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A PRELIMINARY STUDY OF DOLPHIN RELEASE PROCEDURES USING MODEL PURSE SEINES

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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INTRODUCTION

Model fishing nets have been used for many years as an inexpensive aid to improving various types of fishing gear. The most common and successful models are those of trawls that can be observed in flume tanks, thus allowing changes in rigging and construction to be tested without going to sea. The first flume tank was built at Boulogne-sur-Mer, France in 1967. A second, larger flume tank was built in Lorient, France in 1978. The White Fish Authority (Hull, England) built a large flume tank in 1976 that can accommodate models of large pelagic trawls at towing speeds up to 13.5 knots (Noel, 1980).

Model testing in these flume tanks has greatly increased the understanding of trawl dynamics and has led to substantial refinements in modeling techniques. Additionally, it has shown that model studies of net dynamics can be done at a fraction of the cost of using full-sized commercial fishing gear. Not only are the costs of net material, labor and operations lower, the time required to modify a model is considerably less than for the full-size gear. When certain modeling rules are followed and the models are scaled up to full size, accuracy of performance prediction can be maintained (Wileman, 1980).

The first model purse-seine studies carried out by the National Marine Fisheries Service (then the Bureau of Commercial Fisheries) were directed towards improving the overall efficiency of the purse seine. Ben-Yami and Green (1968) built a 1:25 scale model of a 425 fathom-long, seven-strip-deep (a standard net strip in U. S. tuna purse seines is 100 to 120 fathoms long by 100, 4 1/4-inch meshes deep) tuna seine using the modeling rules of Dickson (1959). Ideal materials for model construction were not available, and the weight of the model's leadline and web was reduced at a scale less than 1:25. The authors were able to get reliable results, however, by fully testing the basic design and then modifying the model and retesting. Their conclusions, based on performance comparisons of "before" and "after" tests, were: 1) a lower coefficient of hang-in (K_n) increased sinking speed and maintained the maximum surface area for a longer time, 2) a longer leadline (than corkline) increased the sinking speed, 3) tapered ends saved webbing without impairing fishing depth, and 4) deeper nets maintained their shape

longer. These model studies led to the design of the "hybrid seine" (Green et al., 1971) which was easier to handle, sank faster, used less webbing, and had a greater surface area for a longer time than did the more conventional nets of that time.

A model purse seine designed for studies relating to the tuna-dolphin problem was built by Gary Loverich under the direction of Richard McNeely in 1972 at the Northwest and Alaska Fisheries Center (NAFCA). This model was designed from the same tuna seine used by Ben-Yami and Green (1968). Loverich was able to locate more suitable materials that allowed improved accuracy in scaling.

The McNeely-Loverich model was the scaled equivalent of nine strips deep and had a mid-depth purse line installed throughout its length to test the feasibility of double pursing to separate the tuna from the dolphins. Tests with this model showed a mid-depth purse line to be impractical and saved considerable time and money that might have been expended testing the idea on a commercial seiner.¹ These early tests also provided valuable information on general purse seine dynamics; however, the model was not used to study the backdown maneuver as a method of dolphin release.

A second model was built at the NAFCA in the spring of 1973. This was a 1:50 scale model of a newly designed "Large Volume Net" (LVN) scheduled for construction by NMFS in the fall of that year. The two main features of the model were 1) increased depth (17 strips) to prevent pre-backdown net collapse, provide greater surface area and increase pursing speed and 2) tapered ends to reduce excess webbing and attendant gear malfunctions. The model was set three times to evaluate general sinking and pursing characteristics. It performed well in these tests but appeared to sink too slowly due to greater-than-expected webbing resistance.

All of the studies involving model purse seines described thus far dealt with the dynamics of setting, sinking speeds, hang-in coefficients and pursing. None has examined the process of releasing dolphins by backing-down. The backdown procedure (Coe and Souza 1972) is the primary means of releasing captured dolphins in the eastern tropical Pacific tuna fishery. It is also this phase in the operations that most frequently results in dolphin mortality.

The purpose of this study was to evaluate the usefulness of model purse seines in the design and testing of dolphin-rescue gear and procedures. Of primary interest was the behavior of the models during normal and modified backdown procedures. The effects on performance of various gear malfunctions, such as webbing becoming tangled in the purse rings, were also examined.

MODEL SCALING FACTORS

The two models used in this study were designed to be set from a two-man inflatable raft in a large swimming pool. They were both scaled using the

¹Unpublished working notes of McNeely and Loverich.

modeling rules of Dickson (1959) and Kawakami (1964).

The first model (Figure 1a) is a standard rectangular net fashioned after an early design described by McNeely (1961). It is a 1:25 scale model of a 425-fathom, seven-strip seine. Two additional strips (equivalent) were added to the model to accommodate studies using two purse lines. The model is 31.1 meters long, sinks to about three meters and sets in a 9.8-meter circle. Physical parameters for both the full-sized and model versions are shown in Table 1.

The second model, the Large Volume Net (LVN), was built to test the hydrodynamic performance of a full-sized prototype. The model is 22 meters long, sinks to about 3.4 meters and sets in a 7.0-meter circle. The physical parameters of this LVN model are also shown in Table 1.

The modeling theory used for scaling these nets was based on maintaining Froude's and Reynolds' number equivalent. Froude's and Reynolds' numbers as well as general scaling theory are described by Dickson (1961), Baranov (1948), Fridman (1964) and Kawakami (1959 and 1964). Keeping Froude's number constant maintains a constant flotation-to-drag ratio by reducing the velocity (and time scale) by the square root of the linear scale (Dickson, 1961). This also insures that the forces of gravity and inertia are scaled equally. In order to maintain precise dynamic and frictional forces between the model and full-sized gear, the Reynolds' numbers of both must also be the same. This cannot always be achieved in practice, and some differences in water flow patterns and drag coefficients usually have to be accepted. The slow speeds at which the purse seines operate (as opposed to trawls) tend to minimize the effects of these differences.

Modeling rules used by the builders of these models to ensure a constant flotation-to-drag ratio were:

1. All lengths were reduced by S ,
2. Speed and times were reduced by S ,
3. Weights were reduced by S^3 ,

where S is the scaling factor.

Geometric similarity between the models and the full-sized gear was achieved by reducing all lengths by the linear scale and maintaining all hang-in rates and tapers. Reduction in mesh size was based on the amount of blockage (or water resistance) offered by the web to the water flow and was less than the linear scale. The mesh on the 1:25 standard model was scaled to only one-seventh of the original and that on the LVN model to only one-eighth of its original full-sized design. This technique is valid when the surface areas of the twines are reduced at equal ratios. The twine-diameter-to-mesh-length ratios for the standard model and its original were 0.0216 and 0.0296, respectively, while those of the LVN model and its full-sized design were 0.017 and 0.011. While these ratios are almost equal, researchers at the White Fish Authority in England suggest using the twine-diameter ratio (TDR) to determine mesh size for model nets (Wileman, 1976). Here the model mesh size is directly proportional to the ratio of twine diameters.

$$\text{TDR} = \frac{\text{twine dia. model}}{\text{twine dia. full size}} = \frac{D_m}{D_f}$$

and in the case of the standard 1:25 model

$$\text{TDR} = \frac{0.48 \text{ mm}}{2.26 \text{ mm}} = 0.21.$$

The mesh size is then reduced by 1/5, or to $104.8^2 \text{ mm} \times 0.21 = 22.0 \text{ mm}$. The mesh size indicated for this model was somewhat larger than the 15.2 mm (0.60") used. Consequently one would expect a little more blockage and therefore more resistance to water flow.

The LVN model incorporated a TDR of 0.081, indicating a preferred mesh size of 8.7 mm (0.344 inches). The 12.7 mm (1/2 inch) mesh size used was therefore too large and allowed less drag than if scaled precisely.

The flexibility, elasticity and stiffness of the selected materials used in constructing models are also important factors in the hydrodynamic behavior of model nets. Wileman (1980) doubts that elasticity and stiffness scale down properly (at least in trawls) when forces are reduced by the cube of the scale. These difficulties and uncertainties in building and testing the model nets have certainly introduced some bias in performance. These biases, however, appeared minimal during most aspects of the study.

OPERATIONAL AND EXPERIMENTAL PROCEDURES

Preliminary work included determining optimum operating and experimental procedures for the setting, pursing and backing-down operations. The models were set from a two-man inflatable raft fitted with a small electric trolling motor, keel, ring stripper, winch, and net box (Figure 2). During the early trials, the techniques for setting, pursing and backing down were established, and, with practice, a single raft operator could perform these functions smoothly. The sets were initiated by holding the bow end of the model while the raft completed its circle. Setting speed was controlled at 0.5 meters per second (about one minute to complete the circle).

The purse winch was made by connecting two level-wind-equipped fishing reels together so that both ends of the purse line could be pulled at equal

²Standard 4 1/8 inch mesh.

speeds. Once the net was pursed, and the purse rings placed on the ring stripper, the raft was pulled into shallow water by hand. Here the net and purse cable were "rolled", or pulled in by hand and stacked into the net box, until the stern tie-down point for backdown was reached. The net's stern side was then tied down under the ring stripper, and three bow corkline bunches were pulled. This net-roll procedure represents a complete interruption in the retrieval process and was necessary because scaling of the vessel's hull and skiff drag was beyond the scope of this study and because observation during repeated backdown trials was more easily accomplished in shallow water. Multiple-backdown tests were then carried out under varying pre-backdown conditions and net configurations.

Applying these procedures to the two models allowed for pre-backdown observations of setting characteristics, sinking rates, pursing dynamics, enclosed surface area and volume seined. Various aspects of backdown dynamics such as "stern sway" (Holts et al., 1979; Coe and Butler, 1980), surface and subsurface canopies, channel collapse, changes in the radius of the backdown arc and tie down point locations were of primary interest.

These studies were carried out in the summer of 1980 at the swimming pools of the University of California, San Diego (UCSD) and at the General Atomic Company employees' recreational pool. Both swimming pools were available for only one four-hour session once a week. This schedule did not allow time for setting up support and recording equipment necessary to standardize procedures and measure any changes in the models' behavior between trials. Consequently our results are largely qualitative.

OBSERVATIONS OF PURSE SEINE DYNAMICS

Sinking Speed

The objective of the first two sessions was to establish the operational and experimental procedures as well as to work out any unforeseen problems. Sinking speeds were measured during four subsequent sessions.

Both orientation sets were made with the standard model. It sank very slowly and unevenly during the first set because the webbing was dry and contained numerous air spaces. Wetting the models just prior to setting eliminated this problem on subsequent trials.

The purse cable was always stacked with the model nets and did not unwind (under tension) from the winch during setting as is the case during actual fishing conditions. This may have allowed the models to sink to a greater extent than the full-sized gear, since tension on the purse cable holds up the leadline and prevents full extension of the web.

The standard model averaged 32.3 seconds to reach its maximum depth in four trial sets as measured at the half-net marker (15.6 m). Times were recorded with a stopwatch as the leadline sank past submerged markers at one, two and two-and-a-half meters.

Depth	trial					x
	1	2	3	4		
		Seconds				
1m	11	9	9	-	9.7	
2m	23	20	25	17	21.3	
2.5m	28	30	35	36	32.3	

Scaling these data back to the full-sized gear gives a sinking time of 2.7 minutes to reach a depth of 34.2 fathoms, or 12.6 fathoms per minute (fm/min). This is much too fast for full-sized gear of comparable lengths and depths. Published sinking speeds for nets with seven to ten strips indicate our model may have sunk nearly three times too fast. Ploeger³ (1973) found a 10-strip net to sink at 2.9 fm/min over the first five minutes of setting. Hester (1961) measured the sinking rate of a seven-strip net at about 4.5 fm/min for the first 5 minutes. Green et al., (1971) found 5 different tuna purse seines had an average sinking speed of 5.7 fm/min over the first 5 minutes. The fastest, their 10-strip hybrid nets, sank at 6.6 fm/min. Beltestad (1980) reported a sinking speed of 12.4 fm/min (22.7 m/min) in an experimental purse seine made of six-sided meshes ("hex mesh").

We were unable to obtain sinking rates on the LVN model because its webbing became entangled during each of the trials and consequently did not sink uniformly.

Pursing

Pursing of the models began after connection of the purse cable ends to the "winch." During this time, the standard model sank to its maximum depth and would touch the bottom of the pool if the connection to the winch was not made rapidly. Both ends were pulled evenly until the purse rings came up next to the raft. The standard model was pursed in four to five minutes; this is comparable to pursing times of the older and smaller tuna seiners with slower deck machinery and 400 to 450-fathom nets. The seine used by Hester (1961) was 435 fathoms long and took an average of about 24 minutes to purse (for the model, $24 \text{ min} \div 5 = 4.8 \text{ minutes}$).

Three sets were made with the 1:50 scale model of the Large-Volume Net. On the first of these sets, the leadline sank to the bottom of the pool and the rings and bridles were dragged across the bottom as it was pursed. The next two sets were oriented so that the model's deeper center section was in the deep end of the pool and the tapered ends followed up the sloping bottom to the shallow end. This allowed pursing without dragging on the pool

³Ploeger, J. W. 1973. Cruise report of the M/V John F. Kennedy Bathymograph Summary NMFS Cruise No. 51. Southwest Fisheries Center, La Jolla, California, 26 p.

bottom. This model was pursed in two to three minutes, representing the time for a tuna purse seiner to close a 600-fathom net. As pursing proceeded with both models, the rings pulled in smoothly and evenly and appeared to function as those observed at sea.⁴ The bow and stern bends that normally form around the seiner (or raft in our study) only partially developed during pursing, because we made no attempt to simulate the drag of the vessel's hull and skiff-pulling characteristics. The bends could be easily created by pushing the raft slightly into the net, but no studies were conducted concerning this aspect of the operation.

The corkline on both models collapsed quite badly during the final stages of pursing. The corkline of the standard model completely collapsed, eliminating all open surface area each time the rings came out of water. This was, to a large degree, due to its high length-to-depth ratio (11:1). The LVN model had a much lower length-to-depth ratio (7:1) and remained noticeably more open.

The overall operation from setting to rings-up proceeded smoothly and was judged a good simulation of actual fishing dynamics in both models. After rings-up, the model(s) and raft were moved into the shallow end of the pool, where the stern-half of the net was stacked into the net box and then tied down at the appropriate tie-down point. The three bow corkline bunches were also pulled in at this time and attached to the raft's port bow.

Backdown Observations

Prior to each backdown sequence, the raft was positioned in the corner of the shallow end of the pool so that it could simulate a long, gently arcing backdown path to the pool's deep end. The corkline was opened by hand and the webbing allowed to sink prior to initiating each backdown sequence.

The webbing under the bow corkline bunches of the standard model hung in drape-like folds with elongated meshes, producing a deep bowl-like area directly beneath. As backdown started, the bowl folded under the rest of the channel, as has been observed several times by divers in the full-sized gear. "Stern sway," a subsurface, lateral folding of loose webbing along the stern side of the backdown channel (Figure 4), also occurred, as has been observed in the field (Holts et al., 1979; Coe and Butler, 1980).

The webbing under the three bow bunches of the LVN model did not hang in folds or create a deep bowl as observed in the standard model. This backdown channel formed without canopies; however, stern-sway and a "sausage-like" roll of webbing did develop.

The main stresses or pulling forces during the backdown procedure in both models occurred down the mesh row from the apex corks to the chain directly below. At first, this area of tight meshes formed the floor of the channel,

⁴Holts, D.B., R. McLain, F.G. Alverson, and J. DeBeer. 1979. Summary of research results from the fifth cruise of the Dedicated Vessel. Southwest Fisheries Center Admin. Report No. LJ-79-20, 47 p.

but as backdown proceeded, it continued to rise and contacted the stern side wall of the channel. The gathering of webbing combined with the slack webbing from the stern wall to form a sausage-like roll of webbing. The channel floor was then primarily made up of the webbing on the bow side of the channel (Figure 4). Observations of both models were similar to the underwater observations made in full-size seines (Coe and Butler, 1980).

Effect of the Backdown Arc at the Apex

During backdown trials, the channel's intended apex was susceptible to shifting towards the bow or stern side of the channel, depending on the turning radius of the raft as it moved backwards (Figure 3). In the standard model a straight backdown moved the intended apex about 20 cm (equivalent to 3-4 fathoms on a full-sized seine) around to the stern side of the channel. Too tight an arc moved the intended apex a similar distance toward the bow side. Configuration of the LVN model's backdown channel was highly dependent on the curve of the backdown arc. Minor changes in the degree of the backdown arc would rotate the apex corks out of their optimum position, and the channel would collapse, if the backdown arc was not corrected. The channels of both models could easily be opened or collapsed by changing the arc. Unfortunately, we had no method of standardizing the turning radius during repeated trials. The result was some inconsistency in the location of the apex when the channel first became fully developed. This problem was minimized by the conscious effort of the raft driver to execute the backdown trials as uniformly as possible. However, some variation in canopies and stern-sway development was obvious. The factor of turning radius during backdown may also play an active roll in the backdown operations of commercial gear, and additional investigations of its effect on net configuration and dolphin-release efficiency would be warranted.

Modifications to the Backdown Channel

Four different modifications to the backdown procedure were made during this portion of the study. Based on past experiment and observation, these modifications were designed around the concept that altering the distribution of forces on the excess webbing in the sides of the channel could create a larger, deeper, more canopy-free channel. By creating new stress points or altering the old points normally at work in the backdown channel, we hoped to eliminate some of the slack webbing along the stern side.

Trial 1

In our first attempt, four purse rings (the ring directly below the apex cork and three adjacent sternward rings) were pulled inboard to the leadline to simulate a four-fathom pull. The stern-sway and "sausage" apparently developed faster and involved all the webbing along the stern-going bar markers from the apex to the chain. This did not increase the depth of the channel, nor did it reduce the amount of the slack web responsible for stern-sway.

While these observations were not encouraging, it was decided to test the concept at sea (Butler and Foster, 1981).⁵ On board a chartered seiner, the purse rings, bridles and leadline were pulled inboard of the ring stripper varying distances from two to four fathoms. Underwater observations indicated substantial variability as to where the "sausage" actually contacted the stern wall of the channel; stern-sway however still existed.

Trial 2

The second modification to the backdown procedure was to pull in extra webbing at the stern tie-down point. This simulated a condition where the corkline and leadline had fallen behind the webbing during net-roll, i.e., as if the webbing were rolled aboard at a greater speed, thus potentially reducing the amount of slack web available for stern-sway. In the standard model this reduced the amount of slack webbing in the stern wall of the backdown channel and eliminated the "sausage" but created some minor folds along the apex mesh row at the center and bottom of the channel. We also pulled in 50 cm of extra webbing at the stern tie-down point of the LVN model, which represented 14 fathoms on a full-sized net. This moved the stern-sway and sausage more toward the stern side and resulted in a deeper channel. The major stress points were along the bar markers and not down the meshes as observed with the standard model. Displacing the line of stress to the stern-going bars apparently made the channel deeper without altering the basic configuration. This procedural modification appeared to enhance the backdown channel in tests of both models, indicating a need for follow-up studies to evaluate possible merits of reduced webbing along the stern side of the channel wall.

Trial 3

Our third modification (standard model only) was to increase the channel's base length by attaching the bow bunches as far forward on the port bow as possible, while moving the stern tie-down point as far aft as possible. This approximately doubled the distance between tie-down points. New tie-down points had to be established for this test. The procedure allowed development of a wider channel, which was less inclined to collapse. Additionally, the amount of surface area in the channel was greatly increased. The floor of the channel became quite shallow, so the overall effect on volume was minimal. Follow-up trials should also be conducted for this aspect of backdown.

Trial 4

Researchers with the Inter-American Tropical Tuna Commission (IATTC) designed a single otter board to aid in preventing stern sway and canopies. This "backdown board" (7.6 cm x 12.7 cm) was attached to the standard model's corkline on the stern side of the channel, about two thirds the distance from the apex toward the tie-down point. After some bridle and location

⁵Butler, R. W. and T. Foster. 1981. Cruise report of the M/V Maria C. J. charter. Southwest Fisheries Center, La Jolla, California, 25 p.

adjustments, the board prevented the backdown channel from collapsing and appeared to help in reducing the severity of stern sway by removing some of the slack webbing in that area. The board pulled the stern side corkline out and open, thus effecting a wider channel without any apparent loss in depth. This backdown board concept appears to have some merit by increasing the surface area and by preventing net collapse. It was not tried on the LVN model.

Possible Cause of A Common Gear Malfunction

Some of the problems encountered on full-scale nets were observed in the model, e.g., broken chain line, pre-backdown net collapse, winch malfunction, net collapse during backdown and net caught in the purse rings at rings-up.

During two sets, webbing drifted into the bight of the purse cable as the rings were coming up. This web became caught, or pinched, between the purse rings during the final stages of pursing. In one case the current from a pool water jet caused the webbing to drift into the cable, and in the other an observer's swim fin was the cause. These observations support the idea that ocean currents are probably one of the major factors responsible for this type of malfunction.

LIMITATIONS OF MODEL STUDIES

A major problem in interpretation of all model-net studies is whether hydrodynamic similarity is achieved between the model and actual fishing nets. Generally, the greater the scale reduction the greater the performance discrepancy between the model and full-sized gear (Dickson, 1961). We would expect some degree of discrepancy with our models due to the size reduction. However, some workers (pers. comm., J. A. Eikelman, Jr., SRI International, August 1978) maintain that scaling to 1:100 is possible if one is willing to consider only the forces of drag. This is reasonable, since the behavior of webbing is influenced more by drag than by the effects of gravity and turbulence, at least at the low velocities involved in the pursing and backdown operations of a purse seine.

Three basic conditions precluded precise dynamic modeling of the purse seine system in our studies. First, there is substantial variation in operating procedures and net performance among commercial purse seiners, much of which has not been measured in the field. Second, model nets are rarely perfect miniatures of the full-sized gear, because proper materials are often difficult or impossible to obtain. Lastly, comparative performance tests of scaled gear and/or procedures before and after selective modification(s) are applicable to full scale only when the magnitude of the modeling error is understood.

Aside from the assumptions required for scaling and the difficulty of obtaining suitable building materials, the validity of interpreting purse seine model trials is limited by the inability to precisely control starting configurations of the net. In these trials, for example, it was not possible to standardize the backdown operation so that each test was initiated from the same pre-backdown net configuration. This would require private pool facilities, so that operational and support equipment could be developed to allow repeatability of the backdown net configuration for each trial.

One possible way to achieve this standardization is to use a towing basin. Here the model could be attached to a towing board and mechanically pulled through the water over equal turning arcs and speeds while cameras, attached to the towing board, recorded dynamic changes in the backdown channel. However, in order to simulate the normal backdown arc, a curved towing basin would be necessary. Unfortunately, no curved towing basins exist, and the straight ones would only be good for a few limited studies. The question is just how reliable experimental results would be when extrapolated into a curved backdown arc. Some results such as those for major changes in apron construction, apex canopies, tie-down distances and hang-in rates could be valuable. However, problems such as stern-sway, canopy formation along the channel sides, and backdown channel collapse are greatly influenced by the seiner's backdown arc and therefore cannot be simulated by a straight tow.

RECOMMENDATIONS

There are many difficulties and uncertainties in building and testing model nets and some bias in performance must be accepted. Modeling, however, is an inexpensive tool that can provide a better understanding of mechanical performance and hydrodynamic behavior of fishing nets, even though models cannot duplicate or mimic each detail of any fishing operation. Results obtained from model net dynamics testing must be correlated with observations and measurements of full scale gear performance. The advantage in modeling is that it gives greater assurance that advanced design(s) will work.

Results of tests with the two existing models, however preliminary, were informative within the limits discussed. These tests identified several areas where equipment or procedural modifications might be utilized in the design of new dolphin saving techniques. These areas include 1) alteration of channel tie-down and stress points to further identify factors influencing stern sway and canopy development, 2) apron design and modification studies, 3) tests of optimum hang-in coefficients, 4) channel-enlargement capabilities, 5) alternative placement of "porpoise-safety panels", 6) strategic placement of hexagonal mesh in the channel to facilitate optimum water flow.

A model made of hexagonal mesh would be useful in determining its applicability to dolphin rescue and purse seine dynamics in general. Hexagonal-mesh webbing is currently being produced in Norway and has performed favorably in Norwegian purse seines (Beltestad, 1980). Hexagonal-mesh nets use about 15% less material, sink faster, purse easier, and are nearly as strong as the rhombic mesh purse seines currently in use. Hexagonal meshes are less prone to collapse when being pulled through the water. Nets of this material may be ideally suited for the western Pacific tuna fishery, where nets are often as much as 1000 fathoms long and 22 strips deep.

A suitable scale for hydrodynamic studies of the purse-seine operation, with emphasis in dolphin rescue and release, is 1:10. At this scale, a 850-fathom (1555m), 18-strip seine would measure 156 meters (510 ft.) long, fish to approximately 13.2 meters and set a 50-m diameter circle. Greater precision in dynamic scaling can be achieved at this scale than at greater reductions, and the necessary instrumentation for measuring depth, speeds, volumes, surface areas, etc. is currently available. A 1:10 model is sufficiently large to allow attachment of the necessary instrumentation yet

small enough to allow observation of the entire operation both from the surface and underwater. All net materials are commercially available, as are necessary deck gear for setting and retrieving the model seine. This size is also suitable for making any number of tailoring and design changes quickly and inexpensively. Using a 1:4 mesh scale would allow for making fairly complex modifications with minimal labor, because the larger mesh size would allow use of standard net-making tools. A model at this scale would be a valuable tool where the investigation of a broad range of physical and procedural modifications of the tuna purse seining system could lead to advanced designs in dolphin release techniques at a reasonable cost.

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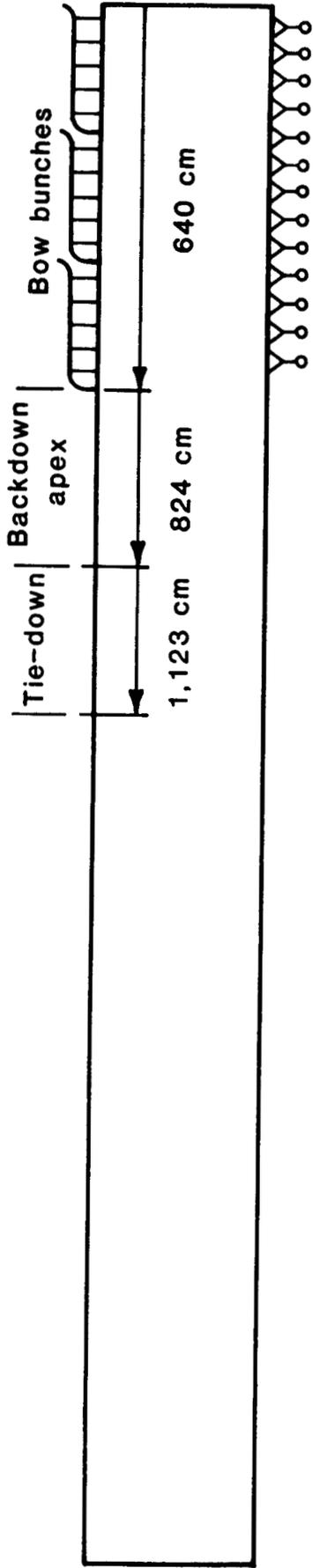
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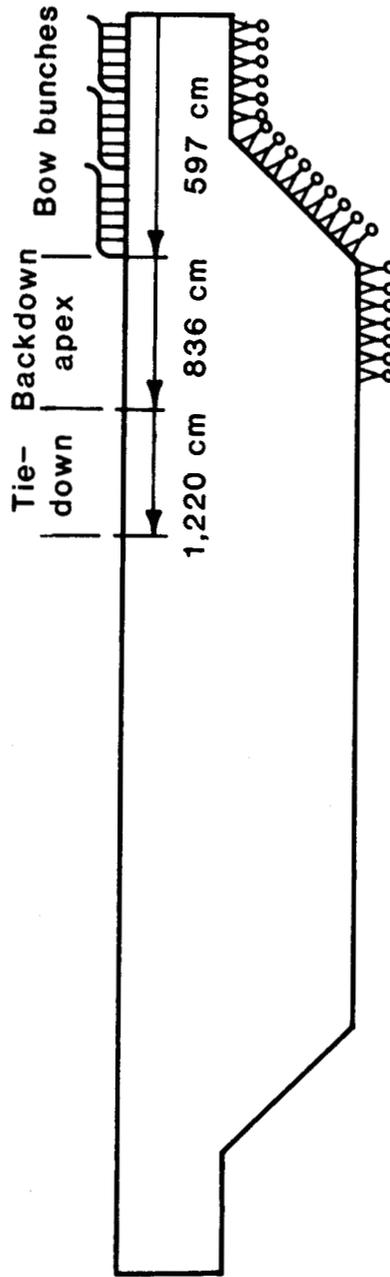
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Table 1. Physical parameters of full-sized purse seines and their models.

Net Parameters	Standard Net		Large-Volume Net(LVN)	
	Full size	Model	Full size	Model
Geometric Scale	1	1:25	1	1:50
Length (hung)	777.8 m	31.1 m	1098 m	22.0 m
Length (stretched)	864.1 m	34.6 m	1378 m	27.5 m
Depth (stretched)	73.5 m	3.1 m	184 m	3.8 m
Web (nylon)	treated	untreated	treated	untreated
Mesh size (L)	1048 mm	15.2 mm	108 mm	12.7
Twine size	#42	210/3	#24	7/2-L2
Twine diameter (D)	2.26 mm	0.45 mm	1.88 mm	0.0057" 0.14 mm
Twine diameter to mesh length ratio (D/L)	0.55 mm	0.75 mm	0.44 mm	0.0114 0.29 mm
Meshes long	8242	2267	12,752	2176
Meshes deep	700	205	1700	300
Ratio twine diameter d/D	1	0.200	1	0.077
Ratio mesh length λ/L	1	0.447	1	0.1176
Hang-in coefficient	.90	.90	.79	.79
Corkline	Nylon, twisted	Nylon, braided	Dacron, twisted	Nylon, braided
Length	777.8 m	27.9 m	1098 m	22.0 m
Diameter	-	2.72mm	15.9 mm	12.9 mm
Floats	spongex	-	spongex	Polyethylm
Size	15.2x9.5 cm	19.1x11.9 mm	16.5x21.6 cm	9.6x12.4 mm
Buoyancy	0.99 kg	3.4 g	3.86 kg	0.00194 lbs 0.88 g
Density	118.0 kg/m ³	32 kg/m ³	118 kg/m ³	32 kg/m ³
Number	7000	1077	1098 m	528
Total flotation	6970 kg	3.64 kg	1389 kg	1.021 lbs 0.46 kg
Lead line	Chain	Chain	Chain	Chain
Length	777.8 m	28.0 m	1098 m	22.0 m
Size	11.2mm(7/16")	1.3 mm	12.7 mm	-
Weight per meter	0.32 Kg/m	2.56 g/m	2.79 0.39 kg/m	0.73 g/m
Weight ratio (w/W)	1	0.008	1	0.05 mm
Total weight	372.5 kg	1.03 kg	4548 kg	0.17 kg
Purse cable	-	Nylon	Steel 9x16	Nylon, Mono.
Size	-	2.97 mm	16.0 mm	0.79 mm
Length	-	30.5 m	1098 m	22.0 m
Total weight	-	-	1078 kg	33 g
Time reduction	1	S	1	S



A. Standard 1:25 model of purse seine 425 fathoms long and 9 strips deep.



B. Large volume net 1:50 model of purse seine 600 fathoms long and 17 strips deep.

Figure 1. General dimensions of model purse seines used in study.

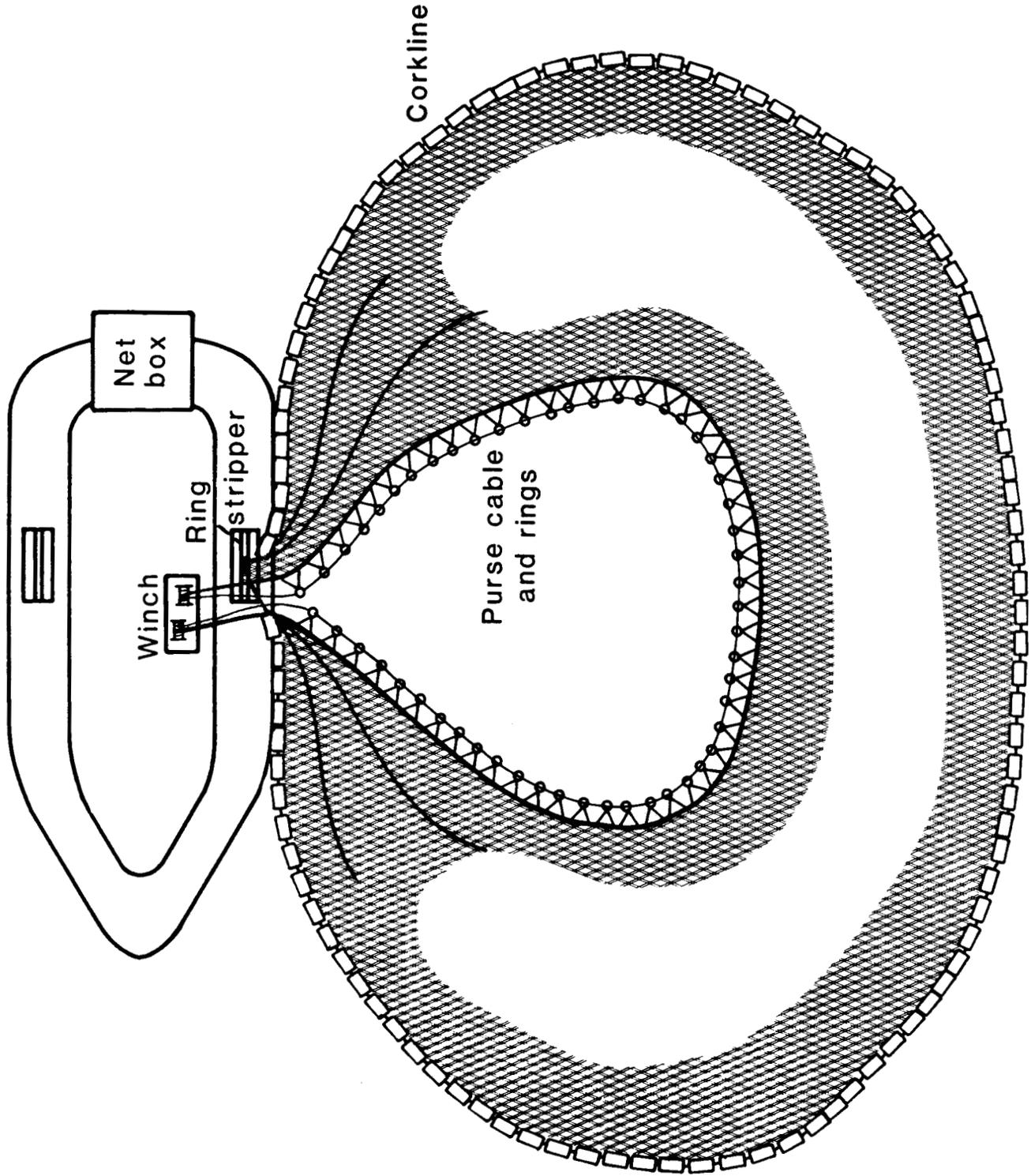


Figure 2. Idealized net configuration during the pursing operation.

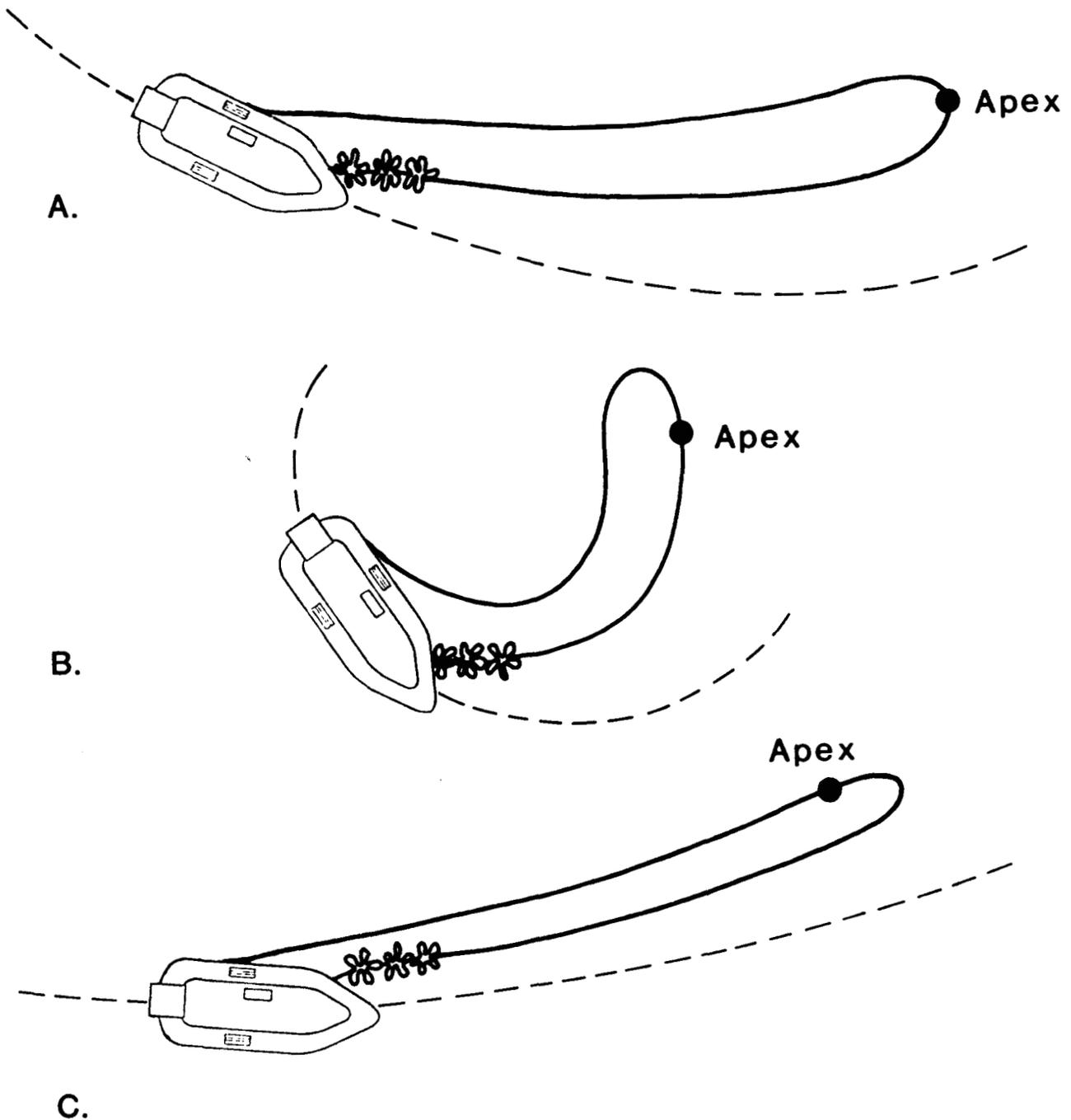
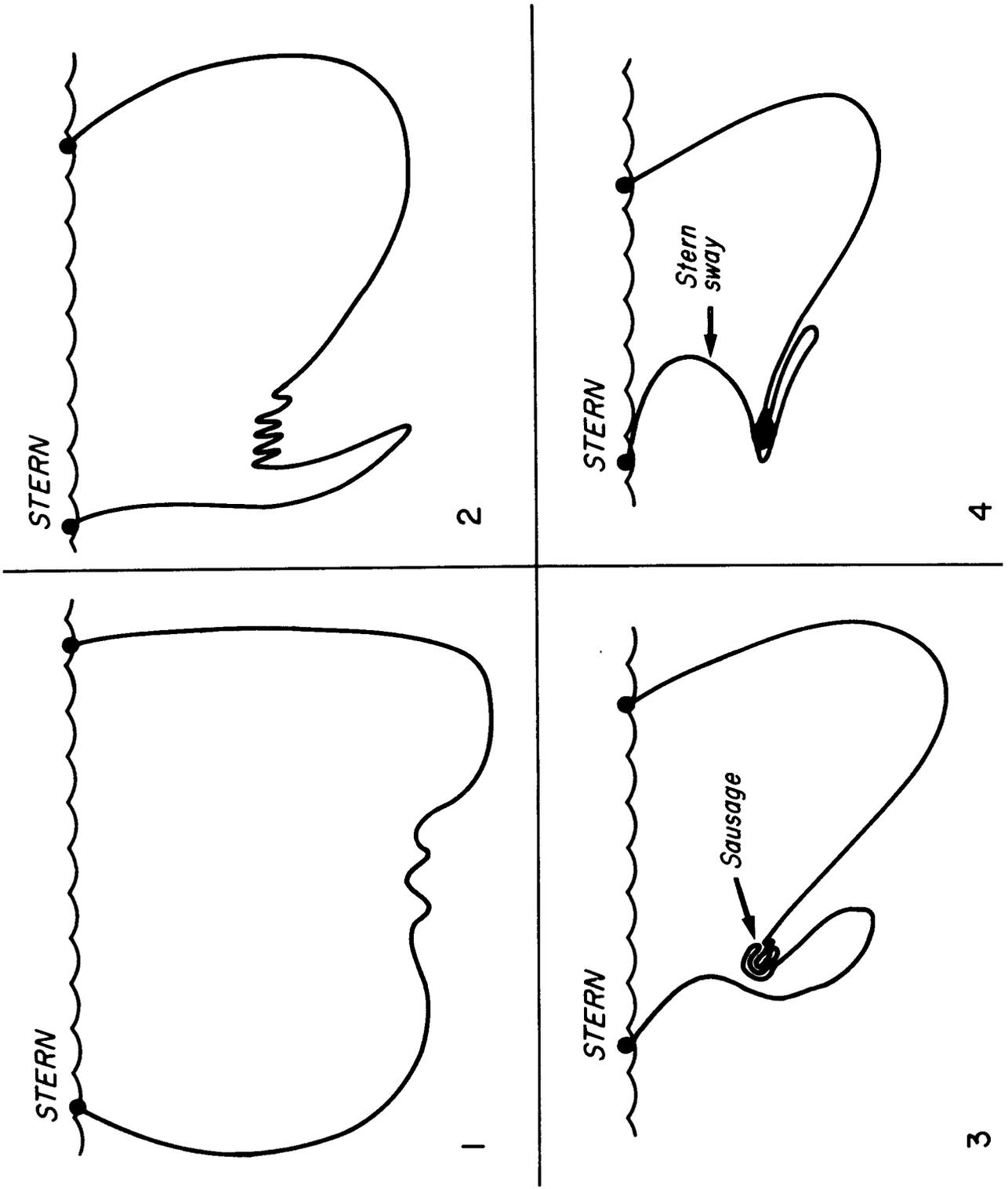


Figure 3. The degree of turning arc during backdown influences the location of the channel apex: A. Backdown channel with proper turning arc for correct apex position, B. A tight turning arc rotates the apex around to the bow side of the channel and C. Too straight of an arc moves the apex to the channels stern side.



3
Figure 4. Cross section of backdown channel showing idealized development of stern-sway.

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