A Survey of Purse Seine Fishing Capacity in the Western and Central Pacific Ocean, 1988 to 2003

Gillett, Preston and Associates

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Robert Gillett
and
Antony Lewis

September 2003
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Cover photographs: A US purse seine vessel in Pago Pago harbor (top) and Korean seiners transshipping at Pohnpei (bottom).

Executive Summary

The survey

A consultancy firm was contracted in July 2003 to determine the aggregate capacity of the purse seine fleets participating in the western and central Pacific tuna fishery over the past fifteen years and compare it to the existing capacity. Work on the review began in July 2003 and was completed two months later.

"Participation"

As the objective of the study is to determine the carrying capacity of purse seine vessels participating in the fishery of WCPO region, it is important to define the term "participation". For the purpose of this study, vessel participation in the fishery means that the vessel was actively fishing in the region at some time during a particular year. It should be noted that this fairly straightforward definition is not without complications.

History/development of national purse seine fleets

Because a knowledge of the purse seine fishery in the western and central Pacific is a necessary prerequisite to understanding tuna fishing capacity in this region, the history and development of the 18 national flag purse seine fleets that have participated in the fishery during the past 15 years are reviewed.

Fishing capacity

The concept of fishing capacity is not well understood in the Pacific Island region, even by those individuals responsible for managing tuna fisheries. One of the simpler definitions is that fishing capacity is the ability of a vessel or vessels to catch fish. Although the term "fishing capacity" was rarely used in the region just a few years ago, a number of initiatives to study tuna fishing capacity are now underway that are relevant to the WCPO.

Carrying capacity: Tonnage vs volume

A seiner's carrying capacity measured in fish tonnage is both variable and difficult to certify or verify. This restricts the usefulness of the statistic in measuring the ability of a seiner to catch fish. Because of this difficulty, there has been a movement recently to use the relatively simple volume of a seiner's fish wells as a measure of carrying capacity. There are still problems with volume carrying capacity, mainly that associated with the lack of ability to verify information.

Sources of data for the survey

The Forum Fisheries Agency Regional Register and SPC/OFP Regional Tuna Fishery Database were the basis of data for the survey. This was supplemented by information from several other sources.

Methods used

The basic method used in calculating the carrying capacity of the various fleets operating in the WCPO region consisted of transforming the FFA Registers into purse seiner capacity inventories by eliminating non-seiners, correcting obvious mistakes, estimating missing information, and cross-checking with as many sources as possible.

Carrying capacity estimate

The total carrying capacity of purse seine vessels participating in the fishery during 1988, 1995, and 2003 was about 140,000, 200,000, and 233,000 cubic metres, respectively. This represents an increase of about 43% during the 1988-1995 period, an increase of about 16% during the 1995-2003 period, and an increase of about 67% during the entire 1988 to 2003 period.

Participating vessels

The numbers of purse seine vessels participating in the fishery in 1988, 1995, and 2003 were 136, 175, and 191, respectively.

Average carrying capacity

The average capacity per vessel has increased from 1073 cubic metres in 1988 to 1222 cubic metres in 2003. Although the average carrying capacity of most major national fleets remained stable, or increased moderately, the fleets of FSM and Vanuatu have increased dramatically in recent years in both numbers and capacity.

Problems in estimates of carrying capacity

- The most important reservation concerning the estimate of carrying capacity is that the calculation relies heavily on unverified information in the Regional Register. Although it was possible to cross check vessel numbers for the three years with SPC data, there was much less opportunity for verification of the data on carrying capacity - in most cases all that could be done was to verify one source of vessel-provided data with another source of vessel-provided data.
- Another major problem is that the Regional Register application blank for "Storage Capacity (cubic metres)" appears to be filled in by various operators as (a) cubic metres, (b) 20^0 F tonnage carrying capacity (in short tons), and (c) 14^0 F tonnage carrying capacity (in both short tons and metric tonnes). In most cases it is not possible to determine which values are in the correct units.

Under-estimation of carrying capacity

The two sources of error above, which apparently are the most common, suggest that estimates of carrying capacity of this survey are less than the true values, perhaps by 10%. Effective carrying capacity of group seiners and seiners operating with carrier vessels is also believed to be underestimated.

Factors contributing to the increase in carrying capacity

Contributing factors include vessel transfers amongst fleets, physical changes to existing vessels, introduction of vessels from other ocean areas, and construction of new vessels.

Is carrying capacity a good proxy for fishing capacity in the WCPO?

The carrying capacity of a tuna purse seiner appears to be an imperfect indicator of the ability to catch fish. Due to special operational characteristics of some of the major purse seine fleets in the WCPO region, the use of carrying capacity as a proxy appears less suitable than in the Eastern Pacific Ocean region where the concept was developed for tuna purse seiners which typically discharge full fish loads.

Proxies for carrying capacity

It appears that the three alternative characteristics investigated (tonnage, length, crew size) are not good proxies for carrying capacity. It is important to note that, to some extent, the suitability of the three characteristics could be distorted by erroneous data in the Regional Register.

Alternatives to the use of carrying capacity

Although the use of carrying capacity as a proxy has its shortcomings, especially in the WCPO, there are no obvious alternatives. Carrying capacity therefore appears to be presently the best of a number of imperfect options for measuring fishing capacity of tuna purse seine vessels. Conceivably, research could be undertaken on other vessel characteristics or combinations of characteristics to formulate a better proxy than carrying capacity. The effectiveness of such work would, however, be tremendously constrained by the large amount of erroneous data in the Regional Register.

Further work required to improve estimates of capacity

- For both improving the estimate of carrying capacity and for developing any alternative proxy to carrying capacity, the key is to upgrade the accuracy of the data in the Regional Register. Independent verification of vessel-supplied information is essential.
- More information is needed on (a) the capacity of tuna purse seine vessels in domestic Asian fisheries which can move into the region or otherwise affect the region, and (b) current vessel construction and plans for expansion of fleets.

1.0 Introduction

1.1 Background

The United States has been negotiating the Western and Central Pacific Fisheries Convention (WCPFC) and its associated preparatory conferences for over eight years. The Convention is expected to come into force in the coming year. One of the major issues that has emerged during the course of the negotiations is that of tuna fishing vessel capacity levels in the western and central Pacific Ocean (WCPO). There has been considerable debate and question as to the exact level of purse seine capacity in the WCPO. These questions are in part based on the fishery's rapid growth over the last 15 years, as well as the lack of comprehensive regional fishing fleet records. While some vessels are regionally registered, it is understood many operate under local or bilateral access agreements and may not appear on WCPO regional databases. The U.S. Department of State, Office of Marine Conservation, has requested that NOAA Fisheries Pacific Island Regional Office, which is the lead technical support office on the U.S. delegation to the Convention negotiations, provide a summary of purse seine capacity growth over the past 15 years in order to better understand this issue and to inform the U.S. position with respect to purse seine fishing capacity in the western and central Pacific Ocean.

To study this issue, the consultancy firm Gillett, Preston and Associates (GPA) was contracted in July 2003 to review the purse seine capacity situation in the WCPO. Specifically, the terms of reference for the study state that GPA is "to determine the aggregate capacity of the purse seine fleets operating in the western and central Pacific over the past fifteen years that fish for skipjack, yellowfin, or bigeye tunas and compare it to the existing capacity. The analysis will include the nationality of the number and capacity of distant water, foreign-flagged locally-based, and Pacific Island registered vessels. The vendor shall collect and report on all available information on purse seine participation in the western and central Pacific from the regional management organizations, as well as local marine resource divisions of key Pacific Island countries".

Work on the review began in mid-July 2003 and was completed two months later. In the course of the study 60 documents were consulted and 51 individuals were contacted. These are given in Appendix 1 and Appendix 2, respectively.

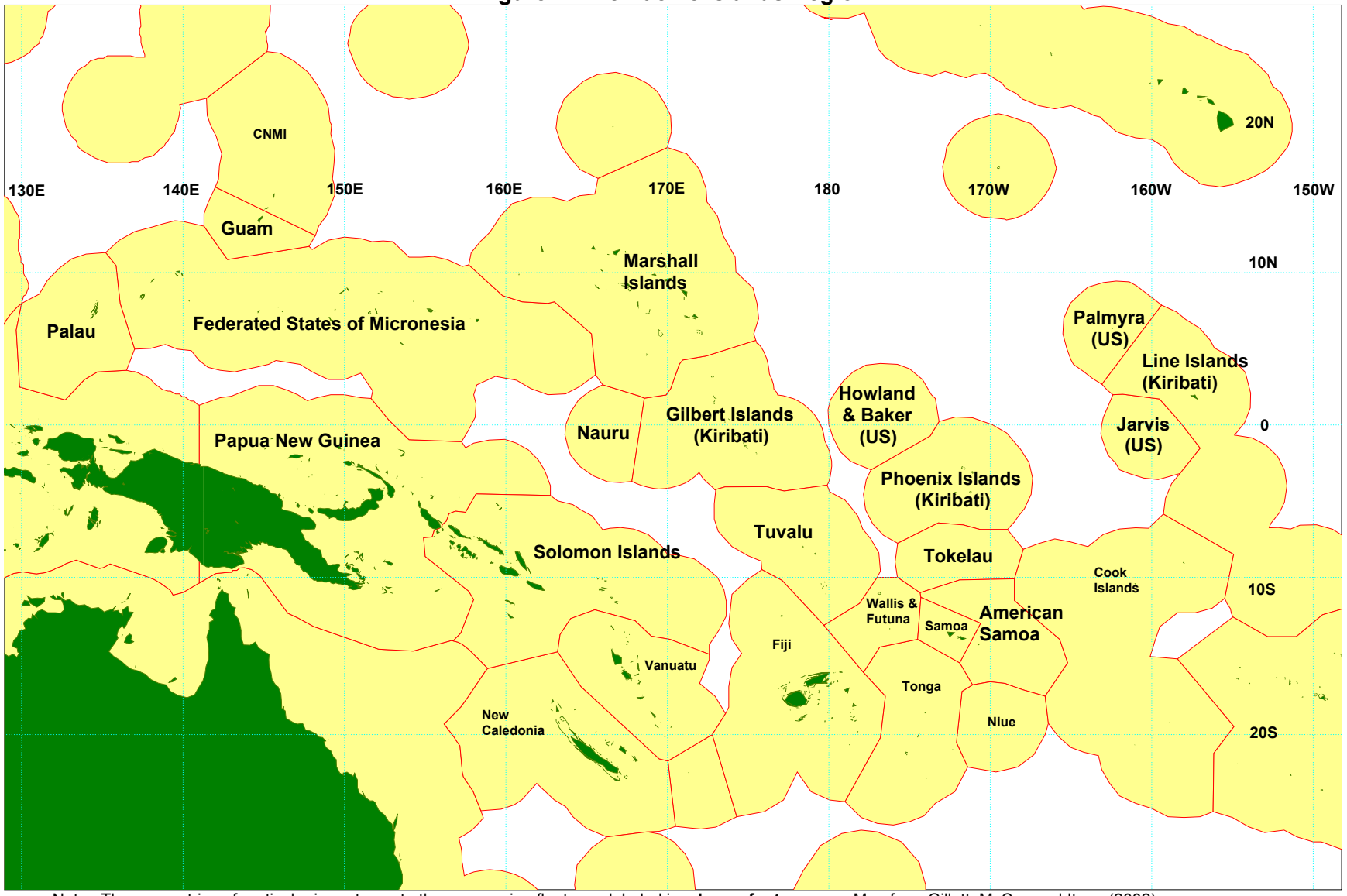
1.2 Scope of the Review and Terminology

Ideally, a study on tuna purse seine capacity would include all vessels that operate throughout the range of tuna stocks being targeted. Time limitations and the difficulty of being able to acquire the necessary information on some fleets, however, required that the scope of the review be reduced. The geographic zone considered in this study is the area of the Western and Central Pacific Fisheries Convention (WCPFC) which extends from the Pacific coasts of Asia to 150^0W. The geographic zone considered in this study is the area of the Western and Central Pacific Fisheries Convention (WCPFC) which extends from the Pacific coasts of Asia to 150^0 W. The vessels covered are those seiners that have fish carrying capacity greater than 400 cubic meters[1]. Although purse seine vessels which presently operate exclusively in the domestic fisheries of Indonesia and the Philippines could be a major factor in future tuna fishing capacity in the convention area, the present study excludes from consideration those vessels which operate only in domestic Asian fisheries. It

[1] Although 500 cubic metres of capacity was suggested in the terms of reference for this study, the 400 cu m lower limit is more practical as the larger limit would exclude some tuna purse seiners active in the WCPO region. A 400 cu m lower limit would also enable comparison with previous capacity studies.

also excludes purse seine vessels fishing seasonally in the domestic fisheries of Australia and New Zealand, but not vessels from those countries which have fished beyond the respective EEZs. In practical fishery terms, this reduced scope results in a study of purse seine capacity in the Pacific Islands area (Figure 1) which nonetheless accounts for over 75% of the WCPO catch.

Figure 1: The Pacific Islands Region



Note: Those countries of particular importance to the purse seine fleets are labeled in a **larger font**; Map from Gillett, McCoy and Itano (2002).

The time periods covered by this study also require mention. Numerous difficulties were experienced in working with the primary source of information for this study, the Forum Fisheries Agency Regional Register of Foreign Fishing Vessels (referred to in this report as "the Register" or "RR"). These included non-availability of electronic copies of the Register prior to the early 1990s, and the time consuming tasks of scrutinizing each annual Register for missing vessels, duplicate vessels, erroneous capacity information, and estimating capacity for vessel entries missing this information. These difficulties dictated that a detailed determination of capacity was focused on three annual periods: 1988, 1995, and 2003.

Although this study was completed in mid-September 2003, due to the time required for analysis and reporting, information on changes to fleets received after the end of August was not considered, including some data on the fleets of the US and Vanuatu[2].

As the objective of the study is to determine the carrying capacity of purse seine vessels participating in the WCPO region, it is important to define the term "participation". For the purpose of this study, vessel participation in the fishery means that the vessel was actively fishing in the region at some time during a particular year. It should be noted that this fairly straightforward definition is not without complications. These include:

- Some of the annual periods important for purse seining are not the same as the calendar year: U.S. Multilateral Tuna Treaty (USMLT - June/June), FFA Regional Register (September/August).
- At least one of the tuna purse seine fleets (U.S.) counts vessels licensed to fish under the multilateral treaty as "participating" in the fishery although, in certain instances, such vessels may not fish in the region in a given year.
- Some of the purse seine fleets are managed in such a way that the retirement of a vessel is followed soon after by the commissioning of a new vessel. In this situation, the two vessels involved would, according to the definition of the present study ("actively fishing in the region during a particular year"), both be considered to have participated in the fishery during the year concerned. A government agency that manages a fleet may, however, consider the participation to be only one vessel because at any point during the year only one of the vessels was fishing and only one vessel-year of effort has been expended.

Due to agreements on confidentiality of data under which the Secretariat of the Pacific Community (SPC) and the Forum Fisheries Agency (FFA) provided information, this report does not give vessel names except when that information is in the public domain. Where information about individual vessels could be deduced (such as a national fleet of one vessel), that data is provided in this report aggregated with other vessels.

2.0 Tuna Purse Seining in the Western and Central Pacific – History and Development

A knowledge of the purse seine fishery in the western and central Pacific is a necessary prerequisite to understanding tuna fishing capacity in this region. Accordingly, the

[2] As appropriate, this recent information given in footnotes.

following sections review the history and development of the 18 national purse seine fleets that have participated in the fishery during the past 15 years.

The WCPO tuna purse seine fishery is the world's largest, producing between 25 and 30% of the global tuna catch each year. From its beginnings in 1950, it has produced an annual catch of over one million tonnes since 1998. It is primarily a skipjack fishery, with this species supplying 70-80% of the catch (Hampton and Williams, 2003). The great majority of the catch is taken in equatorial waters (10^0 N – 10^0 S), with smaller seasonal fisheries in sub-tropical waters. In most years, there is little overlap between the purse seine fishery of the WCPO and that of the smaller Eastern Pacific Ocean (EPO) fishery.

2.1 Japan

Although US vessels had been purse seining for tuna in the eastern Pacific Ocean (EPO) since the early 1950s (IATTC, 2003), Japanese purse seine vessels were the first to actively fish for tuna in the WCPO, beginning in the 1960s in Japan's coastal "homewaters". Between 60 and 70 small vessels (50 to 200 GRT) were fishing by the end of that decade. Purse seine test fishing in tropical waters, to fish outside the summer homewater season (May-September), began in 1960 (Matsuda, 1987). In the early to mid 1970s, larger vessels (499 GT, 349 GRT) were constructed and, recognizing the year-round availability of tuna in equatorial waters, began exploratory fishing on logs, mostly in waters near Papua New Guinea (PNG). These offshore vessels (6 to 7 single and group seiners) took over 15,000 t in 1971, with vessel numbers and catch steadily increasing during the 1970s as fishing techniques in the clearer deeper thermocline waters were improved. By 1979, 17 vessels were taking over 60,000t of fish. The fleet continued to grow, peaking in 1988 at 39 vessels (34 single and 5 group seiners) catching over 200,000t (219,000t @18.9t/set). Vessel numbers (and other aspects of fishing operations) were restricted by Government decree to 32 single purse seine vessels until 1996, when 7 group seiners were withdrawn in favour of three additional single purse seiners. Numbers have remained at around that level (35) since that time. Group seiners continued to fish in equatorial waters until the mid-1990s, and still operate in the homewater fishery. The small vessel coastal fleet has declined to around 20 vessels in recent years (Okamoto et al. 1997; Lawson, 2002). The historical high catch was achieved in 1998, when 35 single purse seine vessels caught 275,000t with an average of 27.2t/set.

Vessel size (LOA, GRT) and age

Japanese single purse seine vessels have traditionally been of standard size (349 GRT, 499 GT class) with several larger vessels built from time to time. No reliable data are available throughout the time series on vessel length (LOA) which seems to vary between 51 and 66m LOA. The group seiners were smaller and of similar size, at 30-31m LOA and 116 GT. All vessels were built in Japan, replaced regularly and sold accordingly to established guidelines.

At present (2003), 20% of vessels fishing are less than 10 years old, and only 23% older than 20 years, with an average age of 14 years.

Fishing operations

Initially fishing almost exclusively on log sets, the Japanese fleet gradually adapted to free school fishing, through the use of deeper nets and other technology developed originally by the U.S. fleet. By 1988, approximately equal proportions of sets were made on free schools and logs, a pattern which persisted through most of the 1990s until a shift to fishing drifting FADs beginning in 1998. Equal numbers of sets were made on free and associated schools in recent years, but in 2002, the fleet considerably reduced FAD fishing (15% of total sets).

The fleet has operated through a series of bilateral access agreements in the region, as well as fishing high seas areas, and has generally operated in more western areas than other fleets, although there has been no access agreement with PNG since 1987.

Landing points/catch disposal

Apart from a brief period of unloading by part of the fleet at Tinian and other ports in western areas, these vessels have been required to return to Japanese ports to unload.

The following table gives the number of vessels on the Regional Register, the number of vessels as determined from SPC logsheet data, the catch estimated by SPC from logsheet data, and vessel characteristics.

Table 1: The Japanese Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
1988	35+9	34+5	219,315	52.2	349	5 (19 vessels)
1995	34	33	204,456	58.2	349	8
2002[3]	34	35	~220,000	59.7	349	13
2003	34	34	N/a	62.5	349	14

2.2 USA

Although the Eastern Pacific Ocean (EPO) purse seine fishery had been operating since the late 1950s, beginning with the conversion of larger pole-and-line vessels to purse seine fishing, the US fleet was a later entrant to the WCPO. Exploratory fishing began in the WCPO in 1970, when 3 vessels made an exploratory cruise (Gillett et al. 2002). The Pacific Tuna Development Foundation (PTDF), a government/industry body formed to encourage tuna resource development in the Pacific Islands, sponsored 11 cruises to the WCPO in the late 1970s to early 1980s, mostly in the PNG-FSM area. Eight vessels, fishing on a part-time basis, took 8,600t in 1979. The first US seiner to operate on a fully commercial basis in the WCPO began fishing in 1979.

Following a gradual build-up in interest over the next few years, the very strong El Niño event of 1982-83, with the greatly reduced availability of fish in the EPO, prompted a large scale movement of the US fleet to the WCPO (Gillett et al. 2002). In 1983, 62

[3] Although this report focuses on three time periods (1988, 1996, 2003), the year 2002 is included in the fleet tables as that is the latest year for which catch data are available.

vessels caught 179,000t @ 20.7t/set, a catch that this fleet did not exceed in the WCPO until 1991 when 43 vessels took 216,000t @ 30.5t/set. A combination of declining fish prices and a difficult financial environment (high interest rates) saw vessel numbers decline during the late 1980s, with many vessels being transferred to Korean interests, initially with US crew and technology. Whilst 62 vessels remained on the Regional Register in 1987/88, only 32 were fishing in the WCPO. Despite a brief revival extending until 1994 when 49 vessels fished, the fleet has been in general decline since that time, with 26 vessels on the Regional Register at the present time (August 2003), but only 20 actually fishing. From an historical high catch of 216,000t in 1991 @ 30.5t/set, the catch has fallen to below 120,000t in 2002.

Vessel size and age

The US fleet was the most innovative during the developmental phase of the fishery, with great variation in vessel size and design. In 1995, the average GRT was 1181, and LOA 64.1m. In 2003, the average GRT was 1241, and LOA 73.2m. In 1988, information available on 23 vessels suggests an average age of 20 years for the fleet. In 1995, this had decreased to 15 years, increased again in 1997 to 20 years, and in 2003, the 26 vessels on the Regional Register now have an average age of 24 years.

Fishing operations

Whilst initially fishing log schools, the US fleet quickly developed the necessary techniques to successfully fish unassociated schools in the WCPO, with its clearer water and much deeper thermocline. By 1988, most sets (80%) were on free schools, but 1996 saw a shift to FAD fishing, such that 90% of sets in 1999 involved drifting FADs. Recent years have seen a reversion to free schools (60% in 2002), though still with 40% of sets made on FADs.

The US Multilateral Treaty (USMLT) was signed in 1987; since that time, the fleet has enjoyed access to most of the region except closed areas in some EEZs. Some vessels have returned at times to fish in the EPO for brief periods.

In recent years much of the US fishing activity in the WCPO has shifted eastward, and appears to fall into two general categories: (1) deploying and setting on drifting FADs in the more southerly region (Tokelau, Tuvalu, southern Phoenix and Gilbert Islands), and (2) setting on baitfish associated schools of yellowfin and large skipjack in the Howland/Baker zone, northern Phoenix Islands, Jarvis Island, Palmyra, and adjacent high seas pockets (see Figure 1).

Landing points/catch disposal

The US fleet has historically unloaded to canneries in Pago Pago directly, with little transshipment, apart from a period in the 1980s and early 1990s when one large component of the fleet (14 vessels) transshipped or unloaded in ports such as Guam and Tinian. Currently, the fleet unloads directly to Pago Pago, with virtually all the catch utilized for canning.

Table 2: The U.S. Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC/NMFS)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
1988	63	32	114,416	61.8	N/a	11(23 v)
1995	47	43	167,553	64.1	1181	16
2002	29	29	118,800	64.4	1248	24
2003	26	20 (6 inactive)	N/a	67.1	1241	24

2.3 Korea

The Korean fleet commenced fishing in the WCPO in 1980, with 2 vessels of unknown characteristics. Through the gradual acquisition of US-built and owned vessels and accompanying technology during the 1980s, 23 vessels were taking 80,000t by 1988 (although only 19 vessels, including one group seiner were on the Regional Register) and construction of new vessels in US yards was well established. The size of the fleet fleet peaked at 39 in 1990 (173,000t), while the catch was at its maximum at an estimated 227,000t in 1991[4]. There has been a steady decline since then to 27 vessels at present, with the catch around 170,000t.

Vessel size and age

Size characteristics of the Korean fleet have been stable over time, since very few new boats have been constructed in recent years. The 16 vessels in 1988 had an average age of 11 years; this had increased to 15.5 years in 1995, and 22 years in 2003, with no new vessels built during the 1990s. Of the 30 vessels on the Regional Register in 1995, 26 were more than 10 years old, and 6 were more than 20 years old. All except two were built in the US. By 2003, the 27 vessels in the fleet had an average age of 22 years, with only five built outside the US (2 Spain, 2 Taiwan, one Chile) .

Fishing operations

The early days of fishing by the Korean fleet involved a mixture of free and log schools, but with time, this steadily became mostly free school sets, as with the US fleet. This has remained the case, despite the movement to FAD sets by other fleets in recent years, and over 80% of sets since 1998 continue to be made on free schools.

The Korean fleet enjoys bilateral access to the EEZs of many nations, and the fleet fishes widely throughout the region, with a tendency to fish more eastern areas in recent years.

Landing points/catch disposal

The Korean purse seine fleet utilizes multiple transshipment points, and vessels rarely discharge a full load. About half of the catch is returned to Korea for canning by domestic packers, with other fish carried to Pago Pago and Bangkok.

[4] Catches and catch rates were poorly estimated for the Korean and Taiwanese fleets prior to 1993.

Table 3: The Korean Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
1988	17 +1	23[1]	79,397	61.1 (20v)	1064	11
1995	30	30	175,464	61.6	1070	15.5
2002	27	28	195,390	61.3	1044	21
2003	27	27	N/a	62.8	1014	22

[1] Although the SPC Yearbook and NFRDI list 23 vessels fishing in 1988, logsheet data and vessel characteristics are available for 20 vessels only.

2.4 Taiwan

Operations by Taiwanese purse seiners started in 1983 with 3 vessels. Based on Japanese vessel designs and modes of operation, the fleet had increased to 18 vessels by 1988 (although only 10 vessels including two group seiners were on the Regional Register), catching an estimated 76,000t. The fleet increased rapidly to 45 vessels in 1992, taking 200,000t. The current fleet size is now around 38, with the sale of older vessels to Chinese and Korean interests. New efficient Taiwanese-owned vessels continue to be built in significant numbers but operate under other flags. It is believed that about 24 such vessels are registered in Vanuatu and the Marshalls, with about three currently not operating.

The annual fleet catch has continued to grow in recent years, with a peak of 258,000t in 1998, and around 230,000t in recent years. This is probably the most efficient of the fleets currently operating.

Vessel size and age

The vessels are mostly around 1000 GRT and 60m LOA; all are now built in Taiwan which has a thriving shipbuilding industry. In 1988, almost all vessels were new, and continued to be built for the next few years, but very few new vessels have been constructed since 1991 (two only) and the average age is therefore increasing. The Taiwanese fleet is still a relatively new fleet by most standards, with an average age of 14 years.

Fishing operations

The fleet began fishing a mix of logs and free schools, following the Japanese lead. There has been some use of drifting FADs briefly in 1999, but most sets have been made on free schools in recent years. It is a diverse fleet in terms of operations, fishing over a very broad area of the WCPO in most years

Landing points/catch disposal

Similar to the Korean fleet, the Taiwanese utilize multiple transshipment points throughout the region, rarely discharging full loads. The catch is often graded and

separated, with larger yellowfin in particular being unloaded separately, often for shipment to Europe. There is no domestic canning of any note, with most fish destined for Bangkok and elsewhere.

Table 4: The Taiwanese Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
1988	8 + 2	16+2[1]	76,000	60.9 (9 v)	N/a	1 (9v)
1995	43	42	182,495	60.6	1064	6
2002	40	41	258,126	60.7	1073	13
2003	38	38	N/a	64.8	1077	14

[1] the SPC Tuna Fishery Yearbook lists 19 vessels fishing; this includes one vessel which fished in both Taiwanese and Solomon Islands fleets at various times of the year

2.5 China

Although two Chinese purse seine vessels were on the Regional Register in 1995, these were Taiwanese registered, and there is no record of actual fishing by Chinese vessels until 2001, when one vessel fished in Solomon Islands and adjacent waters. In 2002, 3 vessels fished for varying periods, taking 8,566t. One new vessel was added to the fleet in 2003 and four vessels are now fishing under bilateral access agreements with 4 countries.

Vessel size and age

Three of the four vessels are ex-Taiwanese vessels, and one is of Portugese origin. All were built in the mid-late 1980s (average age now 16 years), with an average GRT of 1122 and LOA of 62.9 m.

Fishing operations

The vessels fish in a similar way to Taiwanese vessels and there are close links between the two fleets. Both free schools and log sets are prominent. This fleet is likely to continue to expand.

Landing points/catch disposal

Chinese vessels transship at various locations in the region, with fish exported mostly to Thailand.

Table 5: The Chinese Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
2002	3 (1 inactive)	3	8,566	59.9	1166	16
2003	4	4	N/a	62.9	1122	16

2.6 Philippines

Distant water

The Philippine purse seine fleet began to develop domestically in the late 1970s following exploratory work by two Canadian vessels in Philippine waters in the early 1970s. Two companies began to base vessels in PNG in the mid 1980s and by 1988, at least 9 vessels were fishing, taking nearly 12,000t; the following year (1989),10 vessels took 25,000t. Some of these vessels fished at least part of the year in the Philippines and Indonesia. In the mid-1990s, one of the companies withdrew from PNG, but was soon replaced by another company which based its expanding fleet in PNG to supply a cannery built in 1997. Although based in PNG and fishing entirely in PNG waters, most of these vessels remain under the Philippine flag and are regarded as Philippine vessels in this report. Other Philippine vessels however have moved to the PNG flag and are usually not included on the Regional Register. Philippines vessels also fish under bilateral access agreements with primarily PNG, but also in smaller numbers with FSM, RMI and Kiribati.

At present, 27 Philippine vessels are on the Regional Register, with 5 of these currently not fishing – these have not been active for some time. The 22 active vessels take over 70,000t annually (74,360t in 2002) almost entirely in PNG waters. Many of the vessels operate in conjunction with motherships to which short term catch is transshipped at sea, then returned to local ports for processing or transshipment for export.

Vessel size and age

The Philippine fleet is the most heterogenous in the region, vessels having been acquired second or third hand in most cases. It is comprised mostly of smaller vessels, often fishing with the support of carriers or motherships.

In 1988, 15 vessels were on the RR, with 13 listed by SPC (two of the RR vessels were still listed under other flags by SPC); several of these vessels appear to have been included in error and were actually carrier vessels. LOA and GRT data are incomplete. In 1995, the fleet consisted of 16 vessels (13 listed by SPC but two of the RR vessels were still listed under other flags by SPC) built in 7 different countries, with an average GRT of 735t, an average LOA of 50.6m, and an average age of 20 years, with the oldest vessels 33 years (constructed in 1962). By 2003, 27 vessels were on the RR, but with five vessels not fishing. The fleet was continuing to age, with no consistent increase in average vessel size.

Fishing operations

Most of the Philippines fleet has fished almost exclusively on anchored FADs (payaos). There has been a tendency by some vessels to fish more free schools and drifting FADs in recent years, but these contribute in a minor way to overall set numbers. Nearly all of the catch by the Philippine fleet is taken in PNG waters, with minor amounts in adjacent high seas, Indonesia and other EEZs.

Landing points/catch disposal

Most operations, even with bilateral access vessels, involve at-sea transshipment to motherships/carriers in PNG, although this practice is supposedly restricted to vessels under 600 GT. Most of the catch has been transshipped to reefers in PNG ports and mostly exported to Philippine domestic canneries. With the construction of the initial PNG cannery in 1997 and other processing plants to follow, increasing amounts are expected to be unloaded and processed in PNG (~25,000t in 2002).

Table 6: The Philippine Distant Water Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
1988	15	9[1]	25,253	(47.6)	(560)	N/a
1995	16	13	27,873	50.6	737	20
2002	27 (4 inactive)	23	74,362	53.2	720	25 (27 v)
2003	27 (5 inactive)	22	N/a	52.7	724	26

[1] at least three of the vessels listed by SPC as supplying data seem to be carrier vessels

Domestic fishery

The domestic Philippine fishery, comprising a large number of small purse seine and ring net vessels, has been a significant fleet regionally since 1980. Few data are available on the fishery, which has taken around 110,000t of oceanic tunas in recent years, involving around 400 vessels. Large quantities of other species (kawakawa, frigate and bullet tunas, round scad) are taken in the predominantly near-shore fishery which relies entirely on a very large network of payaos anchored throughout the Philippines archipelago but mostly in southern waters.

2.7 Solomon Islands

Ten years after the pole-and-line fishery had been operating, the Solomon Islands purse seine fishery commenced in 1980, with a single group seiner operated by the joint venture company. In 1988, a national fishing company was formed, for which two single seiners were purpose-built in Australia. That year, a total of four vessels caught 11,200t @ 36.1t/set. By 1995, 3 vessels were fishing (2 on the RR), taking 17,485t. Three vessels remained on the RR in 2002, two actively fishing, following the change of ownership of the original joint venture operation, the buy-out of the national company, and a period of civil unrest. In 2003, only two vessels remain, with only one currently fishing.

Vessel size and age

The remaining vessels are those built in Australia in 1988. On the RR they are listed as both having a LOA of 57 m and a GT of 632. Larger vessels have operated in the past.

Fishing operations

These have involved fishing on anchored payaos which were generally required to be deployed outside the Solomon Islands' archipelagic waters, to minimize conflict with the large national pole-and-line fleet. Two of the vessels have fished widely outside Solomon Islands under the FSM Arrangement.

Landing point/catch disposal

The catch of the joint venture vessels was unloaded to the domestic cannery, whereas that of the national company was generally transshipped and exported, mainly to Thailand. The domestic cannery, relocated to Noro during the late 1980s, is now supplied mostly by the remaining pole-and-line fleet.

Table 7: The Solomon Islands Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
1988	0	4	11,221	59.9 (3 v)	753 (3)	<1 (3)
1995	2	3	17,845	57 (2 v)	632 (2)	7 (2)
2002	3	2	8,080	63.1	1260	13
2003	2 (one inactive)	1	N/a	57	632	15

2.8 Papua New Guinea

Although Philippine vessels have been based in PNG since 1982, the first PNG flag vessel, a former Philippine vessel, did not begin fishing until the early 1990s. Three Taiwanese-owned vessels switched to PNG flag during 1995, when a catch of over 12,000t was recorded. By 2002, six PNG flag vessels were operating, although only one was on the RR (Note that registration of national vessels which do not fish beyond their EEZ on the RR is optional). Seven vessels are currently fishing.

Vessel size and age

Most vessels are of medium size and now of considerable age.

Fishing operations

Most fishing is done in association within payaos, within archipelagic waters, and involving carrier vessels.

Landing point/catch disposal

The fish is transshipped in PNG ports, for export to Philippine domestic canneries, but may be processed onshore in the future.

Table 8: The PNG Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
1995	1	3	12,646	54.9	870	7
2002	1	6	20,957	47.5	581	25
2003	2	7	N/a	52.7	725	23

2.9 Federated States of Micronesia

Although purse seine fishing in FSM waters under access agreements had been ongoing since the early days of the WCPO fishery, the domestic fishery commenced in 1991 with 6 vessels. Three were owned by a private company in joint venture with a state-owned enterprise, and the other three were owned outright by a different state-owned enterprises. 11,500t of fish were landed in this initial year. By 1995, eight vessels were fishing (two under Panamanian flag), with a reduced catch of just over 6,000t. By 2002, 5 vessels were fishing. The peak catch of 25,000t was taken in 2000.

Big changes have occurred during late 2002 with the establishment of a new company and the arrival of four large vessels under FSM flag, including ex-European vessels close to 3,000 GRT. This has considerably increased the capacity of the fleet. One older vessel has sunk recently and its future is uncertain.

Vessel size and age

With the recent addition of larger but ageing vessels to the fleet, the average LOA, GRT and presumably fishing capacity have increased sharply.

Fishing operations

All of the current vessels enjoy FSM Arrangement access and fish widely in central areas of the WCPO.

Landing points/catch disposal

All of the catch is transshipped, mostly in FSM ports, and exported, mainly to Thailand.

Table 9: The FSM Purse Seine Fleet

	No. Vessels (RR)	**No. Vessels (SPC)**	**Catch (SPC) (metric tonnes)**	**Avge LOA (metres)**	**Avge GRT**	**Avge vessel age (years)**
1995	8*	5	6,286	51.4	768	14
2002	5	7	18,012	57.4	1155	14
2003	9	9	N/a	70.1	1477	20

* Includes two Panamanian flagged vessels

2.10 Marshall Islands

Marshall Islands' fishing capacity developed with the shift of 3 vessels from PNG to RMI flag in 2000, and the addition of two new vessels constructed in Taiwan in 1999. A sixth newly constructed vessel was added during 2002, when a catch of over 38,000t was achieved. This is expected to increase further during 2003.

Vessel size and age

All existing vessels are of relatively standard design, similar size and of recent construction (oldest vessel just 13 years, average age 7.5 years).

Fishing operations

The fleet takes only a portion of its catch in Marshall Islands waters and operates, under FSM Agreement access, in Kiribati and other adjacent waters.

Landing points/catch disposal

Most of the catch is transshipped in Majuro, to supply Thailand canneries.

Table 10: The Marshall Islands Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
2002	5	5	38,242	63.5	1076	8
2003	6	6	N/a	65	1080	7.5

2.11 Vanuatu

Vanuatu operates an open vessel register, and vessels under this flag often are operationally part of other fleets. One purse seine vessel was on the RR in 1988, but with no record of any catch being taken, whilst another was variously part of the US and Korean fleets. By 1995, two vessels of US and Mexican origin were fishing under Vanuatu flag, and took 6,750t in that year. Four additional vessels (three reflagged from PNG) were recorded on the RR during 1998, and four additional Taiwanese vessels during 1999, when 47,650t were taken by the 7 vessels. The number of vessels continues to increase, despite the relocation of three ex-PNG Taiwanese vessels to Marshall Islands, and the withdrawal of the two vessels fishing in 1995 during year 2000. By 2002, 10 vessels, all but one Taiwanese built since 1998, were fishing. This increased dramatically to 18, all now "new" Taiwanese vessels, during 2003. Three of these vessels are currently not fishing. It is believed more vessels are still under construction.

Vessel size and age

All vessels currently fishing are new (average age two years), and large, with an average LOA of 72m and GRT 1467m. All are equipped with modern technology..

Fishing operations

Although many of the vessels are associated with PNG and may eventually unload some of their catch there to a processing plant under construction, or commit to onshore development of some kind, little of their catch is taken in PNG and none in Vanuatu waters. The large well-equipped vessels fish widely throughout the region, under the FSM Arrangement, and even east of 150^0 W on occasion. Most sets are on free schools.

Landing points/catch disposal

The fleet transships at multiple locations throughout the region, from Kiritimati to Wewak (PNG), for export by carrier. It is expected that some of the catch, from November 2003 onwards, will be unloaded to a large loining plant nearing completion at Wewak, PNG.

Table 11: The Vanuatu Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
1988	1	0	N/a	52.7	794	?
1995	2	2	6,751	64.3	1087	14
2002	10	11	N/a	69.9	1350	4
2003	15 (3 inactive)	N/a	N/a	72	1467	2

2.12 New Zealand

Distant water

Although one ex-US vessel has been on the RR as a New Zealand vessel since at least 1993 and two New Zealand vessels fished in Fiji during the 1980s, distant water (DW) fishing by NZ vessels began with the acquisition and reflagging of four ex-US vessels commencing in 2000. These four vessels now fish under bilateral access arrangements in the central parts of the region.

Table 12: The New Zealand Distant Water Purse Seine Fleet

	No. Vessels (RR)	No. Vessels (SPC)	Catch (SPC) (metric tonnes)	Avge LOA (metres)	Avge GRT	Avge vessel age (years)
2002	4	4	10,668	69.9	1552	13
2003	4	4	N/a	69.9	1552	14

Domestic

Domestic purse seine vessels have been fishing in NZ waters since 1983, triggered by US vessels arriving to fish seasonally. The fishery is highly seasonal, with typically six vessels taking up to 8,000t, for processing by NZ canneries and export to Thailand and other markets. All of the catch by these domestic vessels has been taken in NZ waters.

2.13 Australia

Distant water

Smaller Australian purse seiners, adapted to fish for southern bluefin and skipjack in temperate Australian waters, began exploratory fishing outside the Australia Fishing Zone (AFZ), in tropical waters, during 1988. Up to 8 vessels were fishing at any one time, but with limited success, and the Pacific foray was finally abandoned in 1993. The historical high catch of 5,370t was taken by 6 vessels in 1991. No information is available on vessel characteristics.

Domestic

Small purse seiners, targeting mostly southern bluefin tuna, have been active in the AFZ since the mid-1970s. The catch of tropical tunas, the main concern of this report, has fluctuated considerably since that time, with a peak catch of 6,700t by 13 vessels in 1992. The catch in recent years has been very low (< 500t) as a result of cannery closures and fleet diversification.

2.14 Kiribati

A single joint-venture vessel has operated from Kiribati since 1994, taking up to 7,700t per year. The vessel, now 22 years old and of Japanese origin, transships at various locations, with the fish exported to Thailand canneries.

2.15 Indonesia

Distant water

Three purse seine vessels based in Biak fished in Indonesian and PNG waters from 1984 to 1989, taking up to 13,200t/yr and supplying a cannery in Biak, Irian Jaya. They appear on the 1988 RR.

Domestic

Small domestic ring net and purse seine vessels fish in various parts of the archipelago and have taken around 30,000t in recent years, plus some catch possibly included in the “unclassified” category.

2.16 Mexico

A small number of Mexican purse seine vessels moved to the WCPO during 1984/85, following the strong El Niño and the lead of the US fleet. Two years of part time fishing by 5 vessels saw a peak of 6,600t taken in 1994.

2.17 Russia

Soviet vessels began fishing in the region in the mid-1980s; although 15 vessels were claimed to be on the RR in 1988, there are SPC records of 5 vessels fishing, taking 6,189t, fishing mostly in high seas areas. No information on vessel characteristics is available.

Some fishing under access agreements occurred in Solomon Islands and adjacent waters, concluding in 1994. A peak catch of 9,010t seems to have been taken by 5 vessels in 1987.

2.18 Spain

Spanish-owned vessels, variously flagged as Spain, Guatemala and Ecuador, began fishing in the WCPO in 1999, under the terms of an agreement with one Pacific Island country. Good catches were taken, with 12,900t @ 39.7t/set in 2000, during just several months fishing by 12 vessels. There has been relatively little fishing since that time, and currently there are 8 vessels (five Spanish, two Guatemala, one El Salvador) on the RR but only one of these is currently licensed. Tarte (2002) contains some details of the Spanish-Kiribati licensing arrangement[5].

Fishing has occurred in the far east of the WCPO, as the vessels follow drifting FADs across from the EPO. Some transshipment has occurred at Christmas Island.

[5] In summary, Tarte (2002) states that in July 2002 a bilateral agreement was concluded between the EU and Kiribati. This follows a bilateral agreement concluded in late 1999 between Kiribati and a Spanish industry group.

3.0 Summary of Activity by Fleet

Table 13 below summarizes the number of active vessels in each national fleet in the time periods covered by the study. Only vessels for which catch records exist have been included. The total number of vessels has increased steadily since 1988, though not for all fleets. The largest decline has been in the US fleet, which numbered over 60 vessels at one time. Significant recent increases have been observed in the Taiwanese, Vanuatu, FSM, PNG and Philippines fleets. There has been a slight decrease in overall numbers between 2002 and the present, but this may change if vessels currently not licensed begin fishing. Changes in the major fleets are shown graphically in Figure 2.

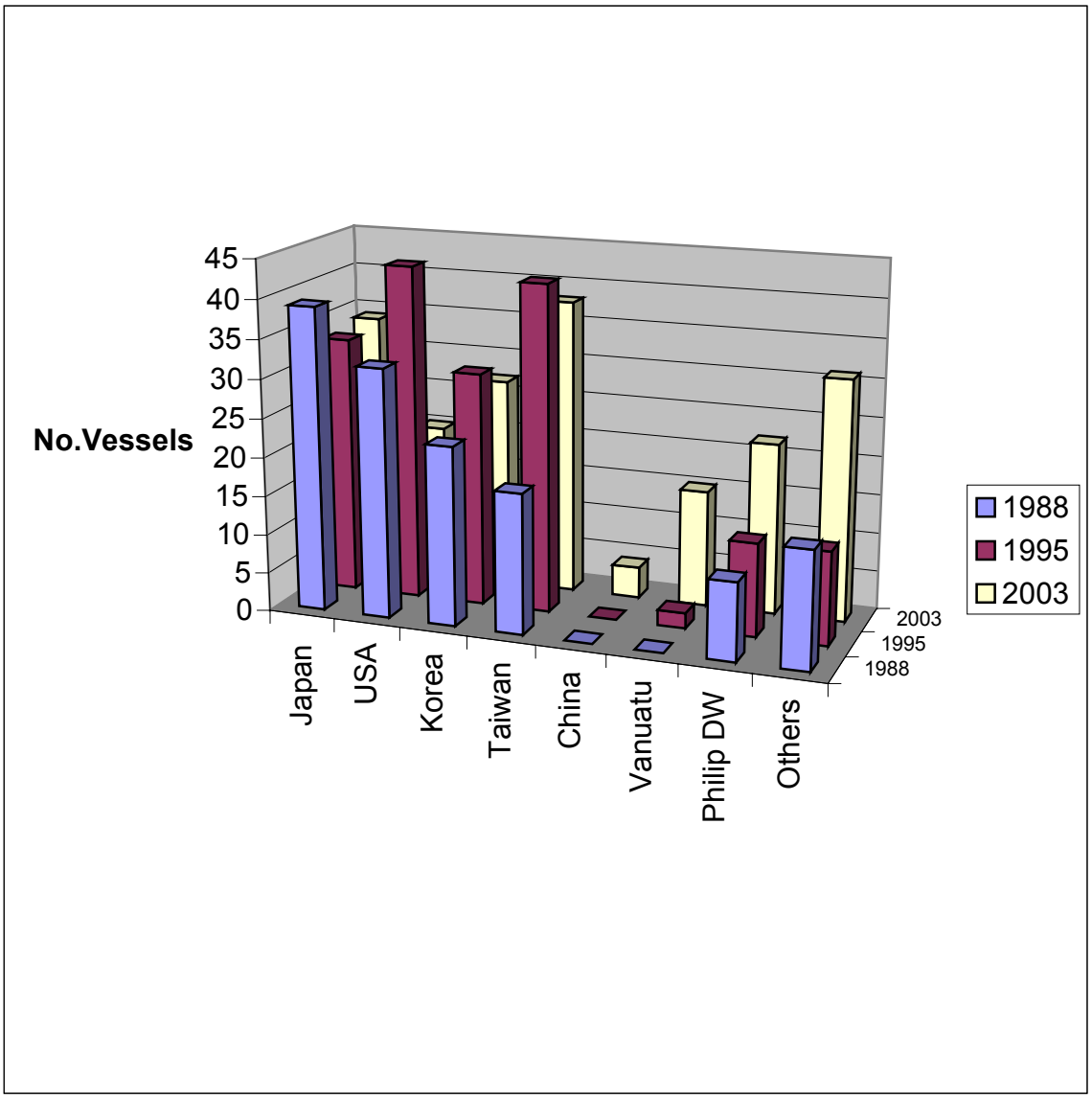
Table 13: Number of Active Vessels in the National Fleets

	1988	1995	2002[6]	2003	Change Since 1988
Japan[7]	34+5	33	35	34 (1)	-5
USA	32	43	29	20 (6)	- 12
Korea	23	30	28	27	+4
Taiwan[3]	16+2	42	41	38	+ 20
China	0	0	3	4	+ 4
Solomons	4	3	2	1 (1)	-3
PNG	0	3	6	7	+7
FSM	0	5	7	9	+9
Marshalls	0	0	5	6	+6
Kiribati	0	1	1	1	+1
Vanuatu	0	2	11	15 (3)	+15
NZ DW	0	0	4	4	+4
Australia DW	3	0	0	0	-3
Spain[8]	0	0	1 (9)	1 (7)	+1
Neth. Antilles	0	0	1	1	+1
Panama	0	0	0	1	+1
USSR	5	0	0	0	-5
Philippines DW	9	13	23	22	+12
Indonesia DW	3	0	0	0	-3
TOTAL	136	175	197	191	+55

Bracketed numbers indicate the number of additional vessels which are on the Regional Register but are not currently licensed to fish under access arrangements; these are not included in the total number of active vessels

[6] Although this report focuses on three time periods (1988, 1996, 2003), the year 2002 is included in the fleet tables as that is the latest year for which catch data are available.
[7] The seven Japan and Taiwan vessels following plus signs in 1988 are group seining operations.
[8] Includes the Spanish-owned vessels flagged in El Salvador and Guatemala.

Figure 2: Changes in the Size of Major Purse Seine Fleets in the WCPO, 1988 - 2003



4.0 The Concept and Measurement of Fishing Capacity

Moving from vessel numbers to fishing capacity represents a considerable progression in complexity. The concept of fishing capacity is not well understood in the Pacific Islands, even by those individuals responsible for managing tuna fisheries. Internationally, there is also considerable uncertainty. FAO (1997) states that "fishing capacity is a term which has not yet been rigorously defined, and there are substantial differences of opinion as to how it should be defined and estimated". One of the simpler definitions is that fishing capacity is the ability of a vessel or vessels to catch fish.

Kirley and Squires (1999) make the observation that capacity related concepts are defined and employed by biologists, resource managers, and economists - each of

these groups defines capacity in terms that are useful for addressing their own particular needs and concerns. This was indeed the case at the recent 16th Meeting of the Standing Committee on Tuna and Billfish, (July 2003, Australia) where a special session convened to consider capacity issues "was unable to agree on a definition of fishing capacity" (Anon 2003).

If simply defining fishing capacity is not straightforward, measuring fishing capacity is somewhat more difficult. Kirley and Squires (1999) indicate that for fisheries in general, the most widely used output-based measure of fishing capacity is hold capacity.

Fishing capacity in the tuna purse seine fisheries is often measured in the amount of tuna a vessel can carry. Although there are difficulties associated with relating a seiner's ability to carry tuna with the ability to catch tuna (Section 11.2), the reality is that there are few other measurements that are both practical and, as put by a former Director of the I-ATTC[9], "people understand".

5.0 Interest in Purse Seine Carrying Capacity in the WCPO

There is presently considerable interest in the issue of tuna purse seine fishing capacity in the western and central Pacific. Although the term "fishing capacity" was rarely used in the region just a few years ago, a number of tuna fishing capacity initiatives are now underway that are relevant to the WCPO. These include the following efforts:

- Food and Agriculture Organization of the United Nations - The objectives of this Japan-funded FAO project are to identify, consider and resolve technical problems associated with the management of tuna fishing capacity on the global scale. Activities consist of a review of tuna resources and fisheries, an estimation of tuna fishing capacity, the determination of demand for tuna raw materials and products, a review of the socio-economic importance and profitability of the tuna industry, and a determination of options for fisheries management, particularly that of tuna capacity. One component of this project has included a calculation of global purse seine carrying capacity, including an estimate for the WCPO region (Joseph 2003).
- World Tuna Purse Seine Organization – The WTPO is calling for a limit to the purse seine and longline fleets currently operating in the WCPO. Two of the main initiatives to limit tuna fishing capacity are the promotion of a world-wide tuna vessel registry and the current requirement that member vessels fishing in the WCPO remain in port for a certain number of days after unloading. The latter applies a scheme of three carrying capacity categories to determine days to be spent in port: (1) < 1300 m^3 , (2) 1300-1700 m^3, and (3) > 1701 m^3
- Standing Committee on Tuna and Billfish – At the 16th meeting of the SCTB in July 2003 the issue of defining and measuring fishing capacity in WCPO tuna fisheries was discussed. The results of the discussions were inconclusive and members were encouraged to consider the issue over the coming year for discussion at next year's meeting.
- Greenpeace - The organization's project "Sustainable and Equitable Tuna Fisheries in the Western Pacific" aims to halt capacity migration from the north

[9] J.Joseph, per. com.

and begin reducing the global over-capacity of fishing fleets, thereby reducing pressure on the tuna fisheries and ensuring that they do not exceed sustainable limits. Greenpeace plans on tabling a report of this study at the 5th WCPFC Preparatory Conference.

6.0 Considerations on Measuring Carrying Capacity

Leaving aside temporarily the issue of whether carrying capacity is a good proxy for fishing capacity (discussed later in Section 11.2), there are numerous considerations in measuring carrying capacity.

In the eastern Pacific where there is a relatively well-studied and observed tuna purse seine fishery, the carrying capacity of a vessel has historically been measured in the amount of tuna (expressed in short tons) which can be carried in a ship's fish holds. Although this measurement appears simple, there are several complications:

- In the early 1980s the tuna processing companies began stipulating that tuna be unloaded at a temperature between 11 to 14 degrees Fahrenheit, or about 9 to 10^0 F colder than the previous requirement. This had implications for the amount of fish that could be carried aboard a seiner. A frozen tuna (being mainly water) expands with colder temperature, much as water expands when it undergoes a phase change from liquid to solid. One vessel operator indicated that fish expansion, as temperature is lowered from 20^0 F to 14^0 F, leads to as much as a 20% decrease in a seiner's tonnage carrying capacity. Other operators stated that the expansion is closer to five per cent. In any case, seiners now carry less fish than in the past due to colder storage temperatures.
- In 1985 a study was carried out by the consultancy firm Living Marine Resources Inc. (Burn 1985) which showed a substantial improvement in fish quality if about 15% less fish is packed into a seiner well. After this study many vessels began lighter packing.

In effect, these two factors above resulted in reducing the carrying capacity of a seiner. Although these changes have been in place for many years, it is still common to refer to the carrying capacity of a seiner in the US, Korean, and FSM fleets in terms of tonnage of tuna at the old temperature and packed in the old manner because, as one vessel operator stated, "old habits die hard".

Another difficulty in measuring carrying capacity in terms of tonnage of fish concerns the size of fish. Small tuna such as skipjack packs tighter than larger fish like yellowfin:

- According to a non US-based purse seine fleet operator, if a full load of yellowfin for a seiner is 1000 tonnes, the same vessel could carry about 1100 tonnes of medium size skipjack, or about 10% more of the smaller fish.
- A US-based operator made a similar observation: a "100 ton" fish well could carry about 92 to 95 tons of large yellowfin, or about 98 tons of medium-size skipjack, about 5% more of the smaller fish.
- Unloading records from two FSM-based vessels show that the maximum skipjack load is about 15% greater than a load of large yellowfin

In addition to the variability in tonnage carrying capacity described above, there are incentives to mis-report. In some regions, charges for observers are based on the

carrying capacity. Some fees, such as industry contributions to the US Multilateral Tuna Treaty, are also related to carrying capacity.

In the past one way of getting around the above difficulties associated with establishing the tonnage carrying capacity of a seiner has been to define carrying capacity as the *maximum* weight of an *observed* unloading (M.Hinton, IATTC, per.com.). However problems still remain with this concept (i.e. vessels that catch more small fish are rated greater). There is also a major difficulty associated with this type of measurement in the WCPO region; unlike in the eastern Pacific, some of the important fleets in the west (Taiwan, Korea) rarely discharge a full load of tuna – they unload the fish when transshipment logistics are favourable, rather than when the vessels are full, and may unload different species or fish grades at different times and/or locations.

The above observations lead to the conclusion that a seiner's carrying capacity measured in fish tonnage is both variable and difficult to certify or verify. This greatly restricts the usefulness of the statistic in measuring the ability of a seiner to catch fish.

Because of this difficulty there has been a movement recently to use the relatively simple volume of a seiner's fish wells as a measure of carrying capacity. In the EPO, the IATTC uses the factor of 1.17051 to convert from metric tonnes of carrying capacity to cubic metres of carrying capacity (IATTC 2002). Depending on the manner in which tuna are frozen and stored aboard vessels, different factors could apply to other fleets and subsets of those fleets.

Despite the simplicity of using volume rather than tonnage to measure carrying capacity, there remain some difficulties. One of the major difficulties is verifying the volume of carrying capacity with an independent source (that which does not originate from vessel operators). Although vessel plans can be used for verification, there is some question as to whether such plans will always be authentic and seiners are often lengthened after the original plans are produced. The Lloyd's Register[10] and the US Coast Guard website contain much useful information on tuna seiners from many countries, but data on the volumes of fish holds are not included. The International Tonnage Certificate issued under the International Convention of Tonnage Measurement of Ships (1969) list fish holds and other spaces, but the holds are measured in such a way that the volume cannot be accurately derived. Various management agencies often have different carrying capacity data on a particular vessel. A NOAA Fisheries official has concluded that until a standard system is developed to directly measure and verify a volumetric standard of measure, it will continue to be difficult to reconcile across various data sources (C.Fanning, per.com).

Measurement of fish holds by a vessel-independent agency appears to be one of the few options available to verify the carrying capacity of a seiner expressed in volume. For this reason NOAA Fisheries is in the process of employing an engineering firm based in Pago Pago to measure and calculate the volume carrying capacity of each vessel in the US WCPO purse seine fleet.

[10] During this study, the Lloyd's Register (January 2003 edition) was searched for information on a sample of 20 seiners from five countries. The register contained entries for only 12 vessels – 60% of the sample.

7.0 Sources of Data

7.1 The Regional Register

The Regional Register of Foreign Fishing Vessels operating in the western Pacific (more specifically the FFA area) came into being in September 1983 and is maintained by the Forum Fisheries Agency on behalf of its member countries[11]. Any vessel wishing to obtain a (tuna) fishing licence or permit from any of the FFA member countries must first register with the FFA and be in good standing on the Regional Register. During the fifteen-year period of the present study, the number of vessels on the register has fluctuated from a low figure of about 900 vessels in 1996 to a high of about 1800 vessels in 1994 (Richards 2001).

The Regional Register originated as an initiative of the Parties to the Nauru Agreement to establish a coordinated approach to the licensing and subsequent monitoring of the activities of foreign fishing vessels. In addition, a set of minimum terms and conditions of access was established.

Applications for registration must be submitted in standard format, and require a series of vessel characteristics to be listed. Initially these included, *inter alia*, for purse seiners: vessel type, number of crew, hull materials, year built, country of construction, gross tonnage (GT), overall length (m), daily freezing capacity (by method, capacity (mt/day) and temperature), storage capacity (by method, capacity (m^3), and temperature), and net details.

Such information was stored in electronic form, with hard copies retained on the Register since September 1983 and was made available only under certain conditions of confidentiality.

In 1992, following severe problems with the FFA central data processing facility, the Register crashed and information could not be recovered. Information prior to that time is known to be available only in hard copy form. A summary of vessels on the Register as at September 11, 1987, with limited ancillary information, has been used as the basic source of information for calendar year 1988 in this report. During 1993, the Register was rebuilt, and from that time forward, information is available in electronic format.

The information on the registration form is supplied voluntarily (though presumably subject to withdrawal of good standing if found to be deliberately falsified) and is not generally subject to verification.

There have been minor changes to the information sought on registration forms. Many of the problems typically encountered with the RR involve confusion over the units of measurement, such as supplying information in short tons when cubic metres was requested (Section 10.2).

In 2002, to overcome some of the problems associated with use of information on the Regional Register, FFA employed the services of a Data Quality Assurance Consultant

[11] The seventeen member countries of the FFA are Australia, New Zealand, Cook Islands, Fiji, FSM, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu and, most recently, Tokelau.

to check and complete Regional Register entries through reference to original registration forms, i.e. going back, rechecking and corroborating where possible. Some substitution was also effected, particularly in the case of storage capacity, such as using average values for vessels of a design group, or using values from identical or similar vessels.

This "rehabilitated" database for the period 1993 to 2001/2002 inclusive (the 2002/2003 data are available but have not been groomed) was used as the main source of information on vessel characteristics, although efforts were made to validate key information from alternative sources, e.g. industry associations, owners, files.

The database nonetheless does have limitations in the documentation of capacity, as follows:

- The RR is a foreign vessel register, and as such, there is no requirement for domestic vessels (those which fish in the EEZ of that country only) to be on the RR. This has primarily applied to vessels flying the PNG flag, where during the current RR period, 5 vessels are not on the RR. This is also an issue in the domestic fisheries of Australia, New Zealand and Japan.
- Vessels may be on the Register, but not licensed for fishing during that RR period. For example, 26 US vessels are presently on the RR but six are currently not fishing; few of the Spanish-owned vessels fished during 2002.
- There may be changes in capacity (vessel "stretching" to add more wells) which are not always recorded on the RR.

7.2 The SPC/OFP Regional Tuna Fishery Database

The SPC established the Regional Tuna Fishery Database (RTFD) in 1981, based on catch and effort logsheet data supplied by member countries, supplemented with aggregated data provided by fishing nations, and other monitoring information from various sources, such as port sampling, observers, and tagging data. Annual catch estimates are compiled and summarized in the annual Tuna Fishery Yearbook, and *ad hoc* requests for information can be entertained provided certain confidentiality requirements are met.

The 2001 Yearbook has been a key source of information for this study and was used to supplement and corroborate RR data. Several features should, however, be noted:

- Catch estimates are often grouped by operational horizon[12] rather than vessel flag. Accordingly, there are few data for Vanuatu since vessels are not based there, but rather associated with other countries, e.g. PNG for purposes of the FSM Arrangement.
- Estimates are compiled or raised from logsheet coverage which may be incomplete. This is particularly the case for the Taiwan and Korean fleets prior to 1993 and the implementation of the new Minimum Terms and Conditions (MTCs), when both non-reporting and under-reporting of catches were widespread. For example, catch data are available for only 20 Korean vessels in 1988, when official records confirm that 23 were fishing.

[12] This represents the flag to which SPC has allocated the catch to, rather than a flag of convenience of the vessel.

- The calendar year is used, rather than the September/August period as for the RR; this can lead to discrepancies in vessel numbers from the two sources.

7.3 Other Sources of Carrying Capacity Data

Attempts were made to supplement the above Regional Register and SPC data by using information from several other sources. These include data from:

- NOAA Fisheries: USMLT data, late 1980s US fleet offloading information, US Tuna Fleet Quarterly Reports, Tuna Fleet database (subset for capacity changes)
- IATTC: capacity information on US fleet in late 1980s, port sampling information, data on re-flagged/re-named vessels, characteristics of specific vessels.
- FFA: observer information, database of vessels on Regional Register but without fishing licenses, and specialized reports on topics such as the Regional Register, EU purse seine fleet, and MCS.
- SPC: observer information, offloading information, Tuna Yearbooks, specialized reports on subjects such as the Regional Register and purse seine technology.
- Korean industry: Korean fleet segregated into three volume capacity categories, 1990 to 2003
- Government of Japan: total volume capacity of single seiner fleet, 1988 to 2003
- Pacific Island countries: carrying capacity information from national registers (where collected), fishing license applications for key countries, and from vessel owners.
- Observer data: FFA, SPC, and some national programmes
- GPA reports dealing with purse seining, 1995 to 2002
- Other: U.S. Coast Guard website, U.S. and Taiwan shipyard websites, cannery reports, SCTB reports, industry data

8.0 Estimating the Carrying Capacity

All electronic copies of the 1988 Regional Register were lost in the early 1990s, as noted earlier. A search of the FFA library archives revealed a print-out of the 1988 register as an attachment to an FFA report. Print-outs of the 1991 and 1992 Registers were subsequently tracked down. The purse seine vessels on those lists, and their available characteristics, were re-entered into an Excel database.

The basic method used in calculating the carrying capacity of the various fleets operating in the WCPO region consisted of transforming the FFA Regional Registers for 1988[13], 1995, and 2003 into purse seiner capacity inventories for those years. These inventories, maintained as confidential, comprise the basic information on which this study is founded.

To transform the Regional Registers for the three years into purse seiner capacity inventories, the following tasks were undertaken:

[13] As detailed in Section 1.2, a year for the Regional Register extends from the beginning of September of one year to the end of August the following year. What is referred to as the "1998 Register" covers the period September 1 1987 to August 31 1988.

- Reviewing the structure of each national purse seine fleet in the region (Section 2.0 above)
- Elimination of all non-seiners on the register lists (e.g. longliners, motherships)
- Elimination of information which was not relevant for estimating carrying capacity (e.g. helicopter model)
- Scrutinizing each vessel entry for obvious mistakes (e.g. a vessel 200 m in length)
- Adjusting the number of vessels by: (a) elimination of duplicate vessel (e.g. a U.S. vessel which was sold to Korea and listed under both old and new names), and (b), adding missing vessels – most often detected by finding SPC logsheet data for a vessel not on the register.
- Estimating cubic metres of fish well volume for those vessels on the register which lack this information. This was done by using the available characteristics of the concerned vessel and the carrying capacity of similar vessels from the same fleet.
- For those purse seine vessels that have limited or even nil carrying capacity (small net vessels of group seining operations), the carrying capacity as stated was used, even though it was clear this did not give a true reflection of fishing capacity.
- Cross checking stated capacity where possible, using sources given in Section 7.2 and adjusting information appropriately.

As a guiding rule, the information in the Regional Register was assumed correct unless there was evidence to suggest otherwise. Similarly, if a vessel submitted logsheet data which showed fishing in the WCPO region during the year in question, it was assumed to have participated in the fishery despite other sources of information, including official government data. Recognizing that the logsheet data of some vessels may not have been available to SPC, especially in the early years, the absence of data at SPC did not necessarily cause the vessel to be considered as inactive.

9.0 Results

Table 14 lists the number of vessels actively fishing with the estimated hold capacity in cubic metres for each fleet, for 1988, 1995 and 2003. Not included, as noted earlier, are various domestic fleets in the WCPO (Indonesia, Philippines, Japan, Australia and NZ).

As was the case with vessel numbers, total fleet capacity, has increased steadily from around 140,000 m^3 in 1988 (no vessel characteristics were available for five Russian and three Australian vessels, and an approximate capacity has been estimated from the reported catch) to just over 200,000 m^3 in 1995, and 233,000 m^3 in 2003, with the estimate for 2003 likely to increase further this year as vessels in some fleets reactivate and more up to date data on capacity become available.

To take this into account for 2003, data are provided on the number of vessels on the RR but not currently licensed to fish under any access arrangement in the WCPO, i.e. “inactive”. These vessels may be undergoing refit, fishing elsewhere or are new vessels not yet commissioned. Not included are vessels which have withdrawn from active participation in the fishery but remain on the RR, i.e. “retired”. Such data to enable vessel operational status to be determined are not available for the previous two periods. Should all of these 18 vessels currently inactive in 2003 be activated, estimated capacity

would increase by somewhat more than 10%. Common sources of error in the Regional Register (Section 10.7) are likely to add 10% to the estimates for the three periods.

Table 14: Carrying Capacity Estimates (capacity in m^3)

	1988		1995		2003	
	Vessels	Capacity	Vessels	Capacity	Vessels	Capacity
Japan	34	37,104	33	37,524	34 (1)	38,599
Japan g/s	5	1,750				
Korea	23	24,492	30	32,950	27	34,074
Taiwan	16	17,807	42	53,969	38	49,472
Taiwan g/s	2	700				
USA[14]	32	45,300	43	56,003	20 (6)	28,205
China					4	5,608
Solomons	4	3,765	2	2,602	1(1)	855
PNG			3	2,751	7	5,401
FSM			5	3,362	9	14,024
Marshall Is.					6	5,850
Kiribati			1	720	1	720
Vanuatu			2	2,424	15 (3)	22,488
USSR	5	N/a				
Philippines	10	3,963	13	8,656	22	14,521
Indonesia	3	2,800				
Spain					(5)	(12,184)
El Salvador					1	2,553
Guatemala					(2)	(3,762)
N. Antilles					1	1,950
Panama					1	3,300
Aust DW	3	N/a				
NZ DW					4	5,869
TOTAL ACTIVE	136	137,448+	175	200,961	191	233,489
Av. Capacity (m^3)		1073 (128vessels)		1148		1222
INACTIVE					(18)	(30,313)
TOTAL					(209)	(263,802)

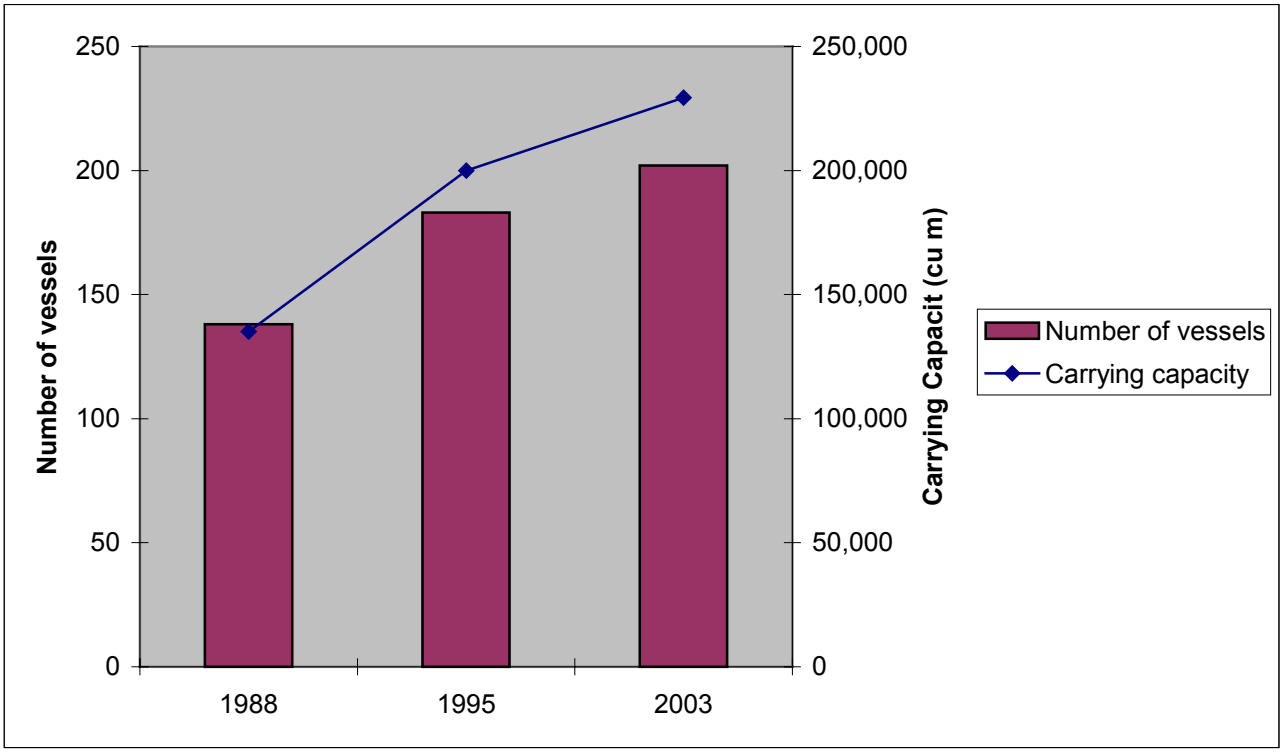
Notes:
1) g/s = group seine operation
2) In the 1988 figures, no vessel characteristics were available for the USSR and Australian distant water vessels; the capacity figure is thus an underestimate, as indicated by the + sign. As the recorded catch by these eight vessels was only 6,300t, or the average catch of less than two vessels, 140,000 m^3 may be a reasonable approximation of total capacity.
3) Inactive vessels (given in parentheses) are those on the Regional Register but not currently licensed to fish under any access agreement in the WCPO

.

The above results and their precision should be viewed in context with the difficulties and reservations of making the estimates (Section 10.0).

Figures 3a and 3b display (a) changes in vessel numbers and aggregate carrying capacity, and (b) changes in aggregate capacity and average capacity.

[14] In mid-September (too late for inclusion in this table) it was learned that four US vessels will be re-entering the fishery.


250
200
150
100
50
0
Number of vessels
250,000
200,000
150,000
100,000
50,000
0
Carrying Capacit (cu m)
1988
1995
2003
Number of vessels
Carrying capacity

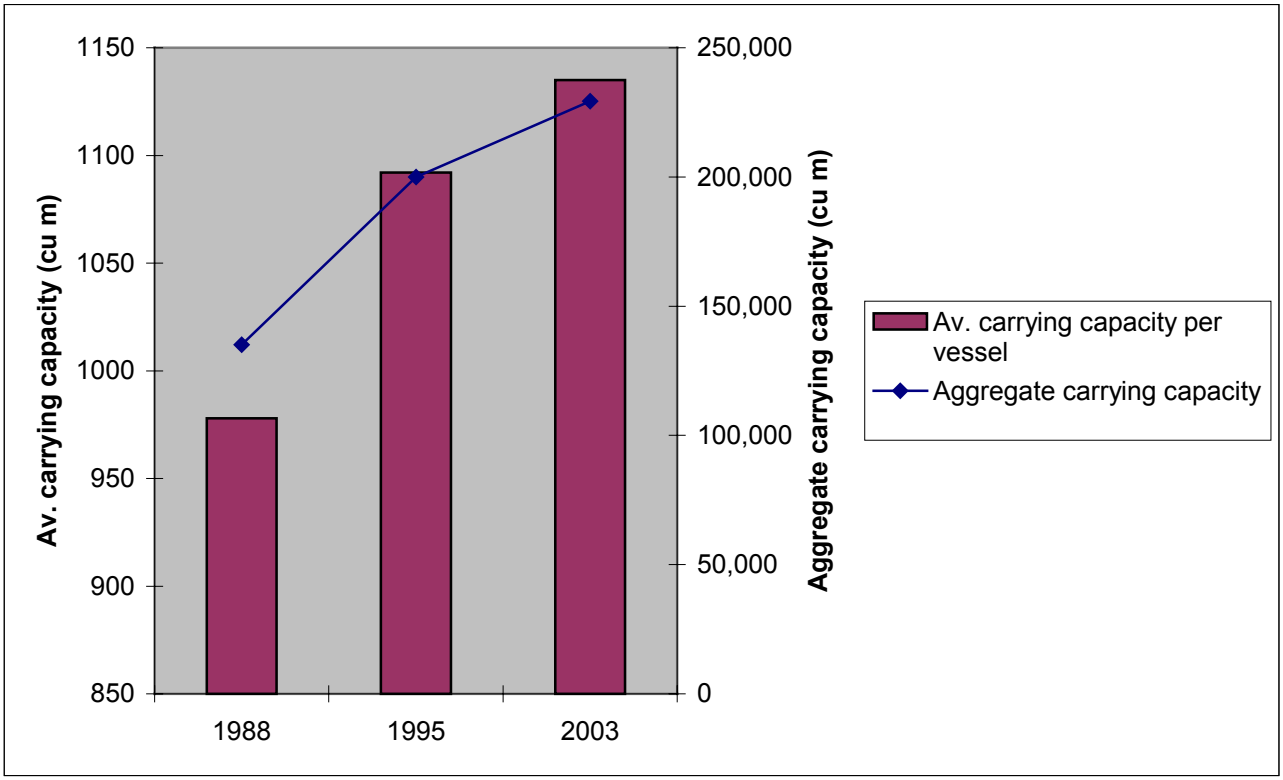


Figure 3: (a) Changes in Vessels and Carrying Capacity, (b) Changes in Aggregate Capacity and Average Capacity

9.1 Consideration of the Results

The average capacity per vessel has increased from 1073 cubic metres in 1988 to 1222 cubic metres in 2003. This increase in average capacity would be more evident if the significant number of smaller Philippine vessels was excluded.

Table 15 gives the percentage change in vessel numbers and carrying capacity between the focal periods of the study. It can be seen that both vessel numbers and aggregate capacity increased more in the 1988/1995 period than during the 1995/2003 period, although the present 2003 capacity figures may be an underestimate of capacity deployed by the end of 2003.

Table 15: Changes in Vessel Numbers and Aggregate Carrying Capacity

	Period from 1988 to 1995	Period from 1995 to 2003	Period from 1988 to 2003
Number of vessels	+ 28.7%	+9.1%	+40.4%
Carrying capacity (cu m)	+43.5%	+16.2%	+66.8%

When the results are considered on a national fleet basis, important differences are evident. Figure 4 shows the change in aggregate capacity of each of the major fleets, and Table 16 gives the changes in average capacity.

Figure 4: Changes in Aggregate Carrying Capacity of the Major Fleets

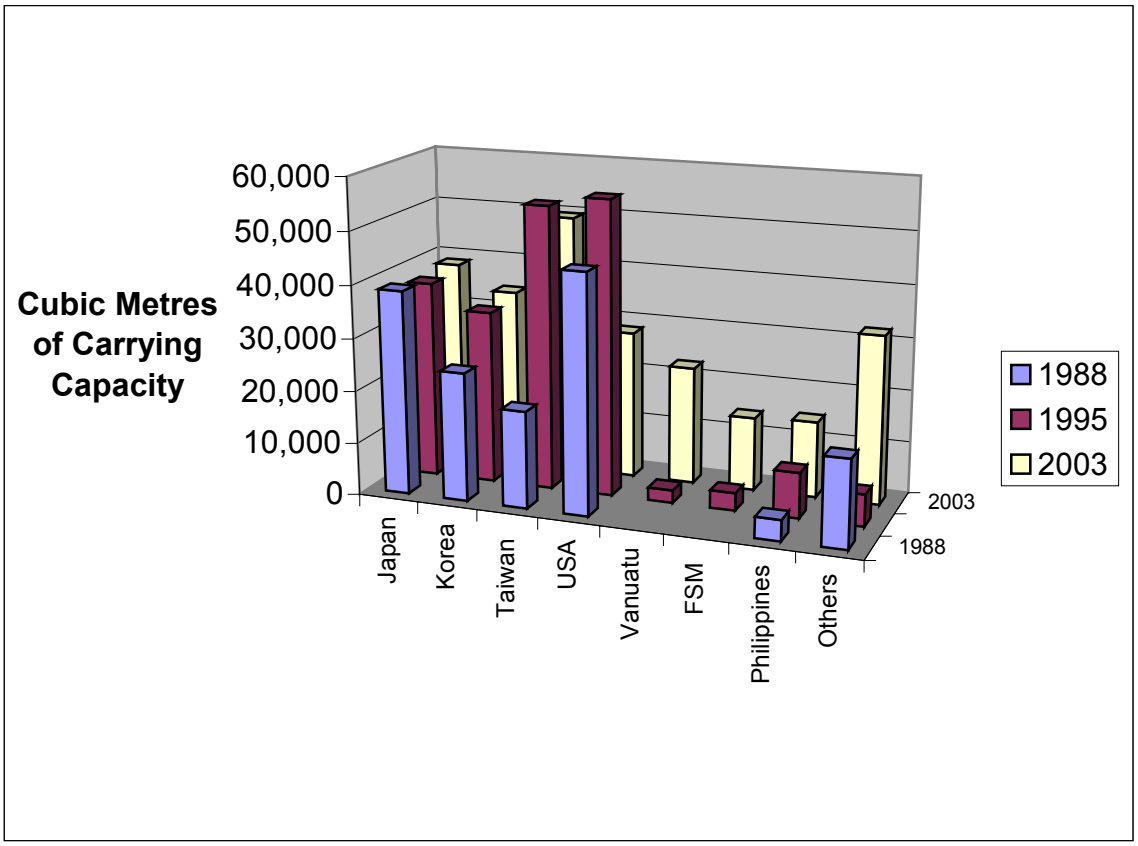


Table 16:
Changes in Average Carrying Capacity of the Major Fleets

	1988	1995	2003	Change 1988-2003
Japan	1091	1137	1135	+4.0 %
Korea	1065	1098	1262	+18.5%
Taiwan	1113	1285	1302	+17.0%
USA	1416	1302	1410	-0.4%
Philippines	396	666	660	+66.7%
				Change 1995-2003
FSM	N/A	672	1558	+232%
Vanuatu	N/A	1212	1499	+24%

Units – cu m

Some notable points with respect to fleet carrying capacity are:

- The Japanese (single seiner) fleet has been relatively stable throughout the study period in terms of both numbers, aggregate carrying capacity, and average carrying capacity.
- The US fleet has sharply declined in aggregate carrying capacity without much change in average carrying capacity.
- The increase in average carrying capacity by the Taiwanese and Korean fleets has been modest.
- The capacity of the Philippine fleet has increased significantly, albeit from a low base. There are indications that carrying capacity of these mothership-associated vessels is underestimated.
- The fleets of FSM and Vanuatu have increased dramatically in recent years in numbers and carrying capacity. Their average carrying capacity per vessel is now the highest of all fleets.

9.2 Comparison of Estimated Carrying Capacity to a Previous Estimate

Joseph (2003) estimated of the carrying capacity of the world's high-seas tuna purse seine fleet for the year 2000. One of the four regions covered was the "western Pacific". Table 17 gives the Joseph estimate for this area.

Table 17: Estimates of Carrying Capacity of Purse Seiners in the Western Pacific in 2000 According to Joseph (2003)

Category of Carrying Capacity	Number of vessels	Total Carrying Capacity (mt)
< 401 mt	23	6,215
401-800 mt	38	21,909
801- 1200 mt	156	162,833
1201 – 1600 mt	24	33,033
1601 – 2000 mt	4	6,909
> 2000 mt	1	2,234
Total	246	233,133

The Joseph estimate is more inclusive than the present study in that it attempted to capture those vessels less than 401 mt and any Asian domestic "high-seas" seiners. Excluding Joseph's smallest size category and converting the remaining total to cubic metres of carrying capacity, results in 223 purse seine vessels with 265,610 cu m of carrying capacity.

This compares to the estimate of the present study of 233,000 cu m for 191 vessels. It is not possible to comment on the source of the difference between the two studies without access to further details of the Joseph estimate.

Joseph also makes an estimate of the global carrying capacity of tuna purse seiners. His calculation of 592,696 mt converts to about 693,757 cu m. The present study's estimate of 233,000 in the WCPO region cu therefore represents about one-third of the global estimate for tuna purse seine vessel carrying capacity.

10.0 Difficulties and Reservations Concerning the Estimated Carrying Capacity

The estimates of carrying capacity given in Section 9.0 above should be considered with caution as there are several factors which could contribute to imprecision. These factors are discussed in the following sections.

10.1 Problems with Unverified Information

The most important reservation concerning the total cubic metres of cubic carrying capacity estimated in Section 9.0 is that the calculation relies heavily on unverified information in the Regional Register. Although it was possible to cross check vessel numbers for the three years with SPC data, there was much less opportunity for verification of the data on volume of carrying capacity.

Despite efforts made to substantiate the carrying capacity information on the Regional Register using multiple sources (Section 7.3), there remains a major problem - in most cases all that could be done was to verify one source of vessel-provided data with another source of vessel-provided data.

Where independent verification was possible, the results were disappointing. Government documentation from the eastern Pacific was available for the volume carrying capacity of six U.S. vessels on the Regional Register. The volume carrying capacity listed on this government documentation[15] was from 6% to 42% greater than that reported on the Register[16].

There were few opportunities for independent verification of carrying capacity data for non-U.S. seiners. Since verification of capacity data is so difficult, it sometimes not possible to distinguish which stated capacity might indicate the correct one. For

[15] Some vessels have undergone stretching; but these six vessels were not on the NMFS capacity change database.

[16] This *could* be an artifact of US vessel owners knowing their capacity in cubic inches (as given on many shipyard plans) and not knowing how to convert it to cubic meters; There are 61,023.74 cubic inches in 1 cubic metre.

example, there can be incentives for operators to under-report, such as when government officials or regional organizations ask for information on a voluntary and unverified basis (this is the case with most licensing regimes, including the Regional Register). There are also occasions when conflicting over-reported information may be made public, such as in advertising by a shipyard, or quotes in the media. This is demonstrated by the example of the seiner Fong Seong 767. For this vessel a carrying capacity of 1198 cubic metres is reported on the 2003 Regional Register. A shipyard website, however, reports different information:

> "Ching Fu Shipbuilding[17] has completed the elongation of Fong Seong Fishery's tuna purse seiner, "Fong Seong 767". In a remarkable feat of engineering and teamwork, Ching Fu successfully cut "Fong Seong 767" in half and inserted new blocks to increase her capacity from 1450 CBM to 1840 CBM. On January 11, 2002 she returned to the fishing grounds…"

During the present study, operator-supplied information on volume carrying capacity was obtained through various means on the fleets flagged in Vanuatu, the Marshall Islands, and FSM. When this was compared to the operator-supplied information on the Regional Register, less than half of the information on volume carrying capacity was found to be similar. Some of the discrepancies were over 50% and 500 cu m. At least some of the differences appear to arise from the use of tonnage carrying capacity on the Regional Register, rather than volume carrying capacity.

10.2 Problems with Units of Measurement

There appears to be a major problem with the units of measurement of carrying capacity on the Regional Register. The Regional Register application blank for "Storage Capacity (cubic metres)" appears to be filled in by various operators as (a) cubic metres, (b) 20^0 F tonnage carrying capacity (in short tons), and (c) 14^0 F tonnage carrying capacity (in both short tons[18] and metric tonnes). This observation is consistent with two recent reviews of the Regional Register that conclude there is "clearly a mixture of units" for carrying capacity (Millar 2001) and "units were not adhered to and there was no way to determine which value is in the right unit" (Clark 2003).

Because fishermen in many fleets often think of carrying capacity in tonnes of tuna, giving tonnage rather than volume carrying capacity could be an honest mistake.

In any case, there is very little opportunity in the WCPO region to observe maximum unloaded catch due to the low observer coverage.

10.3 Problems with Defining "Participation"

In Section 2.0 it was mentioned that some of the purse seine fleets are managed in such a way that the retirement of a vessel is followed soon after by the commissioning of a new vessel. In this situation, the two vessels involved would, according to the definition of the present study ("actively fishing in the region during a particular year"), both be considered to have participated in the fishery during the year concerned. A government

[17] It has been reported that this firm is associated with the management of the Fong Seong 767.
[18] It has been noted that a short ton of tonnage carrying capacity is only about 6% smaller than a cubic meter of volume carrying capacity

agency that manages a fleet may, however, consider the participation to be only one vessel because at any point during the year only one of the vessels was fishing.

Due to data confidentiality and other restrictions, sufficient information was not available for the present study to ascertain the degree (if any) this retirement/commissioning scheme affected the estimate of carrying capacity.

10.4 Problems with Vessel Name Changes

Some of the vessel names cause considerable confusion in the calculation of total capacity. Two examples illustrate this problem:

- In the Japanese fleet, a vessel was decommissioned and then another vessel had a name change to the name of the one just decommissioned. There were a few cases of two vessels of the same name overlapping.
- Two vessels of the same name were built in the US and sold to Korea, one of which has had three other names and five flags.

10.5 Lack of Conversion Factors for All Fleets

The Inter-American Tropical Tuna Commission has established that, for the purse seiners operating in the eastern Pacific, a factor of 1.17051 can be used to convert from metric tonnes of carrying capacity to cubic metres of carrying capacity. This factor has been used in this study to determine the fish hold volumes for U.S. vessels (and former U.S. vessels) where this information is missing on the Regional Register and where the tonnage carrying capacity is known.

Little information was available to the present study on appropriate conversion factors for other fleets[19], and this may have negatively affected the total carrying capacity estimate, especially for the Japanese fleet in the 1980s when volume carrying capacity information was missing on the Regional Register.

10.6 Uncertainty Concerning Group Purse Seine Operations

The estimation of capacity is difficult for a group seining operation, as the net boat may have no storage capacity. The combined total fish hold volume of the two carrier vessels which are characteristically associated is about 350 cu m and this figure has been used in this study. It should be noted, however, that a Japanese group seine operation would be expected to catch more fish per unit time (perhaps a factor of 1.4) than a Japanese single seiner of 600 cu m carrying capacity.

10.7 Thoughts on the Difficulties in Estimating Carrying Capacity

Several observations can be made on the above difficulties encountered by the present study in estimating carrying capacity. The most important are the problems associated

[19] An inspection of the data suggests that the conversion factor is probably much higher for the Japanese fleet, but the sample size available to study the situation is small and neither the tonnage nor volume data is from verified sources.

with the lack of verification of vessel-supplied information, especially that on fish hold volumes.

Measurement of fish holds by a vessel-independent agency is likely to lead to a substantial improvement in the accuracy of any WCPO carrying capacity estimate. Other perhaps simpler measures which could contribute to an improved estimate of carrying capacity include:

- The FFA should consider modifying purse seine entries on the Regional Register with the information from the three capacity inventories developed during this study.
- The Regional Register application forms should require *both* metric tonnes of fish carrying capacity *and* cubic metres of fish hold space to force the distinction and thereby clarifying the units of measurement actually used.
- The Regional Register application forms should require information on tonnage as "GT (International Convention)" and require an International Tonnage Certificate for substantiation.
- On-board fishery observers from FFA, SPC, and national governments should be encouraged to collect carrying capacity information, including vessel-specific factors for converting metric tonnes of fish to cubic metres of fish hold space and information on unloading volumes. It would also be useful from them to obtain information on the use of brine wells vs. storage wells, especially clarification of which fleets these are used interchangeably - there is the suspicion that in some fleets brine wells are used only as a last resort for storage of fish.

In consideration of the difficulties mentioned in Sections 10.1 to 10.6 above, some consideration should be given to modifying the aggregate WCPO carrying capacity estimate. The following can be stated about common problems encountered and how they may affect the estimate:

- If one-quarter of all seiners on the Regional Register supplied carrying capacity in metric tonnes rather than in cubic metres (one of the major sources of uncertainty in the estimate), the estimate for volume carrying capacity given in Section 9.0 should be increased by about 4%.
- If one-quarter of all seiners on the Regional Register understated their carrying capacity (another apparently common source of inaccuracy) by 25% then the estimate for volume carrying capacity should be increased by 6.25%.

On the basis of much examination and consideration of data in the Regional Register and a limited amount of verification of this data, the carrying capacity appears to be somewhat greater than what is given in Section 9.0 above. The two sources of error above, which apparently are the most common, suggest that estimates are less than the true values, perhaps by 10%[21].

[20] There is the suspicion that in some fleets brine wells are used only as a last resort for storage of fish.
[21] Information from Vanuatu received too late for inclusion in this study supports the contention that the estimate (based in the RR) is about 10% too small.

11.0 Considerations on Carrying Capacity in the Western and Central Pacific Ocean Fishery

11.1 Factors Contributing to Changes in Carrying Capacity

The results of examining the purse seine fleets of the WCPO in 1988, 1995, and 2003 show a steady increase in aggregate carrying capacity. Factors contributing to this growth are:

Vessel transfers amongst fleets (flag changes) – this has involved owners selling vessels to other flags (e.g. much of the US fleet being sold to Korean interests in the early 1990s), often with skilled crew transferred at the same time, or owners selling older vessels to upgrade through construction of new vessels (e.g. the recent sale of older Taiwanese vessels to Chinese and Korean owners). Other fleet owners purchase vessels from various sources, and even other vessels types (i.e. non-purse seiners) and completely refit and equip such vessels as has occurred for much of the Philippines fleet. These flag changes can result either in just redistributed carrying capacity (unless the new owner has funds to extend vessel capacity – see below), reduced carrying capacity (where vessels may be sold to interests outside the WCPO) or increased carrying capacity (refitting of other vessel types). Examples of all three situations can be found in the WCPO since 1988, with probably an overall increase in carrying capacity resulting from vessel transfers.

Physical changes to existing vessels – this usually involves extending carrying capacity by "stretching' an existing vessel through the addition of a section amidships with additional wells and increased hold capacity. There have been many examples of this in the WCPO since the earliest days of the fishery but is far from completely documented.

Introduction of vessels from other ocean areas – examples of this can be found in the initial arrival of a large proportion of the US fleet from the EPO in 1983/84 as a result of the very strong El Niño conditions, and the recent arrival of Spanish-owned vessels from the EPO. In general, there has probably been a bigger ingress of vessels constructed outside the region than an egress of WCPO- constructed vessels.

Construction of new vessels – with the development of a flourishing Taiwanese shipbuilding industry in the last decade, this has become the primary source of new vessel construction in the WCPO, supplementing long standing ship building capacity in Japan and the US. Of the 27 vessels fishing in 2003 and constructed since 1995, 18 were built in Taiwan (all but four since 2000), 5 in Japan, 3 in Spain, and one in Chile.

Overall, carrying capacity in the WCPO has been steadily increasing from all sources above.

11.2 Is Carrying Capacity a Good Proxy for Fishing Capacity?

Having examined the various difficulties associated with accurately measuring carrying capacity in the sections above, this next section will scrutinize the issue of whether carrying capacity is a good indicator of the ability of a vessel to catch fish in the WCPO.

The notion that carrying capacity, measured in terms of well volume or fish tonnage carried, can provide a measure of the ability to catch fish is an attractive one. It is associated with the assumption that tuna purse seiners generally fish until existing well capacity is full, then steam into port to unload. Assuming that the fishing efficiency of the vessel is based on how rapidly it can fill the available well capacity, and how many times in a given period the wells can be filled, this capacity measure then serves as an indicator of fishing capacity. This is especially true where unloading or transshipment points may be distant from fishing grounds, and unloading times might be lengthy, this putting a premium on tonnage carried and unloaded on each trip.

This concept has largely been developed in the context of the Eastern Pacific Ocean (EPO), where fishing grounds are extensive and unloading points relatively few, and may also be applicable to the Atlantic and Indian Ocean fisheries.

In the case of the WCPO, the situation is somewhat different, where the fishing area is the largest longitudinally of the four ocean areas, and the main unloading/destination points are at opposite ends of the fishing zones, i.e. Philippines/Bangkok in the west, and Pago Pago/Kiritimati in the east, with many islands (and associated EEZs) in between.

Two of the major fleets operating in the WCPO, Japan and the US, do follow the EPO pattern, with vessels filling up and steaming in to unload in Japanese ports (primarily Yaizu) and Pago Pago respectively. Despite brief periods where this approach has been varied slightly in the past (e.g. Japanese vessels transshipping in Tinian, US vessels unloading in Guam) it has generally been adopted by these two fleets.

In contrast, the Taiwanese and Korean fleets characteristically transship a portion of their catch, rather than continuing to fish until a full load had been achieved, in a variety of transshipment locations throughout the WCPO.

Figure 5 shows the annual average catch per trip for three of the fleets operating in the WCPO (Japanese catchdata could not be included, as high seas catches are not available to enable catch per trip and trip length to be calculated). This clearly shows that while the US vessels unload close to their full capacity (1000 t), this is not the case with the Taiwanese and Korean fleets where around 600 to 700t, or around half their capacity is typically unloaded. Figure 6 shows the annual average days per trip for the same fleets, underlining the point that US vessels average 40-50 days per trip, whereas the other two fleets average 20 to 30 days per trip.

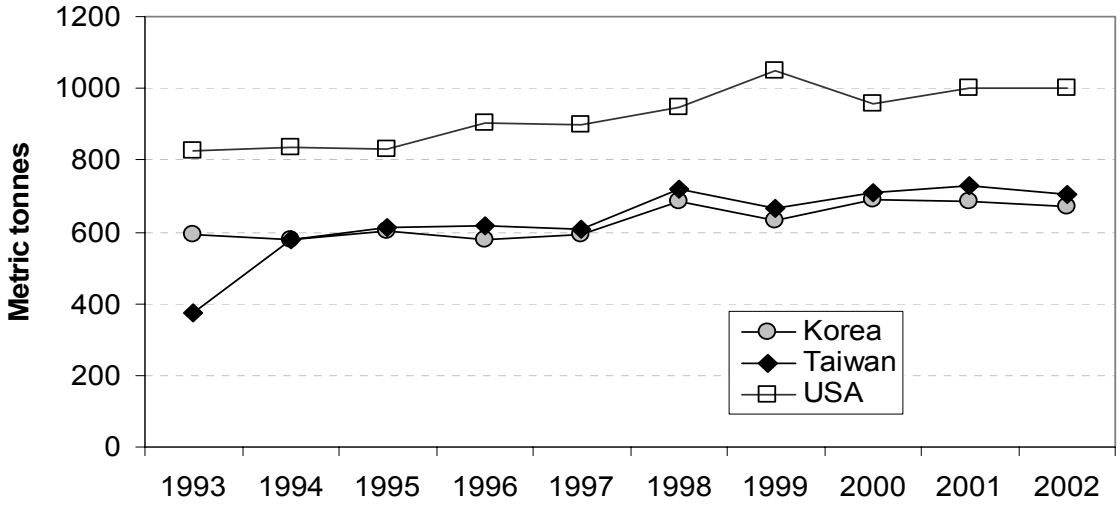


Figure 5: Annual Average Catch Per Trip for Purse Seine Fleets Operating in the WCPO
(excludes logsheets where "trips" were less than 10 days)

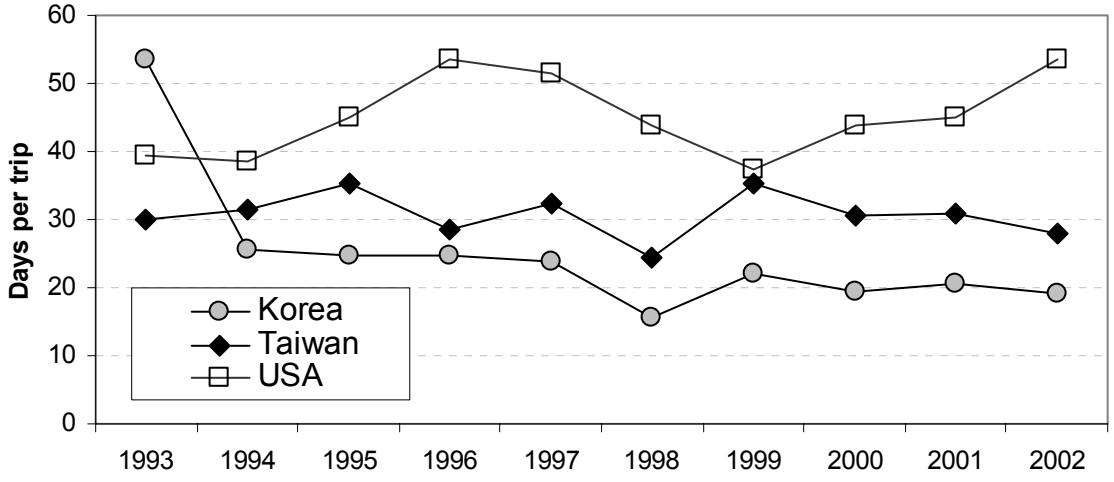


Figure 6: Annual Average Days Per Trip For Purse Seine Fleets Operating in The WCPO
(excludes logsheets where "trips" were less than 10 days)

Table 18 lists the number of transshipments recorded on the SPC transshipment database for recent years for these two fleets. Whilst these may be incomplete, they provide some indication of the extent or transshipment activity and the range of locations utilized. Prior to 1993 and the implementation of Minimum Terms and Conditions under the Palau Arrangement, these transshipments had occurred on the high seas rather than in designated ports.

Table 18: Number of Transshipments Recorded on Logsheets by Year, for Two Fleets

	1999	2000	2001	2002
Taiwan	428 (15)	308 (8)	310 (8)	385 (14)
Korea	204 (10)	193 (14)	217 (8)	266 (12)

Brackets indicate number of locations where more than one transshipment was made

Other fleets operating may regularly use widely dispersed transshipment points (e.g. China and the rapidly growing Vanuatu flag and FSM fleets). On the other hand, the now large Philippines fleet (22 vessels) and the seven PNG vessels operate mostly in the PNG EEZ and adjacent waters, and fish for the most part in conjunction with carrier vessels or motherships, regularly transshipping or unloading relatively small quantities of fish. Even though having small hold capacity (and several vessels have no hold capacity at all), wells would rarely be filled on a trip. This reflects the operations of the successful group seiners of the 1980s and early 1990s, which took comparable, if not larger, catches relative to single seiners.

In the case of both transshipping fleets and fleets which use carrier vessels, the relationship between hold capacity and fishing capacity does not seem as strong as those fleets that do not transship.

Other evidence suggests that a vessel's carrying capacity may not reflect well fishing capacity in the WCPO region. If it is assumed that changes in fishing capacity are related to changes in catch per unit of effort[22] (CPUE, in mt/vessel/year), an examination of recent changes in both CPUE and carrying capacity may provide some insight into the relationship between fishing capacity and carrying capacity (Table 19).

Table 19: Changes in CPUE and Carrying Capacity for the Major Fleets

Fleet	1995 CPUE (mt/v/year)	2002 CPUE (mt/v/year)	Change 1995-2002		1995 Av.carrying capacity (Cu m)	2003 Av.carrying capacity (Cu m)	Change 1995-2002
Japan	4669	6224	+33.3%		1137	1135	-0.2%
Korea	5849	6670	+14.0%		1098	1262	+14.9%
Taiwan	4155	6793	+63.5%		1285	1302	+1.3%
USA	3897	5958	+52.9%		1302	1410	+8.3%

CPUE data source: SPC/OFP

It can be seen that:

- The fleet that had the best improvement in annual catch during the 1995 – 2003 period (Taiwan) had almost no difference in average carrying capacity
- The fleet that had largest increase in average carrying capacity during the 1995 – 2003 period (Korea) had the smallest increase in catch rate.
- For Japan and the USA (fleets that do not transship): (a) Japan enjoyed a substantial increase in annual catch with an unchanged average carrying capacity per vessel, and (b) The US had a large increase in annual catch with only a small increase in the average carrying capacity per vessel.

[22] It should be noted that fishing capacity is more closely related to what CPUE could potentially be, rather than what CPUE was in some point in the past.

The above may suggest that the concept of carrying capacity as an indicator of fishing capacity is not very suitable for the fleets that transship. The proportion of purse seine vessels in the WCPO fishery that do transship is, however, large (well over half of the seiners operating in the WCPO) and likely to grow. The fleets of Taiwan, Korea, the Marshall Islands, and Vanuatu presently transship, as well as parts of the PNG and Philippine fleets.

12.0 Proxies for Carrying Capacity

The terms of reference for the present study call for a review of physical measures which could be used as proxies for vessel carrying capacity.

Because carrying capacity itself is intended to be a proxy for fishing capacity (ability of a vessel to catch fish) there is some question of the appropriateness of this approach: identifying a proxy for a proxy. Perhaps a better objective would be to find a suitable alternative proxy, or a better proxy for fishing capacity. Nevertheless, the following sections explore various physical measures of vessels and comment on their validity for use as proxies for carrying capacity.

12.1 Gross Tonnage

In some of the world's fisheries, gross tonnage is thought to be one of the better vessel characteristic for reflecting fishing capacity. FAO (1998) states: "GT is probably the most significant single variable influencing fishing capacity and, in many respects, it is a good compromise between having a perfect measure or none at all". Some of the purse seiner operators interviewed during the present study felt that gross tonnage is the best proxy for fishing capacity. On the other hand, the IATTC has done some work on the use of gross tonnage as an indicator of fishing capacity, but continue to use carrying capacity as its main indicator (J.Joseph, per.com.).

During the present study it became evident that there is considerable confusion on the subject of tonnage of vessels. As this uncertainty appears to have clouded some of the issues associated with purse seine fishing capacity, a short explanation of ship's tonnage is given in Appendix 3. In summary, GT is an internationally recognized standard, but GRT is an outdated measurement and of limited use in a study of capacity in a fishery with participating fleets from many nations, such as the tuna purse seine fishery of the WCPO.

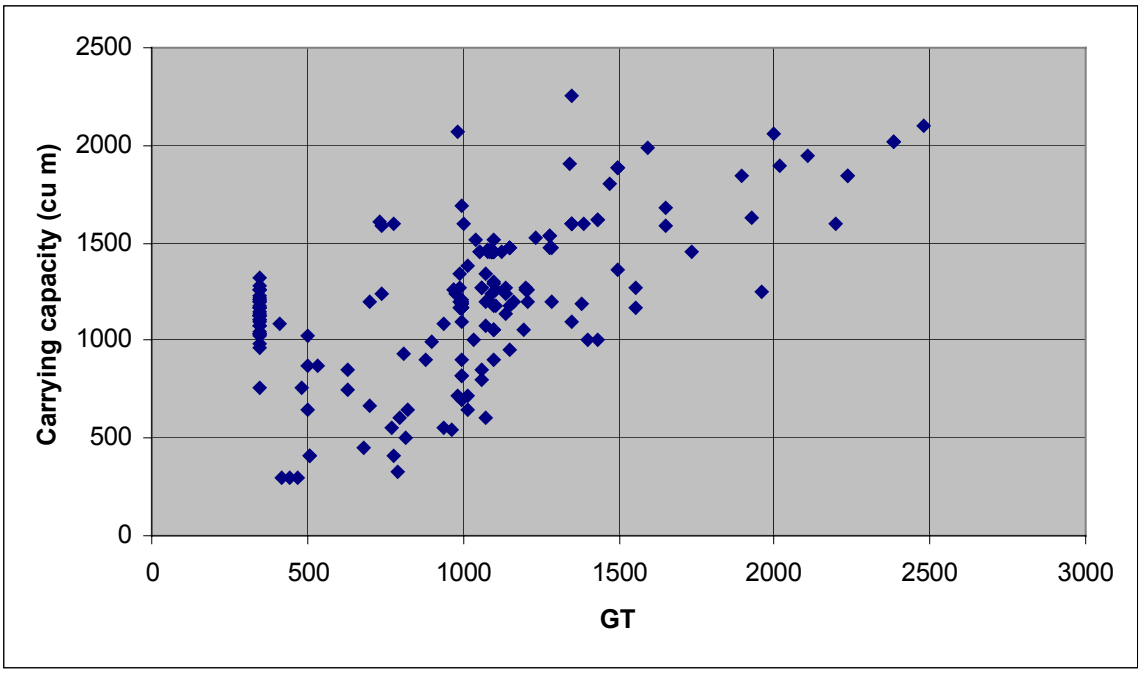
A check of the tonnage information in Lloyd's Register for a sample of vessels on the Regional Register showed that 40% were not listed and therefore had no tonnage information. For the 60% of the Regional Register vessels found on Lloyd's Register, the Lloyd's tonnage information is most often different from the GT given in the RR. In some cases it appears that GRT was used on the RR.

Similar to the situation of carrying capacity information on the Regional Register, the GT information on the RR is apparently a mixture of correct information on GT, correct information on GRT, and information that is not correct for either. Although the GT information on the RR is not verified, it appears less difficult than carrying capacity to

cross-check as the information is available on government certificates and other documentation. A major difficulty is that, despite the international requirements for GT measurement, many seiners operating in the region use the older national GRT measurement which varies considerably between countries.

It appears that gross tonnage from the Regional Register is not presently a useful proxy for carrying capacity of purse seiners in the WCPO because the "GT" entries for many vessels on the Regional Register is not gross tonnage, but rather GRT or erroneous information. Nevertheless, the relationship between GT and carrying capacity (as listed on the 2003 RR, outlying data points eliminated) is given in Figure 7. It can be seen that there is a very large variation in, for example, the GT of a vessel with 1300 cu m of carrying capacity.

Figure 7: The Relationship between GT and Carrying Capacity as Listed on the Regional Register



12.2 Number of Crew

A characteristic of the WCPO purse seine fishery is that the nationality of a vessel has a large influence on the number of crew aboard. The average number of crew on each national purse seine fleet (as given on the 2003 Regional Register) is shown in Table 20.

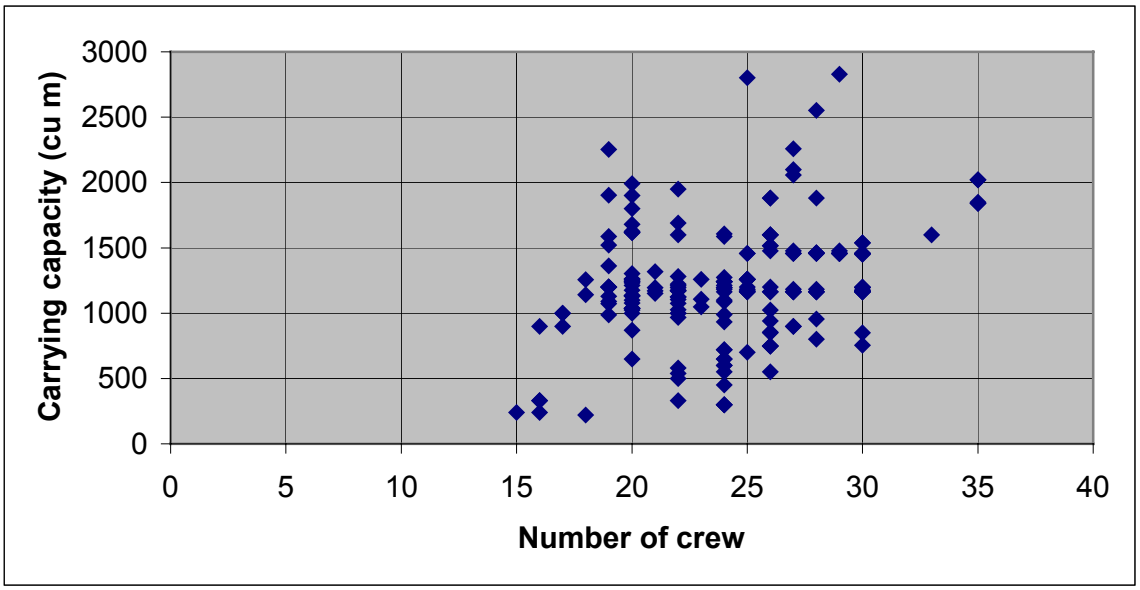
Table 20: Average Number of Crew

Fleet	Av. number crew listed on 2003 RR
China	29.2
Taiwan	27.8
Korea	24.8
Japan	21.1
USA	19.2

The average number of crew appears closely related to both the cost of labour and frequency of transshiping (the process of transshipping is labor-intensive). Crew costs are highest in the Japanese and USA fleets. (McCoy and Gillett, 1997) and these vessels rarely transship. Intuitively, these features would suggest that the number of crew is a poor proxy for carrying capacity across all the fleets in the WCPO purse seine fishery.

This contention is supported by Figure 8 which shows the relationship between number of crew and carrying capacity (as listed on the 2003 RR, outlying data points eliminated). It can be seen that there is a very large variation in, for example, the number of crew aboard a vessel with 1600 cu m of carrying capacity.

Figure 8: The Relationship between Number of Crew and Carrying Capacity as Listed on the Regional Register

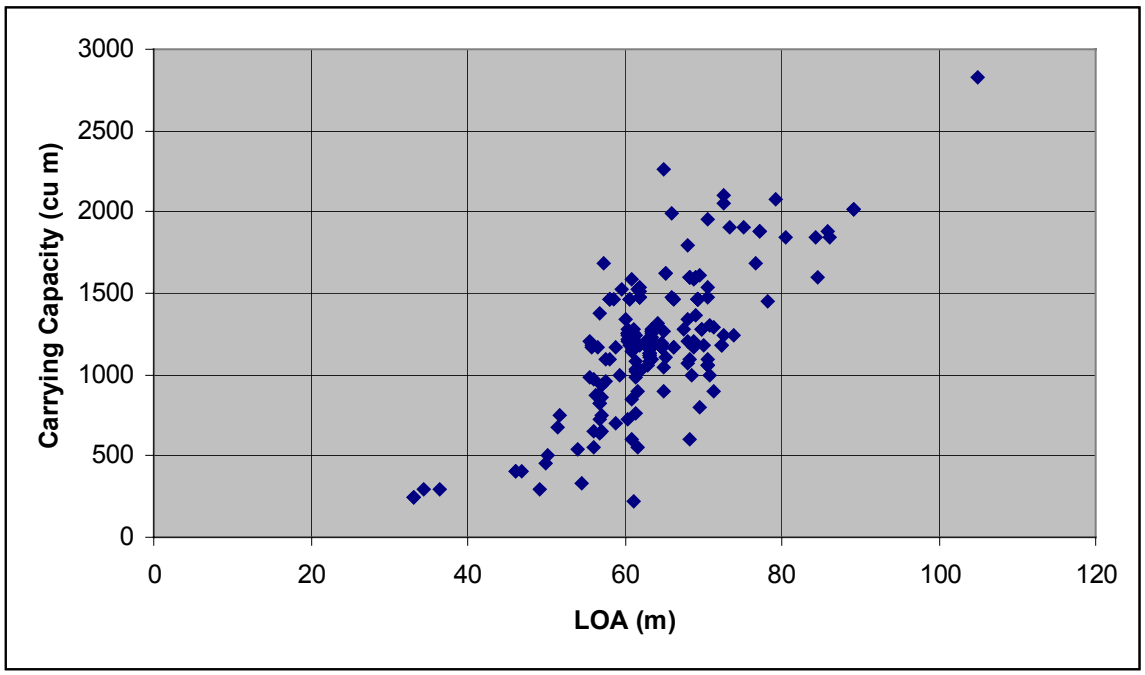


12.3 Vessel Length

As a proxy, there is a certain appeal to using a seiner's length over all (LOA): it is easy to measure, appears on a variety of official documents, is related to the maximum speed that seiners can deploy to chase tuna schools, and gets around difficulties caused by partial load transshipments.

Unfortunately, the information in the 2003 Regional Register does not show a tight correspondence between LOA and carrying capacity. Figure 9 shows the relationship between LOA and carrying capacity (both as listed on the 2003 RR, outlying data points eliminated). It can be seen that there is a very large variation in, for example, the LOA of vessel with 1600 cu m of carrying capacity.

Figure 9: The Relationship between LOA and Carrying Capacity as Listed on the Regional Register



12.4 Conclusions on Proxies for Carrying Capacity

The use of other vessel characteristics besides those investigated above appear to be less suitable due to even greater problems in the Regional Register. For example, vessel engine power suffers from similar problems as with other vessel attributes (lack of verification, obvious erroneous data, etc.) but has the additional problem that the RR application allows the applicant to use a variety of units of measurement (e.g., hp, kw, ps, etc.).

It appears that the three characteristics investigated (tonnage, length, crew size) on the 2003 RR are not good proxies for carrying capacity. It is important to note that to some extent, the suitability of the three characteristics could be distorted by erroneous data in the RR.

13.0 Alternatives to the Use of Carrying Capacity

As noted above, the carrying capacity of a tuna purse seiner appears to be an imperfect indicator of the ability to catch fish. Due to special operational characteristics of some of the major purse seine fleets operating in the WCPO region, the use of carrying capacity as a proxy appears less suitable than in the EPO region where the concept was developed for tuna purse seiners. There are some indications from other regions of the world of the problems of using carrying capacity. Officials of the Indian Ocean Tuna Commission have expressed the opinion that carrying capacity is not a good proxy *per se* for fishing power (D.Ardill, per.com.).

Much of the increases in tuna purse seine fishing capacity in the WCPO region in recent years is likely to have arisen from technological advances, many of which are independent of vessel carrying capacity.

Although the use of carrying capacity as a proxy has its shortcomings, especially in the WCPO, there are no obvious alternatives. Carrying capacity therefore appears to be presently the best of a number of imperfect options for measuring fishing capacity of tuna purse seine vessels.

Conceivably, research could be undertaken on other vessel characteristics or combinations of characteristics to formulate a better proxy for fishing capacity than carrying capacity. The effectiveness of such work would, however, be tremendously constrained by the large amount of erroneous data in the Regional Register.

14.0 Concluding Remarks

The results of this study illuminate a number of features of the carrying capacity of vessels participating in the tuna purse seine fishery of the WCPO region. These include:

- Information in the FFA Regional Register, corrected to the extent possible during the present study, indicates that the total carrying capacity of all seiners participating in the fishery during the 1988, 1995, and 2003 RR years were about

14,000, 200,000, and 233,000, respectively. This represents an increase of about 43% during the 1988-1995 period, an increase of about 16% during the 1995-2003 period, and an increase of about 67% during the entire 1988 to 2003 period.

- A limited amount of information from sources other than the Regional Register suggests that these estimates may be about 10% less than the actual carrying capacities. If the significant number of vessels inactive in mid-2003 were to commence operations, this would add an additional 10% to the existing capacity estimate.
- The Regional Register, the major source of data for making the estimates of carrying capacity, contains much erroneous information. A limited amount of correcting was undertaken during the study, but there are indications that much inaccurate information remains.
- The concept of carrying capacity as an indicator of the ability to catch fish is associated with more difficulties in the WCPO region than in the eastern Pacific where it was developed. The concept appears to be especially inappropriate for vessels that transship – a form of operation that is undertaken by well over half of the seiners operating in the WCPO. Nevertheless, at the present time carrying capacity appears to be the best option for measuring fishing capacity.

On the other hand, a number of important features concerning fishing capacity remain unclear:

- It is uncertain if there is a good proxy for carrying capacity or if there is a better proxy for fishing capacity than carrying capacity, and the present Regional Register information does not allow for research on this subject.
- Another important uncertainty is that not much is known about the capacity of tuna purse seine vessels in domestic Asian fisheries which can move into the region or otherwise affect the region. The scope of the present study excluded those seiners that have fish carrying capacity less than 400 cubic meters and those operating in the domestic fisheries of Indonesia, Philippines, and other Asian countries.
- There is considerable speculation concerning current vessel construction and plans for expansion of fleets. Although this will undoubtably affect carrying capacity in the future, the details of the present building program and likelihood of fleet growth are largely unknown.

An important conclusion of the present study is that for both improving the estimate of carrying capacity and for developing any alternative proxy to carrying capacity, the key is to upgrade the accuracy of the data in the Regional Register. Independent verification of vessel-supplied information is essential.

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Appendix 2: People Contacted

NOAA Fisheries:

- Charles Karnella, Administrator, Pacific Islands Area Office, Honolulu
- Raymond Clarke, Resource Management Specialist, Pacific Islands Area Office, Honolulu
- Al Coan, Southwest Fisheries Science Center, La Jolla
- Dale Squires, Southwest Fisheries Science Center, La Jolla
- Gordon Yamasaki, Tuna Treaty Monitoring Programme, American Samoa
- Chris Fanning, Tuna Tracking and Verification Program, Long Beach

Forum Fisheries Agency:

- Barry Pollock, Deputy Director
- Andrew Richards, Manager Monitoring Control and Surveillance
- Len Rodwell, Manager, Economics and Marketing Division
- Karl Staisch, Observers Programme Manager
- Josie Tamate, Project Economist
- Ramesh Chand, Database Administrator
- Ben Hall, Information Officer
- Josie Tamate, Project Economist
- Albert Carlot, VMS Support Officer
- Les Clarke, FFA Consultant

Secretariat of the Pacific Community:

- John Hampton, Manager, Oceanic Fisheries Programme
- Peter Williams, Fisheries Database Supervisor
- Siosifa Fukofuka, Port Sampling and Observer Trainer

Federated States of Micronesia :

- Bernard Thoulag, Executive Director, National Oceanic Resource Management Authority (NORMA)
- Eugene Pangelinan, Deputy Director, NORMA
- Tim Park, Fisheries Research Analyst, NORMA
- Mathew Chigiyal, Manager, Licesning, Statistics and Computer Branch, NORMA
- Milan Kamber, Manager, Caroline Fishing Company
- Andrea Hillyer, Director, Nieseset Management Company:
- Ms. Yasin, Tri-Marine (FSM) Inc.
- Naomich Suzuki, Overseas Fishery Cooperation Foundation (OFCF)

Vanuatu:

- Moses J. Amos, Director of Fisheries, Department of Fisheries
- Naomi Sope, Senior Finance & Administration Officer, Department of Fisheries
- William Naviti, Fisheries Resources Manager, Department of Fisheries
- Francis Hickey, fisheries consultant

Food and Agriculture Organization of the United Nations:

- Jacek Majkowski, Marine Resources Service
- Rebecca Metzner, Development Planning Service

- Dora Blessich, Marine Resources Service
- Jeremy Turner, Fishing Technology Service
- Andy Smith, Fishing Technology Service

Others:

- Mike McCoy, Gillett, Preston and Associates, Hawaii
- Robin Allen, Director, Inter-American Tropicial Tuna Commission (I-ATTC)
- Mike Hinton, Senior Scientist, I-ATTC
- Jim Joseph, fisheries consultant and former I-ATTC Director
- Holly Koehler, US State Department
- Glen Joseph, Deputy Director - Oceanic and Industrial Affairs, Marshall Islands Marine Resources Authority
- Seiichi Sakamoto, Japan Fisheries Agency
- Valonna Baker, National Fisheries Authority, Papua New Guinea
- Adrian Wickham, General Manager, National Fisheries Developments Ltd., Honiara
- David Burney, Executive Director, United States Tuna Foundation
- Julius Zolezzi, President, Zolezzi Enterprises
- David Ardill, Director, Indian Ocean Tuna Commission
- Nelson Kile, Minister of Fisheries, Solomon Islands
- K. S. Lee, tuna industry representative, Korea
- K. H. Ahn, Silla Co., Ltd., Korea
- David Martin, Marine Surveyor, Billett, Wright, and Associates, Ltd., Suva, Fiji

Appendix 3: Notes on Measuring Tonnage of Ships

During the present study it became apparent that there is considerable confusion on the subject of tonnage of vessels. This is evident from the Regional Register application forms, tonnage information supplied by vessel operators, and discussions with industry representatives and fishery managers. As this uncertainty appears to have clouded some of the issues associated with purse seine fishing capacity, some explanation of ship's tonnage appears justified.

Turner (1998) clarifies the situation:

- Tonnage is often confused with the measure of displacement, or weight, of a vessel. In fact it refers to the size of the vessel, and not to its weight. Its origin dates back to the fifteenth century when a standard-sized barrel, called a tun, was decreed in England for the purpose of measuring ship capacity, eventually referred to as tunnage, or tonnage. However, the method of tonnage measurement has since evolved and differs considerably from country to country.
- Unification of this unit of measure for large ships on international voyages was a slow process. A number of international meetings held since the 1930s concluded with the 1969 International Convention on Tonnage Measurement of Ships (referred to as the London Convention), which entered into force in July 1982. It applies to ships undertaking international voyages, although ships of less than 24 m (and warships) are exempt. Furthermore, GT as defined by this convention only became obligatory for all vessels (more than 24 m long and engaged in international voyages) after 18 July 1994. Until then, the system of tonnage defined by the 1947 Convention for a Uniform System of Tonnage Measurement of Ships (the Oslo Convention) continued to be valid. This system applied the gross registered ton (GRT) as the unit of measure.
- An important point to note is that the GT of a given vessel can be significantly greater than its GRT because, under the London Convention, certain parts of the vessel (e.g. enclosed spaces above the upper deck) are included in GT whereas they were previously excluded from GRT[23]. This means that many vessels that were below 100 GRT prior to 1994 are now being classified above 100 GT.

Although GT is an internationally recognized standard, the calculation of GRT can vary considerably between some of the major fishing countries. An identical vessel design can have very different GRT measurements in various countries. It is therefore considered an outdated measurement and of limited use in an study of capacity in a fishery with participating fleets from many nations, such as the tuna purse seine fishery of the WCPO.

[23] A.Smith of FAO (per.com.) indicates there is no simple relationship between GT and GRT, but a very rough rule of thumb for European vessels is GRT = GT * 0.7

Appendix 4: Abbreviations Used

AFZ	Australian Fishing Zone
ADB	Asian Development Bank
CC	Carrying capacity
CFC	Caroline Fishing Company
Cu M	Cubic metres
DW	Distant water
EEZ	Exclusive economic zone
EPO	Eastern Pacific Ocean
EU	European Union
FAD	Fish aggregating device
FAO	Food and Agriculture Organization of the United Nations
FFA	Forum Fisheries Agency
FSM	Federated States of Micronesia
G/S	Group seine operation
GT	Gross tonnage
GPA	Gillett, Preston and Associates
GRT	Gross registered tonnage
IATTC	Inter-American Tropical Tuna Commission
LBP	Length between perpendiculars
LAW	Length at waterline
LOA	Length over all
MCS	Monitoring, control, and surveillance
MT	Metric tonne
M^3	Cubic metres
N/A	Not available
NF	Not fishing
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NZ	New Zealand
OFP	Oceanic fisheries programme of the SPC
PNG	Papua New Guinea
PTDF	Pacific Tuna Development Foundation
RMI	Republic of the Marshall Islands
RTFD	Regional Tuna Fishery Database
ROC	Republic of China
ROK	Republic of Korea
RR	FFA Regional Register of Foreign Fishing Vessels
SCTB	Standing Committee on Tuna and Billfish
SPC	Secretariat of the Pacific Community, formerly South Pacific Commission
ST	Short ton
T	Metric tonne
USMLT	U.S. multilateral treaty, formally known as Treaty on Fisheries between the Governments of Certain Pacific Island States and the Government of the United States of America
V	Vessel
VMS	Vessel monitoring system
WCPFC	Western and Central Pacific Fisheries Convention
WCPO	Western and Central Pacific Ocean