7107

Development and Testing of the Hybrid Tuna Purse Seine

Mise au point et essais de la seine coulissante hybride a thon

Les échecs observés dans un pourcentage élevé des coups de seines à thon effectués par les Américains sont à l'origine du projet d'étude d'une seine coulissante à thon expérimentale. La mise au point du projet a été réalisée au moyen de modèles à l'échelle. La fabrication et les essais en grandeur réelle de la seine sont décrits. Ce filet diffère des seines à thon américaines classiques sur les points suivants: (1) alèze plus légère, (2) coefficient d'armement plus faible, (3) ailes d'extrémités coupées en diminution, (4) assemblage des bandes de fond avec reprises de mailles progressives, (5) ralingues de flotteurs et de plombs d'égale longueur, (6) anneaux de boursage en bout du filet et (7) fixation des anneaux de coulisse en retrait des extrémités. Cette combinaison fournit une seine qui plonge plus vite, pêche plus profondément, et présente une meilleure configuration générale que les seines à thon classiques. On est venu à bout des difficultés apparues dans la manoeuvre et dans le sauvetage des dauphins capturés avec les thons en éliminant la particularité d'assemblage avec reprises de mailles.

Construcción y ensayo de una red de cerco hibrida para la pesca del atun

Un porcentaje elevado de los lances efectuados en la pesqueria de atún norteamericana con redes de cerco de jareta no tiene éxito. Esto indujo a realizar un proyecto experimental con redes atuneras de cerco de jareta. El desarrollo del disèño se efectuó mediante el empleo de modelos a escala reducida. Se describe la construcción y ensayo de redes de cerco de tamãño natural. Estas redes de cerco se diferencian de las que normalmente se fabrican para tal fin en los Estados Unidos enque tienen: (1) paños más ligeros; (2) un menor coeficiente de armadura; (3) los extremos de las alas en disminución; (4) incremento de la armadura con el empleo de cadenetas inferiores que van en disminución; (5) relinguas superior e interior de iqual longitud; (6) anillas en los extremos; (7) las anillas principales de la jareta colocadas en los extremos de la red. Esta combinación produce una red de cerco que se sumerge con más rapidez, pesca a mayor profundidad y da una mejor configuración total que las redes de cerco normales para pescar atún. Las dificultades que supone su manejo y la recogida de las marsopas capturadas junto con los atunes se resolvieron eliminando el empleo de cadenetas reducidas. Los ensayos de pesca indicaron que aumentaran las posibilidades de éxito utilizando esta nueva red de cerco.

COMPARATIVELY little technological research has been done on purse seines despite the fact that they take increasingly larger portions of the world's catch of fish. Observed differences in performance and construction of existing purse seines and rates of success (percentage of sets catching at least ½ ton) of purse seine sets for tuna in the eastern tropical Pacific Ocean as low as 50 to 60 per cent led to a project to improve the design of these tuna purse seines (Ben-Yami and Green, 1968). This project is here summarized.

DESIGNING HYBRID PURSE SEINE

It was decided to work on a seine design intended for "school fish", as opposed to one intended for tuna associated with porpoise ("Porpoise" refers to tuna associated with porpoise (Perrin, 1969) as opposed to pure schools of tuna. In porpoise fishing, the net is set on a porpoise school for the tuna found beneath them. If the set is successful, the problem is then to separate porpoise from tuna).

The experimental phase of the study (Ben-Yami and Green, 1968) consisted of testing two model purse seines underwater. The first, Model I, was a 1:25 scale model of the standard California tuna purse seine. After testing, it was reworked to form Model II in an effort to produce a better combination of performance characteristics. This experimental approach was based on the assumption that should two different seines be scaled down in a uniform manner, the main differences in performance between the models would parallel those between the full-scale nets. In Model II, the main alteration consisted of varying hanging coefficients (k_h) (hanging coefficient k_h: ratio of stretched length of adjacent sections of webbing or ratio of length of line to stretched length of adjacent webbing (Ben-Yami, 1959)), from 0.7 at the top to 0.9 at the bottom (see Table 1), introducing gavels (vertical lines at the net ends, which can be pursed separately), and tapering the body. Total size, ballast and other common components were not changed.

TABLE 1. CONVERSION OF HANGING COEFFICIENT (K_h) TO "HANG-IN" PERCENTAGE

k_h	*Hang in* (%)
0.62	60
0.7	43
0.75	33
0.78	28
0.79	27
0.8	25
0.83	20
0.85	18
0.86	16
0.87	15
0.9	11
0.91	10

Comparative tests indicated that Model II sank at twice the rate of Model I and offered a smaller escape opening at its ends while retaining the acceptable pursing performance of Model I. In addition, the working depth was less sensitive to horizontal strains observed on the netting in Model II than in Model I.

Results indicate that k_h is probably the most important design variable affecting sinking speed, area encircled, and pursing performance. Low k_h allows a faster sinking rate and greater area of encirclement during later stages of the set. It also causes the leadline to rise earlier during pursing. High k_h gives the opposite effects. Many other factors affect these and other performance characteristics such as weight of ballast, size of mesh, and size of twine.

The above mentioned factors were considered in the final design and manufacture of a hybrid purse seine, which essentially is a scaled-up Model II combined with design features from various other purse seine types.

HYBRID TUNA PURSE SEINE IN COMPARISON WITH U.S. TUNA PURSE SEINE

The main features of the hybrid seine which differentiate it from existing U.S. tuna seines are:

1. Lighter netting
2. Low k_h
3. Tapering of the lower four strips of netting
4. Incremental "hang-in" in the lower four strips
5. Floatline and leadline equal in length
6. Gavels or "breastlines" used at both ends
7. No main rings or bridles connected to the first and last 35 fm of seine.

Lighter Netting

The typical U.S. tuna seine is made up of seven or eight strips, each 100 meshes deep (MD) laced in horizontally, which extend full depth to the extreme ends of the seine. The ends are then baited to a short, 125 mesh long by 15 MD, border, which in turn is laced to a metal triangle. No tapers are used (fig 1, McNeely, 1961).

The hybrid seine (fig 2) was constructed of 100 per cent nylon netting of knotless braided construction. The main body of netting was laced into horizontal, 100 MD strips, except for the two bunts, which were laced in vertically to attain the maximum strength. Strength is needed at that point, as the maximum strain occurs there when drying the bunt prior to brailing. The maximum strength is achieved "with the run" (longitudinal) in knotless netting, which is opposite of that in knotted netting.

The top and bottom borders are 5 in. stretched mesh (M) 10-½ MD #54 (4,022 Tex) nylon netting and 5 in. M, 10-½ MD, #72 (5,512 Tex) nylon netting is used in the gavels at the extreme ends. Twine sizes were increased to #36 (2,706 Tex) and #42 (3,543 Tex) in the 100 fm (183 m) forward of the bunts (rolling strips). The top strip is #36 (2,706 Tex) because this is the area of greatest wear. The four strips in the bottom portion were reduced to #24 (1,984 Tex) twine. The centre bunt is #54 (4,022 Tex) and the main bunt is #60 (4,377 Tex). The netting requirements were planned with the idea of keeping the twine sizes as light as possible, while strengthening the areas of greater strain such as the perimeters and the rolling strips adjacent to the bunts.

Netting twine presently used in conventional tuna seines is rarely lighter than #42 (3,543 Tex) except in the rolling strips, where #54, #60, and #72 (4,022, 4,377, and 5,512 Tex) are used. The bunts and border strips are made up of #84, #96, and #120 (7,440, 9,921, and 11,023 Tex) nylon. The twine sizes used depend on vessel size and its ability to handle bulk and weight and stacking space available.

The lightness of netting and the mesh sizes, together with the weight of leadline, play a direct role in the sink rate of the seine. Thus, to enhance the sink rate the seine should be constructed of the lightest netting possible.

Lower k_h and Tapers

Standard tuna seines are hung using a k_h of 0.87 to 0.91. The k_h used depends on individual preference and varies from vessel to vessel. The body strips are usually laced together at k_h 1 except the seams which are laced to the float and leadline border strips. A common practice is to lace one or two meshes of extra netting every 2 fm to the border strips. This is done primarily because it is assumed that the heavier border strips shrink slightly more than the adjacent lighter strips. Should this premise be true, then the lacing ratio of all seams after shrinkage should be about 1:1.

The hybrid seine (fig 2) was hung at a k_h of 0.85 for the first 35 fm (64 m) at each end, followed by $k_h = 0.80$ for the next 15 fm (27 m). The extra tightness in the ends takes some of the strain from the leadline and floatline and allows easier hauling. The centre portion was hung at $k_h = 0.75$ with the exception of the centre bunt, which was 0.78. This was done to cut down undue bagging at the bunt, thus making it easier to "dry up" the seine for brailing.

The lower four strips (100 MD each) of the hybrid seine were started and ended with two bar, one mesh tapers (fig 2). Each taper was approximately 10.5 fm (19.2 m) long graduating from one mesh to 100 MD over this span. This deepened the hybrid seine by 400 meshes over a taper span of 42 fm (77 m) on each end. These tapers worked extremely well and are considered one of the best features of the new seine. Tapers eliminate unnecessary accumulations of netting at the ends of the seine as well as enabling maximum fishing depths precisely where they are most needed. The elimination of netting at the ends is also a great aid to drying up the catch prior to brailing. For further discussion of tapers the reader is referred to Jurkovich (1967).

An incremental "hang-in" was used in the lower four strips (100 MD) of the hybrid seine. The fifth strip was laced to the sixth strip at the rate of 30 meshes of the bottom of the fifth strip to 29 meshes of the top of the sixth strip (fig 2). The other lower strips were laced together in the same manner. This resulted in a progressive .967 reduction in each of the lower four strips which in turn reduced the k_h at the leadline to approximately 0.86.

Float- and leadlines

The hybrid seine was hung to a chain leadline 450 fm (823 m) long. This leadline was made up of 105 fm (192 m) of ⅜ in (9.5 mm) dia galvanized proof coil chain at each end adjoining two 92 fm (168 m) pieces of $\frac{7}{16}$ in (11.1 mm) dia chain with 66 fm (121 m) of ½ in (12.7 mm) chain in the centre portion (fig 3).

The floatline was also 450 fm (823 m) long. Its centre was ⅝ in (15.9 mm) dia, three strand nylon rope 374 fm (684 m) long spliced to two 26 fm (48 m) pieces of ¾ in (19.0 mm) dia three strand nylon and was terminated with two 17 fm (31 m) pieces of ⅞ in (22.2 mm) dia three strand nylon rope. All lines were cut into shorter lengths for easier stringing of floats.

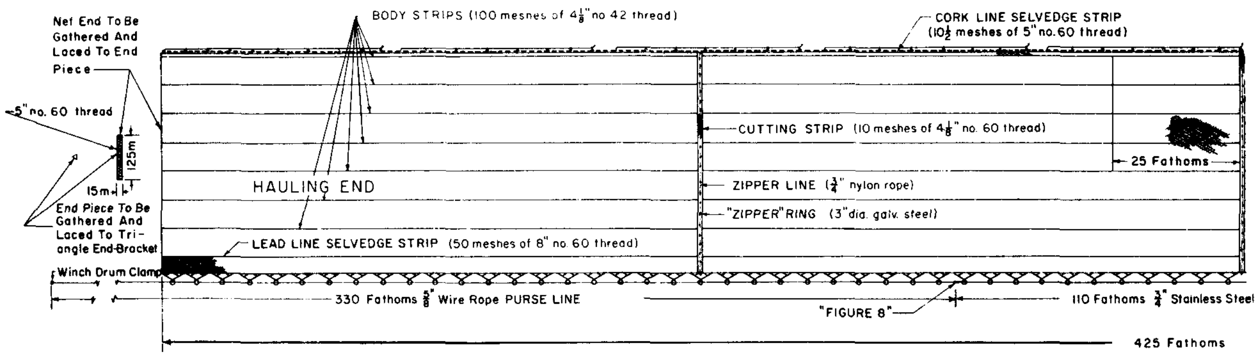


Fig 1. Standard U.S. tuna purse seine constructed of seven or eight strips each 100 meshes deep
M=

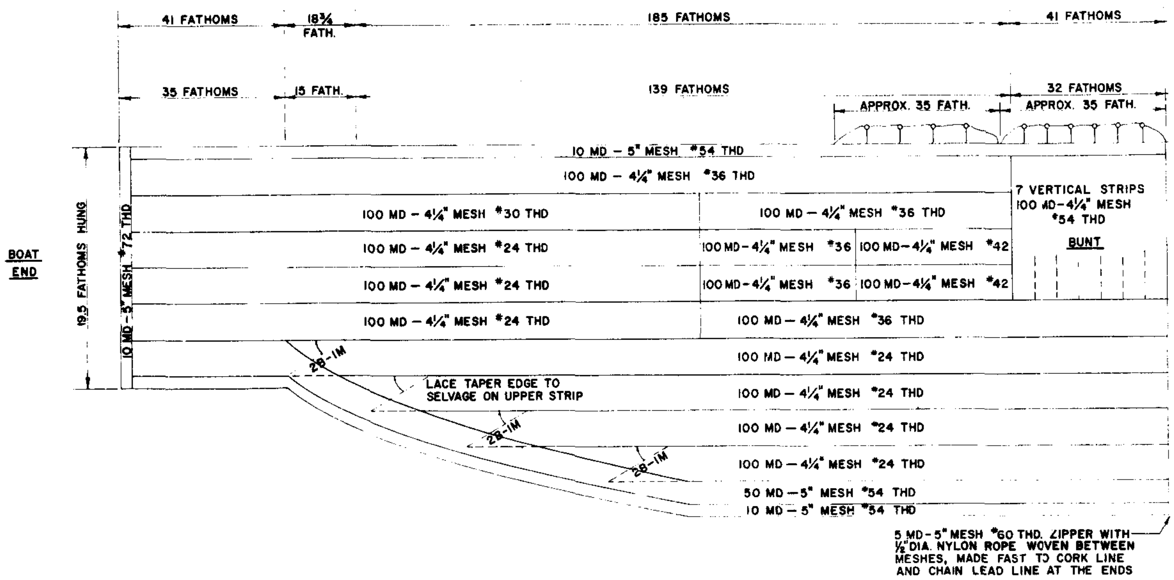
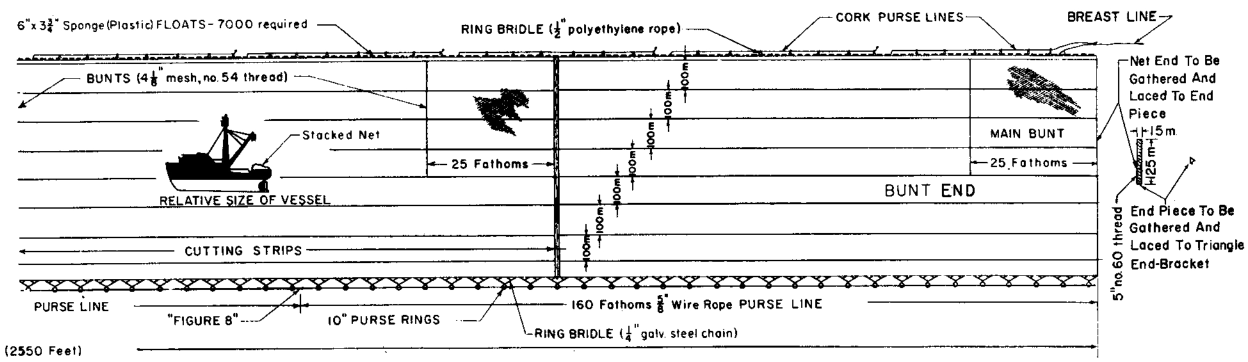
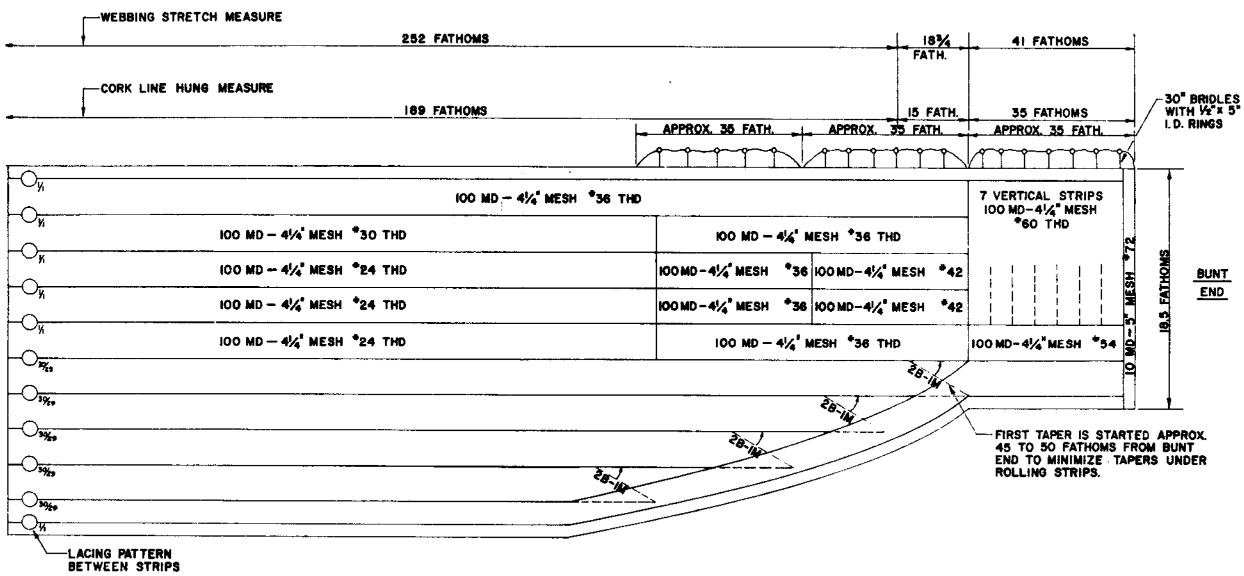


Fig 2. Hybrid tuna purse seine
M = meshes; MD = meshes deep; FATH = fathoms;



which are laced in horizontally, and extend at full depth to the ends of the seine (McNeely 1961)
meshes



—netting and accessories.
THD = thread; B = bar; ID = inside diameter

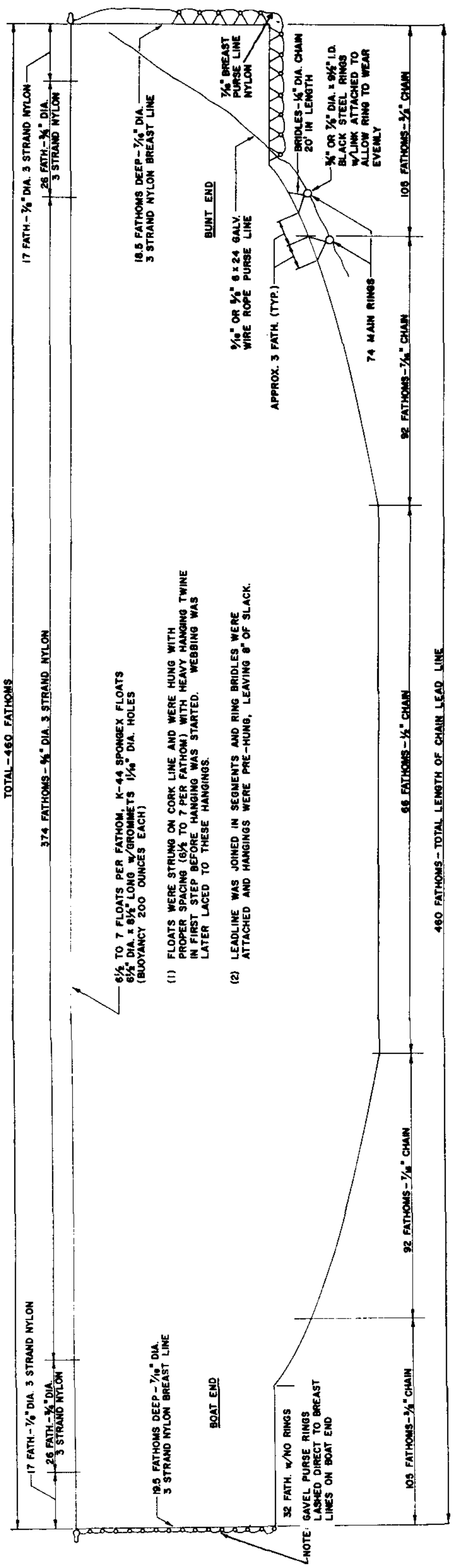


Fig 3. Hybrid tuna purse seine

U.S. tuna seines are usually hung with leadlines 5 to 10 per cent shorter than the corklines. This has been an accepted practice for tuna and salmon seines for many years. Salmon seiners in the Pacific Northwest and Alaska continue the 10 per cent shorter leadline practice because they feel it aids in the holding of salmon, when their seines are held open and towed with the power skiff and vessel. Although U.S. tuna seiners do not tow their seines, the 10 per cent shorter leadlines are possibly a leftover from these early ideas of seine fabrication.

Gavels and setback

The typical U.S. tuna seine has no gavels. The ends are baited to short border strips of netting 125 meshes long by 15 meshes deep, which in turn are laced to terminal stainless steel triangles. The full seven or eight strips are carried to the extreme ends of the seine, and the abrupt baiting of netting gives the appearance of gavels. However, this creates a large gap in the net wall under the vessel, leaving a possible escape route for encircled tuna. To help prevent this loss of fish, gavels or breastlines were installed at opposite ends of the hybrid seine. The bunt end was made 18½ fm (34 m) deep, and the back end was hung 19½ fm (36 m) deep. Small galvanized rings ½ in (12.7 mm) rod dia by 4 in (10.2 cm) inside dia (I.D.) were lashed to the upright breastline, made from $\frac{7}{16}$ in (11.1 mm) dia three strand nylon rope (fig 4). In order to distribute hauling strain on the netting more evenly, 32 meshes of the top of the gavel selvage strip are bunched and hung to the steel triangle or end piece (fig 5).

The hybrid seine was rigged without main purse rings or bridles for the first and last 35 fm (64 m). To fill this gap, a series of galvanized steel rings (½ in (12.7 mm) × 6 in (15.2 cm) I.D.) with nylon rope bridles were required. These rings were lashed under the end bunt with a ½ in (12.7 mm) dia nylon breast-purseline to purse the bunt end while the main purse rings are being drawn to the surface. This was done to permit the main wire purselines to work independently of the gavels, thereby permitting them to hang perpendicularly from the davit. An 18.5 fm (34 m) curtain of netting is thus formed directly under the boat.

On conventional U.S. tuna seines the ring bridles are connected the entire length of the chain leadline or with very little setback.

PHYSICAL PERFORMANCE

Based upon the performance of the scale Model II (Ben-Yami and Green, 1968), a prediction was made of the range of sinking performance of the hybrid purse seine at mid-net prior to start of pursing. This range was graphically compared to the measured sinking range of a conventional tuna purse seine (fig 6). The rather large depth range results from varying wind and current conditions affecting the sets.

A composite time-depth curve of the first five sets of the hybrid purse seine is also shown in fig 6. Agreement with the predicted range for a scaled-up Model II is considered good, allowing that the hybrid purse seine is deeper than the conventional seine by one strip of body netting.

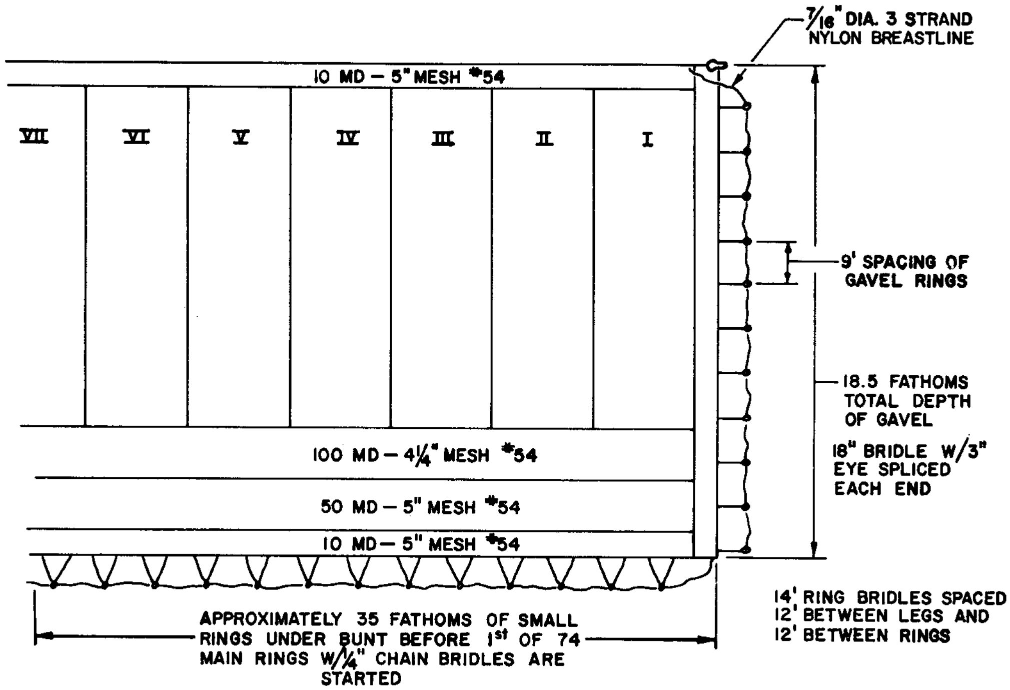


Fig 4. Hybrid tuna purse seine—gavel or breastline and purse ring spacing

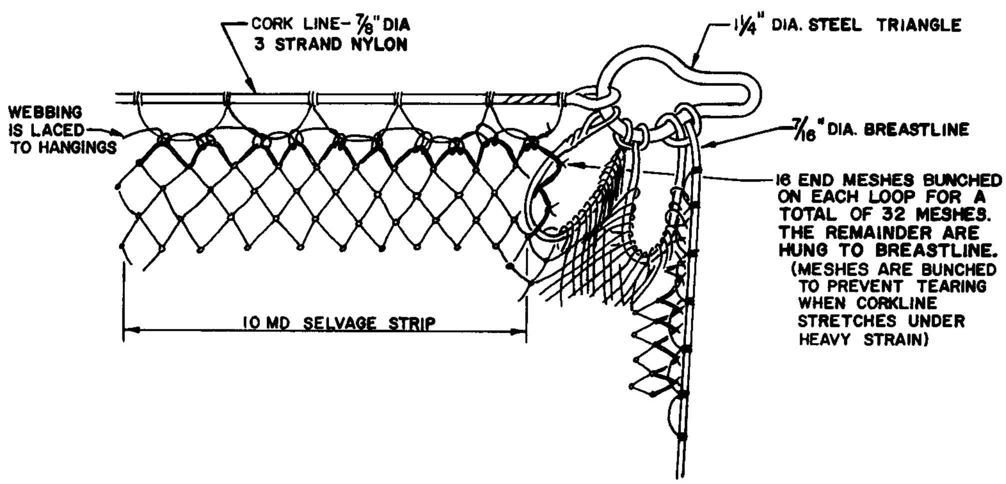


Fig 5. Hybrid tuna purse seine—bunt end detail

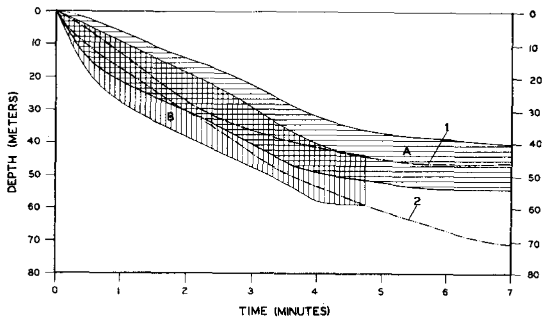


Fig 6. Predicted and actual sinking performance of hybrid purse seine. A = range of sinking performance of standard seven-strip tuna purse seine; B = predicted range of sinking performance of hybrid purse seine; 1 = mean sinking performance of standard seven-strip tuna purse seine; 2 = mean of first five sets of hybrid purse seine

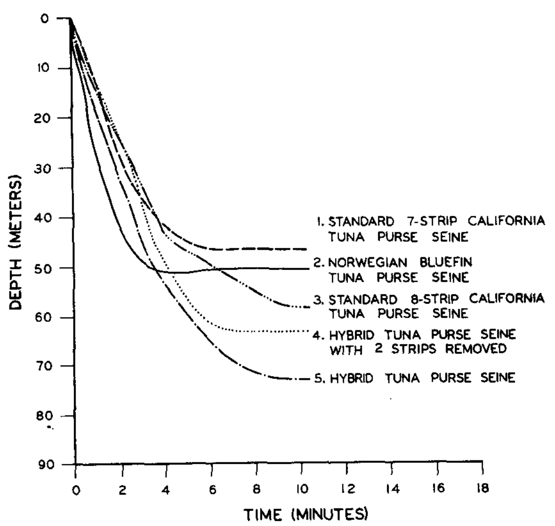


Fig 7. Midnet BKG traces from water entry to maximum depths. Source: 1—original BKG data. Means of nine sets of one net. 2—Hamre, 1963. 3—original BKG data. Means of nine sets of two nets. 4—original BKG data from one set of modified hybrid purse seine. 5—means of first five sets of hybrid purse seine

In fig 7 the sink rates and maximum depths of the Norwegian bluefin tuna purse seine and two California tuna purse seines are compared with those of the hybrid purse seine. While there is some crossing of lines, appearances indicate the initial sink rates generally are inversely related to the k_h of the nets, i.e. the two California purse seines, with $k_h = 0.91$, show the slowest sink rates, and the Norwegian purse seine, with $k_h = 0.40$, the fastest.

It is interesting to compare the hybrid purse seine modified to seven strips (see section 5) with the standard seven-strip California tuna purse seine. The former sinks approximately 9 fm (16.5 m) deeper, even though the numbers of body strips and therefore the stretched depth is the same in the two nets. The improved sinking performance results from the combination of (i) lower k_h, (ii) low ratio of corkline length to leadline length (gavels, in this respect, add to leadline length) and (iii) lighter netting.

Comparison of net ends

One objective of the hybrid purse seine design was to create a better underwater configuration at the net ends, reducing the gap under the boat, through which fish can escape and offering more efficient and economical use of netting. Figure 8 compares the wing ends of the hybrid purse seine and the standard seven-strip California purse seine at average maximum depth. In the section shown, the hybrid net is only four strips deep, whereas the standard purse seine is seven strips deep throughout its entire length. The hybrid purse seine's wing ends fish, on average, about 14 fm deeper with 1.7 times more filtering area using only about 0.62 the amount of body strip netting as the standard net. This improvement is due to three things: (i) the net ends laced to a long gavel line instead of gathering all of the webbing to a single point (the end triangle or swivel), (ii) the decreased k_h, and (iii) the setback of the first main purse rings to 35 fm (64 m) from the net end rings, allowing the gavels to hang free of the influence of the purseline.

Although pursing the gavels represents an extra task over the operation of the standard purse seine, they can be handled without loss of time. It was soon realized that only the front gavel, adjacent to the main bunt,

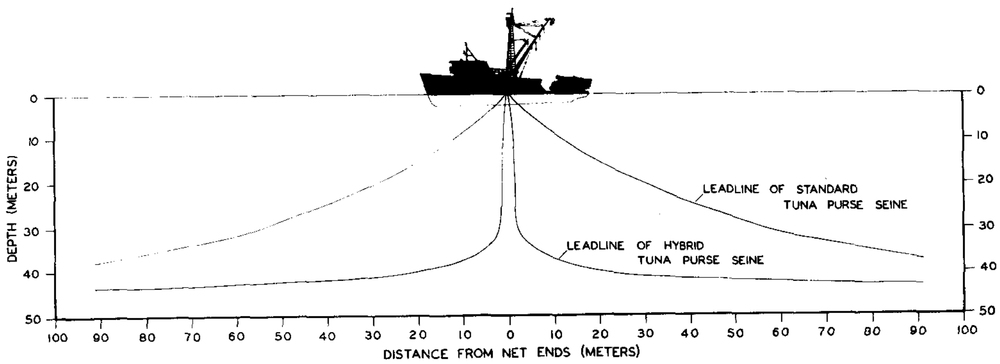


Fig 8. Net ends of hybrid purse seine and standard seven-strip tuna purse seine compared. Profiles shown are deduced from maximum depths of BKG traces. Tuna purse seiner shown to scale

needed to be pursed. There has been no tendency for the gavel to foul or roll up in the purseline.

The circle formed by the hybrid seine maintained its roundness and initial diameter well into the pursing stage. The floatline did not wrinkle up into folds, as is customary on conventional seines with 10 per cent shorter leadlines. The vessel has less tendency to pull itself into the centre with large pockets forming around the bow and stern, as happens with nearly all conventional tuna seine sets. With the hybrid seine, the roundness of the seine allows maximum holding area for the tuna that are encircled, keeping them alive longer. No measurements have been made of these phenomena, but all who have observed sets made by the hybrid purse seine agree in these subjective observations.

FISHING TESTS

The hybrid purse seine was placed on the purse seiner M/V *Liberty*, out of San Pedro, California, for fishing tests beginning August 1968. The previous rate of success of *Liberty* under its present crew (since 1 January 1968) was 56 per cent, not significantly different from that of other vessels fishing in the same area, which averaged 60 per cent. The net that *Liberty* had previously used was a standard U.S. tuna purse seine, seven strips deep by 350 fm (823 m) long with netting hung at a k_h of approximately 0.91.

During the remainder of 1968, after the close of the yellowfin season, *Liberty* made 19 sets with the new net: one on bonito, two on bluefin tuna, and 16 on albacore tuna. Seventeen sets were successful. The captain and crew were impressed with the net's sinking performance, the maintenance of the set's initial diameter well into pursing and, above all, its fish-catching ability. The only complaint was difficulty in stacking the net because of its incremental hang in. With more netting nearer the floats than the leadline, the net left the power block with a twisting motion with occasional large piles of netting falling down near the floatline. The power block had to be stopped often or slowed while the net was straightened out, and the net required 25 to 50 per cent longer than usual to stack.

During the first trip of *Liberty* in 1969, the hybrid seine was used under conditions for which it was not designed—on porpoise and in shallow waters. Because of the rough treatment received by the net when porpoise are involved, stouter than normal netting is usually used and a constant, not incremental k_h is needed for "backing down", a tactic of pulling the corkline underwater to allow porpoise to escape (Perrin, 1969).

Several sets on porpoise confirmed the belief that the hybrid purse seine, as hung, was not suitable for this type of fishing, because of a low rate of porpoise escapement and damage to the net by porpoise. After shipboard repairs were made, the seine was used around the Revillagigedo Islands off Mexico, a place well known for rough, shoaling bottoms (and often plentiful tuna). The ill-fated trip ended with half a load of fish when the net snagged bottom, and over half the leadline was lost. Seven of 13 sets were successful.

In anticipation of further porpoise fishing during the yellowfin tuna season, we temporarily modified the seine by increasing the k_h to 0.83 and removing two strips. The incremental hang-in was abandoned. We replaced 250 fm (457 m) of lost leadline in the back portion of the net with $\frac{7}{16}$ in (11.1 mm) dia chain.

During the following three trips, March to June 1969, there was no opportunity to test the net, in its modified form, on porpoise. On schoolfish—bluefin, skipjack, and yellowfin tuna, and a small amount of bonito—however, it performed well. Of 52 sets, 33 (63 per cent) were successful. Schools as large as 100 short T (91 metric T) were landed, using only the main bunt, thus proving the adequacy of the light-weight netting for handling heavy loads of fish. The sink rate and depth of the hybrid purse seine, although it had been reduced to seven strips, greatly exceeded that of the standard seven-strip purse seine (fig 7).

In June 1969, after the close of the yellowfin tuna season, the hybrid seine was restored to its original configuration with the exception of the incremental hang-in. With incremental hang-in, the mean k_h of all the strips at mid-net was 0.79. We rehung the seine at this new k_h, lacing all the strips together evenly. The leadline, with the chain replacement made in the previous modification, remained the same. We then checked the net's sinking performance with BKG's and found the curves to be nearly identical to those obtained with its original configuration.

Two more trips were made with the hybrid purse seine before *Liberty* ceased fishing for the year. During those trips, a total of 37 sets were made, of which 18 (49 per cent) were successful.

Fishing test results

We compared the rates of success of *Liberty* and other vessels for the period during which *Liberty* was operated under its present ownership and crew (since 1 January 1968). Fishermen's logbook data were made available to us for this purpose by the Inter-American Tropical Tuna Commission (IATTC). Because the rate of success may vary with time, area, vessel size, and type of fishing (e.g. species and "porpoise" fish versus schoolfish—Craig Orange, IATTC, personal communication), data were used only from those vessels most comparable to *Liberty* in these respects. This was accomplished by simply tabulating sets made north of 20°N latitude and in the Revillagigedo Islands—Hurricane Bank area. This northern area of the fishery nearly approximates the traditional fishing grounds of small- to medium-size purse seiners like *Liberty*, whose main strategy is to concentrate on yellowfin, skipjack and bluefin tunas as these fish appear seasonally. The porpoise fishery is centred in southern, more tropical waters (Perrin, 1969). Moreover, at any given time the majority of the small purse seiner fleet may usually be found concentrated in a smaller area within the northern region just defined, as they move with the fish. The few sets made on porpoise were omitted from these data, except during one quarter when *Liberty* made sets on porpoise. For two quarters when *Liberty* fished farther south, we tabulated data from other vessels fishing in the same 5° squares.

The purse seines carried by the other vessels are all versions of the standard U.S. tuna purse seine described by McNeely (1961) with only minor variations in design and size.

In order to examine our set data by time, we tabulated them by trips in the same manner as the IATTC compiles data obtained from fishermen's logbooks—by quarters of year in which the trips originated. The results in success ratio by quarters of years are shown in fig 9. *Liberty's*

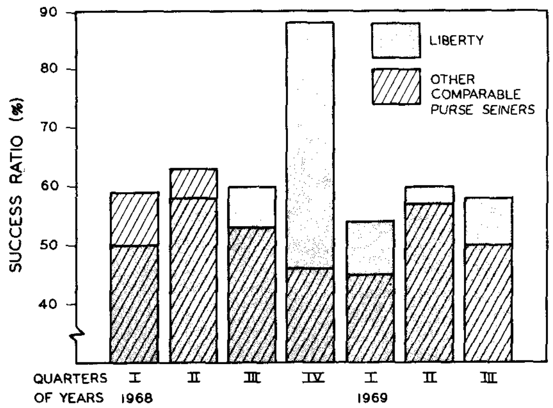


Fig 9. Success ratios of Liberty *compared to similar purse seiners by quarters of years. Hybrid purse seine added to* Liberty *during third quarter of 1968*

success ratio, which commenced below that of comparable vessels, surpassed them in the quarter in which she started using the hybrid purse seine and maintained these higher levels during the remainder of the test period.

For statistical comparisons, all of the set data are summarized in Table 2.

TABLE 2. SET DATA OF *Liberty* COMPARED WITH OTHER COMPARABLE PURSE SEINERS BEFORE AND DURING THE USE OF THE HYBRID PURSE SEINE BY *Liberty*

	Before use of hybrid purse seine by Liberty		*During use of hybrid purse seine by* Liberty	
	Number of sets	*Per cent success*	*Number of sets*	*Per cent success*
Liberty				
Successful sets	44		75	
Unsuccessful sets	35	56	46	62
Total sets	79		121	
Other comparable purse seiners				
Successful sets	2,067		1,525	
Unsuccessful sets	1,473	58	1,416	52
Total sets	3,540		2,941	

All adjacent pairs around the perimeter of the table were tested for significant differences at the 0.05 level using chi-square in 2×2 contingency tables. The only significant difference was between other comparable purse seiners and *Liberty* during her use of the hybrid purse seine.

DISCUSSION AND CONCLUSIONS

Some shortcomings in the fishing test data hampered their accurate interpretation. Among these are the modifications of the hybrid purse seine during the test period, and the variability encountered in fishing conditions and species fished. Our testing vessel was an unpaid volunteer and had to continue normal operations without outside interference in this highly competitive fishery; therefore this phase of the experiment could not be carefully controlled.

Our interpretation of the data is that because there were no differences between the success of the *Liberty* and success of the other boats before the new net was used and because no other variable has been introduced or cause of variation detected, we may ascribe any difference after the new net was adopted as being associated with the *Liberty's* use of the hybrid purse seine.

Difficulty was also encountered in precisely interpreting the sinking data of purse seines because of lack of control over natural conditions affecting the set and because of the absence of basic studies that define relationships between net performance and setting conditions. For example, the effect of wind and current driving boat and net apart is to limit the seine's maximum depth. This relationship has often been observed but never defined quantitatively. Indeed, the presence of a current may often go undetected. It could probably be shown that pursing speed and mesh and twine sizes, among other factors, also influence the wind and current's effect on the seine's sinking. Until such basic research on purse seine performance has been conducted, it is necessary to use averages of repeated measurements.

The ability to make high speed sets is of great importance to eastern tropical Pacific tuna purse seiners which make sets at speeds of 7 to 8 kn, and sometimes faster. This leads us to believe that tuna seines should be hung at k_h of no less than 0.7, preferably between 0.75 and 0.80. Although limitation of k_h does not permit maximum depth per given strip, it does preclude tearing of netting when high speed sets are necessary. Seines can always be made deeper by adding additional strips. Besides, any deviation to one side or the other of the square meshes obtained with $k_h = 0.7$ results in decreasing economic efficiency of use of netting. With $k_h > 0.7$, square meshes will be achieved at some point during sinking or pursing of the seine; but at $k_h > 0.7$, this is never possible.

The effects of the main features of the hybrid purse seine which differentiate it from standard U.S. tuna seines may be summarized as follows:

1. Lighter netting—gives easier handling, large net size for given size of net pile, and faster sinking.

2. Lower k_h—contributes to greater sink rates and fishing depths, uses netting more economically, contributes to more open net circle for a longer time during set but may cause some difficulty for porpoise escapement.

3. Tapering—maintains depth where needed, eliminates unnecessary netting at ends, and aids in drying-up fish prior to brailing.

4. Incremental hang-in—might offer better pur-

sing configuration but contributes to handling difficulty and low porpoise escapement.

5. Floatline and leadline of equal lengths—contributes to greater sink rates and fishing depth and more open net circle longer during set.

6. Gavels with breast pursing lines—uses netting at net ends more economically, reduces escape gap under the purse seiner and adds to the effective length of the leadline.

7. Setback of main purse rings from net ends—contributes to vertical hanging of gavels beneath vessel, reducing this escape gap.

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[R.E. Green, J.E. Jurkovich and B. Petrich]