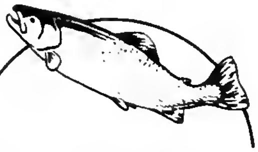
ESTIMATING MAXIMUM FISHING DEPTH OF LONGLINE GEAR WITH CHEMICAL SOUNDING TUBES



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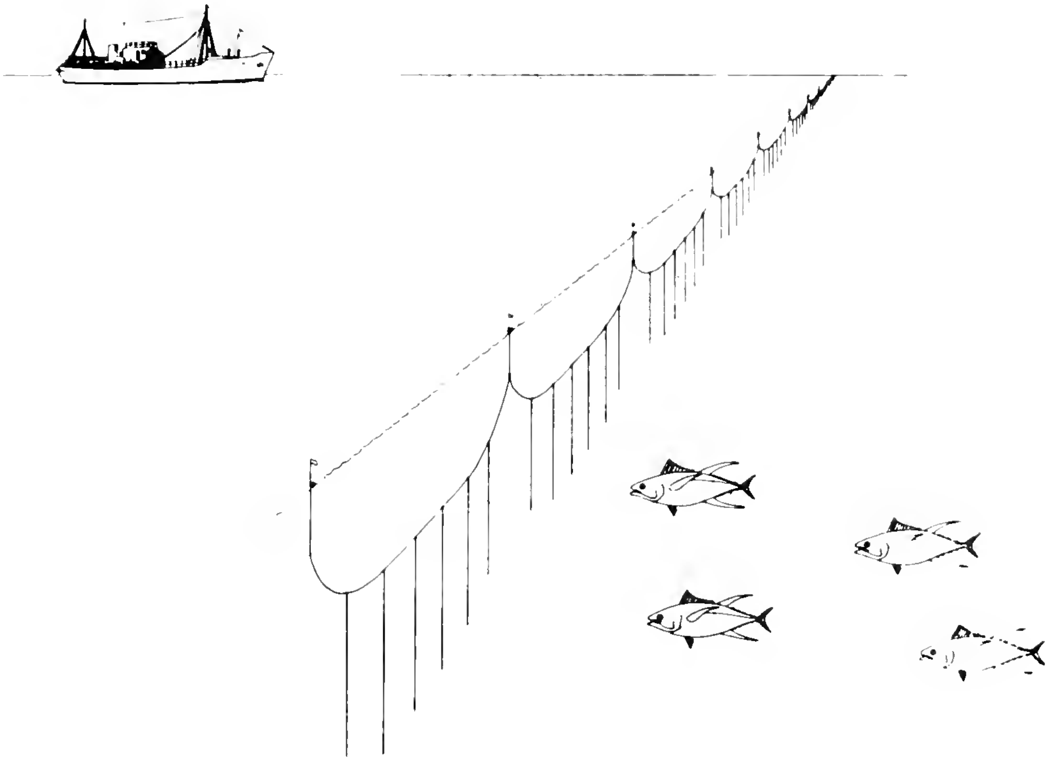

ESTIMATING MAXIMUM FISHING DEPTH OF LONGLINE GEAR WITH CHEMICAL SOUNDING TUBES

By

Joseph J. Graham
Fishery Research Biologist
Pacific Oceanic Fishery Investigations
Honolulu, T. H.

and

Dorothy D. Stewart

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ABSTRACT

A summary of methods used by various investigators to estimate the fishing depth of longline is given. Sounding tubes, used by POFI in conjunction with studies of albacore tuna, *Germo alalunga* (Bonnaterre), in the central North Pacific, measure the depth of the longline with considerable accuracy. A method, using readings provided by the tubes, is developed so that the observed "hang" of a given basket of gear and the theoretical "hang" can be compared. The results obtained suggest that the configuration of the mainline in the individual baskets does not conform to a catenary. We conclude that the skewness in the shape of the line did not occur during the fishing period, but rather during retrieving operations when slack formed in hauling allowed a portion of the gear to sink below the maximum fishing depth. It is suggested that distortions related to retrieving procedures can be overcome. A method is presented by which the maximum fishing depths for individual hooks along an entire set of gear can be estimated.

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Longline gear of the type employed in this study was developed by Japanese fishermen to capture fish swimming at considerable depths below the surface of the ocean (Shapiro 1950). During the past 5 years this gear has permitted an expansion of the Japanese high seas tuna fishery, particularly in the South Pacific and Indian Oceans. The longline has also been used with success by American fishery research organizations[2] to ascertain the abundance of oceanic tunas.

Attempts to determine the fishing depths of longline gear have been made by a number of investigators using various methods. Murphy and Shomura (1955) and associates made echo-sounding measurements of the depth of the deeper portions of the longline with a Bendix depth recorder. Bullis (1955) by use of the Echograph depth recorder obtained excellent traces of entire baskets of the mainline. Such measurements are difficult to obtain with consistency because of the large number of variables involved such as the state of the sea, the type of equipment, experience of the operator, condition of the equipment, tuning, etc. Murphy and Shomura (1955) also determined distances between buoys with the use of radar. A comparison of theoretical depths, derived from the buoy distances, with those obtained simultaneously with the Bendix, showed a low correlation; the Bendix readings being shallower than the theoretical. The authors suggest that this low correlation was caused by the lack of precision in measuring line depth and buoy intervals, and also by the influence of environmental factors such as currents which might have caused shearing and thereby shoaling of the gear. Previous findings (Murphy and Shomura 1953), secured by use of pressure gauges attached to the deeper hooks of the longline, showed that the gear was most likely limited in its penetration of the thermocline, which was probably the boundary between the moving surface water and the stable deeper water, at least in the equatorial region. The use of pressure gauges was abandoned by Murphy and Shomura because of troublesome technical difficulties inherent in the mechanism.

Yoshihara (1954) gave the problem a completely theoretical treatment by deriving depths of individual hooks through a mathematical analysis. His analysis, though exacting, was based on assumptions that certain conditions were stable; i.e., that buoy distances were uniform throughout a set of gear and that the action of currents and winds upon the gear did not vary.

Finally, chemical sounding tubes, which give a measure of maximum fishing depth, have been used by various research agencies and investigators (Anonymous 1940, Yoshihara 1954, Anonymous 1955, Shomura and Otsu 1956, Iversen and Yoshida 1957). The discussion which follows is based on the results obtained by the use of chemical sounding tubes by Pacific Oceanic Fishery Investigations (POFI) in conjunction with studies of the albacore tuna, Germo alalunga (Bonnaterre), in the central North Pacific Ocean. We found that the sounding tube recorded the maximum depth of the longline accurately and showed that the unit or basket of gear was skewed from a catenary. However, the skewness was not related to the environment

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[1] Fishery Research Biologist, Ocean Research, U. S. Fish and Wildlife Service, Stanford, California (formerly Fishery Aid, U. S. Fish and Wildlife Service, Honolulu, T. H.).

[2] The California Department of Fish and and Game and the following Bureau of Commercial Fisheries organizations: Branch of Exploratory Fishing and Gear Research, Division of Industrial Research and Services, Pascagoula, Miss., and Portland, Maine, and the Pacific Oceanic Fishery Investigations, Honolulu, T. H.

wherein the basket is thought to hang as a catenary, but it is suggested that readings in excess of fishing depth occurred during hauling. This difficulty is not insurmountable and a simple method is presented whereby the sounding tube may be fully utilized on longline. It is given to stimulate the study of the vertical distribution of tuna.

We are indebted to Herbert J. Mann (POFI) for his counsel on gear operations, and to the captains, crews, and scientific personnel of the Hugh M. Smith, John R. Manning, and Charles H. Gilbert for their excellent cooperation. We especially wish to thank Richard S. Shomura and Tamio Otsu of the scientific staff for their special efforts in the field.

THE SOUNDING TUBE

The chemical sounding tube, developed in conjunction with a sounding machine by Lord Kelvin (Sir William Thompson) to take soundings while underway, has a long history in oceanographic work (Knight 1945). The glass tube, coated on the inside with a water-soluble chemical, measures 640 mm. in length and 4 mm. in outside diameter and is a relatively simple and inexpensive[3] depth indicator. Its operation is based on the relation between pressure and depth in a column of water. When the tube, open at the bottom and closed at the top, is lowered beneath the surface, water is forced into the open end of the tube. The chemical coating on the inside of the tube is dissolved, thus leaving a line of demarcation at the level reached by the water. From this record of pressure, the depth to which the tube was lowered may be read directly from a calibration scale.

Figure 1 shows the essentials of sounding tube gear used in conjunction with POFI's longline fishing. When the tube is prepared for use it is broken at the scored lower end and then inserted in the brass casing. Small sections of rubber tubing are threaded upon the protruding ends of the tube to retain it in the casing. The casing is then strapped to the longline dropper with plastic tape. Upon retrieving the gear the tube is removed from the casing and placed in the slot of the calibration scale. The depth in fathoms, indicated by the demarcation line in the tube, is read from the scale.

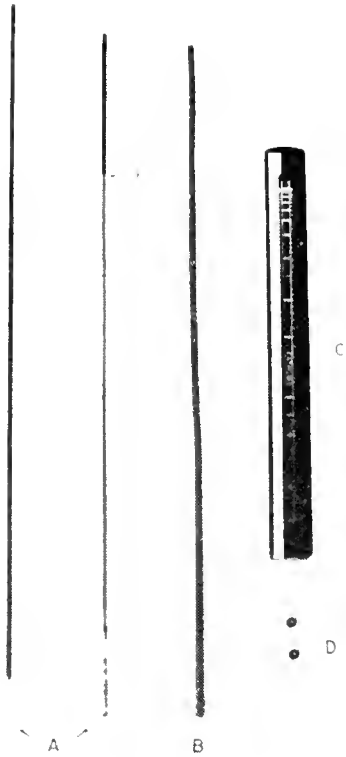

Figure 1.--Essentials of the sounding tube gear: (A) Glass sounding tube, (B) brass casing, (C) wooden calibration scale, (D) rubber hose. The tube on the reader's right has been submerged and shows a demarcation line (E).

Tests performed in the laboratory and in the field indicate that the sounding tube measures depth with considerable accuracy. Figure 2 shows regression lines calculated from laboratory and field data as compared with a theoretical line having a slope of 1. To obtain the laboratory data, 30 tubes were taken from POFI's stock, which represented portions of numerous orders. These were then divided into 6 lots, each of 5 tubes. By means of a pressure tank employed by the U. S. Navy to calibrate bathythermographs, pressures equivalent to depths of 100, 200, 300, 400, 500, and 550 feet were applied to the tubes. One lot of tubes was subjected to each depth equivalent. The resulting measurements of depth were read by three examiners. The difference between examiners was found to be statistically significant ($F = 3.40$, $P_{.05} = 3.11$), but was operationally small; the readings of the individuals did not differ more than 5 percent at any of the testing depths. It is difficult to evaluate this test in regard to field conditions since two of the examiners read the tubes one day following

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[3] Sounding tubes may be purchased commercially for $0.36 each and calibration scales for $1.75 each.

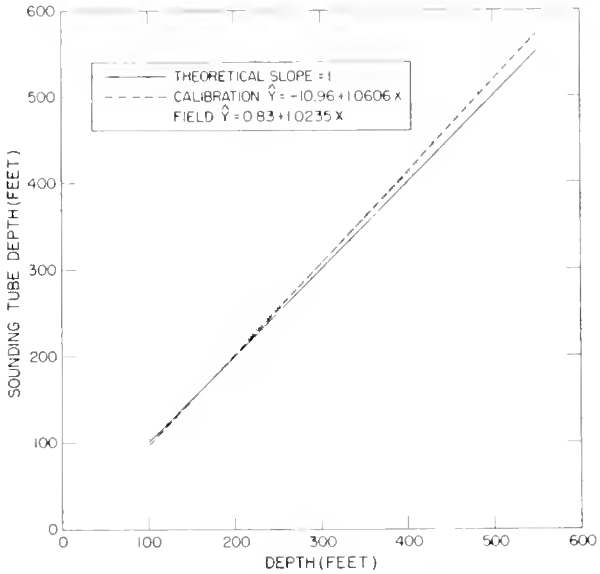

Figure 2.--Regression lines calculated from laboratory and field sounding tube data compared with a theoretical line having a slope of 1. Sounding tube depths are plotted along the y-axis. The x-axis represents depths recorded by bathythermographs and the calibration tank at Pearl Harbor.

the experiment while the author made his observations as the tubes were removed from the calibration tank. Also, one examiner had not read any tubes during the previous 2 years. However, the significant difference would suggest that special precautions should be taken to standardize readings of different observers in the field.

The regression line for the field data was calculated from observations obtained by Shomura and Otsu (1956) using bathythermographs as standards. Their data represent actual field conditions in that the sounding tubes were attached to bathythermographs and suspended with longline gear on fishing stations for the usual period of 5 to 6 hours. They found that their data varied about the theoretical line within the range of error of reading both the sounding tubes and the bathythermographs. The California Department of Fish and Game has also compared sounding tube measurements with those of bathythermographs and found tube readings to vary within 2 fathoms of bathythermograph readings (Anonymous 1955). The calibration line also agrees well with the theoretical line. Differences between the two lines are surprisingly small with variations ranging from 5 percent at 100 feet to no difference at 200 feet and to 4 percent at 500 feet.

APPLICATION TO LONGLINE GEAR

Eight albacore longline cruises have been made by POFI in the central North Pacific Ocean (Shomura and Otsu 1956, Graham 1957). Either 40 or 60 baskets of 13-hook gear (fig. 3) were set per longline station with 5- and 15-fathom floatlines alternated in groups of 5 to 10 baskets. During 5 of the 8 cruises, extra baskets with appropriate floatlines and with sounding tubes attached, generally on droppers 4, 7, and 10, were placed in each set. Hooks were omitted from the droppers of these baskets to prevent excessively deep readings due to the diving of captured fish and to preclude the danger from bare hooks during setting of the gear. It was felt that catches on adjacent baskets generally would not be able to submerge the relatively large buoys or floats (1' in diameter, 2' in length) used by POFI. Thus, these bore hooks and were baited. Such placement of the tubes afforded an opportunity to examine the conformation of the mainline in a representative number of baskets of longline gear.

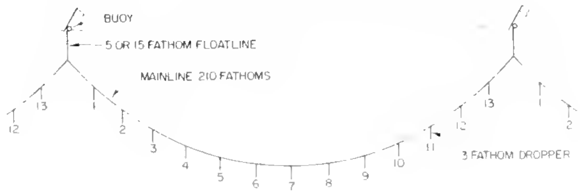

Figure 3.--A diagram of a basket of 13-hook albacore gear used by POFI in the central North Pacific. Leaders, 1-1/2 fathoms in length, are omitted from the above diagram. For a more detailed discussion of the gear consult Mann (1955).

In an ideal situation where, with the exception of gravity, no environmental forces are acting, the configuration of a basket of longline should be that of a catenary, exemplified by a chain hanging freely between two points of support. If it were found that such a gear approached a catenary under fishing conditions (Morita et al. 1955), then a simple method could be devised that would derive the maximum fishing depths of all the hooks on a given basket from a single sounding tube reading.

A scale model was constructed to determine whether the configuration of a basket of gear generally was that of a catenary. An area 25 inches in length and 12 inches in depth was marked off on graph paper having 10 divisions to the inch. Horizontally, the graph was scaled in feet (1 inch = 50 feet) to a portion of the mainline equivalent to a single basket of gear and vertically, from the maximum depth reading (600 feet) of the sounding tube scale (fig. 4). The graph paper backed by plywood was placed vertically against a wall. A unit of mainline was modeled from a silver chain (approximately 14 links to an inch and 1/8 inch in diameter) and the position of each hook marked; the droppers were omitted. With the omission of the droppers in the model, it was necessary to bring the tube readings up to the mainline depth. Therefore, all observed depths were adjusted by subtracting 9 feet, because sounding tubes were usually attached near the center of the 18-foot dropper. A pin, inserted through the link representing hook 7, was driven into the center of the graph at the observed depth for hook 7. The ends of the chain were brought up to and pinned at a depth representing the bottom of the floatline with hooks 4 and 10 of the chain passing through the observed depths obtained for those hooks. By removing the pin holding hook 7 and allowing the chain to swing freely to form a catenary, theoretical values for the 13 hooks could be determined. In this way the model permitted a comparison of the actual configuration of the mainline in the water, as shown by the tubes under fishing conditions, with that of a catenary having the same distance between its supports or buoys. Two very important considerations were thus taken into account by the method: one, that environmental forces may not act uniformly throughout the depth of the basket, and two, the distance between supports governs the configuration of the catenary.

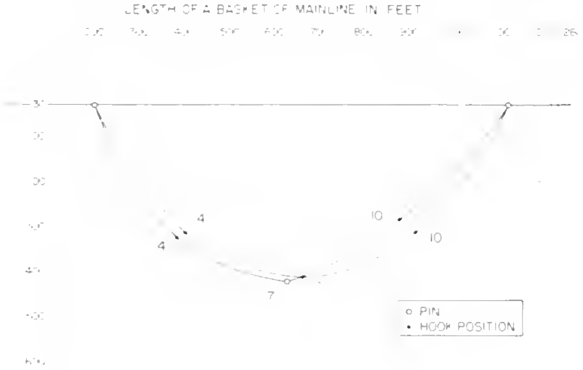

Figure 4.--The scale model, of silver chain, representing the mainline of a basket of longline gear. The method of using the model is explained in the text.

To ascertain whether the baskets of longline gear hung in a catenary, the observed (sounding tube) and theoretical values for hooks 4, 7, and 10 were paired and subjected to the "t" test. Depths, which were obtained from baskets skewed to the extent that either the chain would not reach, or it overshot the buoy line on one side or the other, were omitted from the statistical analysis since theoretical values could not be obtained. (These represented roughly 8 percent of the total number of baskets, which had sounding tube readings at all three hook positions.) A significant difference between any of the paired values would indicate that the baskets did not generally hang in the form of a catenary and the sign of the mean for each hook would suggest the direction that the basket deviated or skewed from the catenary. Table 1 summarizes the results of the "t" test and suggests that generally the baskets did not hang in a catenary. Hooks 7 and 10 show significant differences at the 1-percent level. The significance detected in hook 10 and the negative aspect of its mean difference are a reflection of the positive deviations observed in hook 4. This is illustrated in figure 4 where plots of a 5-fathom floatline basket show that a positive difference (observed > theoretical) in hook 4 is reflected by a negative difference

Table 1.--Summary of statistics for comparison of the mean differences (observed minus theoretical depth values). Lower comparison was carried out with values adjusted to the theoretical slope (fig. 2). Those "t" values attaining the 5-percent level and the 1-percent level of significance are noted by 1 and 2 asterisks respectively.

Hook number	Number of baskets	Mean difference (feet)	Standard deviation (feet)	"t" value
4	99	0.77	14.94	0.51
7	99	-7.03	20.06	3.48**
10	99	-4.75	15.73	3.01**
4	101[1]	1.99	15.32	1.31
7	101	-4.00	17.46	2.30*
10	101	-4.34	17.90	2.44*

[1] Two additional baskets, which previously did not reach or else overshot the floatline, were added to the analysis when adjustments to the theoretical depth were made.

(observed < theoretical) in hook 10 that is twice as large.

In a case where the gear is skewed toward one side, one would expect hook 7 to have a negative mean difference and a standard deviation somewhat smaller than hook 10. Because this is not so (table 1) it is likely that the error with depth shown by the sounding tubes in figure 2 must be unduly influencing the analysis. The data presented in the lower half of table 1 were obtained after an adjustment to the theoretical slope was made. The results were those anticipated; accompanied by a reduction of significance to the 5-percent level.

CAUSES OF SKEWNESS AND EXCESSIVE READINGS

The results show that generally the conformation of baskets of longline fished by POFI was not a catenary. It is thought that the sounding tubes were accurately recording the depths of the gear. Therefore, the cause of skewness noted in the baskets must be related to the environment or operative procedures. The relatively moderate environmental conditions encountered on longline stations during all seasons of the year suggest the latter was responsible (table 2).

However, a more detailed analysis of environmental factors was obtained by determining a measure of skewness, or the difference in feet between the depths of hooks 4 and 10 of the hookless baskets. In order that each set be comparable, only the hookless basket placed between baskets 25 and 26 or close to that position[4] was used in the analysis. Omitted from analysis were data from each hookless basket whenever, on the model, the mainline did not reach, or it overshot the buoy line. Skewness was then compared with a measure of current velocity (the mean longline drift), with possible decrease in current speed at the thermocline resulting in a shearing effect (the ratio of the depth of hook 7 of the hookless basket to the depth of the top of the thermocline)

Table 2. --The average and range of certain physical conditions of longline stations during albacore fishing cruises in the central North Pacific

Cruise	Period	Total stations	Sea[1]		Winds, knots		Mean longline drifts, knots
			Mean	Range	Mean	Range	
Manning-19	1/15- 3/11/54	16	3.1	1-6	11.4	2-24	0.09
Manning-22	9/13- 11/9/54	16	3.1	1-5	17.1	4-35	0.12[2]
Manning-23	12/1- 12/21/54	18	3.2	1-5	15.4	5-24	0.29[3]
Manning-25	5/2- 6/9/55	18	2.2	1-4	8.5	3-14	0.42
Manning-26	7/15- 9/7/55	38	2.7	1-5	11.1	1-24	0.30
Smith-29	5/2- 6/22/55	30	2.7	2-4	15.9	6-30	0.44
Gilbert-23	9/15- 11/2/55	8	2.4	1-4.5	15.1	10-28.5	0.36
Gilbert-27	3/15- 5/4/56	7	2.7	2-4	13.6	8-19	0.24

[1] Coded; for values in feet see Hydrographic Office Observers' Manual, U. S. Navy Hydrographic Office, H. O. Pub. No. 606-c, 1951.

[2] This mean was computed with the omission of station 28 because the drift was undetermined.

[3] This mean was computed with the omission of stations 13 and 17 because the drifts were undetermined.

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[4] In Hugh M. Smith cruise 29 and Charles H. Gilbert cruise 23 the hookless basket was placed at times between 24 and 25 or 26 and 27.

and with wind speed[5]. The three comparisons yielded low, non-significant correlation values suggesting that these effects individually were not related to the skewness observed in the baskets (r = 0.039, r = -0.055, and r = 0.055 respectively).

On the other hand, certain events in retrieving the gear, which could not be evaluated statistically, appeared closely associated with skewness of the baskets. Figure 5 shows three general directions at which longline gear was hauled aboard the POFI vessels: (1) Off the bow with the vessel's speed equalling the speed at which the line is brought in; (2) off midships with the speed of retrieving somewhat slower than that of the vessel; and (3) with the line astern and coming in much slower than the speed of the vessel. Differences in position between number 1 and 2 probably do not have any important effects on sounding tube measurements since the line is retrieved while at or above the maximum fishing depth. But, between 2 and 3, we believe that the vessel actually closes up the buoys of a basket and allows the mainline to sink. Since part of the line would be under tension from the line hauler only a portion would sink; which portion would depend on many conditions such as the speed of the line hauler, the distance between the "lay" of the longline and the parallel course of the vessel, etc.

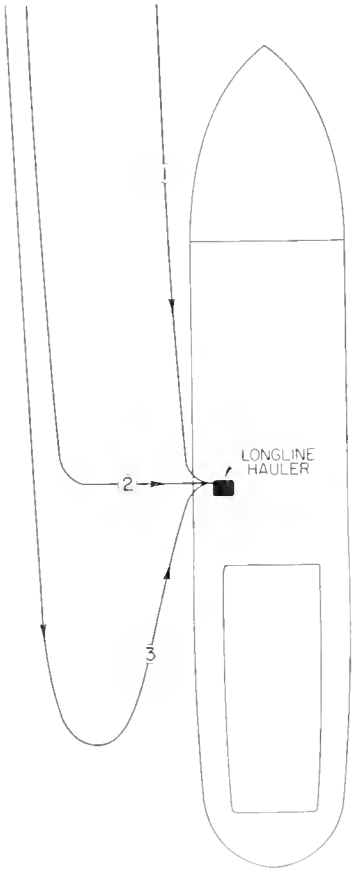

Figure 5.--Three general positions at which longline gear is retrieved: (1) Off the bow; (2) abeam; and (3) astern.

In addition to the effects on the line by the normal hauling procedure, disrupted retrieving could be responsible for obtaining sounding tube readings exceeding the depth at which the longline actually fished. On some longline stations, sounding tubes were attached on hook 7 position (hooks were omitted) at intervals along the set. In a few cases a sufficient number of tubes were attached to allow an examination of the "lay" of the entire mainline. Figure 6 shows the unadjusted depth distribution of hook 7 on baskets of four longline stations. Each station or set was made up of 40 baskets of longline with one hookless basket (unnumbered in fig. 6) inserted between baskets 25 and 26. Stations 17 and 18 of the *Manning* cruise 25 were occupied on consecutive days, as were stations 32 and 33 of the *Gilbert* cruise 27.

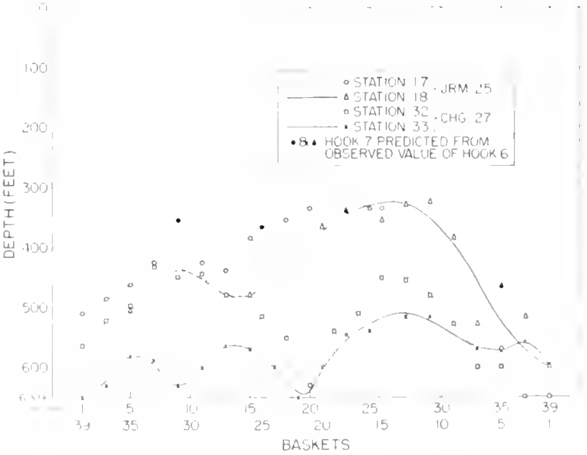

Figure 6.--Depth distribution of hook 7 on baskets of longline at stations 17 (31°36'N., 165°16'W.) and 18 (33°40'N., 165°32'W.) of the *John R. Manning* cruise 25, and 32 (34°31'N., 162°50'W.) and 33 (32°16'N., 163°04'W.) of the *Charles H. Gilbert* cruise 27.

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[5] Wind direction was ignored. It is a general practice on POFI vessels to set longline gear downwind and the vessel captains were reasonably successful in doing so. Of 98 sets made, 80 percent were with, to abeam of the wind and only 20 percent against, to abeam of the wind.

Five-fathom floatline gear was set first on station 17 whereas 15-fathom gear was set first on station 18; a like sequence was followed on stations 32 and 33. Thus, to compare similar gear types along the sets, stations 18 and 33 were plotted in the reverse of stations 17 and 32. The paired stations show considerable consistency and, with the exception of station 33, probably are fairly accurate descriptions of the "lay" of the gear in the water. The ends and center of the sets were deep and separated by two plateaus. This configuration is undoubtedly related to the alternation of a 5-fathom and 15-fathom floatline gear in groups of 10 baskets. Station 33 shows an additional trough and, in general, is considerably deeper throughout than station 32.

Line hauler trouble developed at basket 21 of this set and continued throughout the retrieving to the extent that parts of the gear were hauled by hand. Possibly the line was retrieved primarily from astern and the gear allowed to sink below the maximum fishing depth; or the hauling was so slow as to permit an effect similar to creating another end in the set. Figure 6 shows that the ends of the sets sank deeper than the center. Presumably this occurred because at the center a basket of gear has more or less equal tension applied on either side. However, toward the end of the set there are less baskets and thus less tension on one side of an individual basket than the other. This allows the buoys of the baskets near the ends of the set to close in toward the center dropping their mainline to depths greater than that of the same floatline gear in the center of the set. Operations with POFI longline gear in the equatorial Pacific show that an interruption of 30 minutes during hauling, at which time the gear is freed from the vessel, is sufficient to allow the newly formed end to register depths considerably greater than those shown by tubes on the gear hauled just before the break. When mainline breaks occur the new end formed must be retrieved rapidly to avert a deepening of the gear. Usually, the new ends caused by breaks were retrieved within 5 to 20 minutes during POFI albacore cruises.

Mechanical troubles are not alone responsible for such discrepancies because retrieving of the gear is sometimes delayed for varying periods of time during stormy weather and for the removal of large numbers of fish. Large fish may sound when captured on the longline and could increase the readings of sounding tubes if they were attached to the same dropper as the fish. The effect of the capture of a large number of tuna on longline gear was described by Bullis (1955, fig. 15b). He shows Echograph depth records of 10 baskets of longline in which 9 of the baskets approximated complete catenaries. The fifth basket was distorted with only a portion of the basket being recorded. This basket contained one yellowfin and four "blackfin tuna" while the others had no catch. It is noteworthy that the capture of fish on this one basket did not affect the adjoining baskets.

CONCLUSIONS

It is concluded that the maximum fishing depths of POFI longline, during albacore survey cruises, were recorded by sounding tubes with sufficient accuracy to locate the general depths at which the various sets of gear fished. They also showed the configuration of the baskets to deviate from a catenary. This deviation is thought not to have occurred during the fishing period but rather during retrieving operations when slack formed in hauling allowed a portion of the gear to sink below the maximum fishing depth. Also, deepening of gear below the maximum fishing depth presumably occurred when operational breakdowns or requirements formed a new end to a set. The above analysis is relatively simple and it cannot be ascertained whether the results obtained would be applicable to the longline operations of others. But, possibly most of the error in the catenary could be avoided merely by placing two tubes on a basket of gear on a pair of the shallower hooks, such as 3 and 11 in albacore gear, and accepting only the shoalest reading of the two. In this case, the estimation of individual hook depths from sounding tube readings might be reliable in areas where the physical environment did not distort the "hang" of a basket of gear.

Figure 7 shows the ideal relation of hook depths to the distance between buoys for hooks number 2 and 12, 4 and 10, and 7 without droppers and with 5- and 15-fathom floatlines. The curves were determined empirically using the scaled chain and plotting board described above (fig. 4). With these curves it would be possible to derive theoretical buoy distances from a given sounding tube reading for the above hooks. The scale model of a longline basket could then be pinned at the appropriate buoy interval on the plotting board and the theoretical depths for all hooks of that basket estimated. Reasonable extrapolation between baskets bearing sounding tubes would permit estimation of hook depths for an entire set of longline gear.

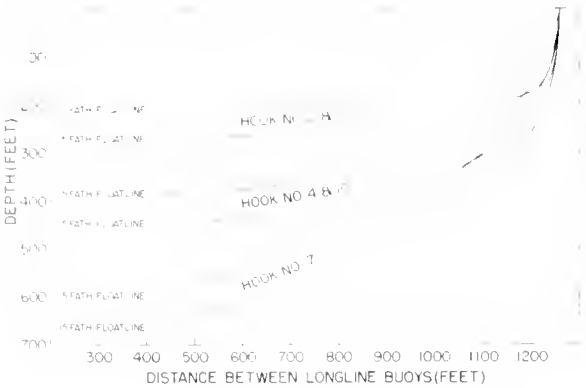

Figure 7.--The theoretical relation of the distance between buoys to the depths of various hooks on a basket of albacore longline. Droppers have been omitted.

SUMMARY

1. A brief summary of methods used to estimate the fishing depth of longline by various investigators is given.

2. Comparisons of field data with laboratory tests show that sounding tubes measure depth of longline gear in the field with considerable accuracy.

3. A method used to plot the observed "hang" of a given basket of gear and the theoretical "hang" is described. The results obtained suggest that the configuration of the mainline in the individual baskets does not conform to a catenary. We conclude that the skewness in the shape of the line did not occur during the fishing period, but rather during retrieving operations when slack formed in hauling allowed a portion of the gear to sink below the maximum fishing depth. It is suggested this may be averted by placing sounding tubes on a pair of the shallower hooks in a basket of gear and accepting the shoalest reading of the two.

4. It is suggested that in areas where the environment, such as currents and winds, does not distort the "hang" of a basket of longline, maximum fishing depths for individual hooks along an entire set can be estimated. An applicable method is given.

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APPENDIX

Table 3.--Analysis of variance to determine whether observers read sounding tubes with the same degree of accuracy

Source	Degrees of freedom	Sum of squares	Mean square	F	$P_{.05}$
Total	89	2,574,995.90	-	-	-
Depths	5	2,573,391.52	514,678.30	-	-
Examiners	2	122.71	61.35	0.68	1.97
Interaction	10	128.74	12.87	-	-
Individuals	72	1,352.93	18.79	-	-
Interaction not significant, so variance pooled:					
Examiners	2	122.71	61.35	3.40*	3.11
Individuals	82	1,481.67	18.07		

* Difference between examiners significant at .05 level.

Table 4.--Observed (sounding tube) and theoretical (computed) hook depths for cruise 23 of the *Charles H. Gilbert*

Station	Hookless gear between baskets	Float-line gear (fm.)	Hooks: Observed depth (feet)			Hooks: Theoretical depth (feet)			Computed buoy distance (feet)
			4	7	10	4	7	10	
16	6- 7	5	-	342	282	-	-	-	-
	16-17	15	324	408	294	320	388	320	1,060
	26-27	5	246	312	264	255	320	255	1,072
	36-37	15	342	414	348	344	422	344	1,005
17	5- 6	5	-	504	312	-	-	-	-
	15-16	15	264	354	312	295	352	295	1,107
	25-26	5	216	324	312	279	353	279	1,024
	35-36	15	384	364	294	350	431	350	993
18	5- 6	15	372	468	390	360	462	360	599
	15-16	5	258	348	288	278	350	278	1,028
	25-26	15	366	504	366	375	475	375	915
	35-36	5	300	402	312	308	400	308	944
19	5- 6	15	354	438	354	354	438	354	984
	15-16	5	282	354	276	278	353	278	1,026
	25-26	15	354	444	378	365	455	365	950
	35-36	5	294	390	306	300	387	300	971
20	5- 6	5	330	420	342	333	446	333	950
	15-16	15	324	414	324	330	400	330	1,043
	25-26	5	240	312	240	245	305	245	1,093
	35-36	15	354	480	378	363	452	363	954
27	5- 6	15	294	336	294	292	356	292	1,112
	15-16	5	168	192	156	163	195	163	1,200
	25-26	15	270	294	246	259	300	259	1,160
	35-36	5	234	288	252	243	300	243	1,098
28	5- 6	15	-	-	354	-	-	-	-
	15-16	5	228	282	228	228	279	228	1,113
	35-36	5	306	354	264	288	367	288	1,003
29	5- 6	5	378	528	342	365	525	365	650
	15-16	15	462	564	438	-	-	-	-
	25-26	5	-	-	384	-	-	-	-
	35-36	15	-	-	426	-	-	-	-

Table 5.--Observed (sounding tube) and theoretical (computed) hook depths for cruise 27 of the Charles H. Gilbert

Station	Hookless gear between baskets	Float-line gear (fm.)	Hooks						Computed buoy distance (feet)
			Observed depth (feet)			Theoretical depth (feet)			
			4	7	10	4	7	10	
1	5- 6	5	306	444	348	331	443	331	854
	15-16	15	396	492	378	385	492	385	881
	25-26	5	312	414	318	315	415	315	919
	35-36	15	438	564	438	433	607	433	574
3	5- 6	15	444	594	444	440	633	440	485
	15-16	5	330	498	402	-	-	-	-
	25-26	15	-	624	504	-	-	-	-
	35-36	5	420	534	342	-	-	-	-
5	5- 6	5	294	516	-	-	-	-	-
	15-16	15	453	-	-	-	-	-	-
	25-26	5	354	564	408	-	-	-	-
	35-36	15	456	594	444	-	-	-	-
6	5- 6	15	504	>600	444	-	-	-	-
	9-10	5	-	534	426	-	-	-	-
	25-26	15	426	486	372	401	522	401	815
	35-36	5	336	474	330	339	455	339	828
8	5- 6	5	372	516	384	377	559	377	540
	15-16	15	372	>600	552	-	-	-	-
	25-26	5	402	558	384	-	-	-	-
	35-36	15	384	594	426	422	570	422	692

Table 6.--Observed (sounding tube) and theoretical (computed) hook depths for cruise 25 of the John R. Manning

Station	Hookless gear between baskets	Float-line gear (fm.)	Hooks						Computed buoy distance (feet)
			Observed depth (feet)			Theoretical depth (feet)			
			4	7	10	4	7	10	
1	25-26	5	186	216	150	176	213	176	1,192
3	"	15	-	-	246	-	-	-	-
5	"	15	402	504	384	392	503	392	860
7	"	5	348	354	306	324	430	324	837
9	"	5	318	414	324	320	418	320	866
11	"	5	150	186	174	162	193	162	1,205
13	"	15	294	306	252	275	325	275	1,138
15	"	5	258	336	270	266	336	266	1,050
17	"	15	294	378	306	305	364	305	1,092
18	"	5	270	348	282	276	350	276	1,031
19	26-27	15	384	396	-	-	-	-	-
20	25-26	15	390	426	324	360	450	360	964
21	"	5	390	444	288	-	-	-	-
22	"	15	378	474	360	372	467	372	925

Table 7.--Observed (sounding tube) and theoretical (computed) hook depths for cruise 26 of the <u>John R. Manning</u>

Station	Hookless gear between baskets	Float-line gear (fm.)	Hooks						Computed buoy distance (feet)
			Observed depth (feet)			Theoretical depth (feet)			
			4	7	10	4	7	10	
1	25-26	15	474	>600	486	-	-	-	-
2	"	5	324	426	282	312	409	312	923
4	"	15	432	534	432	426	588	426	637
6	26-27	15	342	474	378	366	459	366	948
8	25-26	5	300	-	276	-	-	-	-
10	"	15	336	402	330	333	405	333	1,035
12	"	5	330	438	366	346	474	346	784
14	"	15	402	480	360	384	488	384	887
16	"	5	318	414	324	319	420	319	907
18	"	15	402	516	390	397	515	397	830
24	"	5	306	372	288	296	382	296	975
26	"	15	414	534	402	407	537	407	781
28	"	5	306	402	288	301	392	301	960
30	"	5	270	-	318	-	-	-	-
32	"	15	384	486	384	385	488	385	891
34	"	15	354	420	-	-	-	-	-
36	"	5	312	390	-	-	-	-	-
38	"	15	384	474	360	374	471	374	917
40	"	15	-	486	-	-	-	-	-
42	"	5	306	366	294	298	383	298	974
43	"	5	282	366	282	289	370	289	996
48	"	5	360	444	330	343	470	343	793
50	"	15	384	444	342	384	490	384	883
51	"	5	336	396	306	319	418	319	906
53	"	15	402	516	402	401	522	401	814
54	"	5	336	426	324	328	440	328	861
55	"	15	426	564	504	-	-	-	-
57	"	5	258	330	246	256	320	256	1,071
59	"	15	432	558	402	418	566	418	701
61	"	5	258	324	258	258	322	258	1,067
63	"	15	426	534	360	408	548	408	774
64	"	5	324	408	282	308	401	308	937
65	"	15	432	570	432	422	582	422	643
66	"	5	288	402	312	303	395	303	953
67	"	15	402	534	402	402	530	402	793
68	"	5	240	306	234	240	299	240	1,096
69	"	15	426	540	414	420	567	420	698

Table 8.--Observed (sounding tube) and theoretical (computed) hook depths for cruise 29 of the *Hugh M. Smith*

Station	Hookless-gear between baskets	Float-line gear (fm.)	Hooks						Computed buoy distance (feet)
			Observed depth (feet)			Theoretical depth (feet)			
			4	7	10	4	7	10	
1	25-26	15	258	282	234	245	285	245	1,178
5	"	15	378	474	366	374	470	374	923
7	"	5	210	264	222	218	267	218	1,136
9	24-25	15	318	408	324	325	395	325	1,050
13	25-26	5	318	396	306	310	406	310	933
15	24-25	5	330	492	354	348	477	348	782
16	"	15	408	462	342	380	484	380	898
19	"	5	-	306	246	-	-	-	-
21	25-26	15	318	408	324	325	395	325	1,050
23	"	5	324	372	276	300	389	300	963
25	"	15	444	582	444	440	642	440	446
27	"	5	276	354	264	273	346	273	1,034
29	"	15	420	594	414	422	574	422	684
36	"	15	342	474	372	365	455	365	951
37	"	5	288	378	288	290	370	290	1,002
39	"	15	330	402	318	325	394	325	1,057
41	"	5	300	408	300	305	395	305	952
42	"	5	360	462	336	349	477	349	775
43	"	15	396	522	444	425	582	425	632
44	"	5	288	366	282	295	378	295	982
45	"	15	426	558	402	417	562	417	712
46	"	5	324	432	330	331	434	331	873
47	"	15	396	552	438	420	566	420	686
48	"	5	312	414	-	-	-	-	-
49	"	15	426	474	354	400	518	400	822
50	"	5	318	396	300	308	400	308	942

Table 9.--A comparison of skewness[1] with current velocity or longline drift, shearing[2] and wind speed for the *John R. Manning* cruises 25 and 26, the *Charles H. Gilbert* cruises 23 and 27, and the *Hugh M. Smith* cruise 29

Cruise	Period	Station	Skewness	Mean drift velocity (knots)	Possible shearing effect	Wind speed (knots)
Manning-25	5/2-6/9/55	1	36	0.60	2.667	3
		5	18	1.26	1.143	3
		7	42	0.69	1.600	5
		9	6	0.33	1.411	14
		11	24	0.33	3.000	4
		13	42	0.13	1.846	14
		15	12	0.35	1.714	13
		17	18	0.21	1.500	7
		18	12	0.32	0.400	7
		20	66	0.38	1.333	10
		21	102	0.48	1.333	9
		22	18	0.27	1.200	6
Manning-26	7/15-9/7/55	1	12	0.38	0.208	19
		2	42	0.39	0.294	19
		4	0	0.0	0.286	13
		6	36	0.24	0.263	13
		10	6	0.35	0.312	8
		12	36	0.50	0.222	13
		14	42	0.41	0.210	8
		16	6	0.43	0.235	13
		18	12	0.24	0.190	8
		24	18	0.24	0.267	13
		26	12	0.0	0.238	5
		28	18	0.0	0.375	5
		32	0	0.0	0.210	8
		34	84	0.68	0.235	13
		38	24	0.29	0.263	13
		42	12	0.18	0.333	13
		43	6	0.79	0.333	19
		45	90	0.44	0.167	19
		48	30	0.20	0.222	13
		50	42	0.43	0.222	24
		51	30	0.31	0.250	19
		53	0	0.53	0.286	13
		54	12	0.47	0.588	13
		55	78	0.13	0.261	8
		57	12	0.10	1.231	8
		59	30	0.31	0.273	5
		61	0	0.38	0.385	8
		63	66	0.31	0.143	5
		64	42	0.11	0.250	5
		65	0	0.24	0.217	5

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[1] A measure determined by the difference of hook 4 and 10 of hookless baskets between baited baskets 25 and 26.

[2] A measure determined by the ratio of the depth of hook 7 to the depth of the top of the thermocline.

Table 9. --A comparison of skewness with other factors affecting the longline (cont'd)

Cruise	Period	Station	Skewness	Mean drift velocity (knots)	Possible shearing effect	Wind speed (knots)
Manning-26 (cont'd)	7/15-9/7/55	66	24	0.16	0.062	13
		67	0	0.17	0.143	8
		68	0	0.30	0.167	1
		69	12	0.43	0.364	8
Gilbert-23	9/15-11/2/55	16	18	0.39	0.417	11
		17	96	0.27	0.385	12
		18	0	0.38	0.300	12
		19	24	0.35	0.333	10
		20	0	0.36	0.500	13
		27	24	0.29	0.667	28.5[3]
Gilbert-27	3/15-5/4/56	1	6	0.26	0.353	8
		3	120	0.15	0.541	10
		5	54	0.12	0.478	13
		6	54	0.0	0.650	19
		8	18	0.0	0.087	14
Smith-29[4]	5/2-6/22/55	1	24		2.182	16
		5	12		1.263	16
		7	12		2.182	13
		9	6		1.500	11
		13	12		1.500	19
		15	24		1.263	30
		16	66		1.333	9
		21	6		0.188	19
		23	58		0.267	18
		25	0		1.043	19
		27	12		1.714	16
		29	12		1.000	20
		36	30		0.263	23
		37	0		3.333	11
		39	12		0.200	9
		41	0		1.375	11
		42	24		0.889	19
		43	48		1.048	17
		44	6		1.600	14
		45	24		1.091	14
		46	6		1.412	16
		47	58		1.091	6
		49	78		1.263	24
		50	18		1.500	22

[3] This is the mid-point of 17 and 40 knots, the range of the wind speed during the fishing time of this set.

[4] There were no readings of the mean drift velocity for Smith cruise 29 because the raw data were unreliable.