the short-term ghost fishing problem is more difficult. Since the degradable mechanism would be required to fail sooner, it would be more bothersome for the fishermen to keep replacing them. If the fisherman is not fully convinced of the value of this exercise he may replace the degradable mechanism with a nondegradable one. In the sablefish (blackcod) pot fishery, some fishermen laced up the escape vent with nylon instead of cotton twine.

Sublegal Escape Vents

It has been demonstrated many times that sublegal escape vents reduce the catch of sublegals. Pots that retain fewer lobsters are less destructive to the catch both in the normal and ghost-fishing modes. If all traps inshore used sublegal escape vents of 45 mm, the ghost-catch mortality rate would drop 1.0 pound (0.45 kg) per trap for a saving of 525,000 pounds (236,250 kg), or roughly $870,000 in landed value. The many additional advantages of sublegal escape vents have already been reviewed elsewhere.

Catch Escape Panels

The sublegal escape vent and the degradable section could be combined into one unit. Our catch escape panel is 8×8 inches (20.3×20.3 cm) and contains a 1¾-inch (45 mm) high ×6-inch (15.2 cm) long sublegal escape vent. This panel is affixed over a 6- × 6-inch (15.2- ×15.2 cm) hole cut into the parlor end of the pot and is attached by two hog-ring hinges on the bottom and a degradable link on the top.

In the closed state the panel allows sublegal-sized lobsters to escape through the vent. After a period of time the degradable link fails, allowing the panel to drop open so all trapped lobsters can escape.

The choice of panel material would probably depend on whether the panel is provided by the State or made by the lobsterman. The choice of degradable link would depend on the failure-time required.

For the purposes of this discussion, we will assume that the panels would be mass-produced by the States, similar to the way auto license plates are, and contain a stamped license number. Lobstermen could, for example, be required to buy one panel annually for each pot fished. Double-parlor pots would be required to have two panels, one on each parlor.

The possible advantages of the catch

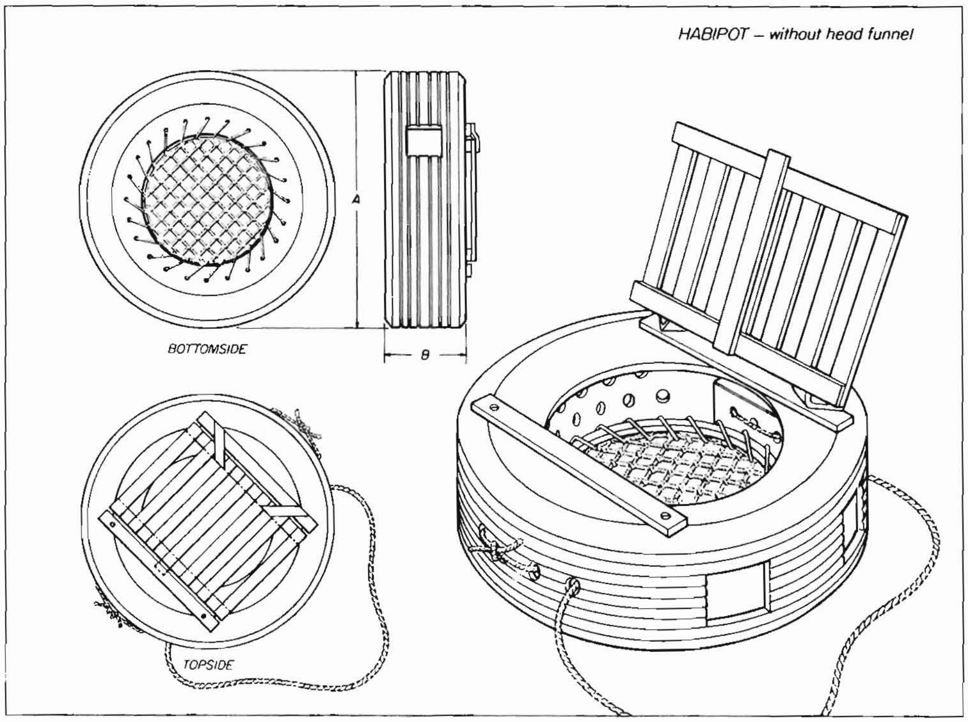

Figure 3.—Basic tire habipot design with two entrance vents and drainage holes. The tires were not negatively buoyant enough and had high drag characteristics during hauling.

escape panel are analyzed in the following discussion.

1. Allows the State to have more accurate knowledge of the number of pots being fished. If the State issues the panels, not only will it have a solid estimate of the number of pots being fished but also of how many are being lost.

2. Easier to enforce regulations due to the high visibility of the panel on the pot. This is one of the major advanatges over lath spacing as a means to regulate sublegal catch. All the enforcement officer has to do is to see the panel and he knows it has the correct vent size.

3. Uniform size of sublegal vent allows more accurate control of pot selectivity. The sublegal vent can be accurately sized and constructed so as not to swell or be worn away.

4. Decreases damage to sublegal lobsters. This is an advantage of any sublegal venting mechanism.

5. Decreases illegal sales of sublegal lobsters. This is not known for sure, because many lobsters just under legal size will still be retained. These are the lobsters a dishonest lobsterman would sell.

6. Reduces and eventually ends ghost fishing. A sublegal escape vent, by reducing the number of lobsters retained, should reduce ghost-fishing mortality. When the degradable link fails, the pot will no longer fish.

7. Improves quality of catch. Fewer lobsters in the pot should cause less conspecific-inflicted injuries, e.g., claw loss.

8. Controls bycatch. Pots with sublegal vents let out most crabs. This may be more of a problem where the crabs are sold commercially.

9. Increases pot efficiency. In areas where there is a large population of legal lobsters, the sublegal escape vent should allow more of them to be caught.

Habipots

During this project we constructed and started to test several designs of habipots, but time and money considerations did not allow for completion of the work. Two types of habipots constructed out of old automobile tires (Figs. 3 and 4) were fished with limited success; they caught sublegal lobsters. A lot more work is necessary to develop a selective nonentrapment type of pot.

CONCLUSIONS

1. The main ghost-fishing danger lies in the cumulative effect on the inshore fishery if the majority of fishermen start using all-metal and/or plastic traps, a trend that is well under way. We recommend that all traps be required to have one untreated wood lath in their construction which, upon rotting out, leaves an opening equal to or greater than 75×150 mm.

2. Any reduction in the total number of traps used will have positive results in reducing ghost fishing and trap-related injuries and mortality even if the fishermen increase effort.

3. We recommend field tests with a 47-mm escape vent, as indications are that this size vent will substantially increase the overall benefits to the fishery attributed to sublegal venting, with only a negligible reduction in legal catch.

4. We recommend that a study be undertaken to determine the causes of trap losses and the means to prevent or reduce them.

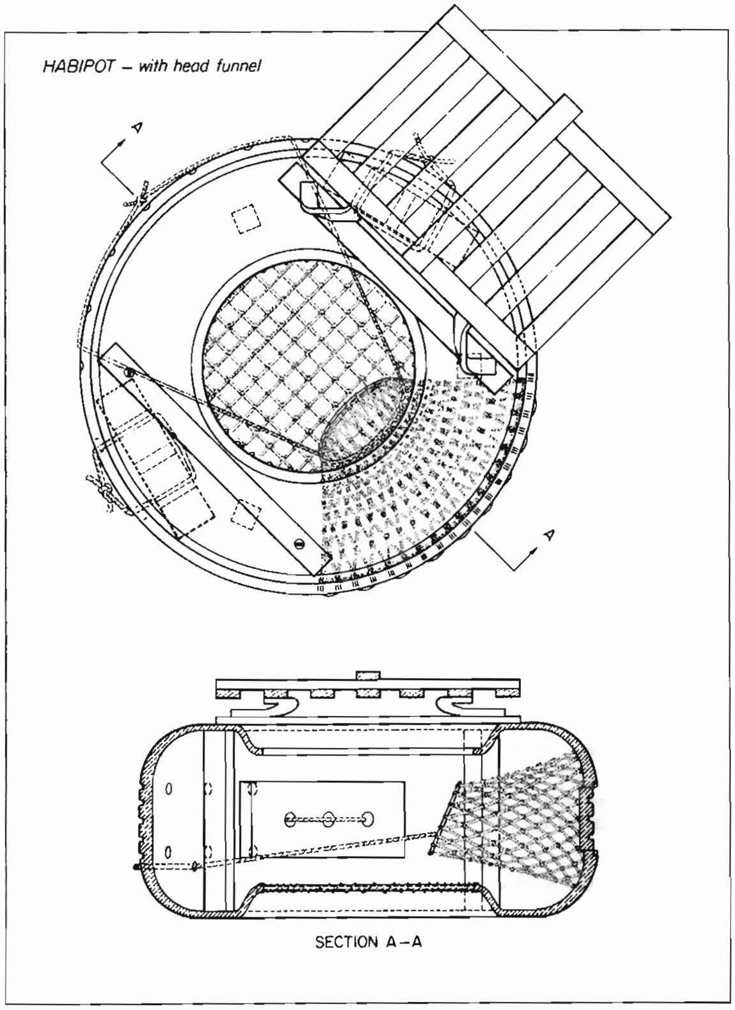

Figure 4.—A head funnel was incorporated into the basic design to prevent escapement during hauling.

5. We recommend that all researchers, where applicable, use a standardized trap to eliminate variable of selectivity and trap efficiency and thus allow for better comparisons of data collected throughout the lobster areas.

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