

The American Tuna Purse Seine Fishery

La pêche américaine du thon à la seine coulissante

La pêche américaine du thon à la seine coulissante a lieu sur l'albacore (*Thunnus albacares*), le listao (*Katsuwonus pelamis*), le thon rouge (*Thunnus thynnus*) et le germon (*Thunnus alalunga*). Cette pêche, qui débuta peu après 1900, s'est développée dans trois directions: pêche à l'appât vivant pour l'ensemble des quatre espèces; pêche à la seine coulissante pour le thon rouge, le listao et l'albacore; pêche aux lignes trainantes pour le germon. La pêche à l'appât vivant a été la plus importante jusque vers 1960. Par suite de la contrainte économique et des progrès technologiques qui ont amélioré l'efficacité de la seine coulissante, presque tous les thoniers clippers à l'appât vivant ont été transformés en seineurs durant la période 1957-61. La période 1961-70 a été caractérisée par le développement et la modernisation de la flottille des seineurs. Actuellement, plus de la moitié du tonnage et environ un tiers de cette flottille sont constitués par de grands navires récents, construits pendant cette période. Avec l'avènement d'une réglementation par quota concernant l'albacore dans le Pacifique tropical oriental et la durée de plus en plus courte chaque année des saisons ouvertes à la pêche, les grands seineurs ont commencé à étendre leurs opérations dans des secteurs en dehors des lieux de pêche américains traditionnels du Pacifique oriental. Ces bateaux sont de plus en plus nombreux à se déplacer vers l'ouest, à l'extérieur de la zone réglementée, et vers l'est, en Atlantique, jusqu'à la côte d'Afrique. La production du thon a commencé à diminuer en Californie méridionale, car la plupart des nouveaux seineurs ont choisi Puerto Rico comme port d'attache. On s'attend à l'avenir à voir un accroissement de la demande et des prix du thon avec des captures en augmentation, une exploitation de nouveaux secteurs et des rendements de pêche en diminution. Si les Etats-Unis veulent rester compétitifs, de nouveaux progrès devront intervenir dans la technologie de la pêche du thon à la seine.

THE American tuna fishery depends mainly on four species: yellowfin (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) found mostly in the tropics and constituting the bulk of American tuna landings; and bluefin (*Thunnus thynnus*) and albacore (*Thunnus alalunga*) in temperate regions. In 1960 to 1968, the annual U.S. tuna catch was about 145,000 to 193,000 t (Lyles, 1969). Principal fishing methods are purse seining, pole and line fishing with live bait and trolling.

The present American tuna purse seine fleet stands out as one of the most modern and efficient in the world. The purse seiners are among the largest, most complex and costly of fishing vessels. The growth of this fishery in a country where fishing has, for many years, declined in relative national and world importance seems almost a paradox. The fishery is marked by alternate crises and massive responses to them.

Knowledge of the origins of tuna purse seining is basic to understanding currently used gear methods. Purse seining for tuna began out of San Pedro, California, about 1914. The first purse seines used were designed primarily for "whitefish" (barracuda, white seabass and yellowtail). A typical "whitefish" net was 200 fm long and 18 fm deep. The stretched mesh size was 2½ in., constructed of No. 12 (827 Tex) cotton twine. The netting was hung tightly to the floatline with hanging coefficients (k_h) of 0.91-1.0 (hanging coefficient (k_h): ratio of length of line to adjacent stretched length of webbing (Ben Yami, 1959)). The rope leadline was 10 to 15 per cent shorter

La pesquería norteamericana del atún con redes de cerco de jareta

La pesquería norteamericana del atún con redes de cerco de jareta se dedica al rabil (*Thunnus albacares*), barrilete (*Katsuwonus pelamis*), atún de aleta azul (*Thunnus thynnus*) y albacora (*Thunnus alalunga*). La pesquería del atún comenzó poco después de 1900 y se desarrolló en tres direcciones: pesca con cebo vivo de las cuatro especies; pesca con artes de cerco de jareta del atún de aleta azul, el barrilete y el rabil; y pesca con curricán de la albacora. Hasta 1960 la más importante fue la pesca con cebo vivo. A causa de la presión económica y de los progresos tecnológicos que incrementaron la eficacia de la pesca con artes de cerco, casi todos los cliques destinados a la pesca del atún con cebo vivo se transformaron en cerqueros en el periodo 1957-61. El periodo 1961-70 se caracterizó por el aumento y modernización de la flota de cerqueros. En la actualidad, más de la mitad del tonelaje y cerca de un tercio de la flota de barcos cerqueros está constituido por embarcaciones grandes y nuevas, construidas durante dicho periodo. Con la implantación de un sistema de cupos para la pesca del rabil en el Pacífico oriental tropical y con la consiguiente reducción progresiva de la temporada anual de pesca, los grandes cerqueros han empezado a extender sus operaciones a zonas situadas fuera de los caladeros americanos tradicionales del Pacífico oriental. Son cada día más las embarcaciones que se dirigen hacia el oeste, saliendo de la zona regulada, y hacia el este, penetrando en el Atlántico en dirección de la costa africana. La producción de atún ha empezado a desplazarse del sur de California, porque la mayor de los nuevos cerqueros han escogido Puerto Rico como puerto base. En el futuro, es de esperar un aumento de la demanda y de los precios del atún, a la par que un aumento de las capturas y de la explotación de nuevas zonas, con una disminución de los índices de captura. Si los Estados Unidos quieren mantener una posición competitiva, será preciso que se introduzcan nuevos adelantos en la tecnología de la pesca del atún con artes de cerco de jareta.

than the floatline. The wing ends terminated at vertical breastlines which were usually about half of the net's depth. This net was adapted from the salmon purse seine design used in the Pacific Northwest. Aside from material and size, these early "whitefish" nets are remarkably similar in basic design to tuna purse seines in use today. Typical purse seiners then were about 50 ft long with 12 ft beam.

The first purse seine designed specifically for tuna was built about 1916 by Van Camp Sea Food Company. This net was 420 fm long by about 35 fm deep. The stretched mesh size was 11.4 cm constructed mainly of No. 36 cotton. A surplus navy tow boat, 33.4 m long was converted to a purse seiner to handle this net. This first experiment with a "big boat" and "big net" was doomed to an early failure. The bulky net proved too unwieldy to manage. In less than a year this experiment ended and two smaller purse seines were made from this net and fished from the *A.M.Z.* and *California*, both purse seiners of about 15.2 m length.

During the first summer with this cut-down tuna purse seine, the *A.M.Z.*, under Captain Anton Zankich, set on a large school of bluefin. All but 10 to 15 t was lost because of handling difficulties. This gave rise to optimism that net handling methods could be improved so that tuna schools much larger than five or six t could be taken for canning. Commencement of bluefin canning about 1918 was probably the salvation of the industry. The increased market attracted more salmon seiners from the State of

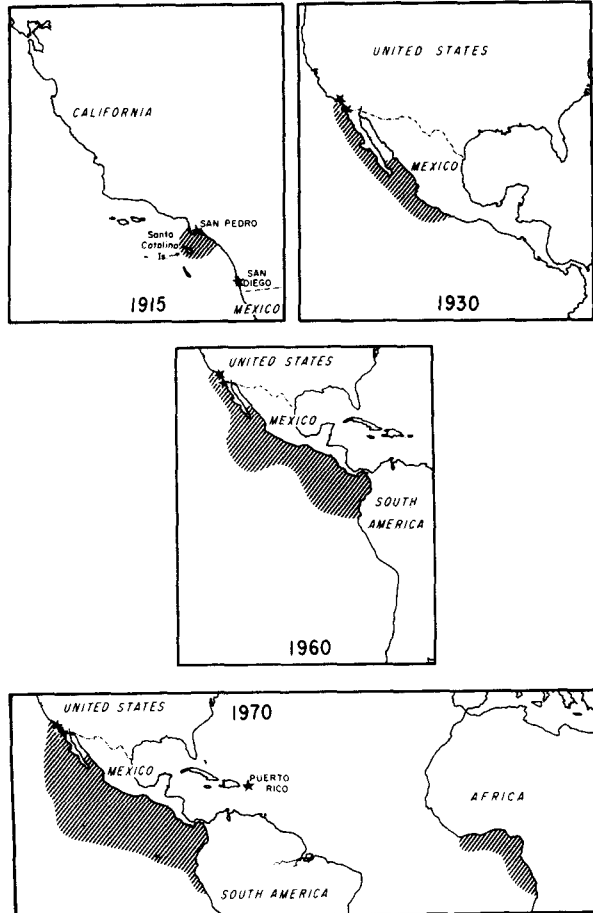


Fig 1. Expansion of U.S. tuna fishing areas, 1915-1969. * = tuna purse seining ports

Washington until a peak of about 125 purse seiners was attained in the San Pedro bluefin fleet. Because of technological difficulties, however, the success of this large fleet was poor and by 1920 most of them had returned to their original ports.

In 1923 the *Diamond*, under Pete De Maria, was the first tuna purse seiner to fish Mexican waters as far south as Cape San Lucas (*Diamond* also had the first diesel main engine in the fleet, a 100 hp Fairbanks Morse). By 1929, led by the *Sea Rider*, built by Captain Peter Dragich, Sr., purse seiners as large as 100 t capacity were being built specifically for operating off Baja California and had begun to take tuna from the Gulf of California.

Power brailing and the boom and winch to haul the net had been developed by this time. The net was strapped and pulled in, a section at a time, with the winch and block from the main boom. The same type of gear was also being used to mechanize the "drying up" operation. A technique for "cutting" the net to divide large catches into more manageable portions was also developed.

With the development of mechanized methods of net handling, the purse seines were made larger—up to 300 m

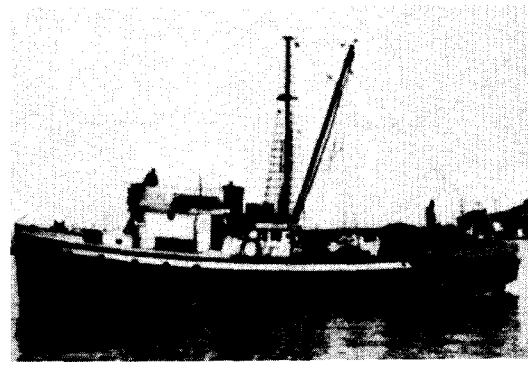


Fig 2. Tuna purse seiner Oakland. 82 ft long with 21½ ft beam. Photo by R. S. Croaker, Calif. Dept. of Fish and Game, Jan. 1931

long by 28 m deep—and of heavier construction. Through more trial-and-error experimentation, optimum mesh size stabilized at 10.8 to 11.4 cm stretched mesh. The main drawback of these nets was still the cotton material. Rapid deterioration started from first use and netting two years old, if it lasted that long, was worthless. Nets were constantly being repaired. Whenever there were spare moments, men were replacing panels, shifting rotten netting to areas of lesser strain and sewing holes and rips in badly decayed cotton.

The use of ammonia refrigeration, in conjunction with crushed ice, began in 1930, when purse seiners *Musketeer* and *White Star* installed refrigeration coils in the fish holds to extend the usefulness of ice. The use of refrigerated brine followed in 1932—preceded by its successful use on a bait-boat. At first the brine was circulated through a cooler and then through the fish wells which did not contain cooling coils. Slowly, vessels of the purse seine fleet began to add, or were built with, refrigeration machinery and by 1945 all these seiners were so equipped.

The purse seiner fleet generally operated locally from the Channel Islands off San Pedro south to the waters along both sides of Baja California. Some of the larger vessels, however, did venture farther south. In 1932, Captain Nick Dragich took the *Sea Tern* (previously named the *Musketeer*), a 32 m purse seiner of 136 t capacity, to the Galapagos Islands. Dragich was also the first to set on porpoise schools for the tuna found with them. A purse seiner of this time period is shown in fig 2. After the late 1930's, the normal maximum run for San Pedro tuna purse seiners was to between Manzanillo and Acapulco, Mexico.

Starting in the period 1925-28, purse seines were adopted for sardine fishing at San Pedro and began to replace the lampara nets previously used. For the next 20-30 years, until the decline in abundance of the California sardine and mackerel resources, purse seining for tuna was of secondary importance for many of these smaller purse seiners. They fished for tunas when they appeared during the off-season for sardines (Shimada and Schaefer, 1956).

With improved refrigeration making longer trips possible, further increased vessel size appeared to be logical. In 1937, the first steel hulled purse seiner,

Paramount, was built. This vessel was 37½ m long with a capacity of 309 t. It carried a net 420 fm long by 42 fm deep. In 1947, the *Santa Helena*, capable of loading 328 t of tuna, was built. Her net was 500 fm long by 45 fm deep—but still of cotton. The practice of tarring nets to help extend their life had long been practised by this time, but the tar added significantly to weight. With the corks then used, the *Santa Helena's* giant net would not stay afloat during pursing, but the problem was solved by lashing about twenty oil drums along the corkline.

The trend to larger purse seiners culminated in the *Falcon*, a converted 53.5 m Navy tow boat capable of carrying about 600 t of tuna. She had the shortest career of the fishing fleet. Her maiden voyage lengthened into weeks, then months as her weary crew bent to the discouraging task of filling her insatiable holds. Finally, she returned to port with about a half load and retired from fishing.

It was found that some of these larger purse seiners could operate more profitably as bait-boats, and several were converted. Paralleling the early growth of the tuna purse seine fishery, the bait-boat fleet at San Diego developed in size and numbers and began to extend operations as far as Peru. Thus, while one segment of the U.S. tuna fleet developed an efficient purse seine technology, but remained largely on local fishing grounds, the other segment, with their large and modern tuna clippers, developed familiarity with distant grounds. By the late 1950's, all the ingredients for a successful high seas tuna purse seiner fleet were present in these two fleets. The catalyst that brought them together was a growing economic crisis for American tuna fishermen.

THE TRANSITION PERIOD

Purse seining in the tropics was carried out by American fishermen from 1925 on, but with limited success because of rapid deterioration of cotton netting. In the 1950's, an economic squeeze caused by low-priced imports of Japanese-caught tuna, forced American fishermen to increase their efficiency, and they concentrated on purse seining technology. This time, due to two major technological developments, nylon nets and the power block, the method became feasible for fishing with very large nets in warm waters. The first all-nylon tuna seine, however, was not an American innovation as popularly thought (and as stated by McNeely, 1961), but was fished by a Peruvian boat in 1954 (Anon, 1959). The first American use of an all-nylon seine for tuna was in 1956 by the *Anthony M.* (Anon., 1956.)

The now well-known advantages of synthetic fibre nets in giving superior strength and larger catches were followed by the pneumatic power block. This was introduced to tuna seining by *Anthony M* in 1955. The largest contribution of the power block was in time saved in retrieving the net after an unsuccessful set. The time was reduced by nearly half (Orange and Broadhead, 1959), thus allowing many more sets of a large net to be made in one day.

Spurred by the success of the *Anthony M* with the new gear, the Peru-based American clipper *Sun King* in 1957 was converted to purse seining, and the first American-based clipper to be converted, the *Southern Pacific*,

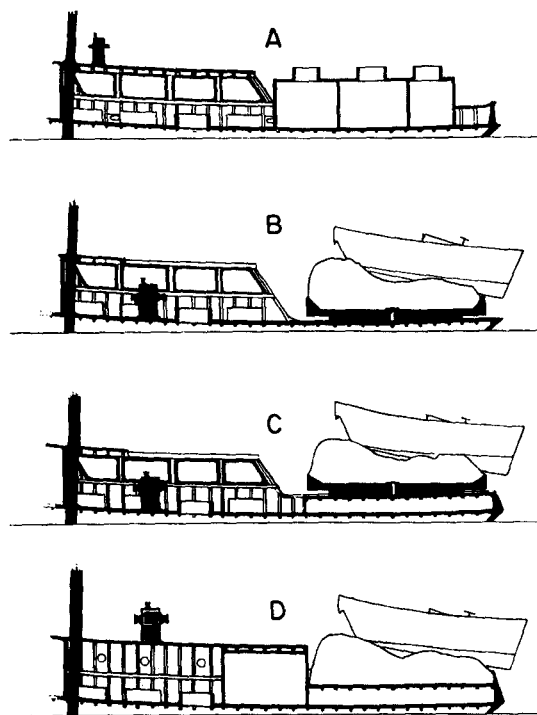


Fig 3. Stern cross sections showing: A, typical tuna clipper; B, turntable, net and skiff on early conversion; C, watertight void space under turntable improves vessel safety; D, enclosed lower deck, raised net platform, and deck-mounted fish well increases fish-carrying capacity. (After McNeely, 1961)

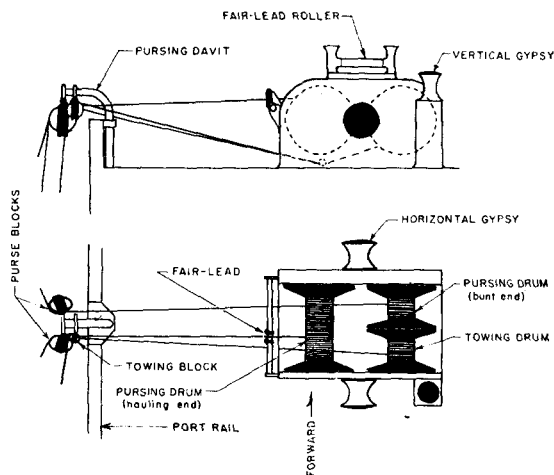


Fig 4. Purse seine winch drum and cable arrangement (After McNeely, 1961)

became a seiner soon after. A chain reaction followed, and by 1961 about 75 vessels were converted or under-going conversion.

Table 1 shows that in 1961 the number of seiners in the long-range fleet was more than twice that in 1958. Today, there are very few bait-boats left (43 out of a fleet of 163 vessels), and the tuna fishery is effectively a purse seine fishery.

TABLE 1. LONG-RANGE CALIFORNIA AND PUERTO RICO BASED VESSELS ENGAGED IN THE EASTERN TROPICAL PACIFIC TUNA FISHERY DURING THE YEARS 1950-1969

Year	Baitboats	Purse seiners	Total
1950	204	67	271
1955	172	63	235
1959	140	53	193
1960	70	83	160
1961	44	114	158*
1962	36	103	139
1965	44	111	155
1968	50	104	154
1969	43	114	157

* Does not include about 22 other (mostly under United States flag) based in Costa Rica, Mexico and Peru.

Source: Inter-American Tropical Tuna Commission, as reported in McNeely (1961) and Annual Reports of the Inter-American Tropical Tuna Commission for 1967 and 1969.

Cost of earlier conversions varied between US\$50,000 and US\$100,000 depending on design and quality of materials and workmanship. Added was the cost of a nylon purse seine averaging about US\$50,000.

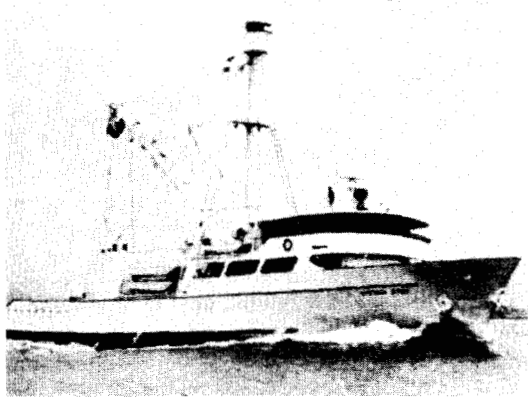


Fig 5. Vivian Anne entered the fishery in 1969. Length 144 ft, capacity 465 tons. Photo courtesy of Arthur DeFever, Naval Architect

Details of conversion

The earliest conversions from clipper to seiner involved little more than clearing away the gear and structures required for bait fishing and installing those for seining. The bait tanks, piping, circulation pumps, fishing racks and accessory gear were removed, leaving a clear afterdeck for the seine-fishing gear. Amid-ship upper decks were partially cut away on the port side aft.

An auxiliary speedboat and accessory gear were stored on remaining upper deck space aft, and guard rails were installed around exposed sections of upper decks. No hull modifications were required.

It was necessary to install masts and booms to withstand the stresses of net hauling, "drying up" and lifting aboard the heavy seine skiff. These were constructed of double strength tubular steel with multiple diameters fitted one inside the other and welded at external joints.



Fig 6. Cabrillo entered the fishery in 1968. Photo courtesy of J. M. Martinac Shipbuilding Corp.

Seining operations also require a heavy-duty winch. The winch used in early conversions had a minimum of three drums, two gypsies and two heavy-duty lashing bits (fig 4, from McNeely, 1961). The following description of the winch is repeated, verbatim from McNeely (1961):

"Drums—Three drums are mounted on two parallel drivershafts running fore and aft in the winch housing (fig 4). The single purseline drum located on the port driveshaft holds about 600 fm of wire rope purseline made of two end sections measuring 160 fm and 330 fm long . . . $\frac{5}{8}$ in (1.6 cm) diameter galvanized steel and a 110 fm centre section made of $\frac{3}{4}$ in (1.9 cm) stainless steel wire rope. Two drums, located on the starboard driveshaft, have independent drives and controls. The forward

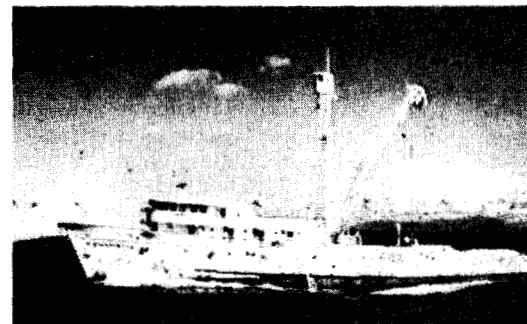


Fig 7. Marietta entered the fishery in 1968. Photo courtesy of J. M. Martinac Shipbuilding Corp.

drum in the double drum section is used to haul in the bunt-end purseline, while the after drum is used to hold approximately 200 fm of $\frac{5}{8}$ in (1.6 cm) galvanized steel wire rope towing cable. Roller fairleads on the base or on top of the winch guide cables from the starboard drums past the port drum and through a purse block and towing block mounted on the purse davit by the port rail. Level-wind fairleads are driven manually or by hydraulic or air motors and usually are installed on the port drum only. Clutches and brake shoes on the pursuing drums and towing drum are operated manually or by hydraulic or air cylinders. One newly designed winch has small control levers, mounted in a control console . . . to allow operation of all drums simultaneously by one winch operator.

“Cargo drum—A fourth drum (cargo drum) of small diameter is sometimes located above and between the two large drum sections. It is used principally for operation of a “choker” rope during “sacking-up” operations. Fairlead blocks on the starboard rail lead the choker rope along the starboard rail aft and then to the port rail where strapping and choking operations are performed.

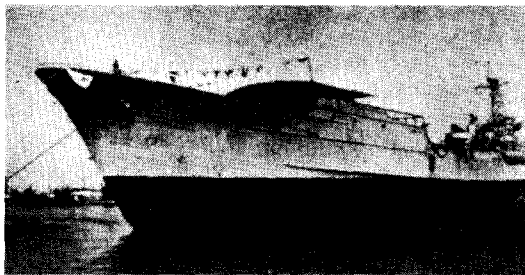


Fig 8. Hull 79 under construction. Length 200 ft, capacity 1,335 tons. Photo courtesy of Campbell Machine, Inc.

“Gypsies—Two 12 in (30.4 cm) horizontal gypsies, and sometimes an additional 10 in (25.4 cm) vertical gypsy, are mounted on the winch for general utility hauling. The forward horizontal gypsy is used more frequently than the other two and has sea water piped to it for cooling purposes during long periods of holding . . . Nylon, manila and wire ropes are commonly hauled on the seine-winch gypsies. When hauling of wire rope is anticipated, surfaces of gypsies are hardened.

“Power supply—A variety of power supplies are utilized to operate seine winches. One of the more common drives is the electric motor which, due to the small space available in the shaft alley beneath the winch, is applicable as well as economical. Some vessels employ hydraulic motors or diesel engine drives coupled through line shafting or mounted directly beneath the winch. The vulnerability of electric motors and controls to damage from salt water, and the advantage of controllable speed and torque in hydraulic drives, makes installation of the latter power source desirable.”

Use of a power block required a hydraulic drive, and complete hydraulic drive systems for boom-topping winches, vanging winches and the pursuing winch were soon adopted by the fleet.

Special fore-deck installations are required for operation of a purse seine, including rail cleats, rope fairlead sheaves and cork purseline winches. The corkline is

pursed by passing lines through a port rail sheave to the corkline winch or to the anchor winch gypsy.

A special heavy-duty davit at the port rail in line with the pursuing winch supports the purse blocks and the towing block. The davit is constructed by bending a heavy steel pipe to form a right angle elbow and welding a steel plate stiffener across the angle for support. Heavy duty purse blocks are mounted fore and aft on hanger eyes constructed of heavy steel plate and welded to the pipe on the outboard end, and a smaller towing block is attached to a third eye on the upper side of the davit.

The turntables, which were included in the early conversions, were about 7.6 m square and constructed of heavy timbers. Support was provided by heavy-duty steel roller pedestals secured to the deck, and the table rotated on a circular steel track attached to its underside.

Fish hoppers to receive brailed fish were constructed in a variety of shapes and materials. The hopper was positioned and pivoted in a socket installed on the deck. A chute from the hopper to the wells was constructed in sections, of sheet metal and Y-shaped pedestals supported it along the deck.

The seine skiff

The size of the seine skiff is directly related to the size of the net and the size of the seiner. The skiffs used initially were about 6.1 m long, 4.6 m wide and 1.2 m deep and constructed of plywood sheathed with fibreglass. To allow the skiff to pass freely over the corkline, tapered skegs are attached parallel to a tapered keel, and the propeller is caged. A heavy steel plate on the bow, with eye attached, provides great strength for hoisting or towing. A towing bit made of steel pipe is mounted amidships, securely fastened to the keel, and braced.

Propulsion is provided by a diesel engine, power varying greatly with size of the skiff and individual preference. Engines in early skiffs were between 75 and 150 hp. Considerable power is required during the towing operation, when the skiff tows the seiner on 91 m of 1.9 cm nylon line and keeps it from being pulled over the net during pursuing and hauling. A 15.4 cm vertical gypsy is driven off the engine and used for pursuing corks and manoeuvring the brail during transfer of fish from another vessel.

A rubber hose of 25.4 cm is fitted over the skiff rail to provide a friction surface for webbing that is pulled over it during sacking-up and also to act as a fender and to provide footing.

Later conversions

Later conversions incorporated features to increase safety and fish capacity. Watertight spaces were built under the turntable (C, in fig 3) to increase buoyancy in bad weather.

In still later conversions, the turntable was eliminated and a raised net platform substituted (D, in fig 3) combined with a completely enclosed watertight lower deck, increasing both safety and capacity. Extra fish wells were sometimes installed under the platform. The purse winch was installed on the raised deck. Fish are lifted to the raised deck and unloaded into hatches that lead to hoppers and distribution chutes between decks.

The fishing operation

Preparing the gear for a set. When a turntable is used, the net is stacked in three parallel piles running athwartships, the corks on the port side and the rings on the starboard. To start the stacking operation, a line is passed over the power block and snapped to the "triangle" end bracket of the hauling end of the net, which is then pulled through the block. The triangle is hung over the stern of the turntable, and the crew spreads out across the after end of the table to stack the net.

A line is passed through the rings as they are stacked and used later as a leader for threading the purse cable. About half the net is stacked in the first of the three piles (closest to the stern), which reaches a height of about 2.1 m. To start the second stack, the main boom is raised, bringing the power block forward. The second stack is allowed to reach a height of about 1.5 before the third is started. The third stack reaches a height of about 0.6 m. The incline yielded by the three different sized stacks is useful in bringing the seine skiff aboard atop the net (after the turntable is rotated).

The turntable is rotated to setting position with a cable from the pursing winch and secured with a pin set in a deck socket.

Next the seine skiff is lifted to its position atop the net pile with a 10 T capacity double block on the main boom. The following description of the hook-up is quoted from McNeely (1961):

"The end of the seine towing cable is pulled from the winch towing drum, passed through the towing block, and connected to the hauling end "triangle" bracket. The purseline is then pulled from the winch, passed through the stern purse block and tied to the purse ring threading rope. The purseline is pulled through the rings . . . a sufficient distance to allow connection to an intermediate hauling cable which is coiled inside the skiff. A long link on the end of the purseline is then connected to a purseline release on the bunt end "triangle" bracket. The next step is to secure the intermediate hauling cable to a cleat near the amidships rail on the starboard side of the skiff."

On the fishing grounds, the skiff is shifted to the rear of the net pile. A steel cable painter is shackled to the bow of the skiff and secured to a pelican hook mounted on the winch. Safety is provided by a pin in the pelican hook.

Setting the net. When fish are sighted the pin is removed from the pelican hook, and when the signal to "Let her go!" is given, the hook is opened with a hammer, allowing the skiff with the net end attached to drop into the water. The skiff acts as a sea anchor and pulls the first portion of the net over the stern. Pull on the skiff is controlled by varying tension on the purseline with the pursing winch.

The set is controlled by the "fishing captain" on the mast or by an observer in an aircraft. The turning rate and speed of setting depend on behaviour of the school of fish. If the circle that can be completed with the net alone is too small, a larger circle can be made by letting out excess purseline and towing line.

When the vessel approaches the skiff at the completion of the circle, engines are reversed to bring it to a stop, and a heaving line is thrown to the skiff. The heaving

line, which is secured to the forward purse block, is attached to the intermediate hauling line in the skiff, whereupon the hauling line and net end are released from the skiff, leaving it free to patrol the open water under the towing line between the vessel and the other end of the net, or, if no towing line is used, to take up its towing station at the opposite side of the vessel. The intermediate hauling line is passed through the purse block to a gypsy that is used to pull in the bunt end of the purse-line and the end of the net, which is attached to a steel hook on the davit. The purseline is then connected to the winch, and the release connecting it to the "triangle" is opened, freeing the purseline from the net end, so that pursing can begin. The bow breastline, after being disconnected from the "triangle", and the cork purseline are secured to cleats along the port rail of the bow.

Meanwhile, the towing line and purseline are being hauled by the winch. When all the towing line is in, the skiff commences its towing operation from the starboard side, attempting to keep the vessel square with the net and from being pulled into the net during pursing. When the towing line is in, the stern "triangle" is attached to a second retaining hook on the davit, towing line is disconnected and wound up on the winch.

The net is pursed until the rings are together and begin to come out of the water. Then the hoisting line, which was previously passed over the power block, is connected to the hauling end "triangle" and the end of the net is hoisted about 4.6 m in the air, away from the purse davit. A retaining line is placed around the netting to remove it from the port rail area so that the rings may be brought aboard. The following description of the handling of the rings is from McNeely (1961):

"As the purse rings come out of the water, cable clamps, joined by a short bridle, are fastened to the purseline and hooked to a double block hoist located on the main boom. Cable is then slacked off the purse winch drums, and the purselines are removed from the purse blocks. The rings, dropper chains, and leadline are then hoisted high in the air. When these are well above the vessel rail, they are lowered slowly to the deck. The rings are then separated into four or five successive groups and tied with retaining chains which are permanently attached to the starboard rail. This prevents their being dragged back into the water.

"Three snatch blocks are then employed to return the purseline, which had been wound up on the starboard winch drum, through the rings and back to the port winch drum. Two of the blocks are attached to the purse davit and one is located near the deck on the forward and starboard side of the turntable base. When this has been completed and the purse rings are free of the purseline, hauling of the net proceeds. Another method used to free the purse rings from the purseline, which results in a saving of time, is to open "figure eights" or split links, remove the line, and reconnect the ends. Twists in the purseline are also removed at this time."

Hauling the net. When the purse rings are free, hauling of the net begins. The retaining line is loosened, and the hauling end is pulled over the power block with the hoisting line. The purse rings are released in groups of two or three and, individually passed over the block, are retrieved, and threaded on a line. The purseline is inserted later as described above.

Now the net is dried up (hauled and stacked) until the area occupied by the fish is minimal. Excessive weight in one area may necessitate pursuing the corkline. This operation is described in "Porpoise Fishing". If the catch is estimated to be very large (over 40 T), it may be split into two or three lots by pulling one or two "zipper lines". The skiff, its towing duties completed, comes alongside and picks up the corkline at the outboard side of the area containing the fish, forming a pocket. The fish are concentrated by further hauling of the net, and the corkline is secured fore and aft to both the vessel and skiff.

The "sack" or bunt is dried up further by strapping aboard 4.6 m sections of webbing with a winch power, using slings. When a section has been lifted, it is secured with a choker line pulled tight by the cargo hoisting drum or a gypsy on the winch, to prevent it from slipping back into the water. This operation is repeated until the fish are concentrated in a compact bag at the surface.

Brailing. The following description of the brailing operation, which follows "sacking up" is from McNeely (1961):

"The small boom, used principally for brailing, is then vanged into the most advantageous position for handling of fish during the brailing operation.

"The brail with hoisting sling attached is then lowered to the skiff men who guide the brail vertically down along the side of the skiff. The skiff men signal the winch operator to lower or hoist the brail by using a small police whistle or voice and hand signals. A 2 in (5 cm) diameter aluminum handle 16 ft (4.9 m) long on the brail allows the skiff men to guide the brail into the fish. When the brail is in position to take a full scoop of fish, the winch man is signalled, and as the brail is pulled up through the fish, the skiff men guide it to the side of the seiners until it emerges from the water full of fish.

"A third man in the skiff holds tension on a brail purse-line made of small chain until the brail is positioned over an unloading hopper. He then releases tension on the brail purseline, which opens the bottom of the brail bag, allowing the fish to spill into the hopper. When the brail is empty of fish, the chain man pulls on the brail purseline which closes the bottom of the brail and helps return it to the skiff men. The operation of brailing is repeated until all the fish are removed from the bag.

"Fish deposited in the hopper are guided to selected brine tanks by a series of sheet metal chutes."

After brailing is completed, the strapped down webbing is released and the corkline unlashd from the vessel and skiff rails, and hauling and stacking is resumed until all the webbing is out of the water. Before the end of the net goes through the power block, the cork purseline and breastline are retied to their original attachment points, to the breastline and to the "triangle" respectively, and the hoisting line is attached to the "triangle" so that it may be passed over the power block for use during the next set.

1961-70 EXPANSION AND NEW CONSTRUCTION

On the heels of mass conversion of bait-boats to purse seiners began a decade that further revolutionized the tuna purse seine fishery. The fleet of today is dominated

by newly-built, large capacity seiners, vessels from 42.4 m to over 76 m long. These seiners are moving into new areas of fishing with new fishing tactics, modern gear, and increased efficiency.

Technology

The most distinguishing characteristic of the purse seiners since 1960 is their size. Before 1961, the largest seiners (converted bait-boats) were of about 591 t carrying capacity. Only two were larger than 455 t and the average size lay somewhere between 182 and 273 tons.

Since 1961, 38 new purse seiners, including nine conversions from military hulls, have been added. The largest of these vessels is nearly 829 t and the average size is 655 t. Typical purse seines of this period are shown in figs 5 to 8. The total capacity of these seiners, at the end of 1969 (23,268 t) comprised 52 per cent of all U.S. purse seiner capacity (44,674 t, 120 vessels). Forty-three bait-boats represented an additional 3,710 t of capacity (Inter-American Tropical Tuna Commission, 1970).

Several other tuna purse seiners are (in 1970) under construction in San Diego, California and Tacoma, Washington. Among these is one of 1,820 t carrying capacity, nearly twice the size of the largest tuna purse seiner now in existence.

TABLE 2. ADDITIONS TO U.S. PURSE SEINE FLEET EXCLUSIVE OF BAITBOAT CONVERSIONS, 1961 TO 1970

Year built or year converted from military hull	Number of vessels added	Added capacity as of 1969 t
1961	3	1705
1962	4	2415
1963	4	3425
1964-1966	3	1769
1967	2	1360
1968	7	5003
1969	13	7375
1970*	2	1592
Totals—	38	24819

* As of 13th March.

Source: Unpublished data of the Inter-American Tropical Tuna Commission.

Increasing size within reasonable limits offers a number of advantages which may help improve profitability: as vessel size increases, cost of construction per ton of capacity decreases, as do many operating costs. The ratio of fishing time to travel time increases with vessel capacity and, of course, large vessels are more seaworthy and have greater range than smaller vessels. At some point in size, depending on conditions of operation, these advantages are offset by the drawbacks of practical limits on net size, crew size, school size of tuna, length of trips, and other factors which tend to increase operating costs per ton of fish caught.

Many owners of small purse seiners are prevented from buying larger, more efficient vessels because of the lack of a market for their older boats. One fleet-owning corporation, after an analysis of optimum sizes of purse seiners (Green and Broadhead, 1965) found a way out by enlarging existing vessels. Over a period of four years, seven steel-hulled purse seiners were cut in two near amidships and sections spliced in to lengthen them by 14 ft to

32 ft (4.26 to 9.7 m) (fig 9). Carrying capacity was thus increased by 73 to 164 t. The changed length to beam ratio also improved speed by about $\frac{1}{2}$ kn and sea-keeping ability. All seven of these vessels were of about 309 t capacity before the operation. They are said to be rapidly paying off, through increased efficiency, the cost of their modification.

Hull design and general arrangement of the first new purse seiners differed little from the familiar tuna clipper of the past. Since that time, new construction has been marked by occasional innovations and establishment of new trends until the seiner of today appears quite different from early conversions. Externally, several new seiners stand out sharply.

Arthur DeFever, designer of several new vessels says: "The seiner of today, which is noted by its rakish bow, conically shaped stem head, tapering to a fine entrance at the water line, appealing bow flare, forward-look side panels, modern superstructure, streamlined stack and slightly curved sheerline with low point near the stern, is good looking, and except for her seine net and skiff on the stern, she has a somewhat modern research ship appearance, or even scaled-up yacht aspect."



Fig 9. Lengthening a tuna purse seiner. Photo courtesy of National Marine Terminal, Inc.

Wooden hull construction, once predominant in the tuna fleet, has been entirely replaced by steel in new construction. A stern ramp for carrying the seine skiff for immediate launching avoids carrying the skiff on top of the net and semi-launching it on the grounds. The older method results in an actual towing situation, slowing the vessel's speed and restricting scouting operations, as well as causing wear and tear on the skiff. The seine skiff, itself, has kept pace with the development of the modern purse seiner, especially with respect to size. The skiff on one of these purse seiners may be 10 m long with 5.8 m beam and weigh 12.7 t. On some, a skin-cooled engine of 300 hp drives a 1.2 m diam. propeller through a 4 $\frac{1}{2}$:1 reduction gear, others use twin diesels for power. The vertical gypsy, used for pursing floatline-ropes, is hydraulically driven (Arthur Yeend, personal communication).

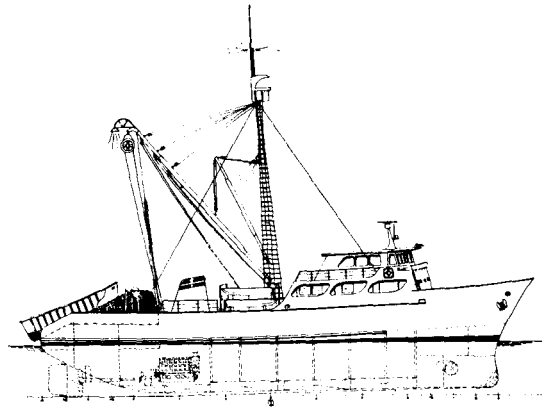


Fig 10. Outboard profile of purse seiner type of Vivian Anne. Note in particular the bulbous bow, bow thruster, short drive shaft, and that the fish holds are forward of the engine space (After DeFever, 1968)

Atop the bridge on several vessels may be found a small helicopter landing pad. Beneath the water line some include a bulbous bow for increased speed and a bow thruster for improved manoeuvrability while in the set. This latter may even be controlled through the autopilot, so that the seiner can maintain a constant heading even while dead in the water (Arthur Yeend, personal communication).

Control of vessel and gear during fishing operations has been simplified by consolidating most control operations into several strategic stations. The "fishing station" is now a standard, built-in convenience. It has an auxiliary set of full controls on the port bridge wing which permits the skipper to operate the vessel while looking down at the deck working area and out over the net. The hydraulic control console for the operation of nearly all of the after deck hydraulic machinery and power block is mounted in a position where the operator has full view of operations on the working deck. Seine winches may be separated for best locations of main functions and for easier maintenance. For example, the towline winch may be separately mounted on the port side in line with the setting of the net, thus eliminating one fair lead on the seine davit (Sverre Jangard, personal communication). The crow's nest may be fully outfitted and carry up to three men. From here, the mastmen, besides scouting for fish, may direct the operations of porpoise chasers by citizens band radio as well as coordinate deck operations with fish movements within the net, communicate with other vessels or spotter aircraft, or by way of another auxiliary set of controls, operate the vessel during the set.

Stern engine rooms (fig 10) with either single or twin main engines are included in several new boats by different builders. This arrangement offers the advantages of better weight distribution; short, one-piece tail shifts, and more efficient utilization of space (DeFever, 1968). Stacks are either offset to starboard on the aft deck just forward of the net platform or ducted forward to the more conventional stack location aft of the pilothouse. Skin-cooling, through the seiner's hull may be used instead of conventional heat exchangers (Arthur Yeend, personal communication).

While the power range of the older purse seiners was about 200 to 1200 hp, there are now purse seiners of 3200 hp or more. Many of these newer boats can sustain speeds of 15 kn, compared to older average of 10 kn.

Conventional ammonia refrigeration through brine is still employed although somewhat improved by the use of smaller wells (40 t capacity) with dual ammonia circuits in each well. Larger wells may have three circuits. Unloading is facilitated with more and larger unloading hatches.

Aft of the bridge deckhouse and on the after working deck is ample stowage room for up to three porpoise chaser boats ready for launching on their hydraulically-operated davits.

The modern purse seiners equipment may also include fuel oil centrifuges, hydraulic steering and pneumatic controls, and anti-roll devices. Included in electronic equipment is the newest Omega navigational system as well as the standard array of modern communications systems, radar, Loran, radio direction-finder, automatic pilot, echo sounders, and sometimes sonar.

Larger fishing vessels require longer trips to fill their capacity. Trips of long duration may adversely affect crew morale and therefore lower efficiency. Designers and builders have realized this and have designed modern tuna purse seiners with the comfort and morale of their crews in mind. Quarters are pleasant and well-appointed and may have built-in hardwood bunks and cushioned settees, ample closet and stowage space, carpeting and ample lighting. A stern engine arrangement makes all living quarters extremely quiet. Several toilets with stall showers and hot and cold water may be available for the crew with private toilets for the captain and engineer. Fresh water makers and ample water storage space have eliminated the water shortages of the past. A spacious, airy galley and dining room with large windows on three sides gives almost the impression of a fine waterfront restaurant. All living quarters are air-conditioned and some vessels even have high fidelity music piped to the various rooms.

Purse seines and related gear

American tuna purse seines have changed little except in size for the last ten years. A typical purse seine at the start of this decade was 420 fm (765 m) long by seven 100-mesh deep strips of netting (McNeely, 1961). Nets carried by the newer purse seiners may be over 600 fm (over 1100 m) long by ten strips deep. While No. 42 thread (3543 Tex) is still used mostly in the main body of the net, some of the larger nets used when fishing tuna associated with porpoise are going to No. 48 and No. 54 (3720 and 4022 Tex).

Interest in tuna purse seine research has been stimulated by the Bureau of Commercial Fisheries development of the Hybrid Tuna Purse Seine. This experimental net features lighter webbing, lower hanging coefficients, tapered wings, floatline/leadline ratio = 1, gavels with breast pursing lines, and a setback of main purse rings from net ends. It has been very successful on "school fish" tuna, especially where erratic fish behaviour makes successful purse seining difficult. A complete report of this experiment is given elsewhere in this volume (Green, Jurkovich and Petrich).

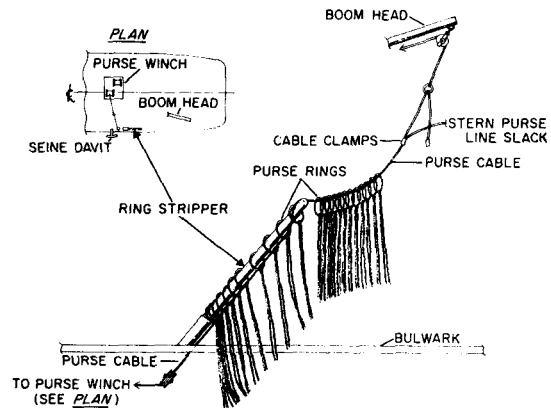


Fig 11. Ring stripper just before purse rings are placed on it. Drawing courtesy of Morris Whaley. Drafted by Kenneth Raymond

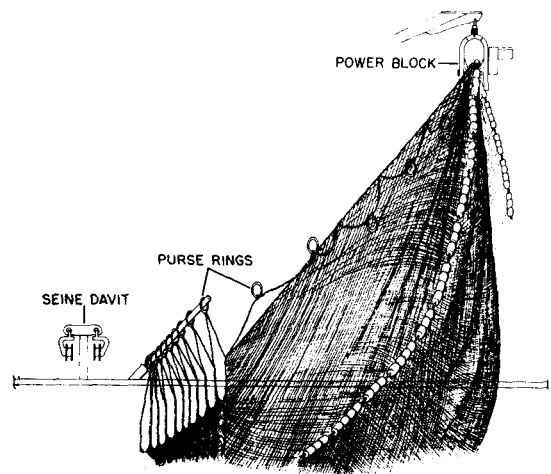


Fig 12. Ring stripper. Purse rings are pulled off as net is stacked. Drawing courtesy of Morris Whaley. Drafted by Kenneth Raymond

There have been tendencies in new net construction of the last few years to introduce tapers in the wings and to be more generous in hanging in webbing, using hanging coefficients as low as 0.82 as opposed to the standard of 0.91 of ten years ago.

Net handling gear has remained essentially unchanged with the exception of the purse ring stripper, a patented method of handling the purse rings so that they and their bridles and the leadline do not obstruct working deck space or create a hazard during net stacking. The purse rings are, instead, threaded onto a steel shaft which is mounted rigidly just aft of the seine davit on the port bulwark. The operation of this device is as follows: the purse rings are hauled up to the seine davit and lifted with cable clamps from a double block hoist on a cargo boom in the usual manner. Now, instead of dumping rings and chain onto the deck, the bow portion of the loose purseline is placed in a groove running over the end of the shaft of the ring stripper. Tension is transferred from the bow cable clamp to the bow purseline

running over the ring stripper and the bow cable clamp is removed so that the rings are now hanging in the bight of the purseline between the end of the ring stripper and the stern cable clamp. This clamp is lifted until the rings slide forward on the purseline and spill down over the ring stripper (fig 11). The purseline is now removed from them as usual. The ring stripper is mounted at such an angle that, as the net is stacked, the rings are pulled off singly by the power block (fig 12) (Morris Whaley, personal communication).

“Porpoise fishing”

American tuna fishermen in the eastern tropical Pacific depend on porpoise for locating much of their fish (Perrin, 1968). Schools of yellowfin tuna usually occur in close association with large schools (up to 1500 animals) of two species of porpoise, *Stenella graffmani* (called “spotter” by the fishermen) and *Stenella longirostris* (called “spinner”). Because porpoise are air breathers and stay at the surface, the fishermen can spot them more easily at a distance. About half of the seine-caught yellowfin tuna from the eastern Pacific is captured from schools associated with porpoise (data furnished by Inter-American Tropical Tuna Commission). Yellowfin tuna make up approximately half the U.S. tropical tuna catch; the remainder is mostly skipjack (*Katsuwonus pelamis*).

The reason for the association of tuna and porpoise is unknown (Petrich, 1965) although some food-based relationship is suspected. Stomach-content analyses thus far carried out are inconclusive but indicate that they feed on some of the same things.

A new aspect of the tuna-porpoise association came to the fore when purse seiners began to replace pole-and-

line boats in the tropical tuna fishery. The fishermen discovered that the association is very tight. They found that the fish seem to follow the porpoise very closely and that they can be herded by herding the porpoise, and that if even a few porpoise escape from the circle of the purse seine, all the fish might follow and be lost. These discoveries led to the development of a unique method of operations, called “porpoise fishing”.

The fishermen spot porpoise schools at the horizon with high-powered binoculars (up to 20 power) sometimes mounted on swivelling racks on the bridge. Most boats carry two such sets of binoculars. While the boat is on the tuna grounds, a constant “spotting watch” is kept during daylight with crewmen rotating the duty. In addition, a lookout with less powerful binoculars is posted in the crow’s nest.

Feeding schools often can be detected over the horizon by sighting the birds (terns, boobies and frigate birds) which gather over them. When a school of porpoise is sighted, the boat runs up on it while the lookouts scan it for signs of fish. If the lookouts spot numerous “jumpers” (feeding fish breaking the surface), “shine” (flashes of reflected light from fish below the surface), or see a “blackspot” (dense school of fish below the surface), the boat prepares to set. If no fish signs are seen, the captain may still decide to set, gambling on the presence of unseen fish.

The boat stops, and the “chaser-skiffs” (also called “speedboats” or “pongos”) are lowered overboard. These boats herd and direct the porpoise, slow them down if they are running, and tighten up the school. Most large seiners use two chaser-skiffs. A popular combination of skiff and engine is a 4.8 m fibreglass tri-hull using an 85 to 105 hp outboard motor. The skiff drivers are strapped in their seats and wear crash helmets (fig 13).

A “cork tender”, a smaller skiff, is also lowered. This skiff follows the boat during the chase, and its driver tends the corkline during pursing and hauling.

The “fishing captain” (who may or may not be the boat captain) directs the chase and set from the mast. He has two-way radio contact with both chaser-skiff drivers.

Making a good set on porpoise is a fine art, and good “fishing skippers” are in high demand in the tuna fleet. The fishing captain directs and uses his chaser skiffs like shepherd does his dogs. When the school is headed properly, the captain sets his net.

When pursing is completed, the fish can no longer escape. Now the problem remains of separating the unwanted porpoise from the valuable tuna. For this purpose fishermen have developed an operation called “backing down”. At the front end of the net (the end which goes overboard first, attached to the seine skiff) are several 30 m lengths of line strung through 10 cm rings attached to the corkline by 0.9 m bridles. As soon as the front end of the net is picked up at the completion of the set circle and secured to the pursing davit, the man in the cork tender passes three or four of these lines to the deck, and they are pulled with the bow winch and secured.

This action causes the corks to bunch and a “balloon” to form in the back of the net. The net is then “dried up” (taken aboard) to approximately “half net” (farther if the catch is small). The net is strapped down, the rings are

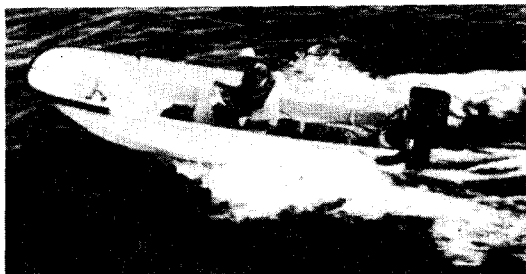


Fig 13. A light, powerful combination of skiff and engine is used for chasing and herding the porpoise. (After Perrin, 1969)

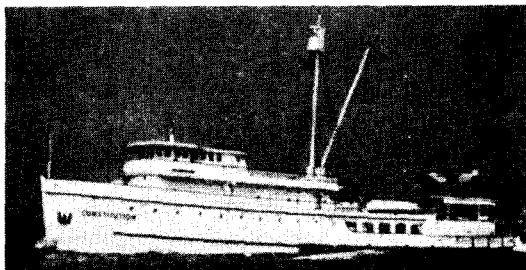


Fig 14. Seaplane lashed to canopy of tuna clipper Constitution. Photo by Allied Craftsmen, courtesy of Vernon M. Brown

secured, and backing down begins. The fishing captain directs from the mast. When the fish are near the boat and the porpoise at the far end of the net, he gives a signal, and the boat backs down, opening the net and at the same time sinking the corks at the far end.

Most of the porpoise are spilled over the corkline. The fish tend to swim upcurrent and into the balloon formed by bunched corks. Great care must be taken to avoid losing the fish as well as the porpoise. If the fish head toward the end of the net, the captain signals, and the engines are immediately put into forward allowing the corkline to rise to the surface. The cork tender is stationed at the end of the net to assist porpoise over the corkline.

After the backing down, the net is dried up to the bunt (reinforced section at the back of the net). The bunt is "sacked up", that is, webbing in excess to that needed to hold the fish is gathered up from the bottom and tied down. The seine skiff comes alongside, and the corkline on the side of the "bag" opposite the boat is secured to the skiff's rail. A portable rack is hung on the skiff, and a crewman stands in the rack and assists the remaining porpoise over the corkline. The bag is then sacked-up farther, and the fish are brailed aboard.

The Bureau of Commercial Fisheries has in recent months begun research to develop improved methods of eliminating mortality of porpoise in the fishing operation.

Fish finding

Visual scouting, whether it be from the bridge, crow's nest or aircraft, is still the most important method for finding tuna in this fishery. After a fishing area is chosen by experience with seasonal movements of fish, current contacts with other tuna boats, etc., all available crewmen act as lookouts whenever the vessel is on fishing grounds. During daytime they search from vessel to horizon with high-powered binoculars or with the naked eye for such signs as birds, whales, porpoises, basking sharks, floating objects or surface disturbances from tuna. If night fishing is done during the dark of the moon they search the water for bioluminescence caused by tuna presence. The glow may be intensified by stimulating the tuna to increased activity with occasional sweeps of a searchlight.

An airborne observer can be a useful adjunct to the fishing operation in two ways: (1) he can spot fish at great distances from the vessel because of the aircraft's height and range of operation. Under ideal conditions (sun overhead and clear skies), an observer flying at 182 m can scan a swath of ocean 60 miles wide as compared to 19 miles for an observer in the vessel's crow's nest at 18.2 m, having a good view of the fish and their position relative to the vessel, or to the porpoise school in the case of "porpoise fishing". (2) He can "set the boat", telling the vessel when and where to release the net and how to manoeuvre in completing the circle of the set.

The first use of a ship-based aircraft in the tuna fishery was in 1946. A helicopter (Sikorsky S-55) was taken out on the *Espiritu Santu*, but proved too expensive to maintain (personal communication from Robert Jones). In the 1940's some boats began to carry small seaplanes (fig 14). By 1952, 21 seaplanes were in use in the fleet, but a period of economic hardship cut the number until by 1955 there were none left.

In the early 1960's, after conversion of the fleet to seiners and after economic improvement, interest in ship-based aircraft was renewed, and since then helicopters have been in sporadic use, two or three being in operation every fishing season. In very recent years, with the advent of very large seiners (546 to 1,900 t capacity), the use of a helicopter has become economically more feasible, and some new designs include built-in helicopter pads.

There are advantages and disadvantages in the use of both fixed-wing aircraft and helicopters. A helicopter has the great advantage that it can take off from and land on the vessel, but is expensive and extremely difficult to maintain properly, especially under at-sea conditions, and is easily crippled if forced to land in other than flat-calm seas conditions. A seaplane has greater range than a helicopter (up to 7 h) and is more dependable and economical to maintain, but it must be lowered into the water to take off and be picked up after it lands. If a simple method of launching and recovery, perhaps with a special large boom, could be developed, the seaplane, because of its range and dependability, would seem to be the better-suited craft for use at sea. The chronic problem of rapid metal corrosion due to prolonged exposure to salt-laden air could easily be eliminated aboard the large vessels through a system for washing down with fresh water.

The use of shore-based aircraft spotting services has proven more cost effective than maintaining aircraft aboard ship. A percentage of the value of fish caught with such assistance is usually paid to the spotter pilot. The service is limited, however, by the distribution of adequate shore facilities and the range of the aircraft used.

Sonar has seen little use in this fishery. Of the few purse seiners carrying it, we know of no one who uses it for making sets on tuna. Our fishermen, inexperienced with this gear, are loath to make sets on anything whose species or size cannot be identified. A set on a school of mackerel or undersized tuna may result in a "christmas tree" (purse seine loaded with gilled fish).

Several seiners have had navy surplus, bathythermograph (BT) winches installed in a cooperative research project with the Bureau of Commercial Fisheries. BT data collected during their fishing operations established a direct relationship between the depth and temperature gradient of the thermocline and the success of purse seine sets (Green, 1967). This fact has been increasingly used in searching tactics for tuna. The use of the more modern expendable BT system is now beginning to replace the older mechanical type.

Automatic water temperature recorders with read-outs conveniently located in the pilot house are replacing the use of the engine room water intake temperatures for fish scouting. All tuna fishermen have learned through experience the optimum sea surface temperature ranges of the tunas that they fish for and use this knowledge in their scouting tactics. Temperature changes are used to locate oceanic "fronts"—lines of convergence of different water masses. Tuna fishermen often follow these fronts as they scout for fish.

Expansion of the fishery

Along with technological development of the American tuna purse seine fleet in the 1960's has come major

changes in the distribution of production centres and fishing areas.

Production centres. As late as 1953, the southern California canneries accounted for 87 per cent of the national pack. In recent years the situation has changed due to the attraction of processors and vessels to Puerto Rico. Processor interest in Puerto Rico stemmed from availability of low cost labour, proximity to eastern markets, and tax incentives. In 1953, tuna canning operations started in Puerto Rico with the establishment of one packing plant. At present, four canneries operate there.

As canning in Puerto Rico increased, tuna vessels from southern California transferred there also. The logistics of operating there, however, favoured only the larger vessels. In 1958, ten bait-boats with a combined capacity of 3,840 t, 11 per cent of the total U.S. tuna fleet's capacity (both bait-boats and seiners), were based at Puerto Rico. Since 1966, an added incentive to the large purse seiners has been the proximity to the burgeoning tuna fishery off the west coast of Africa. In 1969, 21 purse seiners totalling about 15,015 t capacity or 31 per cent of the total fleet's capacity were based there. Of these, 15 vessels were among the new additions to the fleet since 1961 (section 4.1.1). At present, no U.S. bait-boats operate from Puerto Rico.

Of the U.S. total annual tuna pack in 1967, Puerto Rico produced about 32 per cent, southern California 44 per cent, the rest of the continental U.S. 12 per cent and American Samoa and Hawaii 12 per cent (Forbes, Stevenson and Baldrige, 1969).

Regulations and shift from eastern tropical Pacific. In 1966, for the first time, conservation measures for yellowfin tuna in the eastern tropical Pacific recommended by the scientists of the Inter-American Tropical Tuna Commission (IATTC) were adopted by member nations. These recommendations included a "catch quota" (72,163 t in 1966). That year the closure date was September 15. After this date, no vessels were to leave port to fish yellowfin, but more than 75 per cent of the fleet was still at sea, unloaded, and fishing therefore continued in almost full swing for most of the rest of the year.

In 1967, however, the closure date was June 24th, and the fleet suddenly found itself faced with the alternatives of fishing exclusively for skipjack or going farther afield in search of yellowfin outside the IATTC regulatory area. Three vessels chose to seek yellowfin on the west coast of Africa in the Gulf of Guinea, where tuna vessels, mainly bait-boats, of France and other nations, have long operated. The three vessels, the *Caribbean*, the *Southern Seas* and the *Day Island*, fished as a group and shared the spotting services of a helicopter (Simmons, 1968). About 1,365 t of tuna were caught in two months of fishing (unpublished data furnished by IATTC) including 81 t of yellowfin "on porpoise" (*Delphinus delphis*).

In 1968, the closure date again came in June, and spurred by the success enjoyed by the three vessels that visited Africa the previous year, eight vessels went to the Gulf of Guinea. In 1969, closure came even earlier, in April, due to the increased capacity of the fleet, and 23 vessels went to Africa. In 1970, closure came in March, and the fleet is still larger, so the move to the Atlantic can be expected to be still greater.

Some vessels of the U.S. fleet have begun fishing far offshore, outside of the regulated area after the closure of the yellowfin season. Interest is being shown in other areas, including the Indian Ocean and the central and western Pacific Ocean. A cannery-financed exploratory trip, in the latter areas, by one purse seiner was carried out in the summer of 1970.

PROSPECTS FOR THE FUTURE

Total world demand for tuna has increased rapidly in recent years. World consumption of tuna and tuna-like species (in round weight) increased from 0.99 million t in 1958 to 1.4 million t in 1968 (FAO, 1969). *Per capita* consumption of canned tuna in the U.S. has increased from an average of 0.49 kg to 1.1 kg reported in 1969 (Forbes, Stevenson and Baldrige, 1969). This rising trend is expected to continue at a higher rate because of increases in population and, more importantly, standard of living.

Bell (1969) estimates that world consumption of tuna would double in each of the next two decades if supplies are adequate and there is no rise in prices. He estimates, however, that the world's oceans can supply only about 2.6 million t of tuna on an annual sustainable basis, and that prices and costs of tuna will double by 1990, with a world catch of about 2.1 million t, and triple by the year 2000 when the world's maximum sustainable yield is reached. This assumes that overfishing will be prevented as each of the stocks are exploited.

The American tuna fleet, since its inception, has been constantly responding to both foreign and domestic developments affecting their operations and markets and will continue to do so. The present trend to new construction of large purse seiners shows no signs of abatement. At the end of 1970, total U.S. tuna fleet capacity will be about 58,695 t. While many of these larger vessels are designed with the potential of worldwide operations in mind, it must be expected that they will also compete with the smaller, older vessels on the closer, traditional fishing grounds of the eastern tropical Pacific. With the entry of the newer vessels in this fishery, and the yellowfin season being progressively shortened, many smaller boats, which have no other place to fish, may be forced out of business as competition is intensified.

Expansion of the newer vessels of the U.S. fleet into waters outside of the yellowfin regulatory area, however, is certain to continue. Prospects may include the central and western Pacific Oceans and Indian Ocean. Catch per unit of effort cannot be expected to remain as high as present levels as new resources, such as central Pacific skipjack are relied upon. Although the stocks of these fish may be high, they are diffusely distributed, and with present technology, difficult to find and harvest. Production costs will therefore increase.

Competition from foreign tuna fisheries, using lower cost labour, is apt to increase. Japan, now experimenting with purse seining for tropical tunas in the eastern Pacific may decide to enlarge that segment of her long-range tuna fleet. Ecuador is proceeding with plans to build a tuna purse seine fleet with financing from the United Nations' International Bank for Reconstruction and Development.

In spite of developments of the past ten years, purse seining methods and gear have remained basically the same. But, with longer-range operations, higher production costs, and competition with low-cost labour, the U.S. fleet may be forced to raise its level of technology in the years to come. Improved refrigeration methods and partial processing at sea may be able to increase the value of the catch. Loading the catch aboard should become more mechanized to avoid loss of time on the fishing grounds and similarly more mechanized off-loading, such as containerized fish holds, can reduce turn around time by as much as two to three days. Diesel electric or turbine electric main drives should be considered (DeFever, 1968). Net handling may be improved by developing methods of mechanized net stacking. The use of articulated cranes instead of the old style mast and boom rigging may further speed the fishing operation. The purse seine, itself, has only recently come under scrutiny for possible improvements in design (Green, Jurkovich and Petrich, 1970). Methods for quickly changing the hang-in percentage and depth of nets are waiting to be tried (Petrich, 1968). Nets, in the future, may be of more highly specialized designs for particular fishing conditions.

As tuna inevitably become scarcer we must expect to develop and improve scouting and fish finding methods. Sonar may eventually play a more important role in the U.S. tuna fleet. We may expect to see refinements in the use of ship-based aircraft including the development of airborne, automatic sensors. Work has already begun in the use of satellites to locate fishing areas.

References

- ANONYMOUS *Anthony M* pioneers all-nylon tuna purse seine. 1956 *Pac. Fish.*, 54(5):38-43.
- ANONYMOUS Peru pioneered in all-nylon tuna seines. *Pac. Fish.*, 57(8):22.
- BELL, F W Forecasting demand for tuna to the year 1990. 1969 *Comm. Fish. Rev.*, 31(12): 24-31.
- BEN-YAMI, M Study of the Mediterranean trawl net. *In* 1959 *Modern Fishing Gear of the world*, ed. Hilmar Kristjonnsson. Fishing News (Books) Ltd., London. 213-221 pp.
- DEFEVER, A Modern U.S. tuna vessel construction, design and future trends. *In* The future of the fishing industry of the United States, ed. DeWitt Gilbert. Univ. Wash. Publ. Fish., New Series, 4:134-140.
- FAO Catches and landings, 1968. Yearbook Fish. Statist. 1969 (26):318.
- FORBES, STEVENSON and BALDRIDGE Feasibility study. A tuna trans-shipment plant in San Diego and other ocean-oriented facilities. Prepared for Office of Technical Assistance, Economic Development Administration, U.S. Department of Commerce (Project No. 07-6-09121, Items I and II), May 1969:207. Forbes, Stevenson and Baldrige, Economics Consultants, 350 California Federal Building, 608 Silver Spur Road, Palos Verdes Peninsula, California 90274, U.S.A.
- GREEN, R E and BROADHEAD, G C Costs and earnings of 1965 tropical tuna vessels based in California. *Fish. Ind. Res.*, 3(1):29-45.
- GREEN, R E Relationship of the thermocline to success of 1967 purse seining for tuna. *Trans. Amer. Fish. Soc.*, 96(2): 126-130.
- GREEN, R E, JURKOVICH, J E and PETRICH, B P Development and testing of the hybrid tuna purse seine. Paper No. 75, FAO Technical Conference on Fish Finding, Purse Seining and Aired Trawling, Reykjavik.
- LYLES, C H Fisheries of the United States . . . 1968. U.S. 1969 Fish Wildl. Serv., C.F.S. No. 5000: 83 pp.
- MCNEELY, R L The purse seine revolution in tuna fishing. 1961 *Pac. Fish.*, 59(7):27-58.
- ORANGE, C J and BROADHEAD, G C 1958-1959—A turning 1959 point for tuna purse seine fishing? *Pac. Fish.*, 57(7): 20-27.
- PERRIN, W F Using porpoise to catch tuna. *World Fishing*, 1969 18(6):42-45.
- PETRICH, B What I know about deep sea fishing. V. A. 1965 Sandoval Enterprises, Philippines. (Irregular pagination).
- PETRICH, B. Tuna purse seine of today and tomorrow. 1968 *In* The future of the fishing industry of the United States, ed. DeWitt Gilbert. Univ. Wash. Publ. Fish., New Series, 4:169-170.
- SHIMADA, B M and SCHAEFER, M B A study of changes in 1956 fishing effort, abundance, and yield for yellowfin and skipjack tuna in the eastern tropical Pacific Ocean. *Inter-Amer. Trop. Tuna Comm., Bull. 1: 351-469* (in English and Spanish).
- SIMMONS, D C Purse seining off Africa's west coast. *Comm. 1968 Fish. Rev.*, 30(3):21-22.

[R.E. Green, W.F. Perrin and B.P. Petrich]