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# The Improvement of Fishing Vessels and Gear

*Fishing vessels and gear all over the world have evolved by processes of trial and error. In some regions they have come to be very well adapted to local conditions and requirements, in others they are grossly inadequate and are retained only by the forces of tradition and ignorance. Very small changes in the equipment of fishermen in primitive countries could increase production manyfold. An example in point is the addition of outboard motors to dugout canoes. In advanced fisheries, the design and layout of fishing vessels as well as the mechanisms of propulsion could all be improved to good effect. This chapter reviews various fields in which improvements are indicated. A special laboratory for the design and testing of vessels and fishing gear is suggested. This should be integrated with a laboratory where research on behavior and on environment is being conducted.*

Obviously there are many ways to enlarge the harvests of the seas. None of these alone can bring about a brave new world in which people will be nourished largely by marine organisms. Any great total increase must come through the sum of many actions—through the development of new fisheries, the proper application of husbandry, the control of predators and diseases, the scientific balancing of different fisheries so as to direct the weight of fishing pressures among different species. Chapter 7 stressed the importance of studying behavior of marine animals to provide a basis for improving fishing and techniques. Several of these measures imply the necessity of improving the efficiency, speed, capacity, and safety of fishing vessels. That alone could result in great increases in the production of sea foods, especially in primitive areas where fishing is still conducted on the level of a folk culture.

To peoples of northern countries the phrase "great fisheries" evokes an image of vast fleets of otter trawlers, purse seiners, tuna clippers—vessels which sail far out over the ocean with mechanized equipment and large crews, bringing back catches of many tons to canneries and filleting plants or to refrigeration centers for reshipment far into the interior. It brings to mind ports like Gloucester, Hull, Grimsby, San Pedro, Tokyo, San Sebastian, and Murmansk. Actually, a large part of the world's fisheries are not like this at all, but are conducted by thousands of individual men scattered along lonely coasts working in tiny boats out of settlements that could hardly be called ports, for they have neither harbor nor anchorage.

Such a fisherman may live in a small village. He gets up at dawn every day that the weather is good enough for his work. He goes down to the beach and meets his fellow fishermen. Together they load a dugout canoe with gear, drag it down to the water, push off, and paddle out to their usual fishing grounds. In some places such men will fish with hook and line, in others with spears, in still others with nets, depending on the tradition of their region. After a few hours they must return with their day's catch, rarely consisting of more than a dozen or so shorefishes, which must arrive in good condition, preferably alive, and in good time for the day's market. No one knows how much fish is handled in this way throughout the world, for it is impossible with present facilities to collect meaningful statistics. The quantity probably is very high, for hand-powered craft are the principal types of fishing vessel along all the coastal countries of Middle and South America and Africa, and of all the countries of the Indian Ocean and the western Pacific. If these little boats are widely used, it is because they offer distinct advantages. The boats are simple enough that a man can make one himself. He might even buy one, for they are cheap compared with motorized vessels. They are easily handled, require no important special equipment and, most important of all, cost nothing for upkeep—no docking expenses and no mechanical repairs. In short, they are the kind of vessel that a poor man can possess and operate.

On the other hand, there are disadvantages to these small craft. Fishermen cannot paddle far enough to find the most productive grounds. They dare not go beyond the narrow range of their familiar areas for fear of being caught in bad weather or of staying out too long and thereby spoiling their catch and missing their market. Fishermen can overcome this problem by using sailing craft to extend the range of their operations. This is the maximum reached in propulsive power in a large part of the world's fisheries. Sailing, however, has serious limitations, too. Fishermen can operate effectively only when winds are optimal. In a study of Malayan fisheries, Firth [1] found that about 5 per cent of possible fishing days were lost because winds were too light for fishermen even to reach the fishing grounds. Besides that, there was a much higher percentage of good fishing time lost because of the slow passage to and from the grounds.

Poor wind conditions also reduce the opportunity to scout for fish on the grounds and impede effective handling of gear. Even a little motor power would expand the time of these fishermen tremendously—time which they could use for preparing gear, baiting hooks, handling catch, maintaining boat and equipment, exploring for new fishing grounds, and traveling to more distant areas than hand propelled or simple small sailing boats afford. Such a seemingly minor change, if widely accepted in the many parts of the world where fishing is still at a primitive level, could increase production of sea food tremendously. This has been demonstrated in India, where Setna [2] has compared the performance of vessels variously powered. Sailing vessels fishing for threadfins can operate 60 to 75 drift nets. During five months of 1953, their average catch of these large fish was 485. Powered vessels, on the other hand, can operate 100 to 110 nets. For this reason, and also because of their greater fishing range and speed, they averaged 2,000 fish during the same season.

Such a change in so ancient a craft as fishing can have a very profound effect on a conservative society, introducing many problems that ramify throughout the intricacies of the economic and social structure. Here I shall touch only on the mechanical problems, which are formidable enough.

Perhaps the simplest innovation in a fishing community that depended on dugouts would be an outboard motor. How about outboard motors? Most of them are designed for relatively light-duty work in waters where corrosion is not a great problem. Available types of outboards, of which there are many, would need to be thoroughly tested and certain types recommended for particular purposes. Probably, special motors would have to be designed to stand heavy work and abuse, and manufacturers would have to be encouraged to build them. The Food and Agriculture Organization has initiated such tests to help solve the motorization problems of the dugout canoe.

Ziener[3] describes difficulties encountered with outboards in a study of the motorization of Chilean fishing craft. Since Chilean fishermen must import motors from foreign countries, the necessary parts for repair are often not locally available, and at best it is usually a lengthy and difficult process to obtain them. The outboard motors themselves corrode rapidly, wear badly, and require frequent repair. Among 330 motors in operation on the Chilean vessels studied, 307 were of a model produced by one manufacturer, which proved to be the only one that could stand up well under extreme wear and corrosion. But this is still not an ideal motor. An even better type could be produced if designed especially for this type of operation. Traung suggests (in a personal conversation) that a small diesel engine might be the solution to the present difficulties of outboard motors, but that has yet to be developed.

That is only one of the problems of mechanization. There are others. Outboard motors can sometimes be adapted effectively to the existing craft. But in many instances a new type of boat would have to be introduced to make motorization possible. The new boat must be designed with an eye to the fact that local boatyards must be able to build it and of materials locally procurable. Moreover, they must be able to sell it at a price which fishermen or their entrepreneurs can afford to pay. And finally, the fishermen themselves must favor the new type of vessel over those of the old style.

Designers would, of course, think of benefits other than mere speed. Craft which can be paddled or sailed effectively usually are narrow of beam and are not optimally safe or seaworthy. These faults could be corrected in a power-motored vessel. At the same time, designers must not lose sight of local necessities. For example, in many primitive fisheries, harbor facilities are not available and the boats must be operated from the beaches. Consequently, the new craft should be so constructed that it could be easily launched in the surf and beached and hauled up away from the reach of tide and waves.

Culture, tradition, and religion, which are very important in certain primitive fisheries, must be considered and respected in the design of boats, or motorization may not win favor with the fishermen. A background of tradition has been built up around the special types of boats used in many fisheries, involving special features of construction and adornment. The fishermen may not readily accept the improved types of boats unless these special features, superfluous though they may seem, are carried forth in the construction of the new craft.

With better boats fishermen could advance their means of catching fish. The expanded range of the boats could carry the fishermen to places where greater quantities of fish are available and perhaps concentrated into dense schools. Here the old traps, drift nets, and hooks would probably in some places be superseded by gear more effective for catching pelagic schooling species. The extra power and maneuverability of the motor boats would make it possible to use a round haul seine with which whole schools could be encircled and caught. This sort of fishing would probably be conducted by a group of boats, one of which would be a large and sturdy craft to handle the net. The behavior of the species involved and their reactions to the nets would have to be studied in order to provide a net of the maximum efficiency for their capture. Fishermen would have to be trained to construct, operate, and maintain these new nets.

Perhaps the greatest impediment to motorization will be in the lack of modern shore facilities. Procuring fuel would by itself introduce a complex of problems, necessitating the construction of docks, storage tanks, roads, and distribution centers. Shops would have to be established to repair the motors. A supply of new parts and new motors would have to be maintained. Mechanics would have to be trained especially to do the repair work and fishermen would have to be taught to operate and take care of the motors. With greatly increased quantities of fish landed, means must be provided to preserve and store them, to sell them, to transport them to distant inland markets.

A great expansion of the fisheries in primitive fishing communities would change the whole economic structure. Change in the social structure would undoubtedly follow. The rather extensive ramifications of these changes are very well stated by Firth, as follows:

> Any radical change in the fishing industry will almost certainly lead to far-reaching changes in the way of life and social institutions of the fishermen. To take only two aspects. Attempts have been made together with the introduction of power boats to get the fishermen to remain at sea for several days in succession instead of returning to shore each evening (or morning if they are engaged in night fishing). This has proved difficult. The fishermen are disturbed at the prospect of leaving their wives and families for so long, and if the period lasts seven days or more they miss the break from work on Friday, the Muslim Sabbath, when they normally attend the mosque, and then repair and dye their nets. Any system of deep-sea fishing which kept them away from their villages for more than a week at a time would involve changing these established patterns of behavior. Again, the introduction of power boats, with their greater capital outlay, would tend to change the existing pattern of economic relationships in the community. The common practice of lending boats would become less simple because of their greater value, greater liability to damage in unskilled hands, and the less general knowledge

of how to handle them. Capital would probably have to be found in new ways, the increased costs would demand a rearrangement in the established systems of distributing earnings, and there would be more likelihood of the gap between wealthy and poor fishermen being widened. A special group of power-boat owners with superior economic status to the ordinary fishermen might even be created. Since in these communities economic relationships are closely bound up with other social relationships, from kinship to recreation, the structure of the peasant society itself would be affected.

In brief, substantial changes in the fishing industry mean substantial changes also in the kind of society in which the fishermen live. Experience has already shown in Africa and elsewhere how peasant societies have reacted to modern technological and economic changes: the traditional structure has tended to become disrupted and community ties loosened, the old system of social values loses much of its force and the new values are apt to lack that cohesive quality for individual behaviour which gives strength to communal activity. Change in the structure of these peasant societies is not a new phenomenon. For instance, it took place in Malaya and parts of Indonesia with the coming of Islam. But it was then mainly the religious and social structure that was affected; the economic foundations remained much the same. The new influences of the last half-century or so have been responsible for economic modifications which, when fully developed, will be more radical in their effects than anything that has gone before. There can be no question of repressing these changes. The problem is to understand them, to try and predict their effects, to safeguard and to stimulate those community ties and values which give meaning to individual and social life and give a basis for cooperation. Much of the traditional social structure will doubtless long remain, and some of its elements at least will serve as rallying points. But the rather narrow concepts of the old peasant community will have to be built up into something wider. It will be necessary to create additional bases of loyalty, new foci of interest.[4]

It need not be assumed that improvement must always carry the threat of dire economic and social consequences for the fishermen. Quite the opposite may be expected and must be striven for.

It should be apparent, however, that fishery development programs must be preceded by extensive economic, sociological, and technological research and thorough scientific planning. Furthermore, fisheries improvement must be evolved gradually and executed systematically. Overly ambitious expansion programs are bound to fail and the memory of failure is long lasting and detrimental to further efforts.

The literature is full of warnings against the danger of too rapid expansion. For instance, Qureshi and others, quoting Chapelle, write that "it would be very wise indeed to motorize and otherwise improve the small primitive types of fishing boats (rather) than to introduce European and American launches, draggers, seiners and trawlers."[5] In another instance, Bergius concludes, "The main lesson learned from the story of the Scottish fishing industry is that a start should be made in a modest way and every endeavor made to encourage the fisherman to build up slowly and surely and so retain his independence. The main aim should be to help the fisherman to help himself." [6] Osorio-Tafall warns, "For any immediate increase in fish supplies it would, perhaps, be advisable to carry out a number of small, less ambitious but economically sound projects which, in the aggregate, would considerably increase production. For each Latin-American country, the nationwide development of fisheries must be a slow and gradual process, of the evolutionary type, because any hurried spectacular measures are bound to fail. The pace of development will largely depend on the training and experience of the personnel engaged in the fishing industry." [7] Zimmer states, "Development must, on account of the human element, be gradual, and the main problem is the persuasion and education of the fishermen." [8]

The type of boat used in each fishery has gradually evolved through generations of trial and error. This process has produced some excellent craft which are perfectly adapted to local conditions. It has also produced others which are poorly constructed, unwieldy, unsafe, or otherwise completely unsatisfactory.

The first step in any program to improve fishing boats should be thorough investigation and testing of the existing types. It is necessary to understand why and how each type of boat has evolved, and why certain materials and methods of construction have been used. Boats must be tested for seaworthiness, sea-kindliness, stability, hardiness, speed, and general suitability for the kind of fishing operations involved.

Such a survey might conclude that present boats are perfectly adequate as they are, or would be with a few modifications. On the other hand, it might be found that new designs need to be developed. The survey would make available to the architect information concerning the special vessel characteristics in present types which specific conditions of local weather, sea, and fisheries require.

Fishing vessels fall roughly into about five size categories, each identified by certain characteristic features and each with its own individual set of problems: (1) small open boats propelled usually by paddles, oars, sails, or in some cases by outboard motors; (2) larger craft, usually open, powered with small, often air-cooled, inboard motors or large outboard motors; (3) lightly constructed craft of shallow draft usually partially decked and with partial shelters, often with converted automobile engines, running up to about 40 feet in size; (4) ocean-going, fully decked craft with enclosed shelters, large fish holds, marine engines, crew accommodations, usually of wooden construction, and having a size of not less than 40 feet; (5) larger, all-steel, fast moving vessels with heavy duty engines built for long range, distant operations and of large carrying capacity.

Improvement possibilities for the smallest boats have been covered in a general way in preceding pages. There is need for research, guidance, and development for larger sizes as well. Modern methods employed by naval architects and engineers could be used to advantage in the design of fishing boats. Usually small fishing boats are constructed by individual boat builders without benefit of naval architect. Prepared plans are usually either very rough or entirely absent. Choice of lines, general arrangement, engine and propeller, deck layout, material, fastenings, and so forth are made on the basis of tradition, sometimes of whimsey, but rarely of scientific knowledge.

The approach to improvements in hull shape through preliminary testing of scale models developed by Froude over eighty years ago has been used mostly in the development of large ships. The techniques developed could readily be utilized for designing of fishing craft and thus minimize the errors in the design of the boats. Detailed objective measurements of the important characteristics can readily be made from studies of the action of models.

Tank studies are conducted in the following way: [9] From a provisional plan of the ship's hull a model is constructed for study under experimental conditions. It is subjected to all sorts of tests. For example, it is towed in a tank while the resistance is measured at various speeds, and observations on the wave patterns are made to discover possible defects in hull shape. Self-propulsion tests can then be made with installed electric motors; at the same time torque and thrust measurements are made. The model can be modified and the tests repeated until the optimum shape is achieved. Further tests can be conducted to study such features as maneuverability, rolling, and general seaworthiness. The histories of the ships actually constructed are subsequently followed to provide comparisons of test results with actual operation in order to improve future testing. The ship model facility thus becomes a center of knowledge and experience in this particular field. The value of a ship model testing installation exclusively for fishing boat studies becomes apparent. Such a center, specializing in fishing boat studies, could greatly reduce the expense of trials and would build up a background of knowledge and experience from which boat designers and builders the world over could benefit.

Traung [10] has written of the special problems of predetermining the speed of fishing vessels. He says:

> There is seldom time or money enough, after the completion of a fishing boat, to carry out trials to investigate the true speed at different engine loadings. It is therefore difficult to get any reliable data about fishing boat speed; published data from trials and tests made at time of delivery are often exaggerated. . . . Complete and reliable tests take time.

Traung describes one of his own experiments, financed by a research grant, thus:

> Three models were used in the experiments and every model was altered several times in order to study the effect of single alterations. The ships were tested in several displacements corresponding to (a) light ship (b) ship "ready to go to sea" with full bunkers and ice and (c) ship homebound with cargo. The following results are taken from tests in the "ready to go to sea" condition, which was done with a displacement of 115m³ (corresponding to 118 tons).
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> First a design was chosen of a 68-foot boat, considered good by many fishermen. The boat was carefully tested in full scale trials. The stability and the datum waterline, and thus the displacement or hull weight were investigated. Then a model, designated 250, was made and tested in the tank at Göteborg. The results were compared with the full-scale tests and were in full agreement. . . . In order to study the effect of sharpening the forebody, the model was sharpened twice. The half waterline angle was first 36°, then 33°, and finally 28.4°. The biggest sharpening in the datum waterline on each side was 0.1 m. the first time and then 0.2 m. or a total sharpening of 0.3 m. The resistance decreased, which means that fuel consumption will be lower or the speed higher.
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> Some tests had been made for another purpose with a model of an icebreaker tugboat, called 258a, which had shown especially good nondimensional values. The boat had a long overhanging cruiser stern, which made the model somewhat longer than the 250 model. . . . It was decided to try to adopt this type as a fishing boat. The long cruiser stern would not be suitable for fishing so it was simply cut away and the stern was finished with a transom, the transverse section of which was "V" shaped as in the cruiser stern, and the model now was called 258b. The resistance increased somewhat. Then the stern was sharpened to a cruiser stern, as similar as possible to the stern of fishing boat model 250, and called 258c. The resistance increased considerably. . . . The next step was to replace the sloping icebreaker stem with a stem profile similar to the fishing boat model. This causes a slightly higher resistance.
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> The altered tugboat model now had the same profile, beam, and displacement as the fishing boat model, but the resistance was lower. With the transom stern, however, it should be still lower, especially in the loaded condition, and it was decided to investigate whether a fuller cruiser stern would be better than the fishing boat shape. The stern was made as full as construction in wood would allow, and the model was called 258e. In the light condition, the result was a considerable improvement but, surprisingly, the fuller cruiser stern was still better than the sharper one in the loaded condition. The result was a boat with much lower resistance than the original fishing boat model.

. . . At 9 knots the resistance was 26 per cent less in the "ready to go to sea" condition and 29 per cent less in the loaded condition.

These studies illustrate how much time can be saved and how many frightfully costly mistakes can be avoided by such testing.

The performance of a vessel in a seaway is determined by the skill of the crew and certain features of the design and construction of the boat. Much of the information needed to study and improve the qualities of stability, seaworthiness, and sea-kindliness must be studied at sea during actual operations. Data must be collected during running and fishing in all types of weather, including icing, for various stages of loading and trim.

Möckel [11] had the opportunity to conduct such a study aboard five German trawlers. As a result of his scientific collection of data, he learned that certain characteristics of a boat govern its loss of speed in rough weather. He determined when fishing had to be discontinued because sufficient power to maintain towing speed in rough weather was lacking.

He accurately determined the amount of power necessary to overcome air resistance, as well as the combined effect which loading of fish, distribution of weight, and consumption of fuel and water have on stability and sea-kindliness. He studied the behavior of the boat in rough weather. As a result of his observations, he made recommendations for operating a vessel under stress and listed the following points for consideration in the design of trawlers:

1. Sufficient reserve buoyancy, particularly forward. A good freeboard should be aimed at, though this is unpopular with many fishermen because they consider it makes handling of the trawl difficult. Well flared sections above the water line in the foreship and as large a forecastle as possible also contribute to extra buoyancy.
2. In calculating stability, the shipping of considerable quantities of water should be taken into consideration. To keep rolling acceleration low, heavy equipment should be arranged towards the ship's sides, if possible, as this will increase the radius of gyration without decreasing GM (i.e., the metacentric height).
3. Scuppers must be large enough to allow the water to run rapidly off the deck.
4. The superstructures astern must be built over the entire breadth of the ship, as is sometimes done on modern trawlers, for protection against overtaking waves.
5. The stern above the water line must be as full as possible, to provide extra displacement and to adapt itself easily to the waves coming from astern.
6. According to experienced trawler skippers, a GM of about 2.8 feet

at departure, and one of 1.65 feet at arrival is considered to be very good.

7. To obtain a satisfactory damping of rolling, it is not desirable that the floor rise and bilge radius be too great.

Möckel summarizes as follows:

> Model tests can give practical results only if they are correlated to the data collected on board ship showing the behavior of the ship in all conditions of service. Such research on large cargo boats has been carried out in several countries, but little information is available concerning fishing vessels.

The following passage illustrates the benefit of developing superior hull shapes:

> The shape of a fishing boat's hull is important in relation to efficiency and running costs. It has been shown that even well designed fishing boats can be improved to such an extent that the fuel consumption is reduced by 30 per cent without sacrificing speed, seaworthiness or carrying capacity. If the fuel cost is about 15 to 20 per cent of the boat's total expenses (including depreciation) the total saving is therefore around 5 per cent. It has been considered satisfactory if a fishing boat can give about 5 per cent profit. A saving of 30 per cent on the fuel account would correspond to an amount which is almost equal to this profit.[12]

The question of V-bottom versus round bottom construction is a matter of some controversy. Experts disagree as to whether V-bottom boats can be produced more cheaply than conventional fishing boats and whether they have as good qualities of sea-kindliness and seaworthiness. Authorities also argue over the relative merits of stern types—cruiser sterns, transom sterns, and so forth. The limited results of studies published are not convincing in either direction. These are two specific examples of current controversy which could be settled by model studies combined with full scale trials.

The whole question of vessel construction requires investigation. People disagree on the merits of wood and of steel construction. Many authorities claim that wood greatly limits the possibilities of design and construction, and that vessels made of wood are much more costly to maintain and are shorter-lived than those of steel. Others take a contrary view. Size seems to be the determining factor at present. Smaller boats are wooden, larger boats are of steel, and intermediate sizes may be of either material. The optimum strength of fishing vessels must be related to economy of construction. If a vessel is too heavily constructed, it becomes unnecessarily costly. If it is too weakly constructed, it is unsafe and therefore also too costly. Japanese researchers in the field of vessel design have begun a program of deliberately breaking fishing boats to determine their points of weakness. At the same time they test the scantlings to study their properties and to improve their design.

The local availability of materials has governed the design and construction of boats in all fisheries, but particularly in the more primitive areas. The many difficulties of structure and design might be solved by using new materials. New synthetic materials are constantly being developed and improved and should be tested for vessel construction. Such materials might be molded into hulls. As a matter of fact, fiberglass is used for that purpose now.

The use of laminated beams in vessel construction appears to be particularly promising. These can be made stronger than solid members and can be produced in a greater variety of shapes and sizes than solid pieces. The opposition to laminated construction usually stems from the use of inadequate glue and poor control of the moisture content of the wood. These seem to be simple technical problems for which solutions ought not to be difficult.

Another important and particularly promising field for research is in the development of improved fastenings, that is to say, the dowels, nails, screws, lags, and so forth that hold the boat together. The types of fastenings and the methods of using them in wooden construction have much to do with strength of the vessel. Improving the fastenings increases the strength, or it makes possible the use of lighter members to obtain the equivalent strength, thus reducing the weight, the cost, and the power required for propulsion, and extending the life of the boats.

There are special problems concerning the design and construction of beach-landing craft. Many fisheries are carried on in areas where natural harbors are not available. The building of artificial harbors is generally prohibitively expensive, and in some areas they are not feasible because of unfavorable physical conditions. Consequently, where there can be no harbors, boats must be built that can be operated from the beach. They must have special qualities of seaworthiness which will enable them to be launched in heavy surf. They must be very light so that they can be easily hauled across the beach, strong enough to withstand the exceptional abuse to which they are subjected and give years of useful life. The bottoms must be designed in such a way that the boats will remain upright when beached and hauled. The propeller installations must be constructed so that the propeller will not be damaged by beaching.

Many types of beach-landing craft have evolved throughout the world, most of which could be improved through research into design and construction. This is of particular importance in relation to mechanization of primitive craft which are now propelled by oars or sails.

Zimmer [13] recommends considering some recent improvements in the construction of lifeboats, which were based on extensive research. This research has resulted in the development of superior hull types, which might be applied in the construction of fishing boats. Various types of jet propulsion have been tested. Improved launching methods have been developed. Hulls have been constructed of novel materials such as laminated moldings, various types of metals, double diagonal wood, and plastics. Further research should be conducted into the specific problems involved in the design and construction of beach-landing fishing craft, however, because of their entirely different function.

One of the important tasks in vessel improvement is to increase the efficiency and reliability of propulsive power. To do this requires very advanced and specialized engineering research, whether the problem concerns the smallest outboard or the largest high-powered diesel engine. Let us consider a few of the opportunities in this field:

The difficulties associated with the use of such a simple machine as the outboard motor have already been discussed. Ziener also recounts problems involved in inboard installations of engines. He states that the lack of progress and poor results of the motorization of the Chilean fishing fleet are due to technical and economic difficulties "the origin of which nobody has bothered to discover." [14] These difficulties are caused by factors far beyond the fisherman's influence. Vessel problems in Chile are worth discussing at some length, because in many ways they typify those which people in a number of underdeveloped countries experience.

In the absence of proper guidance, Chilean fishermen have usually bought engines unsuitable to their requirements, that is, a lightweight gasoline engine which is very expensive to operate, or a high-speed diesel which is very expensive to maintain. Fishermen are now being encouraged to buy semidiesel engines which, though costly to buy, are economical to operate and maintain. The efficiency of propulsion (the proportion of power produced by the engine transmitted by the propeller) is a serious shortcoming in Chilean boats. Ziener states, regarding conversion ratios, that "the average for the whole fleet may be estimated at 30 per cent, but several boats work with no more than 15 to 18 per cent." Since 50 to 55 per cent is possible, there must be a waste of as much as three quarters of the fuel. Ziener cites an example in which a 25 horsepower, 3,600 rpm gasoline engine was replaced by a 10 horsepower, 800 rpm semidiesel with a suitable propeller. For the same speed the fuel cost was reduced to one fifth the former amount.

Maintenance problems for the Chilean fleet are great. Engine repairs are expensive, parts are hard to obtain, and in many instances engines that are out of order are discarded when they could perfectly well be repaired. The frequent breakdowns are often due to faulty installation. Crankshaft breakage is common owing to misalignment of bearings, torsional vibration caused by improper propellers, deficient reversing gears, poor engine adjustment, propeller posts that are too heavy, improper propeller shafts, and so forth. These troubles result chiefly from lack of knowledge, training, guidance, and technical assistance.

Obtaining proper diesel fuel is another serious problem which troubles Chilean fishermen using motorized vessels. With improper fuels such as are often supplied, carbon residues build up so fast that in many cases engines have to be dismantled for cleaning every twenty-four to forty-eight hours of running time.

Electrolysis also causes much trouble. If metal parts are not properly installed and protected, galvanic action proceeds very fast with disastrous results. In some cases, iron fittings on brass cooling tubes were eaten away in less than two weeks, resulting in flooding of the motors and boats. Ziener cites one extreme case of improper design and faulty installation of engine and propeller:

> . . . a new-built boat of 40 ft. length, 10 gross register tons, should, for a speed of 9 knots, have had a motor of about 60 h.p. at 600 r.p.m. and a propeller with 28 in. diameter and 24 in. pitch. Instead, on recommendation of the motor-importing firm, a motor of 90 h.p., 3600 r.p.m., direct drive, with a propeller of 13 in. diameter and 13 in. pitch, was installed. In sheltered water the boat did not exceed 5 knots and outside the breakwater, under average weather conditions, less than 4 knots. The maneuverability was dangerously bad even in sheltered water. The small propeller of 13 in. hidden behind a sternpost of 7 in. width, worked with an efficiency estimated at 13 per cent. The lack of slipstream impaired the rudder action. The boat was useless for its purpose and the motorization proved a complete failure. Generally, such cases can be remedied by the installation of a reduction gear and a bigger propeller, but it was not possible in this instance because the stern was built too small to accommodate a normal propeller.

Several lines of engineering research are indicated for improving propulsive power. For example, efficient jet propulsion might advantageously be adapted to certain types of fishery vessels. Eliminating propellers and bearings would solve many of the propulsive problems of beach-landing craft. It would obviate the trouble caused by sand in stern bearings and bushings. With the necessity of protecting rudder and propeller removed, the design and construction of a vessel would be much simplified. Launching in heavy surf would be much easier with jet propulsion because power could be applied much sooner. A type of jet system is now available, but because the power is supplied by a high-speed gasoline engine which is expensive to operate, it is not likely to be widely accepted by fishermen.

Electric systems have been considered for fishing-boat propulsion but have not been very successful. Research may result in improvements and demonstrate these systems to have advantages under certain circumstances.

Various modifications of standard propulsion methods are already available. A rather recent development is the use of "father and son" systems. In this arrangement, two engines of different power are installed. The larger engine is the main propulsion unit, assisted when required for extra speed or power by the smaller unit. The smaller unit is used to power the winch, pumps, electrical system, and so forth. The smaller engine can be connected alone to the shaft to propel the boat in emergencies. This system has the advantage of great flexibility and improves efficiency of operations. It also adds to safety and reliability by providing a reserve engine for propulsion in the event of breakdown of the main engine. This type of system would be of greatest benefit to larger boats.

The Kort nozzle has proved advantageous for certain boats. Essentially, the Kort nozzle is a metal shroud over the propeller, which reduces the amount of power required for a given amount of thrust. The fact that these systems have won popularity with tugboats indicates their desirability for net towing operations such as otter trawling.

The conventional type of propeller is a compromise between efficiency of running and efficiency of towing. A controllable pitch propeller increases efficiency, for it can be adjusted by a simple control in the pilot house to give the best pitch either for running or for towing, whichever is desired. Their effectiveness has been demonstrated by widespread successful use in such countries as Sweden. Those made in countries other than Sweden are delicate and expensive, and therefore not widely used on fishing vessels. Engineering studies are needed to make them more rugged and cheaper.

Vibration in fishing boats is usually considered to be an unavoidable source of discomfort. Actually, discomfort is the least of its effects. Much more important is the fact that vibration can cause serious mechanical troubles.[15] For example, it leads to breaking of the propeller shaft. This sometimes happens in rough weather, with the consequence that the vessel becomes helpless and sometimes founders. Excess vibration can also damage the structural parts of the vessel by loosening rivets and fixtures. Vibration is avoidable, but constant study is necessary to determine how and where to reduce it. There may be a number of remedies, such as a proper choice of propeller, shaft, engine, and mountings, proper engine and shaft installation, and proper hull construction.

A fertile field of research is in the development of improved types of deck gear. The efficiency of all mechanized fishing operations depends upon the capability and reliability of the deck gear. For the most part this means winches of all kinds, from the small power gurdies used to haul line trawls to the massive winches which haul nets aboard the large trawlers. Although at least one winch is on every mechanized fishing boat, it is rarely completely suited to its job. Breakdowns occur frequently and power conversion is often poor.

Winch types, like boat types, have evolved gradually, under various circumstances, and the effectiveness of different designs is extremely variable. The steam winch was reliable and successful in the days of steam propulsion but now has become outmoded. Most fishing boat winches are operated through mechanical linkage to a power takeoff from the main engine. Severe strains affect the whole system, causing frequent mechanical breakdowns. Clutch, brake, and speed controls are often troublesome. Electric and hydraulic winches, which eliminate many of these mechanical shortcomings, have not been generally accepted, partly because of the cost of installation. The more extensive use of these better winches depends on further research and development and testing of models suited to various operations.

Deck gear problems may become the most important in the mechanization of primitive fisheries. There has been no evolution of types of gear to provide a basis of experience for the design of such equipment. Not only must deck gear be designed, but methods of handling the fishing gear will have to be developed.

Setna comments further on his example of increasing catches with mechanized vessels as follows:

> The performance of the mechanized boats would have been still more remunerative if they had possessed small winches. It is realized that mechanization will not be fully complete without the use of mechanical equipment aboard. At present, power is used only for propulsion; it can profitably be employed to perform work which engages the tedious and exhausting labor of a number of hands. For instance, power vessels using drift nets carry 7 to 8 men for setting and hauling the nets. Similar work is, in other countries,

done by four men through the use of winches driven by the engines. This economy can be achieved in India also and the problem of installing winches in mechanized craft is now before the Department of Fisheries. This will lead to an increase in the number of boats as crews will be smaller and there will be more fishermen available to man new boats and, consequently, increased supplies of fish made available.[16]

Included in the field of vessel design is the art of devising the proper layout of boats for maximum convenience, comfort, safety, and economy. The general layout of a vessel is often established more by tradition than by practical considerations. Fishermen and boat builders are usually content to follow the accepted standard rather than attempt any novel departures. This is owing in part to general conservatism but mostly to the fear of expensive modifications after the boat is built. Neither the fisherman nor the small boatyard has capital enough to experiment properly with expensive fishing boat construction.

There are many questions about the internal and external layout of fishing vessels which require engineering research before they can be answered authoritatively. The positioning of winches, bollards, gurdies, poles, tanks, and other deck equipment has great influence on the efficiency and safety of fishing vessel operations. For example, the development of bait storage facilities on American Pacific tuna clippers came by a process of trial and error.[17] The error resulted in loss of life and ships. As faster and larger boats were built, bigger and bigger bait boxes were carried on deck. Designers tried carrying part of the bait in wells in the hold so as to improve stability. However, this arrangement not only limited capacity, but it was unhandy for transferring bait to the deck boxes and for handling the ice and the catch. Consequently, the owners built additional boxes on deck, thus making the boats very tender and topheavy. Eventually two of these vessels capsized while a third was lost with all hands. Of course more attention was paid to improving stability after these disasters.

There is a good deal of controversy concerning the location of engine, fish hold, crew's quarters, storage space, pilot house, and galley. Layouts vary widely geographically and from one fishery to another. Small Pacific salmon trollers have pilot house, engine, galley, and bunks forward and the hold aft. Small Atlantic draggers have the galley and bunks forward, engine and pilot house aft, and hold in between. Tuna clippers have galley and crew's quarters on deck, engine forward, and hold aft. Large Atlantic draggers have the galley aft of the pilot house on deck; below they have the crew's quarters forward and aft, the engine aft, and the hold in between.

Layout in fishing boats is in large part determined by the type of fishing done. In trollers and draggers on the Pacific coast of the United States, fishing is carried on from the stern; therefore, the hold must be aft to be easily accessible. This necessitates placing the engine and pilot house forward. The layout of Atlantic trawlers is influenced by the arrangement of the sailing schooners and beam-trawlers from which they developed. With the hold amidships, the pilot house had to be placed aft and fishing was done from the sides. The engine was placed aft to shorten the shaft, control linkage, and solve other mechanical problems, thus leaving the crew forward. Fishermen believe that having galley and crew's accommodations aft is most conducive to comfort when bucking into heavy weather and to convenience and safety, for this arrangement minimizes movement about the deck, an important consideration in stormy weather. Tyrrell,[18] in discussing Irish fishery boats, cites further advantages of having the engine forward and the crew aft. He gives these arguments: trim is unaffected by loading, since the hold is situated about the center of buoyancy; and full use can be made of the stern space, permitting the aft bunks to extend to the rudder. Forward installation of engine permits a convenient drive to the winch, which is placed forward. The engine is in a completely accessible position and is always clear of bilge water.

On the other hand, Tyrrell also points out disadvantages of this layout: The length of the propeller shaft with its support bearings becomes much increased. Mechanical controls over the considerable distance to the wheelhouse aft are complicated. The weight of the engine forward makes the vessel heavy forward. This tends to increase pitching in head seas, perhaps also to broach in following seas. Thorough research into these matters would probably provide the means of correcting such faults. Special shafts and bearings could be developed, as well as methods of precise alignment. Mechanical controls might be improved, or hydraulic or electric systems developed instead. Hull types could be designed which would reduce the heavy pitching and the tendency to broach. Here again, model tests would be of great benefit.

As was brought out in Chapter 5, fishermen would profit by diversifying their activity in response to seasonal changes, fluctuations in abundance or availability of species, and market conditions. However, to catch different kinds of sea animals requires different equipment and techniques. Each type of equipment requires a special deck layout. Each fishery usually employs a type and size of vessel which is more or less peculiar to itself. This may be culturally picturesque, but it is not economically feasible to operate a boat for only a few months and tie it up for the balance of the year. A fisherman desiring to diversify his fisheries must have a boat which he can adapt easily and quickly to any of several kinds of operations. Until recently little thought had been given to such a possibility. Attempts to modify specialized vessels for multiple use have met with only limited success. The boat designer must consider each type of fishing to be done, and then design a new vessel which strikes a happy compromise among the important features required for each. There can be no universal combination boat. Hull form is not the only problem involved in designing multi-purpose boats. It is necessary to develop special winches and winch positioning to provide maximum efficiency for the various operations. Many other factors must be considered such as the deck and interior layouts, kinds of propulsive and supplementary power, and methods of handling different kinds of sea animals.

In recent years a trend toward building combination boats has developed in some areas. For instance, Hanson [19] describes a type of combination fishing vessel developed for the Pacific coast of the United States which can be arranged for tuna fishing, purse seining for salmon and herring, longlining for halibut, dragging for groundfish, and trolling for salmon. Most of these are seasonal fisheries which could not individually justify the investment but collectively could provide for successful year-round operations.

The heavy capital investment required for a boat is a serious obstacle to expansion of fisheries. A major factor contributing to the high cost is the diverse nature of the boat-building industry. Fishing craft are for the most part constructed individually in small yards. Each boat is built according to the whims of designer, owner, and builder. Very few attempts have been made to introduce mass production methods into fishing vessel construction. There is great diversity of opinion, however, as to whether this would make very good sense at present.

Hardy concludes that mass production of fishing boats would be possible if "designs were frozen." [20] Traung argues that the adoption of a world standard fishing boat would be impractical because of the multiplicity of special local requirements and the diversity of boat-building facilities. He feels that small individual yards would still be able to produce boats more cheaply than great factories.[21] On the other hand, Ringhaver has shown that mass production is practical, at least in the United States. Since his boatyard shifted from conventional construction of individual shrimp boats to a mass production method, there has been a constant demand for his standard 60-foot shrimp trawler. By mass production operations combined with a financing system, his output has more than tripled to the rate of ten vessels per month.[22]

The solution may not lie in the development of a "world standard" fishing boat, but rather in a family of standard types, each suitable for certain types of operations and operating conditions. With minor modifications these could be adapted to any particular situation. The standard types would be suitable for many if not most purposes. At the same time, it is likely that some vessels would continue to be built to individual order for special purposes.

Standardization of boat types is progressing at present in varying degrees on a regional scale. Zwolsman,[23] for instance, reports some progress in standardization of Dutch fishing boats. Three types of cutters were developed after considerable investigation into design, construction, upkeep, propulsive power, and other features. The difference between the three types of boats is mainly one of size, the boats being of 55, 60, and 65 feet in length.

The standardization of part of the Irish fishing fleet was made possible through the development of multiple-use boats which represent the best compromise between the requirements of various types of fishing. A 50-foot boat is being built for fishing with driftnet, seine net, longline, and trawl. Various modifications can be quickly made, such as the relocation of engine and winch when the vessel is to be used for seine netting only. In addition, a 60-foot boat, which is being built for seine net fishing and trawling only, can haul larger nets in deeper water than has been possible with smaller boats. Because the larger vessels will be using deeper harbors and can have more draft, there is much opportunity for improving their design.

Setna [24] proposes the development of two standard types for Bombay, India. One is of shallow draft and flat bottom to harbor in shoal water inlets and creeks which dry up at low tide. This type would be about 35 feet long and would make only day trips. The other is larger, capable of making extended trips even during the less severe parts of the monsoon season. Provision would be made for minor variations to fit the boat most suitably for its particular operations. This standardization would enable fishing boats to pass easily the required government certification.

Boavida [25] mentions another advantage of the development of standard types. As a part of a motorization plan for small Portuguese fishing boats, investigations are currently being made to provide the information needed to establish standard types. When the investigations are completed and standards developed, fishermen will be able to obtain loans to build boats of these accepted types. It is apparent that well designed, thoroughly tested and accepted standard types of boats would encourage both private investors and governments to provide capital for building fishing craft. There would be other advantages. These boats would be designed for safety as well as efficiency; consequently, insurance costs, which are a major factor in the economy of many modern fisheries, could be reduced.

The present stage of development of electronic equipment is largely the result of research supported by the military during the past war. Fishermen need inexpensive, reliable models of all types of electronic equipment, and indeed, such are being developed. For instance, intricate radar sets developed for the Navy have evolved into much simpler types that are within the financial means of the larger boat owners. Perhaps further simplification could lead to production of an inexpensive short-range set which the smaller offshore boats could afford.

In the past, depth finders have been too expensive for the average small boat operator. Consequently, manufacturers have resorted to rental plans in order to make the expensive sets available to fishermen. However, depth finders have become simpler and cheaper so that now a type of shallow range set is available at well under $200. Some highly sensitive sets are being made specifically for the fishing industry. These are primarily fish locating devices. The presence of fish can be observed and an experienced operator can recognize species or even sizes of fish by the characteristic of their trace. Individual fish have even been spotted on these locators. Types are being developed that can be operated through a 90 degree angle vertically from bottom to surface. Others will provide an extended horizontal sweep. With these modifications it will be possible to explore the waters in any direction from the vessel. One model has been specifically developed for the use of whalers. With this finder a whale can be tracked through the water so that the boat can be ready for the kill when it surfaces.

Perhaps the most significant recent development for offshore fishing boats is the loran position locating system. Unfortunately, loran is very costly equipment. For a while after the war, United States fishermen were able to buy cheaply sets which were surplus property of the Air Force. As this source of supply has diminished and as demand has expanded, the need for a simple inexpensive loran instrument has grown apace. Manufacturers in various parts of the world are developing instruments to meet this need and are gradually bringing the price to a level that fishermen might be able to reach.

Radio receivers, transmitters, and radio direction finders are all necessary equipment for offshore fishermen. However, the combined cost of all the separate electronic aids needed prevents the average fisherman from being fully equipped. Compact, moderately priced combinations of radio transmitter, receiver, and direction finder have been available for some time. It may be possible to go even further and produce various simplified combination sets including most or all of the electronic aids needed—sounding machine, loran, simplified radar, radio receiver, transmitter, and direction finder. Such a unit or units should sell at a much lower price than the collection of individual items and be more adaptable to shipboard installation and operation.

Improvement of fishing vessels should be aimed toward increasing safety and comfort and toward reducing operating and maintenance costs and the time required to reach fishing grounds. Electronic equipment helps to find the grounds and the fish. There remain to be considered the problems of improving the means by which the fisherman actually captures the fish. Here a new type of specialist must appear. It is hard to prescribe the exact education and background he must have, particularly since his is a science which has yet to be developed. The fishing gear expert must be imaginative and at the same time practical. He must be able to study like a scientist, design like an architect, build like an engineer, speak like a fisherman, and think like a fish.

Thanks to recent advances in submarine photography and diving, we will now be able to watch and photograph his gear in operation. He can observe how the fish react to its action. The lens of the underwater television camera can penetrate beyond the depths which man can safely explore with his frog's feet and bottles of compressed air. A less spectacular, but economical and perhaps more fruitful way to study the action of trawls is by towing models in tanks (which need be no larger than an ordinary swimming pool), observing their action under controlled conditions and experimentally altering their design. Such studies are carried on at several laboratories in Japan (at the Tokai Regional Experimental Station in Tokyo, for example), and in Germany.

The opportunities for improving fishing equipment seem endless. To suggest a few ideas:

There has been much discussion in recent years about the possibility of capturing fish with electricity.[26] Electricity is used extensively in fresh water to guide, attract, repel, and paralyze fish. If it could have similar effect in the sea, it might reduce tremendously the labor and time required to concentrate and catch fish.

Unfortunately there are technical difficulties to overcome which have seemed formidable enough to discourage developmental research in sea fishing by electricity. Because the conductivity of sea water is very much higher than that of fresh water, and because there are no natural boundaries in the sea to contain an electric field as there are in a stream or a shallow lake, the amount of power required to produce a field which could control the movements of fish in the open sea is theoretically too great and costly for practical purposes.

Dickson, reviewing these difficulties in 1954, wrote:

> . . . there remains the possibility of using electrical fishing apparatus as a marine research tool and even as a commercial gear in particular circumstances, and these possibilities seem worth exploring.
>
> Better results could be anticipated using electrical fishing apparatus in conjunction with a trawl or other gear. It has been observed that the reaction of some species of fish to an electric field is more marked when they are facing the cathode, and that they do not remain in such an alignment. This gives rise to the possibility that, even without the field being strong enough to impel a fish towards the anode, its normal escape reactions to a trawl can be upset in a manner that increases the efficiency of the trawl. In mid-water trawling, where the fish have so much more possibility of escape, this could be particularly important.[27]

That electricity already has practical applications in sea fishing is shown by the fact that German fishermen use it to shock large tuna after they have caught them by trolling with a hooked lure which is also an electrode. The other electrode dangles a short distance behind the lure. After the fish are hooked they are electrocuted to make them easier to handle, thus speeding the operation of bringing them into the boat.

Otis Smith, a fishery industrialist in Delaware, has experimented for several years with electricity in menhaden fishing. He persisted through the discouraging early stages of his work, when it did appear to require a tremendous amount of power to generate the amount of electricity that was needed. He has overcome this problem to the point where relatively negligible amounts are required. He has not only demonstrated the practical value of electrical fishing when the apparatus and process are properly designed, but he uses it throughout his fleet. After the menhaden have been impounded in the usual way with the purse net, the current is turned on to raise the fish in the net and attract them to the opening of a hose, the bell-shaped end of which is made of copper and functions as an electrode. This method is so successful that Smith is encouraged to continue his developmental research with the aim of eventually abandoning nets entirely in favor of electricity alone for menhaden fishing. His optimism should encourage fishery people all over the world to experiment along similar lines.

Not all improvements in fishing equipment need be installations of large costly machines. Sometimes a very small thing can be enormously effective. For example, a simple device is an artificial fishing bait made of rubber and shaped like a worm. This idea is not new. Baits had been made of rubber for years, but were not successful until recently when new materials and shapes were developed in Norway. Many of these artificial baits are connected to a single line so that the struggles of one captured fish set the rest of the bait into tempting motion.

There is room for an infinite number of other inventions, small and large, to reduce the time, labor, and cost of fishing. There is an infinite number of questions to study about all the processes of fishing. To suggest a few: What are the engineering principles involved in the successful operation of a net? Why do slight modifications in the way a net is hung make very large differences in catches? Which new synthetic materials are most suitable for nets and lines? What are the most effective ways to prepare baits? How can the handling of a catch be reduced so as to get it into the hold most quickly in a most nearly perfect condition? What are the most efficient layouts for dock and wholesale market facilities? Such matters can best be attacked by a staff of appropriately educated people—probably chiefly engineers, all-around scientists, time-and-motion specialists, naval architects—working full time, devoting themselves wholly to the ideal of making the exploitation of the sea scientific. They should not be temporary project employees, but permanently attached to a research center especially built and equipped for their work. This should be an adjunct of a laboratory of marine research where studies of behavior of fishes are a prominent feature of the program. Several such units should be established in various parts of the world to serve differing cultures, climates, sea conditions, and fisheries. The size of a unit must depend on the degree of advancement of the area where it is established. A naval architect, a marine engineer, an expert in fishing methods, perhaps two or three apprentice-technicians, and draftsmen could form the nucleus of a unit.

The theme of this book is research. What kind of research is needed to provide knowledge for expanding the use of the seas' biological resources? That is the principal question being examined. However, we must not lose sight of practical applications. Learning how to exploit the sea scientifically is one thing; inducing fishermen to accept your advice is quite another. Fishermen every-where are more or less conservative; in primitive places they are excessively so. Suppose that a research center were established in an undeveloped area, complete with all the facilities suggested in the preceding chapters; then as information accumulated, means should be provided to teach it to fishermen so that they could profit by it. The scientists should not be expected to assume this duty. Rather, special teachers should be trained for the purpose. In other words, a school for fishermen should be founded close by the research center. Here young fishermen from many countries in the area would gather for training in navigation and the safe handling of boats; in the operation, maintenance and repair of engines; in the general principles of vessel design and construction; in the construction and repair of fishing equipment and the techniques of fishing; in the proper handling, preparation and preservation of their catch; in natural history; and in the ideas and principles of conservation.

People conducting such a program would have to be supremely patient. Years might go by before the results of their labors would even begin to show. Beever says on this:

> New techniques or the use of superior equipment must be taught in a similar fashion and must be adapted to the capacity of the fishermen to absorb instruction. Revolutionary changes of craft and techniques may alarm and repel, while too many changes all at once usually confuse the fisherman. It is usually more profitable to introduce changes one at a time, so that the characteristic features are retained. A fisherman who successfully tries out a new craft or a new engine on his familiar grounds with his own methods is more likely to cooperate in further improvements than one who is introduced simultaneously to new grounds, different working hours, new equipment, new craft and so on. That is one of the more important lessons learned from past efforts at development.[28]