maintain his frozen fish business on quality he will freeze only strictly fresh fish. Very few realize that one of the regular phases of deterioration of quality in fish is loss of flavor. During this phase the fish appears fresh for the flesh has no off flavor or odor, in fact there is practically no odor at all, but the sea-fresh flavor and odor are gone. In this stage many people condemn the species as being tasteless, not realizing that they are eating poor quality fish.

The Fish and Wildlife Service now has underway a project by which it hopes to devise a means of enabling the fishing industry to market "sea fresh" fish and fish fillets. It is referred to as the "Freezing-fish-at-sea" project. Laboratory and pilot plant tests have indicated that it is possible to freeze strictly fresh fish in the round at sea, bring them to port and hold them in frozen storage for a period, then remove the fish from storage, thaw and fillet them, package the fillets in the usual manner and refreeze them. To test the method under commercial conditions, the Service has obtained a New England trawler. One-half of the hold of the vessel will be heavily insulated and freezing equipment will be installed, the other half of the hold will be used for icing down the fish, as is now practiced, in order to compare the quality of the frozen and iced fish and to get information on the cost of the two methods. If the freezing-at-sea process can be successfully worked out it will have many advantages over the present methods. First, there will be no question of freshness, for the fish will be frozen almost as soon as they come from the water. At present there is some question about freshness because fish caught by New England trawlers must be held in ice as long as 8 to 10 days before being filleted. The distance of the fishing grounds from the filleting plants makes it impossible to land all fish in less than this time. The second advantage is that the vessel can remain on the fishing grounds until it has a full load of fish. Third, the liver and all other material now discarded at sea will be brought ashore, in perfect condition for conversion into by-products and pharmaceuticals. Fourth, the shore plants and labor will be able to operate on a fixed work schedule since the round fish will be drawn from the freezer as needed. This will eliminate the troubles caused by the glut and slack seasons which now occur each year. Above all, however, is the advantage that all the fish and fish fillets produced by this method will be of uniform high quality.

It is realized that in this paper many important phases of freezing of fish have not been mentioned, such as glazing, dehydration, and oxidation problems with oily fish. Time does not permit a complete discussion of all methods but it is hoped that the few points on the icing and freezing of fish which have been discussed will help someone to improve the quality of the fish he produces and thus help both his own business and the entire fishing industry.

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The Use Of Echo Sounders In Fisheries

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SINCE THE EARLIEST KNOWN TIMES man has been interested in fish, and for almost as long he has taken fish commercially. The tools of the commercial fisherman have changed little in recorded history. True, bone hooks have long since been replaced by steel, and fabric netting has in some cases given way to nylon, and elbow grease has in some cases been replaced by powered net hoists; gasoline or diesel engines for motive power have replaced oars and sails—not alone in fishing boats, and automatic power reels have been introduced to aid the deep water line fisherman. But of all the advances in the fisheries industry the most outstanding has been the introduction and use of echo sounding gear.

Echo sounding gear has given the fisherman new eyes, eyes that see through water, clear or cloudy, to depths once called unfathomable. "Under-water Radar," "Electronic Fish Finder," "Under-water Road Map," these are only a few of the familiar nicknames given to this equipment by fishermen. The praise given to echo sounding gear by fishermen is well deserved, as this gear is revolutionizing the methods of operation of almost all types of commercial fishing. Fishermen throughout the world, cautious in accepting new ideas, are now demanding echo sounding gear in such quantities that manufacturers are hard pressed to meet the demand. For a thorough understanding of the importance of this revolution it is necessary first to understand the principles of echo sounding as now employed.

Echo sounding is literally the function of measuring the depth of water by means of echos bounced off the bottom and timed in their passage. The equipment to accomplish this could be, and once was, simply a sound-making device, plus a stop watch or other timing mechanism, and a sound amplifier for reception of the echo. The sound employed for this purpose may be of any frequency within the audible or superaudible range. Years of research and practice, however, have shown that frequencies of from 20 to 50 thousand cycles per second are best suited to this purpose. Sound frequencies within the sonic and ultrasonic range have the characteristic of traveling at essentially the same speed in a given medium, and of being effected little by changes in the salinity or temperature of the water. Actually, large changes of salinity or temperature of the water do cause minor variations in the speed of sound. The speed of sound in any liquid is given by the relation: velocity in meters per second = the square root of k/p. Where k is the adiabatic bulk modulus of elasticity, and p is the density of liquid. In fresh water at a temperature of 8°C this velocity is 1427 meters per second or 4,681.7 feet per second. In sea water at 35 parts per thousand salinity the relation becomes: Velocity in feet per second equals 4,756 ($13.8\ t + 0.12t^2$, where t is the temperature of the water). At 8°C the velocity from this relation is 4858.7 feet per second. It will be noted that the difference in velocity between fresh water and sea water at the same temperature is small enough to be of interest only to surveyors and of no importance to the commercial fisherman. As most echo sounders are designed for use in sea water, and not provided with compensators for changes in density or temperature, the maximum error of approximately 177 feet per second (only 3.6%) is encountered only by the unusual fishing boat which may operate in both sea water and fresh water. Incidentally, some time ago a rumor was circulated to the effect that the energy emitted from some echo sounders was harmful or disturbing to fish. This rumor was without foundation. In fact, there is conclusive evidence that fish are oblivious to energies of the strength and frequency emitted by most such machines.

Present day mechanisms for producing the sound, timing the passage and receiving and indicating the echo are generally combined into a single unit system. The timing, which is the heart of the mechanism, is accomplished by means of a constant speed motor which carries the transmitter keying contact, and some means for producing an indication of the echo and relating the time of reception to the time of transmission, along a graduated scale. An indicating echo sounder commonly employs a revolving disc to which is attached an electric lamp. At the zero position of the disc, the transmitter is energized and the sound is emitted from the under-water soundhead, or oscillator, mounted in the hull. When the echo is received and amplified it causes a flash in the electric lamp which has meanwhile been rotated to an angular position corresponding to the elapsed time. The indicator is so constructed that the flash of light from the lamp is immediately comparable to a graduated scale, marked in units of depth, so that a direct reading of depth is obtained. To obtain maximum benefit and utility from such an indicator it would be necessary to observe the flashes continuously and to record the data thus obtained in the form of a graph. This would require two operators, one to observe and one to record. For this reason the depth indicator has limited application except for purely navigational purposes, as a single operator finds it impossible to observe the indications continuously and to visualize the true contour or other characteristics of the surfaces from which echoes are received.

A recording echo sounder employs the same basic principles as the indicator type, but produces its data as a permanent (or in some machines semi-permanent) mark on a graduated chart, thus doing automatically and instantaneously the complete job which might be done by an indicator and two efficient operators. The recorder completes the job started by the indicator, and produces a complete picture, in profile, of the bottom contour, or of the size, shape and density of any reflective matter between the surface and the bottom. There is importance in this last statement, as it is from this ability that the name "Fish Finder," and a whole new field of application, has arisen.

The balance of this discussion is concerned with recording echo sounders only, and all technical details and references to actual applications and installations refer to the Ultrasonic Depth Recorder, as manufactured by the Bendix Aviation Corporation.

The Bendix Ultrasonic Depth Recorder produces its record on dry graduated paper by means of a moving wire stylus, through which the amplified echo is passed to remove, electrically, the light gray coating from the surface of the record paper so that the black of the graphite-bearing paper bulk shows through. This system avoids the disadvantages of inking pens and wet paper. It has the further advantage of producing a detailed record, as the amount of surface coating removed is dependent upon the strength of the echo which, at a given depth, is dependent upon the hardness and compactness of the bottom or other reflective surfaces. The sonic energy has the ability to penetrate most matter to a greater or lesser extent, and echos are obtained from the depth of the penetration, descending in strength with the depth of penetration. Thus, by darkness of initial echo indication and by the fine degrees of shading resulting from the penetrating energies, the record produced gives an accurate indication of the hardness, or compactness of the bottom. It is, therefore, possible to distinguish between rock, sand, and mud, and, with some experience and familiarity with the minute peculiarities of the particular machine, to go further and determine the approximate consistency of mixed bottoms, or to detect small patches of harder material embedded in soft mud or sand, etc.

As a navigational aid the Depth Recorder is extremely valuable. By following the contour of the bottom, grounding and stranding may always be avoided, and by comparing the record graph with navigational charts, pin point positioning may be obtained. Thus a Depth Recorder may be considered a necessity for navigating shoal waters, particularly in uncharted areas, or areas unfamiliar to the boat's navigator. The bottom contour is shown in great detail, the presentation of bottom irregularities being most faithful, and dependent only on the number of soundings per lineal unit of bottom covered, and the scale range of the recorder being used. For the utmost in accuracy, the recorder used should take the maximum possible number of soundings per lineal unit of bottom covered, and should have a scale range not exceeding the maximum depth of interest, so as to obtain greatest enlargement of contour. Reference to soundings per lineal unit may be misleading, as this will actually depend only upon the lineal speed of the boat. The rate of sounding is limited by the scale range, as sufficient time must be allowed between the soundings for passage of sound from the soundhead to the bottom and return, and for recovery of the electronic circuits. Thus, soundings cannot be emitted more frequently than given by the relation: soundings per second = v/2d; where v is the velocity of the sound and d is the depth in feet. Assuming a nominal velocity of 4800 feet per second, it may be seen that for a depth range of 400 fathoms, soundings cannot be taken more often than one per second, as it would take approximately one second for the sound to travel to the bottom and return. Actually the recovery time of electronic circuits, the necessity for avoiding any possibility of over-lap, and certain mechanical consideration, dictate that soundings be taken at from ¼ to ½ of this maximum rate. As the lineal distance traveled by the boat between soundings may be sufficient to result in a serious loss of bottom detail, it is important that the boat be held to a low speed when ultimate in bottom detail is required. For average use, however, depth recorders have been designed to give sufficient detail at average boat speeds of from 8 to 15 miles per hour.

As has already been mentioned, the depth recorder has the ability to detect and present the evidence of any reflective matter suspended in the water between the soundhead and the bottom. Thus, heavy masses of seaweed or suspended debris may be detected, and, most important to fisheries industries, schools of fish may be detected. There is much which is not yet known about the abilities of various materials to reflect sonic energy, but these things have been determined by actual experience. Light or occasional patches of under-water vegetable growth will not be indicated. Sponge and live coral will not be detected, unless in growths of considerable mass. Wrecks, whether of wood or steel, will be detected, with steel generally producing a much stronger echo. Pelagic fish, either at surface or in deep water, will be detected, and the penetration of the sonic energy into the school will provide an immediate indication of the density and/or thickness of the school. These functions have brought the depth recorder to a position of prominence in fisheries operations, to the extent that this equipment is now becoming standard on most new boats, and is being installed on thousands of older boats.

Many types of fishing are dependent upon the knowledge of the ocean's bottom, and conditions existing thereon. Fish may be attracted by the vegetation to be found at various depths and on various types of bottom, and many species are found only where certain bottom conditions exist. In years gone by, the location of these so-called fishing "banks" was often a closely guarded family or company secret. Usually the banks were found by pure chance, or by the study of hydrographic charts. These methods have now been supplanted, in many cases, by the use of echo sounding electronic devices, which have revolutionized the commercial fishing industry. The guesswork has been partially taken out of "prospecting" for new fishing grounds. With a depth recorder the master of the fishing vessel can accurately locate the fishing banks. Many of the secrets of by-gone generations are now available to progressive fishermen, if their vessels are equipped with a depth recorder.

All types of fish that school closely and at not too great depth, such as tuna, sardines, mackerel, herring, and anchovies, are taken with purse seines. This method consists of encircling a school of fish with a net that hangs vertically in the water, supported at the top by corks and held down at the bottom by weights. When the fish are completely encircled, the "purse" line is drawn, closing the net at the bottom end, making escape for the fish virtually impossible. Purse seine nets range in size up to 1800 feet long, and 180 feet deep. Once a school of fish has been located, the purse seine captain must determine the depth of the water, and whether or not there are obstructions on the bottom that would damage his net.

Before echo sounding equipment became available it was often necessary to sound by hand before proper pursing of the net. Frequently this hand-sounding method did not reveal the presence of jagged pinnacles or other obstructions, with the result that nets were sometimes torn or completely lost. With a depth recorder, it is now possible, not only to locate fish and to estimate closely the size of each particular school, but also to know exactly the bottom conditions that will be encountered during the seining operation. With the large purse seine nets being valued as high as $18,000, it becomes readily apparent that a depth recorder appeals to the fisherman as most valuable insurance against damaged gear, as well as a profitable aid in making bigger catches.

Many species of fish, such as sea bass, salmon, shark, and others are taken by the use of gill nets. The nets themselves consist of webbing, with the mesh size depending on the size of fish desired. Sections of net are strung in places where the fish are known to feed or to pass. The position of the nets is perpendicular to the bottom, and usually placed in a series. The nets are suspended with floats along the top, and weights along the bottom and are held in by anchors or allowed to drift with tidal or river currents. Their position is indicated by floats and flags on the water's surface. The fish are caught by swimming into the open mesh. Unable to swim through the mesh, the fish try to back out and the mesh catches in the gill cover.

The proper location of gill nets is important. Frequently the gill net fisherman finds that by placing his nets along the edge of a ledge at a certain specified depth his catches are considerably larger than if the nets are placed along a flat bottom. Before depth recording was available, it was necessary for the gill net fisherman to take accurate shore bearings so that, in letting out his net along a ledge, he did not drop part of it off into the deeper water. Where poor visibility made shore bearings impossible, the successful placement of his nets was dependent on luck. With the use of the depth recorder, it is now possible for the gill-netter to determine exactly where a ledge is and in which direction it runs, regardless of visibility. The recorder enables him to spot his gear near the edge of the ledge, and to know that when it goes down it will be where he wants it.

Trawling is performed with a net that consists of two wings and a "sack" which is dragged along the ocean's bottom, scooping up the fish in its path. The mouth of the net is held open by otter boards, to which are attached the dragging cables. The net is held in proper position by floats affixed to the top and leads to the bottom. This type of gear is utilized for the taking of all types of bottom fish and has become standard in the shrimp industry. Trawling operations, perhaps more than any other, demands an accurate knowledge of the bottom, as the trawling net is usually dragged at a speed of from 2½ to 5 knots, and must be conducted over a reasonably smooth, unobstructed bottom. Larger trawl nets may cost as much as $5,000, and the normal wear and tear on trawl nets is high. For this reason it is often considered economically unsound to fish where unknown bottom conditions exist. Serious damage or loss of nets, coupled with the loss of time involved, can make this type of fishing very unprofitable.

With the depth recorder, the trawler captain can now "see" his way over the bottom, avoiding obstructions and fishing in areas most likely to be productive. An experienced user of the recorder can frequently detect the presence of fish several minutes before his trawl reaches them, and, if necessary, he can change his course so that his net will pass through the heaviest concentration.

Fishing by set lines or long lines is of great importance. The set line gear consists primarily of a long main line with leaders (to which the hooks are attached) fastened to the main line, at intervals. The main line is strung out along the bottom and held in place with anchors at each end. Marker buoys on the surface indicate the position of the anchors. The hooks are baited.

This fishing is applicable to all types of bottom fish, and was the method used initially in the taking of shark, for which such a large market developed during World War II. It is of importance to the fisherman to know what the bottom conditions are before he drops his gear. Without recording equipment a set line fisherman may let out a string of gear only to find that only one-half of the line has actually "fished" for him. The set line fisherman equipped with a depth recorder reduces his number of non-productive sets.

Live bait fishing is used in Southern California by tuna boats. The method is used to catch tuna which frequently move at a speed that makes netting them impractical. Migratory schools are attracted by "chumming" with live bait, and then by fishing with hook and line from individual poles, much as the sport fisherman does. The securing of a supply of live bait, is sometimes as hard as catching the tuna themselves. These vessels are equipped with large bait tanks, through which there is constantly circulated fresh sea water.

The bait fishes are caught in small purse seine nets from launches (usually carried aboard the mother vessel) and the bait is then kept alive in the bait tank. When the tuna are located, the chumming is started. Live bait thrown into the water attracts the tuna to the boat, where they strike at nearly anything moving in the water. Feathered jigs are then substituted for the live bait hooks and the tuna are pulled aboard.

Echo sounding equipment aboard the tuna clippers can aid materially in the location of off-shore banks where the tuna occur. The depth of water is sometimes too great to be sounded by the old lead line methods. Echo sounders are employed to do the job much more efficiently. In addition, tuna clippers have recently begun to use echo sounding equipment to assist them in finding the schools of bait. This equipment is repeatedly paying for itself in the hours and sometimes days of time saved in securing bait.

The use of echo sounding equipment in shrimp fishing is described in an article entitled "Shrimping Electronically," written by Mr. R. P. Geddes, Jr. of the Bendix Aviation Corporation and printed in Pacific Fisherman in June of 1947. Parts of this are quoted:

"Extensive tests just concluded show the application of echo sounding to the problem of locating schools or beds of shrimp. The tests were conducted in the Gulf of California near the mouth of the Colorado River aboard a vessel engaged in actual shrimping operations.

"On March 5, 1947, a Bendix Model DR-3 supersonic depth recorder was installed aboard Fomento Maritimo's *El Padre* at Guaymas, Mexico. The unit selected for the tests was a standard depth recorder taken from the assembly line of the Bendix plant, in North Hollywood, Calif.

"The purpose of the trip to the Gulf of Lower California was to determine whether or not beds of shrimp could be located with the machine. At the time of the writer's visit in Mexico, shrimping operations of the Guaymas fleet were being conducted at the head of the Gulf of Lower California, in water ranging from 20 to 30 feet in depth. It was therefore decided that during the long run from Guayamas to the head of the Gulf that experiments would be made in an attempt to locate shrimp in deep water, it having been the contention among old fishermen that shrimp had been taken in deep waters years ago by the Japanese when they had the exclusive concession to these waters.

"However, efforts towards this end were unrewarded and the *El Padre* proceeded to join the fleet. Immediately upon arriving on the "grounds," dragging operations were commenced. The first three days of fishing brought little more than manta rays and fish commonly known on the west coast of the United States as "tom cod"—the lack of shrimp being attributed to the full moon.

"During all of the dragging operations of these first three days the recorder was in constant use and it was interesting to note that the only break in the monotony of the flat bottom line appearing on the chart was an occasional mark caused by the reflection of the signal from one of the mantas.

"Due to the shoal water, the Bendix was operated entirely on "foot" scale. When operating on this scale, 288 soundings per minute are made, or at the speed of five knots, a sounding was being made every 1½ foot of the bottom.

"On the fourth day of the tests, an entirely new mark began to appear on the chart—a mark that was in the bottom line.

"Due to the extremely soft bottom encountered, the bottom line was approximately ¾" in thickness. This condition was caused by the signal "mushing" into the bottom rather than bouncing back clearly as it would from a hard bottom. This new mark appearing within the confines of the "bottom line" was at first spasmodic, but as the day wore on it became more and more frequent. At the conclusion of the first drag of the fourth day of operations it was found that a small quantity of shrimp had been caught. Succeeding drags rewarded the crew's efforts with increasing amounts of shrimp. It soon became apparent that some connection existed between the new heavier mark appearing on the chart and the shrimp that were being caught. Experiments were then instigated to endeavor to find a definite tie-in between these marks and the shrimp.

"Buoys were thrown overboard simultaneously with the appearance of a mark and a close watch was kept on the dragging cables as the net approached the buoys. In each case, perceptible tightening of the cables took place as the net came abeam of the buoys. From this observation it was apparent that the net was encountering a material denser than the mud in which it was being dragged. Charts were made up on which all of this information was entered, and the figures thus tabulated proved conclusively that these darker lines appearing within the confines of the bottom line were actually shrimp buried in the soft mud. The shrimp being of greater density than the mud about them, they reflected a sharper signal, and therefore a darker and more precise line appeared on the chart. One drag of 36 minutes duration was made that netted 2200 lbs. of shrimp. The chart made during this drag showed an almost continuous "darker" line, and it was observed that during the entire drag, no slack appeared in the dragging cables.

"These findings of course were met with great interest from all of the observers. If this instrument could actually detect the presence of shrimp it would mean many hours of futile dragging saved each day; it would mean hundreds of dollars saved in wear and tear on gear, plus additional hundreds of dollars saved in operating costs to the boat owner.

"Here, indeed, was the dream of all shrimp fishermen—an instrument that could *see* shrimp.

"It is still too early to make the statement that the Bendix Recorder will "see" shrimp under any and all conditions, but it is a substantiated fact that under conditions encountered on the initial tests locating and charting schools of shrimp electronically has become a reality. Further tests are being conducted in an effort to prove further that shrimp can be located with such an instrument in this manner."

It is fully appreciated that not nearly all of the important aspects of the use of echo sounders in fisheries have been covered in this paper. Almost daily entirely new applications or variations of older applications are being discovered and the writer is incapable of keeping currently abreast of these new developments throughout the world. The principal applications and considerations have, however, been discussed and it is hoped that this discussion will provoke thought which may lead to the discovery of new applications in this area.

The Role Of Exploratory Fishing In The Development Of Commercial Fisheries

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ALL EXISTING COMMERCIAL FISHERIES have been discovered and expanded by exploratory fishing, performed either by private fishermen in the normal course of their business or by exploratory work of various governments. In established fisheries the pattern of development is a gradual exploration over increasing distances paralleled with the development of equipment suitable for developing the fishery. Eventually, the expansion is stopped either permanently or temporarily by the range of species and its ability to stand the drain of exploitation, by the limitations of standard fishing equipment and aids, or by the economics of production and marketing considerations. Many of our present fisheries have reached or are approaching one or more of these limitations.

For economic reasons commercial fishermen seldom make a bold jump to new areas remote from markets or make radical changes in equipment unless there is assurance that profitable fisheries are available for development, or that changes will add to their income. Pioneering in the fields of exploration and the development of superior equipment is expensive and usually beyond the means of the relatively small fishing enterprises. It must in part be a function