Notes on the improvement of fishing power and efficiency in the western tropical Pacific tuna purse seine fishery

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1. Introduction

The development of the western tropical Pacific (WTP) purse seine fishery by the Japanese and subsequent mass movement of the US purse seine fleet from the Eastern Tropical Pacific (ETP) in the late 1970s and early 1980s is well known and has been adequately documented (Doulman 1987). However, gradual improvements in fishing power and the adoption of new fishing techniques from 1980 to the present have not been properly investigated or recorded. Improvements in gear efficiency and the adoption of new technology can significantly bias CPUE time series and mask real trends in catch and effort. These notes briefly describe historical and recent developments in this fishery that have altered and improved the fishing power of purse seine vessels operating in this region during the past 15 years.

Initially, Japanese vessels built in the style of U.S. tuna purse seiners were the first to developed the WTP seine fishery in the area between Papua New Guinea and the Federated States of Micronesia by developing techniques to exploit mixed tuna schools found in association with floating objects (Suzuki, 1981; Watanabe, 1983). Sets were made just before dawn when tuna can not see to avoid the encircling net before pursing is accomplished (Itano, 1990). U.S. vessels entered the Pacific region due to a combination of subsidized exploratory fishing cruises, personal initiative and a seasonal skipjack fishery in New Zealand. Fishing conditions in New Zealand were similar to those found in the Eastern Tropical Pacific, with cool, productive waters of reduced clarity and a shallow thermocline which promoted successful fishing operations by ETP vessels without significant modification to their nets or fishing gear. Many of these vessels had previously concentrated on capturing large yellowfin in association with porpoise schools in the ETP, using shallow, heavy mesh nets and correspondingly small purse winches and power blocks.

Many of these vessels remained in the western Pacific region, making necessary adjustments to their gear and fishing methods for successful operation in the warm, clear equatorial waters of the western tropical Pacific, as described in a number of technical documents (Habib 1984; Hutton 1984). This essentially meant much deeper nets and more powerful purse winches, power blocks and associated deck machinery capable of handling these nets. Published observer accounts of WTP purse seine operations during the period of 1982 - 1986 offer detailed descriptions of western Pacific purse seine vessels, gear and fishing methods from this period that had successfully converted or been purpose built to operate on associated and non-associated tuna schools in the WTP (Gillett 1996[a]; 1996[b]; Farman 1987). US purse seiners of this period generally used purse seines designed by Casamar, Inc. measuring approximately 1500 m in corkline length with a maximum depth[1] of 220 m.

Several fishing strategies are employed by western Pacific purse seine fleets as described by Itano (1990), but most fishing is conducted on schools found in association with floating objects or on unassociated schools, which are actually free schools actively feeding on surface baitfish. Setting on floating objects remains the main activity of many WTP fleets and is the most consistent producer of tuna in this region. However, setting on the free schools of yellowfin and skipjack found 'boiling' or 'foaming'

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1 The rated depth of a purse seine is a maximum measurement that is never achieved during normal fishing operations, i.e. a purse seine having a recorded depth of 300 meters may purse to a depth of only 150 - 200 m depending on current and pursing speed.

on surface baitfish concentrations is an attractive alternative to log fishing. Given a choice, many purse seine captains prefer to chase and set on school fish despite the lower success ratio. Successful operations on unassociated, or free schools requires a higher degree of skill and experience by the fishing master and fast pursing speeds. ***Most of the modifications to purse seine technology in the western Pacific during the last 15 years have been driven by a desire to improve the success rate on unassociated schools and to be able to load and store the large catches that are possible on free schools.*** Additional developments have concentrated on increasing the number of productive sets possible during a trip through increased use of drifting fish aggregation devices (FADs) and faster net hauling machinery.

2. Fishing Gear

2.1 Net size and design

U.S. style purse seines[2] are constructed of long panels, or 'strips' of pre-fabricated, knotted nylon webbing that lie parallel to the corkline and chainline that are laced together with nylon twine. According to Ward (1993) one strip of netting measures 4.25 fathoms in depth (7.77 m) with the U.S. seiner he observed in 1993 utilizing a 28 strip net. The shallow 14 to 16 strip nets commonly used in the Eastern Tropical Pacific had to be completely remade for use in the western Pacific, and were initially increased to 20 to 24 strips during the early years of the western Pacific fishery. Gillett (1996[a]) conducted an observer trip on a U.S. seiner in 1984 that was equipped with a net measuring 1536 m (corkline) x 241 m depth x 2012 m (chainline). Farman (1987) and Gillett (1986[b]) conducted observer trips on Japanese purse seiners in 1984 and 1984 that suggest the Japanese were using significantly deeper nets during this period (318 m and 280 m respectively). Itano (1991) conducted an observer trip on a Japanese purse seine vessel during 1990 that was equipped with a net measuring 2121 m (corkline) x 396 m depth x 1959 m (chainline) length. This net had a hanging ratio[3] of 26.6% on the corkline and 16.6% on the chainline.

Net length appears to have stabilized in the U.S. fleet at approximately 1800 meters but net depth has continued to increase over time with many vessels currently deploying seines of 30 or more strips in depth. Increases and adjustments in the hanging ratio and net design have also been made that allow faster pursing speeds.

Japanese purse seines are constructed of large, vertical panels of lightweight, knotless nylon webbing in contrast to the knotted, horizontal strips used by the U.S. vessels. For example, the vessel observed by Itano (1991) used a net constructed of 31 vertical panels of knotless webbing with mesh sizes ranging between 240 mm (stretched mesh measurement) in the bow and center sections of the net to 75 mm in the sack with most of the webbing outside the sack constructed of lightweight twine of Japanese size 50 to 70 which corresponds approximately to U.S. twine sizes of 24 to 36. Over time, U.S. nets have become lighter in construction with larger mesh sizes, more similar to the Japanese nets. However, the U.S. vessels object to the use of knotless webbing as they feel it is not strong enough to withstand high pursing speeds under adverse current conditions. ***The use of thinner twine and larger mesh sizes in the first half of the net (bow section) allows a much larger net to be stacked in the same area, and produces a net that will sink and purse faster due to a reduced resistance to currents and seawater.***

Most vessels have adopted roller equipped purse rings that increase pursing speed and reduce

2 Used by USA, Taiwanese, Korean, Philippine, Russian, Australian, New Zealand and Pacific Island purse seiners.

3 Ratio of net webbing to corkline or chainline that it is laced to.

wear on the purse cable. The roller rings either open up or can be released from the chainline prior to passing through the power block which eliminates the danger of purse rings falling on crewmen during the net stacking procedure. ***Release rings significantly speed the net hauling operation by the elimination of the time consuming ring stripping procedure*** which is described by Stequert and Marsac (1983). Most vessels also use two deck chokers which speeds the sacking up or drying of the net prior to brailing.

2.2 Hydraulic gear

Successful purse seining in the western tropical Pacific requires adequate net depth combined with adequate pursing speed. It appears from observer reports and anecdotal information that a pursing speed of 15 - 20 minutes is necessary to consistently capture free schools in this region (pers. obs.). Pursing speed has been maintained at 20 minutes or less by several means while the nets have grown considerably in length and depth. ***Primarily, the hydraulic power systems on U.S. seiners were significantly modified during the mid-1980s to supply adequate power to the larger winches and power blocks*** required to purse and haul the larger nets. Prior to this time, hydraulic power supplied to deck machinery was produced by electric motors mounted directly to hydraulic pumps. Direct hydraulic power take-off units supplied additional hydraulic power for the purse winch and power block, but were of limited capacity. Continued deepening of the nets prompted the vessels to install an additional diesel auxillary engine below the purse winch with the sole purpose of supplying massive amounts of hydraulic fluid directly to the purse winch and power block. It is not clear when or if purse seiners from the other DWFN fleets have made these modifications, but the purchase of U.S. seiners by Korean companies in the mid to late 1980s may have encouraged the spread of this development.

Increased net length and depth has meant that purse cables have also increased in diameter and length with time requireing larger purse winches with higher cable capacities. ***In recent years, there has been a shift away from the industry standard of Marco winches and power blocks to Canadian built machinery of larger sizes and power ratings.***

2.3 Electronic equipment

Descriptions of standard electronic fish finding and navigation equipment used by western Pacific purse seiners (c. 1990) is given by Itano (1990; 1991). The Observer Program of the Forum Fisheries Agency has documented electronic equipment on U.S. seiners operating under the conditions of the South Pacific Tuna Treaty (SPTT) since 1988 as have the observer program of the Micronesian Maritime Authority (MMA) of the Federated States of Micronesia. However, these data have never been specifically examined.

The Japanese fleet has historically lead the way with marine electronics, and were the first to utilize omni-scan sonar, doppler current meters, satellite derived oceanographic data, select-call radio buoys, net depth recorders and bird locating (S band) radar. There has also been some experimentation with remote tele-sounder equipped radio buoys for monitoring aggregations under floating objects from a remote location. Most of these items are now standard equipment on U.S., Korean and Taiwanese vessels. ***Apparently, there have been few if any significant developmens in marine electronics within the past ten years aside from steady improvements in design and an increased use of satellite imagery.***

3. Catch loading and on board refrigeration

Larger nets and more powerful deck machinery have significantly increased the potential size of catches to over 300 tons per set. ***The ability to load and refrigerate large individual catches has been the most significant development in fishing power to occur in recent years.*** The WTP fishery operates within or adjacent to the largest warm water mass on the planet (Western Pacific Warm Pool) with sea surface temperatures that remain consistently above 28.5 °C. Tuna decomposition and histamine formation is rapid at these temperatures, and fish loading must be accomplished soon after the commencement of brailing to maintain adequate fish quality. Once loaded, the catch must then be cooled and frozen as quickly as possible to arrest spoilage.

Fish quality begins to deteriorate as soon as the school is surrounded by the net and the fish become stressed and begin to die. Therefore, every subsequent stage of the fishing operation has been optimized for speed, such as the net retrieval, sacking or drying up of the net and brailing. ***The most important development in this process to occur in recent years has been the adoption of a European style of fish brailing that does not require the net skiff for the sacking up or brailing operation.*** For the sake of comparison, conventional skiff brailing is accurately described and illustrated by Stequert and Marsac (1983).

The new brailing systems utilizes a strong brailing davit/boom located aft of the purse davit and an auxillary loading boom to support the corkline instead of using the net skiff. A large, very heavy brailer capable of loading approximately 5.5 short tons of fish at a time from the sack is operated in a fore to aft direction alongside the hull in contrast to the less efficient outboard/inboard scooping motion of skiff style brailing. The new brailers simply sink into the sack under their own weight rather than relying on crewmen pushing down on the old style brailer handles. Some vessels use a brailer without a handle which is completely controlled by hydraulic cables. Other systems use a long handle mounted to the brailer that slides and pivots from a fixed location on the purse davit which controls the swing of the brailer for increased safety and greatly speeds the entire operation (pers. obs.). **These brailing systems are reported to be capable of loading approximately six short tons per minute.**

Cooling and freezing of large catches that can result from successful free school fishing is the next priority. In recent years, modern tuna purse seiners have ***increased the size or number of ammonium compressors and installed brine chiller units in line with their refrigerated brine circulation systems.*** The brine chillers are designed to draw down the temperature of the circulating brine that rises rapidly when brailing and loading hot tuna having core temperatures of ≥29 °C.

The Japanese and Taiwanese WTP purse seiners make use of dry freezer space located on the wet deck to increase their total holding capacity and to high grade catches. At least one U.S. vessel is similarly equipped and others may be shifting to this practice (pers. obs.). Normally, the catch from a set containing large yellowfin is brined and frozen for one to two days after which the well is drained. The crew then sorts the fish by species and size category into the dry freezers, with some priority on storage space given to the higher value, medium to large yellowfin. During this process, the crew has an opportunity to sort and discard bycatch, undersize tuna and smashed or damaged tuna. This high grading at sea is a source of unreported catch unless an observer is present. ***Sorted wells greatly speeds transhipping in port if a buyer wants a certain grade or size of tuna.*** For example, the author conducted an observer/tagging trip on a Taiwanese purse seine vessel that was equipped with dry freezer holds in addition to conventional brine holds. During transhipment operations in Chuuk Lagoon, one buyers specifically requested yellowfin greater than 20 pounds at a good price while others wanted the skipjack and smaller tuna. The vessel shifted from carrier to carrier and was able to discharge the sorted catch in a fast and efficient manner and return to the fishing grounds.

4. Increase in fishing effort per trip

4.1 Transhipment

Significant inter-annual variability exists in WTP catch rates that may be more a factor of variable catchability than true shifts in abundance. In particular, the abundance of surface flotsam or surface baitfish concentrations have a significant impact on the amount of fishing effort that the seiners can direct on tuna schools within a given amount of time. Western Pacific purse seiners have in recent years adopted strategies to minimize their search times and increase their mean fishing effort per trip. Primarily, this has been accomplished by the ***increased use of refrigerated carrier vessels that reduce time lost in transit to regional canneries or waiting to discharge catch and an increased utilization of drifting FADs***. Regional requirements to tranship in only in designated ports (i.e. no high seas transhipment) have reduced the potential benefit of this strategy. However, transhipping remains an important option for vessel owners to reduce turnaround times in port, especially when several vessels are lined up to unload at a cannery. Both strategies result in a reduction in the number of "no set" days during the year resulting in increased annual production rates.

4.2 Drifting fish aggregation devices (FADs)

Japanese purse seiners operating in the WTP have made extensive use of free drifting FADs since the beginning of the fishery, and the use of drifting FADs is well documented by Gillett (1986[b]). At least a few U.S. seiners used drifting FADs as early as 1980, but their use was sporadic and secondary to sets on natural drifting objects or unassociated schools (pers. obs.). ***The 1997 season marked the first year when the majority of sets made by the U.S. WTP fleet were on drifting objects***, with a heavy reliance on drifting FADs. Vessels deployed as many as 14 FADs per trip with a success rate of for sets on drifting objects of 96% during the 1997 season (Coan, et. al, 1998).

The construction of these FADs is similar to those described by Armstrong and Oliver (1995) in their report on the use of FADs in the ETP purse seine fishery covering the years 1990 - 1994 (pers. obs.). These drifting FADs are usually constructed from surplus purse seine corks and heavy net webbing of #54 or higher. Approximately 4 - 5 meters of corks are rolled together in webbing or secured to a board or bamboo poles, with 15 to 25 meters of net webbing draped below the floats and weighted down with used chain or automobile tires. Additional rope or streamers are usually added to the sub-surface webbing. A perforated receptacle holding chum is sometimes added in the belief that the chum will promote the aggregation of baitfish and tuna. This type of drifting FAD can be easily rolled up and stored in a small space on board the vessel.

This generalized design varies from vessel to vessel, but there is a consensus among fishermen that a significant amount of subsurface area is important to a successful FAD. It is common 'knowledge' in the fleet that the most successful natural drifting object besides a dead whale is a large log that has become waterlogged and floats vertically with only a small portion above the surface (Hampton and Bailey, 1993). Several theories have been put forth to explain the importance of sub-surface structure to drifting and anchored FADs, including:

- vertical logs are vertical because they have become waterlogged with time and have been in the water longer and have had more time to aggregate tuna;

- sub-surface mass 'holds' or tracks better in the water column, positioning the FAD in productive current gyres or current boundaries, rather than drifting with surface winds;
- sub-surface structure offers greater surface area for shelter and habitat for baitfish and associated drift communities, including juvenile tuna;

- tuna can discern, locate and aggregate to logs or FADs with large a sub-surface area at greater distances either through auditory, visual or other means.

The reason for the apparent success of FADs with large sub-surface structure is not clear but the fishermen believe this to be true and fashion their drifting FADs accordingly. The predictable drift of FADs that hold well in the prevailing current is an additional benefit as one vessel may be tracking and monitoring more than 10 FADs at the same time.

Another point that becomes clear when examining observer data is that ***the distinction between 'logs' and 'drifting FADs' is seldom clear as the fishermen usually enhance natural logs with netting or straps or tie several logs togther***. Natural logs are also lifted on board and deployed at new locations with select-call radio buoys making them essentially a drifting FAD. The heavy reliance on drifting FADs has also ***clouded the definition of 'searching' as many days are spent simply steaming from one radio buoy marked log or FAD to another that are assessed with sonar and depth sounder*** with minimal visual searching conducted between FADs in the conventional sense.

5. Summary

Western Pacific purse seine vessels have increased their annual production throughout the history of the fishery by several methods. Most of the advancements in recent years have been driven by a desire to capitalize on large surface schools that are often composed of the higher value medium to large yellowfin or premium size skipjack. When these surface schools appear, very large catches are possible necessitating methods and equipment to load and freeze the catch as quickly as possible before spoilage or smashing in the net occurs. These developments can be summarized as follows:

- larger, deeper, better designed nets;

- more powerful hydraulic gear to maintain fast pursing and net hauling speeds;

- use of satellite imagery to reduce search times and position vessels and FADs in productive areas;

- faster sacking up and brailing procedures;

- higher capacity and more efficient refrigeration systems;

- minimization of in port time by pre-sorting catch and transhipment;
- incorporation of drifting FADs in the fishing strategy.

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