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ASSESSMENT OF SMALL-SCALE TUNA LONGLINE POTENTIAL KINGDOM OF TONGA

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RDA INTERNATIONAL, INC.
801 Morey Drive
Placerville, California 95667-4411
Telephone: (916) 622-8800
Facsimile: (916) 626-7391

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Credit for much of the success of the small-scale horizontal longlining trials can be attributed directly to the fishing knowledge and innovativeness of Master Fisherman Joe Marks.

The difficult jobs of compiling, analyzing, and assessing reams of marketing and economic data were handled adroitly by Marketing Consultant Paul Bartram and Fisheries Economist John Rowntree.

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ABBREVIATIONS

FAD	Fish Aggregating Device
kg	Kilogram
m	Meter
MOF	Ministry of Fisheries
mt	Metric ton
PIMAR	Pacific Islands Marine Resources
RDA	RDA International, Inc.
SP	South Pacific
T$	Tongan dollars
USAID	United States Agency for International Development

1.0 EXECUTIVE SUMMARY

The Tonga Small Scale Tuna Longline Project, a cooperative venture between the Government of Tonga and the United States Government, is a component of USAID's Pacific Islands Marine Resources (PIMAR) program. The project was situated in Vava'u, a relatively undeveloped island group roughly 280 km from Tonga's Capitol, Nuku'alofa. The contractor, RDA international, Inc., began field operations in November 1991 and will complete its assignment in December 1994.

The purpose of the project is to alleviate pressure on deep bottomfish stocks by introducing alternative fisheries for the local small-boat fleet. In general, the brief was to adapt large-boat tuna longline techniques to smaller boats, and to assess the commercial feasibility of these techniques. Two horizontal longline methods were tested during the project: a standard 32 km, 800-hook monofilament system, and a modified 8 km, 200 hook system. In addition, a vertical longline system and two handline techniques were tested. Since little was known of the tuna fishing grounds adjacent to the Vava'u Islands exploratory fishing was an important component of the trials. The emphasis was on comparing open ocean to seamounts. Further, seven Fish Aggregation Devices (FADs) were deployed to test their effectiveness in Vava'u waters.

Two important adjuncts to the central theme were also completed: an assessment of tuna longline baitfishes in Vava'u and preparation of a bottomfish management plan.

The results of small-scale horizontal longlining (8 km line) were particularly encouraging. The catch from 50 fishing days exceeded 40 mt, including 20 mt of high-quality tuna. The catch rate of 10.6 fish per hundred hooks was roughly five times higher than those recorded in regional longline fisheries. The greatest potential was at Capricorn Seamount which, which exceeded 18 mt of *sashimi*-grade tuna from just 25 sets and with a tuna catch rate of over 13 marketable fish per hundred hooks.

The results from trials involving the longer 32 km longline (800 hooks) were not as positive with total catch rates of 2.02 marketable fish per hundred hooks, about average for the region.

The 126 days of small-boat trials using vertical longline and two types of handlines indicated that tuna are extremely seasonal around Vava'u, and that the small snapper boats can do well fishing tuna during short seasonal peaks.

The baitfish resource assessment resulted in landings of about 400 kgs of tuna baitfish per night. The catch was mostly round scads and sardine. Tuna fishing trials indicated that this local bait is superior to imported baitfish and cost half as much.

The new longline technology introduced by the project, if used from relatively lowcost 40-45 foot boats, is commercially feasible. The potential internal rate of return exceeds 50%. However, a number of critical constraints must be overcome if a commercial fishing operation is to succeed in Vava'u. The most important of these is the timing of inter-island ferry service from Vava'u to Nuku'alofa. Other critical constraints are long-distance communications, air cargo rates and space on international flights from Nuku'alofa, water quality for ice production, and dock space. Tuna companies would be well-advised to operate from Nuku'alofa until these constraints are addressed.

The 32 km longline, usually operated from 46-55 foot vessels, did not have a favorable economic outcome and is not recommended.

The results from vertical longlining and handlining suggest that the smaller snapper boats can conduct profitable tuna fishing during the four months of tuna availability. This will at least reduce some of the pressure on the heavily-fished snapper resource.

Export market trials conducted by the project resulted in favorable prices from Japan, Hawaii, New Zealand, and Australia. The quality and size of Tongan tuna meets the criteria of these markets.

A small baitfish industry can be established in Vava'u to provide bait for the potential longline fishery.

The overall potential for tuna longline development in Tonga is 15-30 vessels producing 1500-3000 mt per year. However, it is recommended that growth of the fleet be carefully controlled until the tuna resources and economic yield are fully understood. Using a conservative fleet growth to ten vessels over the next five years, the annual landings would amount to 1,000 mt per year, of which 500 mt could be exported. The direct income, about T$4.5 million, would circulate through Tonga's economy. A minimum of 70 new jobs would be created, and the additional fish for local consumption would result in import substitution of about T$0.5 million.

The costs to the Government of Tonga should not exceed T$1.0 million (primarily dock construction). These costs should be offset by company tax revenues over a five-year period.

2.0 INTRODUCTION

2.1 Background

The Tonga Small-Scale Tuna Longline Project, a cooperative venture between the Government of Tonga and the United States Government, is a component of USAID's Pacific Islands Marine Resources (PIMAR) program. The project is situated in Vava'u, a relatively undeveloped island group roughly 280 km from Tonga's Capitol, Nuku'alofa. The contractor, RDA International, Inc., began field operations in November 1991 and will complete its assignment in December 1994.

The purpose of the project is to alleviate pressure on deep bottomfish stocks by introducing alternative fisheries for the local small-boat fleet. In general, the project was to adapt large-boat tuna longline techniques to smaller boats, and to assess the commercial feasibility of these techniques. Specific objectives were to reduce the bulk of line required by fishing in areas of fish concentration, such as FAD's and seamounts, explore fishing methods requiring lower capital costs, and find market opportunities having higher returns. The specific tasks were to test three sizes of vessels (28 foot, 35 foot, 40 foot) and various types of horizontal and vertical longline gear. After testing the various combinations and assessing commercial viability, the contractor was required to develop an optimal vessel design and determine whether such a vessel was available in the region. Other required elements were the assessment of baitfish resources in Vava'u, their effectiveness as tuna bait, and the development of baitfish and bottomfish management plans.

Two horizontal longline methods were tested during the project: a standard 32 KM, 800-hook monofilament system, and a modified 8 KM, 200-hook system. In addition, a vertical longline system and two handline techniques were tested. Since little was known of the tuna fishing grounds adjacent to the Vava'u Islands, exploratory fishing was an important component of the trials. The emphasis was on comparing open ocean to sea mounts. Further, seven Fish Aggregation Devices (FADs) were deployed to test their effectiveness in Vava'u waters.

The project was situated in Vava'u, a relatively undeveloped island group roughly 280 km from Tonga's capitol, Nuku'alofa.

Two important adjuncts to the central theme were also completed: an assessment of tuna longline baitfishes in Vava'u, and preparation of a bottomfish management plan.

2.2 Purpose

The purpose of this document is to present the findings of the Tonga Small-Scale Tuna Longline Project, and to offer recommendations to the Tongan Government and the Tongan private sector on strategies for the development of a local tuna longline fleet. Section 3.0 gives an overview of the current tuna fishing situation in Tonga; Section 4.0 presents project findings; Section 5.0 offers recommendations for fleet development; and Section 6.0 briefly describes the national benefits from fleet development.

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3.0 CURRENT SITUATION

3.1 Tuna Fleet

3.1.1 Local

Until 1992 the Tongan longline fleet consisted of a single vessel, the 30 m *Lofa*, owned and operated by the Government of Tonga. *Lofa* was donated by Japanese aid in 1982 as a training vessel and is equipped with the traditional tarred mainline system using around 2000 hooks. The vessel targets albacore, which is frozen for cannery use.

In 1992, *Lofa* was transferred to Sea Star Ltd., a parastatal company with some private shares. Sea Star has since invested in two Japanese longliners (20 m and 25 m) of traditional design, but with hydraulic reels and monofilament longlines. Also in 1992, a private operator placed a 20 m Hawaiian longliner, the *Otomuamua* in service for a short period. With insufficient cash reserves, the vessel made only a few trips before switching to other fisheries.

Two new companies entered the fishery in 1993/94, Capricorn Fishing Co. and Tonga Seafood Co. Capricorn operates two vessels (13 m and a 15 m) both equipped with 10 km monofilament mainline systems. Tonga Seafood operates a 20 m vessel (former shrimp trawler) equipped with a 32 km monofilament system.

The Tonga PIMAR Project utilized an 18 m fish carrier, the *Ekiaki*, and two smaller snapper vessels (10 m and 11 m) for tuna fishing trials. None of these vessels can be considered commercial tuna boats.

Thus, the current longline fleet now stands at six vessels, of which five are using modern monofilament systems.

3.1.2 Regional

The inventory of tuna vessels in the region varies from year to year depending on the movement of fish concentrations. The fleets consist of purse seiners, longliners, pole-and-liners, and trollers. The bulk of both purse seine and longline catches are made by vessels of distant water fishing nations such as Korea, China, Japan, Taiwan, and the United States. These vessels either operate from their own ports or reside at cannery ports in Pago Pago, American Samoa or Levuka, Fiji. Table 1 lists tuna vessels fishing in the region.

In the last few years, small domestic longline fleets have developed in the region. Fiji's longline fleet is the largest, consisting of 23 vessels in the 15-30 m range. French Polynesia has 47 vessels, but they are generally smaller inshore longliners. New Caledonia has recently received six new vessels, bringing their fleet to nine. Smaller domestic longline fisheries exist in Western Samoa and French Polynesia.

Table 1. Estimated number of tuna vessels operating in the Tonga Region

Country	Purse Seine	Longline	P&L	Troller
Tonga	0	6	0	0
Japan	37	351	39	0
Korea	36	167	0	0
China	0	319	0	0
Taiwan	43	254	0	0
United States	42	6	0	47
Philippines	14	0	0	0
Australia	8	84	10	39
Fiji	0	22	9	2
New Caledonia	0	9	3	0
FSM	7	7	0	0
Solomon Is	3	0	27	0
Marshall Is	0	5	0	0
Kiribati	0	0	3	0
New Zealand	5	20	0	252
French Polynesia	0	47	0	4
Cook Is	0	1	0	0
Western Samoa	0	1	0	0
Total	195	1299	91	344

Source: Various SPC Documents

3.2 Tuna Landings

Although no official figures are available, the current longline tuna landings in Tonga are estimated at around 300 mt per year. *Lofa's* catch is around 400 mt (mostly albacore), while the other five vessels account for a cumulative total of less than 200 mt of albacore, yellowfin, and bigeye.

3.3 Estimated Tuna Resources

Since tuna are highly migratory species, it is virtually impossible to estimate the stock sizes for discrete areas such as Tonga. However, the South Pacific Commission Tuna and Billfish Assessment Program has provided some estimates of regional tuna populations, as follows:

- Skipjack - The largest resource is skipjack tuna (Tongan = *atu*), with a regional population estimated at 3-4 million metric tons. Current catches exceed 1 million mt and is believed that another 1 million mt may be harvested without stressing the population. As skipjack are primarily surface fish, they are caught by purse seiners and pole-and-line vessels. Neither technique is appropriate for Tongan waters.

- Yellowfin - Yellowfin tuna (Tongan = *takuo*) constitute the second largest resource, estimated at around 1.2-1.6 million mt. It is believed the current catch of about 400,000 mt can be increased by about 100,000 mt: however, since most of the catch is young fish landed by purse seiners, the impact on larger longline fish may be detrimental.

- Albacore - Albacore tuna (Tongan = *alpakoa*) catches have steadied at about 30,000 mt for the Southern Hemisphere, and it is believed that the stocks can sustain these yields. Approximately two-thirds of the catch is adults caught by longline, with the remainder being sub-adults taken by surface troll fisheries. The albacore longline catch rates in Tongan waters are among the highest in the Pacific.

- Bigeye - The population size of bigeye tuna is unknown, but the regional catch has remained reasonably steady at around 50,000 mt. The fact that catch rates have not decreased significantly in the last few years (after an abrupt decline in the late 1960s) indicates a reasonably healthy resource.

  The current Tongan tuna longline fishery of about 300 mt is a tiny fraction of the South Pacific fishery. Fiji, over the past ten years, has developed a modest 2,000 mt longline fishery with no noticeable drop in catch rates. As a first approximation, it can be assumed that Tonga could develop a 3,000 mt longline fishery, with catch composition of about 1,200 mt of albacore, 900 mt of yellowfin, 600 mt of bigeye, and 300 mt of billfishes and other bycatch.

3.4 Markets

The dominant tuna markets are in Japan, Western Europe, and the United States. However, different product forms are demanded in the various markets. Japan is by far the biggest consumer of fresh and frozen raw tuna (480,000 mt in 1992), while the Europeans favor canned or steaked tuna. Americans consume over 50% of the

canned tuna supply, but have also become an important component of the raw and steaked market.

The frozen albacore caught by *Lofa* have been landed at canneries in either American Samoa or Fiji. The rest of the catch (yellowfin, bigeye, billfishes, etc.) is sold to the public in Nuku'alofa. Until the past two years, no export shipments of fresh tuna were attempted from Tonga. The PIMAR Project initiated *'sashimi'* exports in trials to Japan, Hawaii, Australia, and New Zealand. In the past year, the three Tongan longline companies have made shipments to Hawaii and Japan on an irregular basis.

The bulk of fish from these companies is still sold in Tonga. Sea Star, as the largest producer, set the price standard at around T$2.50/kg, and the other companies have had to live with that ceiling. Although the local market is limited, it can probably absorb 700 - 1,000 mt of fresh tuna per year.

3.5 Infrastructure

3.5.1 Shoreside

Dock space for fishing vessels is available at Tuimatamoana Wharf at Nuku'alofa, Tongatapu and at the main wharf in Neiafu, Vava'u. Although dockage is now adequate, any expansion in the commercial fleet, particularly medium to large vessels, will require additional frontage. Neither electric outlets nor drinking water are available at any of the docks where fishing vessels are allowed.

The Government of Tonga and several private firms operate ice facilities at Nuku'alofa, Vava'u, and Ha'apai. The total capacity of approximately 20 tons per day is barely adequate for current fishing vessel needs, and will need to be expanded for any substantial growth in the fleet. Further, the texture of ice produced by the government machines is not suitable for high-grade *sashimi* tuna. Microbiological tests on the town water supplies which are used by ice makers in Nuku'alofa and Vava'u have indicated unacceptable levels of Coliform bacteria.

The government freezer facilities are located at Nuku'alofa, Vava'u, and on several other islands in the Kingdom. These are adequate for holding bait, but the blast freezers cannot quick freeze tuna. Further, there are no chill boxes for holding fresh tuna.

As there are no dockside fuel facilities for fishing vessels, fuel is delivered by truck to the larger boats. This is often a problem in Vava'u when the single fuel truck is busy or broken down.

3.5.2 Transport

Four international air carriers service Nuku'alofa, with flights to Honolulu, Auckland, and Nadi (Fiji). Cargo space is adequate for the current level of fish exports, but may become a problem in the future. Inter-island air transport is currently provided by small planes with no capacity for carrying large fish.

Fish transport between Vava'u and Nuku'alofa is limited to a twice-weekly surface ferry, which usually runs on Wednesday and Thursday. Since the ferries have no reefers, all fish must be packed in ice and transported in insulated containers which are not provided by the ferry operators.

3.5.3 Communications

Telephone and facsimile services from Nuku'alofa utilize a modern satellite communications system, and are adequate for business purposes. Communications from Vava'u and Ha'apai are much more problematic. An obsolete tropospheric scattering system was installed for these outposts only seven years ago, and no plans have been made to modernize. Long distance telephone and fax services from Vava'u are unreliable and costly.

3.6 Available Financing

Financing for the small snapper boats built by the Government has been handled through a United Nations Capital Development Fund involving both the Department of Fisheries and the Tonga Development Bank. This revolving fund might still be used to finance additional small snapper and tuna boats, but is inadequate for larger vessels.

Funds for modern tuna boats are available only from private banks or the Tonga Development Bank. As is normal practice, the private banks are not interested in either high-risk ventures or in dealing with applicants with little credit history. For the average fishing entrepreneur, the private banks are not a viable option. The Tonga Development Bank has recently made its first loan for tuna longliners, but the repayment schedule is for only five years without a grace period. This has placed an undue burden on the operator.

3.7 Government Regulation

All fishing activities in Tonga are the responsibility of the Ministry of Fisheries. The Ministry is empowered to regulate specific fisheries, license commercial fishing vessels, and enforce regulations. With regard to tuna fishing, only general regulations now apply. During the past two years there was confusion over certain exclusive

rights granted to Sea Star by a Cabinet Decision. Those rights have since been rescinded and the tuna fishery is now regulated by MOF, the same as other fisheries. However, in addition to vessel licensing, MOF will also be responsible for either grading tuna exports or certifying the grades assigned by exporters.

Two other government agencies directly affect fisheries development. The Ministry of Finance sets import duties on vessels, fishing gear, bait, and fuel, while the Ministry of Commerce and Industry issues development licenses exempting companies from these duties and corporate taxes for varying periods of time.

4.0 PROJECT FINDINGS

4.1 Fishing Trials

4.1.1 Fishing Gear

The four basic fishing techniques tested to-date were vertical longline, Hawaiian daytime handline ('palu ahi'), Hawaiian night-time handline ('ika shibi'), and horizontal longline.

The vertical longline (Figure 1) consisted of a 400 m monofilament line (400 lb. test) attached to a 25 cm plastic float, and weighted at the bottom end with 2 kgs of rebar. The branch lines, or snoods, are made up of 3 m of 300 lb. test monofilament attached to the mainline by longline snaps with medium longline hooks. The number of snoods varied, but was usually twenty per set. Normally, the snoods were attached at 15 m intervals starting at a 100 m depth. The mainline was stored, set, and retrieved on a wooden hand-powered reel.

The daytime handline (Figure 2) is made up of 200 m of 3 mm nylon mainline with 200 m of 6 mm nylon backing. The terminal gear consists of a chum rag, 8/0 McMahon swivel, 2 kg 'pancake' weight, 6 m of 300 lb. test monofilament, and a number 14 tuna circle hook. Depth of setting varied from 60 to 200 m with the excess line stored in circular tubs.

The night-time handline (Figure 3) consists of 100 m of 3 mm nylon, backed up by 200 m of 10 mm nylon. The terminal gear is made up of a 0.5 kg banana weight swivelled on both ends, 2 m of 400 lb. test monofilament, and a number 14 tuna circle hook. This gear is set at 10 to 40 m, in conjunction with a 50 watt underwater light.

Three types of horizontal longline were tested during the project: a modified 8 km monofilament system (small-scale boxing line), a 32 km monofilament rig (standard longline), and a small 1.6 km hand-reel line.

The small-scale horizontal longline (Figure 4) is set and retrieved from a 10-km capacity general-purpose hydraulic reel. The normal set consists of 8.0 km of 3 mm monofilament mainline with 200 branch lines and hooks attached at 40 m intervals. Each branch line consisted of a standard longline snap, 6 m of 400 lb. monofilament, 45 gram lead swivel, and 3.4 mm longline hook. The lead swivel was placed 4 m down the 6 m leader. Spar buoys (125 cm) and flags are located at each end of the 8.0 km mainline, and at 1.6 km intervals. Plastic floats (300 mm) are placed midway between the spar buoys. Thus, the distance between floats is about 800 m and contains 20 hooks. The float line (joining float to mainline) is 30-40 m of 6 mm tarred kuralon.

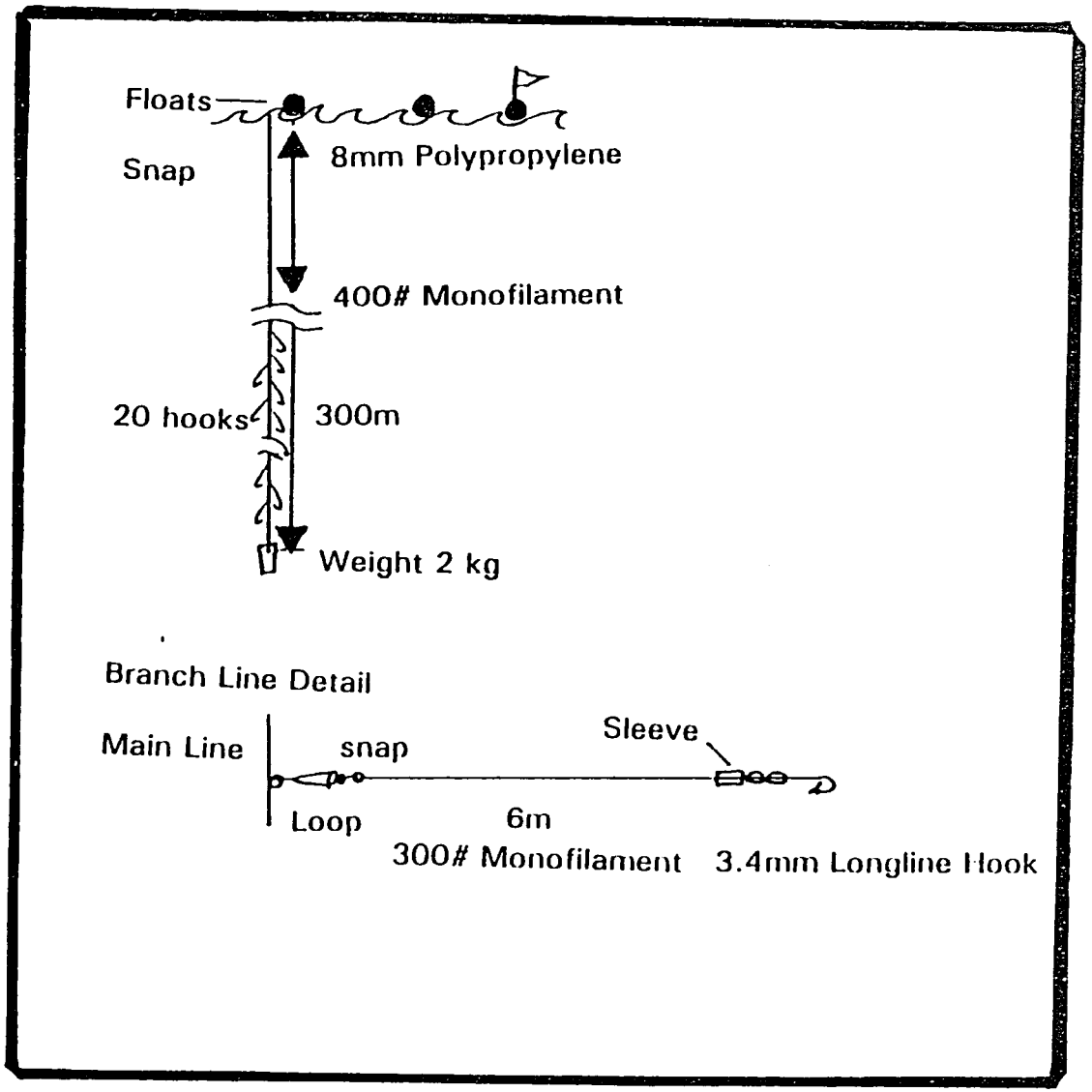

Figure 1. Vertical Longline

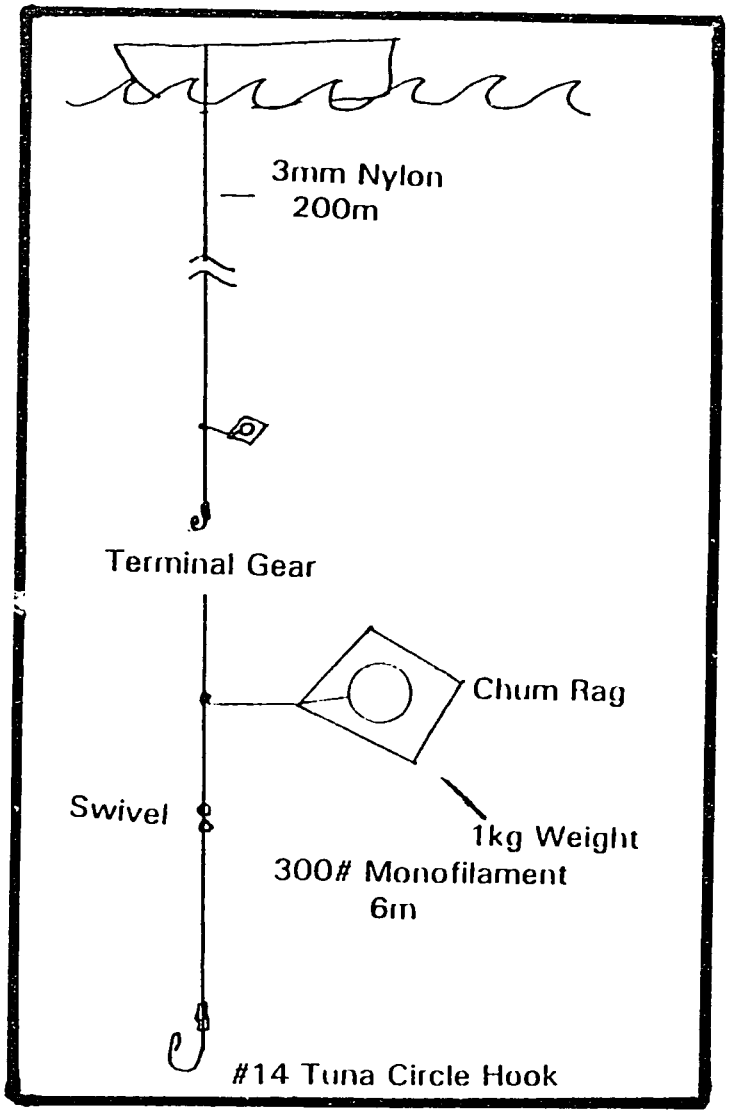

Figure 2. Daytime Handline Gear

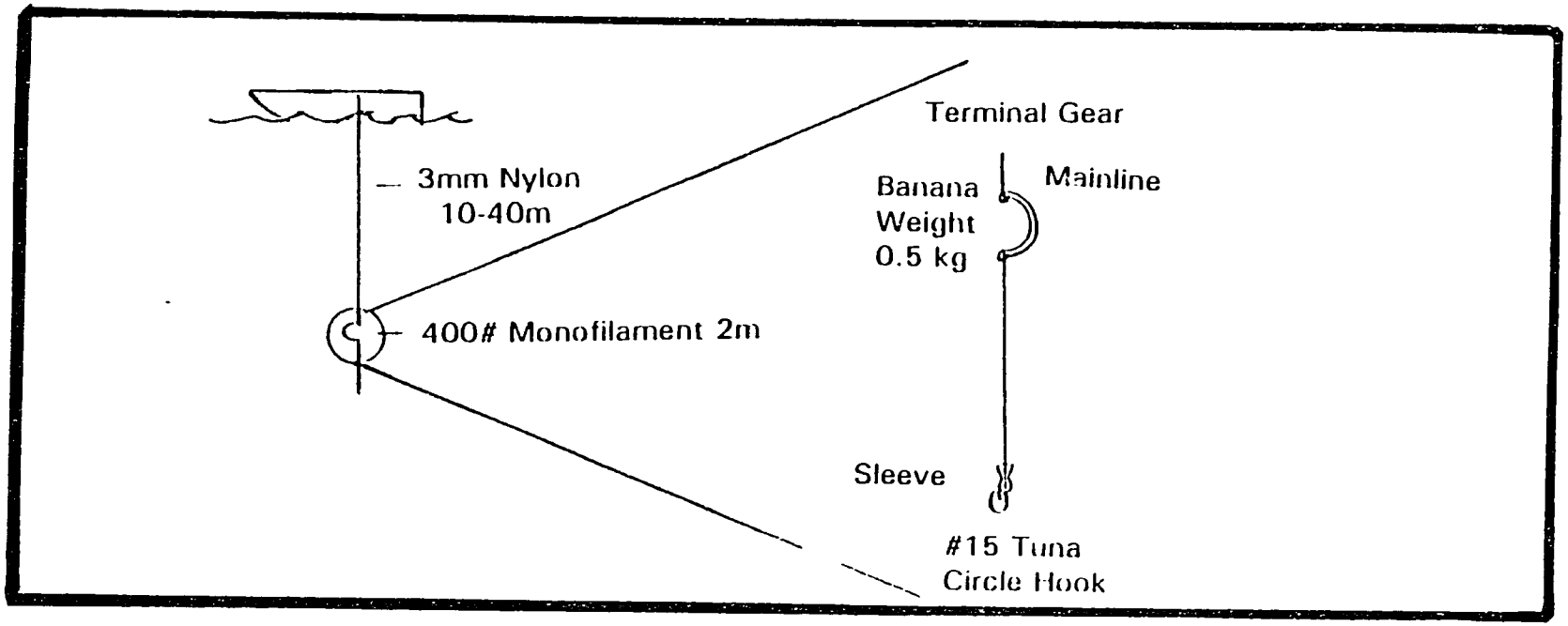

Figure 3. Night-time Handline

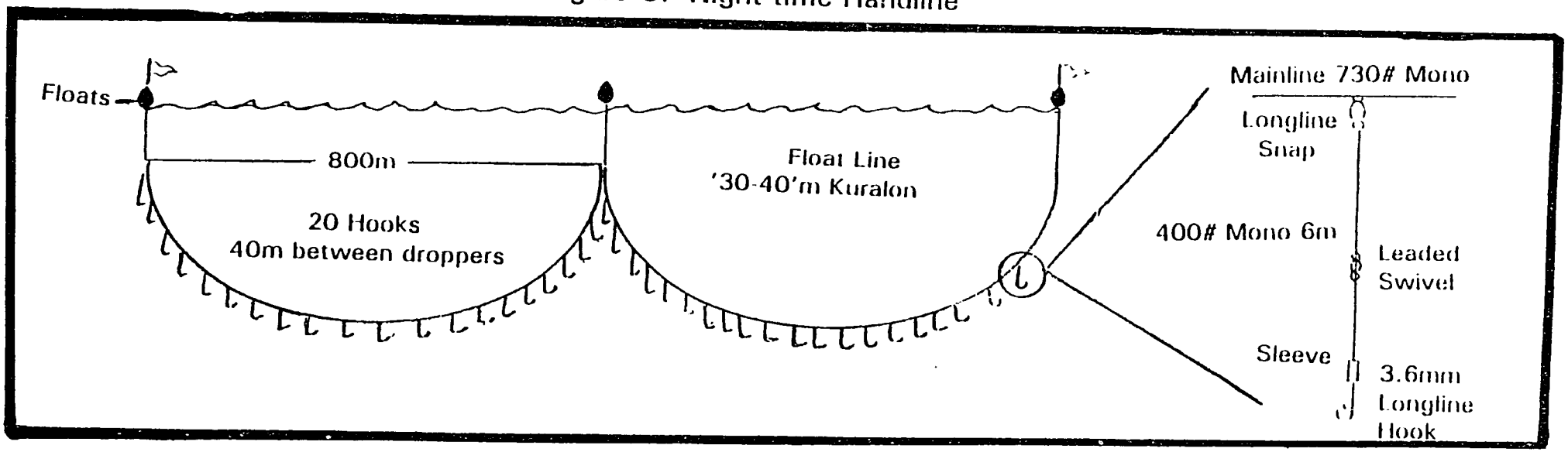

Figure 4. Small-Scale Horizontal Longline (8.0 km, 200 Hooks)

The "standard" monofilament system has the same general configuration as the shorter gear, with 20 hooks between floats. The major difference (other than length) is the deletion of leaded swivels and the introduction of a line shooter to seemingly increase hook depth. The length of leader is increased to 10m.

A third small-scale horizontal longline system was developed for the local 28 foot snapper boats. It is a maximum of 1.6 km of 2.5 mm monofilament, with up to 40 hooks, and is set and hauled with a manual reel. In this shorter 400 m version, the mainline and snoods are essentially the vertical longline run horizontally.

4.1.2 Fishing Vessels

Three primary vessels were used for tuna fishing, the 35 foot *Dora Malia*, the 52 foot *Ekiaki*, and the 30 foot *Seini Koula*.

The *Dora Malia* is a wooden-hulled larger version of the Tongan snapper boat with an effective range of 120 km. The vessel was equipped with a 2 KW color echo sounder, GPS, and SSB, and VHF radios. Since the *Dora Malia* has no hydraulic capabilities, all the gear was hauled by hand or hand reels. Fishing methods employed by *Dora Malia* included vertical longline, trolling, short horizontal longline (1.6 km manually pulled), and daytime handline.

The *Ekiaki* is a glassfibre, Japanese-aid funded fish carrier with large fish holds and limited work space. The vessel was equipped with both 10 km and 32 km hydraulic reels, 2 kw color sounder, GPS, and SSB and VHF radios. The *Ekiaki* was used for horizontal longlining and night-time handlining. The smaller horizontal longline gear was designed for use on a 38-40 foot work vessel, but the 52 foot *Ekiaki* was the only suitable government vessel available.

The *Seini Koula* is a standard wooden snapper boat built by the government boat yard. Like the *Dora Malia*, this vessel has a low speed displacement hull (about 7 kts), little available workspace, and no hydraulic capabilities. *Seini Koula* was primarily used for vertical longline and night-time handline.

4.1.3 Fishing Results

4.1.3.1 Vertical Longline

The *Dora Malia* made 107 trips during the 18-month period August 1992-January 1994 (Table 2). The vessel spent 159 days at sea using vertical longlines on 89 days. The remainder of sea time was spent scouting and trolling. About 90% of the 432 vertical longline sets were made around FADs with the balance over sea-mounts.

TABLE 2

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VERTICAL LONGLINE CATCH SUMMARY

TONGA LONGLINE PROJECT

AUGUST 1992 - JULY 1994

TRIP		SEA	FISH	NO.	NO.	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
NO	DATE	DAYS	DAYS	SETS	HOOKS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
DM1	5/8	1	1	6	80	22	390	10	165	12	225	0	0	0	0	0	0	0	0
DM2	6/8	1	1	6	80	4	93	2	55	2	38	0	0	0	0	0	0	0	0
DM3	11/8	2	1	12	160	25	437	15	254	10	183	0	0	0	0	0	0	0	0
DM4	13/8	1	1	7	110	10	143	5	73	3	57	0	0	1	4	1	9	0	0
DM5	17/9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM6	22/9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM7	25/9	2	2	6	120	20	172	2	37	1	23	0	0	17	112	0	0	0	0
DM8	30/9	2	1	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM9	1/10	1	1	4	80	8	112	4	85	0	0	0	0	4	27	0	0	0	0
DM10	2/10	1	1	2	40	1	6	0	0	0	0	0	0	1	6	0	0	0	0
DM11	6/10	2	2	11	220	18	347	1	13	13	254	0	0	3	23	1	57	0	0
DM12	7/10	1	1	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM13	8/10	1	1	3	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM14	16/10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM15	22/10	3	1	2	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM16	26/10	1	1	5	100	4	55	0	0	2	46	0	0	2	9	0	0	0	0
DM17	27/10	1	1	6	120	2	26	1	12	1	14	0	0	0	0	0	0	0	0
DM18	29/10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM19	6/11	2	1	6	100	1	32	0	0	0	0	0	0	0	0	1	32	0	0
DM20	10/11	1	1	4	80	6	53	0	0	0	0	0	0	6	53	0	0	0	0
DM21	11/11	1	1	7	140	12	69	1	4	0	0	0	0	11	65	0	0	0	0
DM22	16/11	1	1	2	40	2	12	0	0	0	0	0	0	2	12	0	0	0	0
DM23	19/11	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM24	25/11	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM25	30/11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM26	1/12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM27	3/12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM28	7/12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM29	8/12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM30	14/12	2	2	12	240	34	539	24	343	7	160	0	0	0	0	1	3	2	33
DM31	17/12	1	1	7	140	1	30	0	0	0	0	0	0	0	0	0	0	1	30
DM32	21/12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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VERTICAL LONGLINE CATCH SUMMARY

TONGA LONGLINE PROJECT

AUGUST 1992 - JULY 1994

TRIP		SEA	FISH	NO.	NO.	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
NO	DATE	DAYS	DAYS	SETS	HOOKS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
DM33	5/1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM34	13/1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM35	15/1	1	1	4	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM36	20/1	2	1	4	80	3	49	1	7	0	0	0	0	1	12	0	0	1	30
DM37	21/1	1	1	4	80	2	39	0	0	0	0	0	0	1	9	0	0	1	30
DM38	22/1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM39	26/1	2	1	6	120	4	68	2	30	1	16	0	0	0	0	0	0	1	22
DM40	28/1	1	1	4	80	4	68	3	59	0	0	0	0	1	9	0	0	0	0
DM41	2/2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM42	3/2	1	1	2	40	1	16	1	16	0	0	0	0	0	0	0	0	0	0
DM43	5/2	1	1	2	40	2	25	2	25	0	0	0	0	0	0	0	0	0	0
DM44	11/2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM45	17/2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM46	19/2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM47	24/2	2	2	17	340	20	386	15	288	3	54	0	0	1	9	0	0	1	35
DM48	25/2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM49	3/3	1	1	6	120	9	244	8	184	0	0	0	0	0	0	0	0	1	60
DM50	4/3	1	1	8	160	12	263	11	245	1	18	0	0	0	0	0	0	0	0
DM51	6/3	1	1	9	180	15	322	15	322	0	0	0	0	0	0	0	0	0	0
DM52	9/3	1	1	15	300	26	578	25	558	1	20	0	0	0	0	0	0	0	0
DM53	16/3	1	1	5	100	2	40	2	40	0	0	0	0	0	0	0	0	0	0
DM54	22/3	1	1	5	100	7	142	7	142	0	0	0	0	0	0	0	0	0	0
DM55	23/3	1	1	8	160	8	101	3	39	0	0	0	0	5	62	0	0	0	0
DM56	24/3	1	1	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM57	25/3	1	1	2	40	6	70	6	70	0	0	0	0	0	0	0	0	0	0
DM58	30/3	1	1	3	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM59	31/3	1	1	3	60	1	52	1	52	0	0	0	0	0	0	0	0	0	0
DM60	1/4	1	1	6	120	3	77	2	22	0	0	0	0	0	0	0	0	1	55
DM61	6/4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM62	30/4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM63	11/5	1	1	5	100	3	10	3	10	0	0	0	0	0	0	0	0	0	0
DM64	18/5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 2

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VERTICAL LONGLINE CATCH SUMMARY

TONGA LONGLINE PROJECT

AUGUST 1992 - JULY 1994

TRIP		SEA	FISH	NO.	NO.	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
NO	DATE	DAYS	DAYS	SETS	HOOKS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
DM65	19/5	1	1	4	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM66	21/5	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM67	1/6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM68	3/6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM69	17/6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM70	23/6	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM71	1/7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM72	6/7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM73	7/7	1	1	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM74	8/7	1	1	5	100	2	80	0	0	1	20	0	0	0	0	0	0	1	60
DM75	16/7	1	1	6	120	9	204	0	0	6	120	0	0	1	14	0	0	2	70
DM76	22/7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM77	23/7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM78	28/7	1	1	3	60	1	8	0	0	0	0	0	0	1	8	0	0	0	0
DM79	5/8	3	3	11	220	29	280	0	0	9	180	0	0	20	100	0	0	0	0
DM80	13/8	3	3	7	140	8	78	1	16	2	39	0	0	5	23	0	0	0	0
DM81	17/8	1	1	5	100	5	93	0	0	5	93	0	0	0	0	0	0	0	0
DM82	19/9	2	2	9	180	11	446	3	13	5	103	0	0	2	30	0	0	1	300
DM83	29/9	2	1	2	40	8	43	0	0	0	0	0	0	8	43	0	0	0	0
DM84	7/10	4	2	12	240	9	109	0	0	4	77	0	0	5	32	0	0	0	0
DM85	8/10	2	2	11	220	5	117	0	0	0	0	0	0	2	12	0	0	3	105
DM86	17/10	4	2	8	100	9	490	1	21	0	0	4	69	0	0	0	0	4	400
DM87	19/10	1	1	3	60	1	16	0	0	1	16	0	0	0	0	0	0	0	0
DM88	22/10	1	1	7	140	3	146	0	0	0	0	0	0	0	0	1	46	2	100
DM89b	28/10	3	2	4	80	12	151	0	0	0	0	0	0	8	71	4	80	0	0
DM90	2/11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM91	11/11	4	2	9	180	16	165	1	5	0	0	0	0	3	20	0	0	12	140
DM92	17/11	1	1	4	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM93	25/11	5	2	11	280	2	21	2	21	0	0	0	0	0	0	0	0	0	0
DM94	30/11	1	1	5	100	5	76	3	52	1	15	0	0	1	9	0	0	0	0
DM95	1/12	1	1	4	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM96	8/12	2	1	11	220	27	357	19	201	8	156	0	0	0	0	0	0	0	0

TABLE 2

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VERTICAL LONGLINE CATCH SUMMARY

TONGA LONGLINE PROJECT

AUGUST 1992 - JULY 1994

TRIP		SEA	FISH	NO.	NO.	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
NO	DATE	DAYS	DAYS	SETS	HOOKS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
DM97	9/12	1	1	9	180	31	267	25	180	2	45	0	0	4	42	0	0	0	0
DM98	17/12	1	1	7	140	10	126	6	28	1	18	0	0	0	0	0	0	3	80
DM99	23/12	1	1	4	80	3	98	2	68	0	0	0	0	0	0	0	0	1	30
DM100	24/12	1	1	7	140	7	122	3	40	3	62	0	0	0	0	0	0	1	20
DM101	28/12	1	1	8	160	8	61	6	25	2	36	0	0	0	0	0	0	0	0
DM102	29/12	1	1	8	160	14	77	13	57	1	20	0	0	0	0	0	0	0	0
DM103	30/12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM104	3/1	1	1	2	40	2	59	1	40	1	19	0	0	0	0	0	0	0	0
DM105	4/1	1	1	3	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DM106	6/1	2	1	2	40	2	24	1	4	1	20	0	0	0	0	0	0	0	0
DM107	12/1	2	1	9	180	10	88	8	54	2	34	0	0	0	0	0	0	0	0
TOTAL		159	89	432	8390	547	8868	267	3975	112	2181	4	69	116	816	9	227	39	1600
AVE/FISHDAY				4.85	94.3	6.15	99.6	3	44.7	1.26	24.5	0.04	0.78	1.3	9.17	0.1	2.55	0.44	18
CPHH						6.52		3.18		1.33		0.05		1.38		0.11		0.46	

TABLE 2

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VERTICAL LONGLINE CATCH SUMMARY

TONGA LONGLINE PROJECT

AUGUST 1992 - JULY 1994

TRIP NO	DATE	SEA DAYS	FISH DAYS	NO. SETS	NO. HOOKS	TOTAL CATCH #	TOTAL CATCH WT	YELLOWFIN #	YELLOWFIN WT	ALBACORE #	ALBACORE WT	BIGEYE #	BIGEYE WT	MAHIMAHI #	MAHIMAHI WT	OTH MARK #	OTH MARK WT	UNMARKET #	UNMARKET WT
SEINI KOULA VERTICAL LONGLINE																			
SK3	18/2	3	2	2	30	9	93	6	34	3	59	0	0	0	0	0	0	0	0
SK4	15/2	2	2	6	90	4	71	2	13	1	18	0	0	0	0	0	0	1	40
SK5	22/2	3	1	4	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SK6	2/3	2	2	2	20	1	20	0	0	0	0	0	0	0	0	0	0	1	20
SK8	23/3	1	1	5	100	18	156	16	129	1	21	0	0	1	6	0	0	0	0
SK9	7/4	1	1	5	66	2	11	1	7	0	0	0	0	0	0	1	4	0	0
SK10	19/4	3	1	6	120	10	171	5	95	0	0	0	0	3	16	0	0	2	60
SK12	20/5	3	1	1	20	1	14	1	14	0	0	0	0	0	0	0	0	0	0
SK13	9/6	1	1	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SK14	10/6	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SK19	21/6	4	1	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		24	14	33	526	45	536	31	292	5	98	0	0	4	22	1	4	4	120
AVE/FISHDAY				2.36	37.6	3.21	38.3	2.21	20.9	0.36	7	0	0	0.29	1.57	0.07	0.29	0.29	8.57
CPHH						8.56		5.89		0.95		0		0.76		0.19		0.76	
ALL VERTICAL LONGLINE TRIALS																			
TOTAL		183	103	465	8916	592	9404	298	4267	117	2279	4	69	120	838	10	231	43	1720
AVE/FISHDAY				4.51	86.6	5.75	91.3	2.89	41.4	1.14	22.1	0.04	0.67	1.17	8.14	0.1	2.24	0.42	16.7
CPHH						6.64		3.34		1.31		0.04		1.35		0.11		0.48	

The total catch from 8390 vertical longline hooks was 547 fish (8868 kgs), giving an overall hook rate of 6.52%. The average catch per day was 99 kgs, of which 82 kgs were marketable. The number of marketable fish was 508 (93%), and 383 (70%) of these were tunas. In terms of weight, 7268 kg (82%) of the catch were marketable species, including 6225 kg (70%) of tuna. The catch of *sashimi* species (yellowfin and bigeye) was 271 pieces weighing 4044 kgs. However, only three of the tuna were of desirable export size; i.e., over 40 kgs. Thus, virtually all of the marketable catch was sold within Tonga.

Because the tuna generally disappeared from the FADs after February, the *Seini Koula* made only eleven trips on which vertical longlines were set (Table 2). The total of *Seini Koula's* vertical longline catch was 536 kgs, with an average catch of a paltry 38 kgs per day (only 30 kgs per day of marketable species).

4.1.3.2 Horizontal Longline

4.1.3.2.1 8 KM Line

The *Ekiaki* conducted tests of the 8 km monofilament longline system on 34 trips during the nine month period of mid-March to mid-December 1993 (Table 3). The vessel spent 85 days at sea, including 50 fishing days. The remaining days were running days. *Ekiaki* set the small-scale horizontal longline 50 times, 25 sets in the open ocean and 25 sets around Capricorn Seamount. A total of 12,870 hooks were deployed, an average of 257 per set. In the early trials, sets were made at different times of day and night. The pattern that emerged was that night-time sets were more productive than daytime, but large numbers of unmarketable fish (sharks and oilfish) were caught if the set was made before 3 AM.

The total catch from all the 8 km horizontal longline sets was 1367 fish weighing 41,444 kgs. The catch of marketable species was 987 pieces weighing 21,919 kgs (72% by number, 53% by weight). The tuna catch was 921 pieces weighing 20,044 kgs (67% by number, 48% by weight). Approximately one broadbill swordfish was caught per set. The overall catch rate was 10.6%, but the catch rates between open ocean and seamount were significantly different.

The catch rates for the 25 open ocean sets averaged 5.2%, but the catch of marketable species was only 2.6 per hundred hooks. The tuna catch rate was 1.93%, primarily albacore.

The total catch rate for 25 seamount sets (Table 4) was 16.4%, with catch rates of 13.1% for marketable species and 12.7% for tuna species. Bigeye tuna (38% by number) and yellowfin (32% by number) dominated the catch, especially after the time

TABLE 3

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EKIAKI HORIZONTAL LONGLINE SUMMARY

TONGA LONGLINE PROJECT

MARCH 1993 - JULY 1994

TRIP NO	DATE	SEA DAYS	FISH DAYS	NO. SETS	NO. HOOKS	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
						#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
8 KM LINE																			
E1	16/3	1	1	1	50	3	39	0	0	2	27	0	0	1	12	0	0	0	0
E2	18/3	1	1	1	130	3	50	0	0	0	0	0	0	2	14	1	36	0	0
E3	24/3	1	1	1	200	5	103	2	33	0	0	0	0	1	12	2	58	0	0
E4	25/3	1	1	1	120	3	28	0	0	0	0	0	0	1	19	0	0	2	9
E5	26/3	1	1	1	250	1	20	0	0	1	20	0	0	0	0	0	0	0	0
E6	31/3	3	2	2	600	26	510	2	35	3	67	0	0	0	0	2	18	19	390
E7	22/4	4	1	1	300	19	637	0	0	0	0	0	0	0	0	0	0	19	637
E8	11/6	5	3	3	900	93	2327	2	8	3	53	10	456	0	0	1	20	77	1790
E9	17/6	4	1	1	300	31	462	2	25	3	55	0	0	0	0	1	25	25	357
E10	24/6	1	1	1	280	7	169	5	54	0	0	0	0	0	0	0	0	2	115
E11	1/7	4	2	2	680	76	2699	11	200	3	58	15	481	0	0	0	0	47	1960
E12	8/7	2	1	1	360	56	2881	0	0	1	22	0	0	0	0	1	59	54	2800
E13	21/7	1	1	1	280	22	675	6	222	12	162	0	0	0	0	2	91	2	200
E14	[illegible]	1	1	1	400	12	745	2	80	4	102	0	0	0	0	1	63	5	500
E15	27/7	1	1	1	400	22	1568	2	11	5	114	0	0	0	0	0	0	15	1443
E16	29/7	1	1	1	400	27	1374	8	127	6	124	0	0	0	0	3	123	10	1000
E17	4/8	3	1	1	400	60	1831	13	215	18	257	27	1059	0	0	0	0	2	300
E18	11/8	1	1	1	300	9	228	0	0	5	103	0	0	2	25	2	100	0	0
E19	13/8	1	1	1	300	23	515	8	136	9	110	0	0	0	0	4	119	2	150
E20	17/8	1	1	1	240	12	693	3	70	6	123	0	0	0	0	0	0	3	500
E21	21/8	3	2	2	480	14	247	2	22	2	45	0	0	4	55	4	111	2	14
E22	2/9	4	2	2	480	73	2202	37	684	5	87	18	491	4	40	2	100	7	800
E23	9/9	4	2	2	480	94	2438	41	690	19	355	20	576	0	0	3	172	11	645
E24	17/9	1	1	1	240	13	1207	1	45	3	67	0	0	0	0	2	75	7	1020
E25	23/9	4	2	2	480	107	3009	42	776	3	62	35	988	2	20	2	78	23	1085
E26	29/9	3	1	1	240	48	1874	25	451	2	44	11	479	0	0	0	0	10	900
E27	6/10	2	2	2	540	20	613	3	123	12	235	0	0	1	10	2	45	2	200

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TABLE 3

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EKIAKI HORIZONTAL LONGLINE SUMMARY

TONGA LONGLINE PROJECT

MARCH 1993 - JULY 1994

TRIP		SEA	FISH	NO.	NO.	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
NO	DATE	DAYS	DAYS	SETS	HOOKS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
E28	14/10	4	2	2	480	33	1000	15	298	4	81	7	232	2	22	2	57	3	310
E29	28/10	4	2	2	480	87	2030	42	635	3	64	28	512	0	0	1	19	13	800
E30	11/11	5	3	3	520	134	3019	34	642	7	136	84	1571	2	20	0	0	7	650
E31	18/11	2	2	2	480	18	817	0	0	8	160	0	0	1	7	4	200	5	450
E32	25/11	4	2	2	400	31	880	17	325	3	62	9	293	0	0	0	0	2	200
E33	2/12	4	2	2	480	147	3257	36	602	4	90	106	2515	0	0	1	50	0	0
E34	10/12	3	1	1	200	38	1297	16	266	1	19	17	712	0	0	0	0	4	300
TOTAL		85	50	50	12870	1367	41444	377	6775	157	2904	387	10365	23	256	43	1619	380	19525
AVE/FISHDAY				1	257.4	27.3	828.9	7.54	136	3.14	58.1	7.74	207.3	0.46	5.12	0.86	32.4	7.6	390.5
CPHH						10.6		2.93		1.22		3.01		0.18		0.33		2.95	

TABLE 3

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EKIAKI HORIZONTAL LONGLINE SUMMARY

TONGA LONGLINE PROJECT

MARCH 1993 - JULY 1994

TRIP		SEA	FISH	NO.	NO.	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
NO	DATE	DAYS	DAYS	SETS	HOOKS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
32 KM LINE																			
E35	22/3	1	1	1	300	2	62	0	0	0	0	0	0	0	0	1	50	1	12
E36	24/3	1	1	1	400	14	1101	2	61	2	38	0	0	0	0	3	72	7	930
E37	30/3	2	2	2	800	9	632	2	102	4	80	0	0	0	0	0	0	3	450
E38	6/4	2	2	2	750	25	1179	14	293	2	43	4	135	0	0	2	108	3	600
E39	13/4	3	2	2	750	25	1157	5	115	7	175	5	114	0	0	1	53	7	700
E40	19/4	3	2	2	1200	32	2352	1	22	10	201	1	59	1	14	1	56	18	2000
E41	9/5	4	2	2	1600	86	1648	20	226	5	92	40	455	0	0	2	325	19	550
E42	17/5	3	2	2	1000	9	335	2	44	1	20	0	0	1	15	1	56	4	200
E43	25/5	1	0	0	0	SET	BAD												
E44	26/5	3	2	2	1200	30	821	0	0	21	421	0	0	0	0	0	0	9	400
E45	31/5	4	2	2	1400	35	689	1	14	27	502	1	58	0	0	0	0	6	115
E46	6/6	4	3	3	1900	36	830	2	56	27	497	3	112	0	0	0	0	4	165
E47	13/6	5	3	3	1800	56	1342	11	228	15	284	2	140	0	0	5	320	23	370
E48	29/6	4	2	2	1500	20	587	4	100	3	55	1	30	1	13	8	339	3	50
E49	12/7	5	3	3	2100	65	1150	27	421	1	20	12	212	1	3	24	494	0	0
TOTAL		45	29	29	16700	444	13885	91	1682	125	2428	69	1315	4	45	48	1873	107	6542
AVE/FISHDAY				1	575.9	15.3	478.8	3.14	58	4.31	83.7	2.38	45.34	0.14	1.55	1.66	64.6	3.69	225.6
CPHH						2.66		0.54		0.75		0.41		0.02		0.29		0.64	

ALL HORIZONTAL LONGLINE SETS																			
TOTAL		130	79	79	29570	1811	55329	468	8457	282	5332	456	11680	27	301	91	3492	487	26067
AVE/FISHDAY				1	374.3	22.9	700.4	5.92	107	3.57	67.5	5.77	147.8	0.34	3.81	1.15	44.2	6.16	330
CPHH						6.12		1.58		0.95		1.54		0.09		0.31		1.65	

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TABLE 4

EKIAKI HORIZONTAL LONGLINE SUMMARY

CAPRICORN SEAMOUNT

MARCH 1993 - JULY 1994

TRIP		SEA	FISH	NO.	NO.	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
NO	DATE	DAYS	DAYS	SETS	HOOKS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
8 KM LINE																			
E8	11/6	5	3	3	900	93	2327	2	8	3	53	10	456	0	0	1	20	77	1790
E11	1/7	4	2	2	680	76	2699	11	200	3	58	15	481	0	0	0	0	47	1960
E17	4/8	3	1	1	400	60	1831	13	215	18	257	27	1059	0	0	0	0	2	300
E22	2/9	4	2	2	480	73	2202	37	684	5	87	18	491	4	40	2	100	7	800
E23	9/9	4	2	2	480	94	2438	41	690	19	355	20	576	0	0	3	172	11	645
E25	23/9	4	2	2	480	107	3009	42	776	3	62	35	988	2	20	2	78	23	1085
E26	29/9	3	1	1	240	48	1874	25	451	2	44	11	479	0	0	0	0	10	900
E28	14/10	4	2	2	480	33	1000	15	298	4	81	7	232	2	22	2	57	3	310
E29	28/10	4	2	2	480	87	2030	42	635	3	64	28	512	0	0	1	19	13	800
E30	11/11	5	3	3	520	134	3019	34	642	7	136	84	1571	2	20	0	0	7	650
E32	25/11	4	2	2	400	31	880	17	325	3	62	9	293	0	0	0	0	2	200
E33	2/12	4	2	2	480	147	3257	36	602	4	90	106	2515	0	0	1	50	0	0
E34	10/12	3	1	1	200	38	1297	16	266	1	19	17	712	0	0	0	0	4	300
TOTAL		51	25	25	6220	1021	27863	331	5792	75	1368	387	10365	10	102	12	496	206	9740
AVE/FISHDAY				1	249	40.8	1115	13.2	232	3	54.7	15.5	414.6	0.4	4.08	0.48	19.8	8.24	390
CPHH						16.4		5.32		1.21		6.22		0.16		0.19		3.31	
32 KM LINE																			
E41	9/5	4	2	2	1600	86	1648	20	226	5	92	40	455	0	0	2	325	19	550
E49	12/7	5	3	3	2100	65	1150	27	421	1	20	12	212	1	3	24	494	0	0
TOTAL		9	5	5	3700	151	2798	47	647	6	112	52	667	1	3	26	819	19	550
AVE/FISHDAY				1	740	30.2	559.6	9.4	129	1.2	22.4	10.4	133.4	0.2	0.6	5.2	164	3.8	110
CPHH						4.08		1.27		0.16		1.41		0.03		0.7		0.51	

of setting was modified to reduce incidental catch. The average tuna catch per fishing day was 701 kg, including 415 kg of bigeye and 232 kg of yellowfin.

The average size of yellowfin tuna caught with horizontal longline was larger than those caught on vertical longline, with the number of export-size fish being considerably higher. The bigeye tuna from the seamount averaged 27 kg, with about 30% of export size.

4.1.3.2.2 32 KM Line

Tests of the 32 km monofilament longline system were made during 15 trips of the *Ekiaki* in March-July 1994 (Table 3). A total of 29 sets were made during 45 sea days resulting in a total catch of 444 fish weighing 13,885 kgs. The average catch rate for all sets was 2.66 fish per hundred hooks, but the two trips to Capricorn Seamount resulted in a hook rate of 4.08%. The composition of the catch was 7343 kgs (53%) marketable fish, and 5425 kgs of tuna (39%). The average tuna catch per day was 187 kg from the open ocean and 285 kg from Capricorn Seamount.

4.1.3.2.3 Comparison with Regional Longline Fisheries

The validity of the horizontal longline trials can be indirectly ascertained by comparing project catches with those of other longline fisheries in the region. Table 5 is derived from the SPC Regional Tuna Bulletin, Fourth Quarter, 1993. Only marketable fish are included in the comparison.

The project catch rates with both the 8 km and 32 km lines compared favorably to catches made by established commercial fleets. The 8 km system was comparable when fished in the open ocean. However, when fished on Capricorn Seamount, the 8 km line provided remarkable catch rates, four time higher than most other fleets. Further, the catch rates for the higher value bigeye and yellowfin tunas were substantially greater than those of other fleets.

4.1.3.2.4 Handline Trials

Tests of the Hawaiian handline techniques were limited, but productive (Tables 6, 7). Only 14 days of daytime trials were conducted, using three lines for a total of 27.5 hours. All trials were around FADs. The catch was 56 fish weighing 947 kg, including 807 kg of marketable species. The catch consisted of mostly yellowfin, with a few albacore and one large bigeye. The average catch was 68 kg/day, with a marketable catch of 58 kg per day.

TABLE 5 1993 REGIONAL LONGLINE CATCH RATES (# OF FISH/HUNDRED HOOKS)

	TONGA PROJECT 8 KM REEL		TONGA PROJECT 32 KM REEL		OTHER FLEETS									
SPECIES	SEAMOUNT	OPEN SEA	SEAMOUNT	OPEN SEA	TONGA	AUST	CHINA	FSM	FIJI	JAPAN	KOREA	N. CA	TAI	US
ALBACORE	1.21	1.23	0.16	0.92	1.92	1.18	0	0	0.77	1.84	0.05	1.99	2.7	0
BIGEYE	6.22	0	1.41	0.13	0.05	0.03	0.41	0.18	0.21	0.07	0.57	0.05	0.02	0.23
YELLOWFIN	5.32	0.69	1.27	0.33	0.37	1.94	0.38	0.36	0.32	0.55	0.52	0.75	0.1	0.47
OTHER	0.35	0.67	0.73	0.19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL	13.1	2.59	3.57	1.57	2.48	4.16	0.95	0.61	1.82	3.44	1.23	3.08	2.85	1.08

TABLE 6

DAYTIME HANDLINE SUMMARY

TONGA LONGLINE PROJECT

MARCH 1993 - JULY 1994

TRIP		FISH	NO.	NO.	LINE	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
NO	DATE	DAYS	LINES	HOURS	HOURS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
DAYTIME																			
A1	1/9	1	3	4	12	19	417	17	380	2	37	0	0	0	0	0	0	0	0
A3	8/9	1	3	5	15	8	52	0	0	0	0	0	0	7	47	1	5	0	0
SK1	2/2	1	4	6	24	3	52	2	12	0	0	0	0	0	0	0	0	1	40
SK2	3/2	1	3	3	9	7	163	4	80	0	0	1	63	2	20	0	0	0	0
SK3	8/2	3	3	3	9	8	118	7	58	0	0	0	0	0	0	0	0	1	60
SK4	15/2	2	3	1	3	2	46	2	46	0	0	0	0	0	0	0	0	0	0
SK6	2/3	1	2	0.5	1	1	4	1	4	0	0	0	0	0	0	0	0	0	0
SK8	23/3	1	2	1	2	6	76	4	36	0	0	0	0	0	0	0	0	2	40
SK10	19/4	1	3	2.5	7.5	2	19	2	19	0	0	0	0	0	0	0	0	0	0
SK15	13/6	1	3	0.5	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SK17	16/6	1	3	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		14	32	27.5	87	56	947	39	635	2	37	1	63	9	67	1	5	4	140
AVE/FISHDAY			2.29	1.96	6.21	4	67.6	2.79	45.4	0.14	2.64	0.07	4.5	0.64	4.79	0.07	0.36	0.29	10
CPLH						0.64	10.9	0.45	7.3	0.02	0.43	0.01	0.72	0.1	0.77	0.01	0.06	0.05	1.61

TABLE 7

NIGHT-TIME HANDLINE SUMMARY

TONGA LONGLINE PROJECT

MARCH 1993 - JULY 1994

TRIP		FISH	NO.	NO.	LINE	TOTAL CATCH		YELLOWFIN		ALBACORE		BIGEYE		MAHIMAHI		OTH MARK		UNMARKET	
NO	DATE	DAYS	LINES	HOURS	HOURS	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT	#	WT
CAPRICORN SEAMOUNT																			
E25	22/9	1	6	1	6	74	981	0	0	0	0	74	981	0	0	0	0	0	0
E28	11/10	1	6	0.5	3	47	739	2	40	0	0	45	699	0	0	0	0	0	0
E29	26/10	1	6	0.5	3	30	493	0	0	0	0	30	493	0	0	0	0	0	0
E30	9/11	1	6	0.5	3	22	411	0	0	0	0	22	411	0	0	0	0	0	0
E33	30/11	1	6	1.5	9	122	1726	0	0	0	0	122	1726	0	0	0	0	0	0
E34	9/12	1	6	1.5	9	85	1540	0	0	0	0	85	1540	0	0	0	0	0	0
E41	9/5	1	6	1.5	9	74	1171	22	370	0	0	52	801	0	0	0	0	0	0
TOTAL		7	42	7	42	454	7061	24	410	0	0	430	6651	0	0	0	0	0	0
AVE/FISHDAY			6	1	6	64.9	1009	3.43	58.6	0	0	61.4	950	0	0	0	0	0	0
CPLH						10.8	168	0.57	9.76	0	0	10.2	158	0	0	0	0	0	0
VAVA'U AREA																			
A2	4/9	1	3	4	12	21	362	19	349	0	0	0	0	2	13	0	0	0	0
SK11	12/5	1	3	12	36	7	102	6	52	0	0	0	0	0	0	0	0	1	50
SK17	16/6	1	3	12	36	20	248	19	178	0	0	0	0	0	0	0	0	1	70
SK18	17/6	1	3	12	36	6	78	5	56	0	0	0	0	0	0	1	22	0	0
SK20	29/6	1	3	12	36	7	141	5	58	0	0	0	0	0	0	0	0	2	83
SK21	30/6	1	3	12	36	10	84	6	59	0	0	0	0	2	15	1	5	1	5
SK22	11/7	2	3	18	54	11	159	10	122	0	0	0	0	0	0	1	37	0	0
SK23	14/7	1	3	12	36	3	24	2	19	0	0	0	0	0	0	0	0	1	5
TOTAL		9	24	94	282	85	1198	72	893	0	0	0	0	4	28	3	64	6	213
AVE/FISHDAY			2.67	10.4	31.3	9.44	133	8	99.2	0	0	0	0	0.44	3.11	0.33	7.11	0.67	23.7
CPLH						0.3	4.25	0.26	3.17	0	0	0	0	0.01	0.1	0.01	0.23	0.02	0.76

Night time hand-lining (the Hawaiian "ika shibi" technique) gave promising results, particularly for longer range vessels. Trials were conducted in the open ocean close to Vava'u, around FADs, and at Capricorn Seamount.

The small boat trials around Vava'u produced an average catch of 133 kgs per night, of which 110 kgs were marketable. It should be noted that the bulk of these trials were conducted during the tuna "off-season" when virtually no surface schools were seen in the daytime. Only one trial was made next to a FAD, and this produced 362 kgs in four hours.

Seven "ika shibi" trials were conducted at Capricorn Seamount in conjunction with longline sets and all produced promising results. Typically, the vessel was put on sea anchor at the conclusion of setting the longline (about 4 A.M.). With the underwater light in place and chum dispersed, fishing commenced with six lines. The catch for 7 hours (approximately one hour per trial) was 7,061 kgs, almost all of which was bigeye tuna. The overall catch rate was 168 kgs per line hour, or 1009 kgs per night. Fishing effort was limited by ice and hold space.

4.2 Market Trials

This section describes the composition of tuna catches and exports during PIMAR/Tonga fishing trials. Thirty-four shipments of fish were made during 1993 to overseas destinations including Australia, Hawaii, Japan and New Zealand. A total of 271 fish with a headed and gutted weight of 7,840 kg were exported in 1993, with an additional 500 kg (two shipments) exported in 1994 through a local firm.

4.2.1 Species Composition

Bigeye tuna comprised about three-quarters of the catches and exports during 1993 fishing trials. Yellowfin tuna accounted for most of the remainder. A few albacore were also exported. Bigeye tuna is preferred over the other two species in the *sashimi* market, so the species composition was favorable for export.

Bigeye tuna have also predominated in tuna catches made by a private longline vessel fishing the same seamount areas as the PIMAR/Tonga project since December 1993. Available information suggests year-round availability of this valuable species.

4.2.2 Size Composition

Small fish predominated in the catches made by "vertical" longline and handline gear in nearshore waters and around fish aggregation devices, within 50 nautical miles of Vava'u. Only horizontal longline and handline fishing on offshore seamounts produced a significant catch of exportable fish (>18kg). Typically, about 25% of the seamount catch was of prime export size (>27kg), 25% was of acceptable export size (18-27 kg), and 50% was too small for export (except to low value specialty markets). A private longline vessel fishing the same seamount areas since December 1993 has had similar results: about 28% of the fish have been larger than 27 kg; 17% between 18-27 kg; and 55% smaller than 18 kg.

4.2.3 Grade Composition

The quality of each tuna entering the *sashimi* market is evaluated by "grading" the flesh. This qualitative assessment, usually made at every level of tuna distribution, is directly linked to pricing and to consumer satisfaction. During the PIMAR/Tonga export trials, fish were graded according to the Hawaii scales of 1 through 4, where 1 is prime *sashimi*, 2 is acceptable *sashimi*, 3 is marginal for *sashimi*, and 4 is unacceptable for *sashimi* but satisfactory for cooking.

Tuna grading during the marketing trials was limited to fish exported to *sashimi* markets in Hawaii and Japan. Australia and New Zealand tuna buyers do not usually grade tuna, so reports on grade composition were not available for shipments to these latter destinations. Tuna grades were determined in three ways: (a) inspection of fish by the PIMAR/Tonga Marketing Consultant after arrival in Hawaii; (b) inspection of fish by the PIMAR/Tonga Marketing Consultant in Vava'u prior to export; or (c) inferral from reports by Japanese marketers.

About 3,150 kg of tuna were graded. Of this fish, 24% were considered prime (grade 1, and grade 2+) *sashimi*, 46% were considered acceptable 18% were unacceptable for *sashimi* but suitable for cooking.

4.2.4 Marketing Alternatives

Frozen *sashimi*-grade tuna can bring high prices in Japan but the technical difficulties and investment required to produce acceptable quality are beyond the capabilities of small-scale longline fleets. Not only do harvester vessels need special and costly refrigeration systems to produce frozen *sashimi* tuna but so do all carrier vessels and shoreside cold stores throughout the distribution chain.

The primary buyers of conventionally-frozen tuna are canners, who pay low prices for all species except albacore (US$2.00/kg or more). Albacore tuna fishing grounds in the vicinity of Tonga are south of Tongatapu and this species is only caught in the Vava'u-based longline fishery.

The PIMAR/Tonga tuna project has emphasized fresh tuna markets because of the relative ease of product handling and the potential for higher prices for fresh bigeye and yellowfin tuna (the primary catch). This is compared to conventionally-frozen products. There are major distinctions between fresh tuna marketed for use as *sashimi* (raw fish) and for use in cooking. The primary use of tuna in Tonga, Australia, and New Zealand is for cooking, whereas the primary use of tuna in Hawaii and Japan is for raw fish preparations. Marketing trials were conducted in each of the five locations to determine purchasing standards and preferences.

4.2.4.1 Tonga

There are few species preferences in local fish markets in Vava'u and Nuku'alofa. Tuna is substituted with many other fish and, like most other species, can usually be sold for US$1.70/kg - $2.00/kg, unless the market is flooded by large landings. No *sashimi* market has developed in Tonga and purchasing standards are flexible. Local markets are the most convenient and least demanding outlets for catches of small, lower-grade tuna. Whenever there are large church conventions or other gatherings requiring feasts (pola), the demand for fish is much higher than normal. At other times, however, demand is readily satisfied and local markets can be flooded by an oversupply of fish.

4.2.4.2 Australia

Australia lacks a well-developed *sashimi* tuna market and most of the demand for tuna is for cooking use. About 20% of the fish weight exported during PIMAR/Tonga marketing trials was shipped to an Australian buyer. Market prices averaged about US$5.00/kg. The buyer indicated that the Australian market does not consider flesh color and fat content to be important but that freshness is paramount. Australian tuna fishermen make an effort to deliver fish to market no later than 3-5 days from capture, with an outside limit of 7 days. Best suited for this market are Grade 3 tuna between 15-30 kg. However, the requirement of delivering tuna within 7 days of capture is a virtual impossibility with the present ferry and plane schedules in Tonga.

4.2.4.3 New Zealand

The primary demand for tuna in New Zealand is for cooking. About 8% of the fish weight exported during marketing trials was shipped to a New Zealand fish processor. The average price was US$4.18/kg, lower than in any other overseas market, but costs were also much lower. The product was steaked but no reports of the grade were available, presumably because of unfamiliarity with the *sashimi* tuna grading scales. Best suited for this market are small, Grade 3 tuna.

4.2.4.4 Hawaii

About two-thirds of the tuna weight exported during marketing trials was shipped to Hawaii. Prices for "normal" shipments ranged from US$6.38/kg to US$7.70/kg, while two substandard shipments sold for as low as US$2.60/kg -- barely enough to cover handling and shipping expenses.

Hawaii is both a final market destination for fresh tuna exports and a gateway to continental U.S. tuna markets. Hawaii residents utilize tuna mainly for raw fish preparations, but restaurants use tuna both for *sashimi* and for cooking. Fresh tuna is a staple in every segment of Hawaii's seafood industry, from wholesale to retail. Seafood companies who export seek mainly 2 tuna for trans-shipment to the continental U.S. Retailers, who loin tuna for household consumption and processors who loin tuna for restaurant use require a full range of grades from 1 to 3. Wholesalers have a strong preference for fish over 27 kg (headed and gutted), but tuna between 18-27 kg are acceptable to restaurant fish processors and retailers.

In the continental U.S., fresh tuna is primarily a restaurant, rather than a household, food item. Restaurants serving raw or rare fish entree's purchase higher grades of tuna, whereas those who grill seafood purchase lower grades of tuna. There is a strong preference for tuna over 27 kg (headed and gutted) and smaller fish have to be sold at greatly discounted prices.

4.2.4.5 Japan

About 6% of the tuna weight exported during marketing trials was sent to Japanese markets. The average price received was US$8.88/kg, with a top price of nearly US$16/kg for one high-fat bigeye tuna. Shipments to Japan during the PIMAR/Tonga marketing trials were through New Zealand. Freight, packing costs and sales commissions for the small quantities of fish shipped were so high that there was little return after deducting these expenses.

Considerable savings in air freight to Japan are possible by trans-shipping through Hawaii, with a freight cost of approximately US$3.50/kg for medium to large shipments. Further, fish to be marketed in Japan should be consigned to specialty tuna importers, which customarily charge no more than a 5% sales commission.

There is considerable market segmentation in Japan's *sashimi* tuna buying patterns. The upscale end of the *sashimi* market places a premium on the fat content of tuna. Fat in tuna flesh is a natural phenomenon related to water temperature of the fish habitat and diet. These factors are not under the control of fishermen and are unaffected by fish handling.

Few of the tuna exported during 1993 PIMAR/Tonga marketing trials contained high fat. Bigeye tuna taken in April-May 1994 by a private longline vessel fishing at the same offshore seamounts contained moderate to high fat. Apparently, there is a seasonal fluctuation in tuna fat content offshore of Vava'u.

The Japanese tuna market has greater breadth than many imagine and preferences for fresh tuna products vary considerably with geographic location, degree of urbanization

and income. In Tokyo, for example, bigeye tuna with high fat content (i.e., visible marbled fat) is appreciated, but lean tropical yellowfin tuna is not. By contrast, in southern Japan, yellowfin tuna is more appreciated than bigeye. The majority of bigeye is used for restaurant *"sashimi"*, whereas the majority of yellowfin is used for household *"sashimi"*. Tuna over 25 kg are strongly preferred in Japan.

4.2.4.6 Value-added tuna products

4.2.4.6.1 Tuna loins

The PIMAR/Tonga marketing trials focused on export of headed and gutted tuna. The next level of processing (after deheading and evisceration) is quartering of tuna into loins. There are major distinctions between tuna loins marketed for use as *sashimi* and for use as processed products.

Frozen loin production for the *sashimi* market is more demanding and more expensive than chilled loin production. Freezing requires more labor and power, as well as more costly shoreside infrastructure. It is far more economical to produce chilled loins than frozen loins for the Japanese *sashimi* markets, especially when working with low-fat tropical yellowfin tuna. Chilled yellowfin loins processed in the Philippines are exported directly to supermarket chains in Japan. Channels to this market cannot be opened without much larger scale and more consistent production of tuna than is possible in the Vava'u longline fishery.

It is also unrealistic to expect that frozen loins could be processed in Vava'u for the *"sashimi"* market. To maintain red flesh color, the freezing of tuna needs to be rapid and deep. The temperature of the center of the tuna should be reduced to -30 C to -40 C within 4 hours of loining and should be maintained below -55 C throughout storage and transportation. Any lapse in the holding temperature above -55 C will cause undesirable color changes in the flesh. Only the largest tuna processors in Japan go to the trouble and expense of deep freezing tuna from harvest to final distribution.

Processing of frozen yellowfin and bigeye tuna loins for canning or steaking is less demanding but would be uneconomical in Vava'u, PIMAR/Tonga marketing trials. Approximately 900 kg of small and medium yellowfin and bigeye tuna were quartered into loins, blast frozen, glazed (to prevent oxidation and weight loss) and stored in holding freezers. Metal freezer trays were used to maintain the shape of loins so they did not twist. The procedures generally followed those employed in the Seattle Seafoods' tuna loining operation based in Bali, Indonesia.

The loins retained *sashimi* quality for up to three weeks in freezer storage but then deteriorated to steak quality. It was determined that better longevity could be attained with more expensive packing materials and lower holding temperatures. However, the

near-term market outlook for steak-grade tuna loins is not favorable for Vava'u. The main reason for this is that the market has been established by processors in Singapore and Indonesia who are loining grade 3 fish for which the market ceiling is a relatively low US$ 3.85/kg (c.i.f.U.S. west coast). It is estimated that US$7.70/kg would be necessary for loining to be economically attractive in Vava'u, where onshore freezing costs are on the order of US$1.00/kg. Furthermore, the infrequency of container ships serving Vava'u (one per month) and the need to ship to another Pacific port mean that loins would probably be at least two months in storage and transit before reaching market. The market would have to improve before an investment in better holding freezers is warranted.

4.2.4.6.2 Tuna jerky

Dried tuna jerky products are being processed in Hawaii, Guam and Kiribati. The cost of production is on the order of US$17/kg. Marketing has been aimed at duty-free stores and upscale food distributors. This type of manufacturing is labor intensive and Tonga, with low labor costs, could possibly compete in the tuna jerky market if finished products could be shipped to distributors by sea freight and if processing skills and facilities were upgraded to manufacture uniform high-quality products.

4.2.5 Evaluation of Fish Handling Procedures

Proper handling of fresh tuna from the time of capture through marketing is essential to maintain high quality and maximize market value. Various organizations have published guidelines and handbooks implying that standardized rules should be rigidly applied in handling fresh tuna. In reality, no two situations are exactly alike and there are always trade-offs between what is theoretically beneficial and what is practical on fishing vessels. The development of workable tuna fishing and handling systems usually involves a large measure of trial-and-error and the Vava'u project was no exception. Furthermore, tuna handling technology continues to evolve and improve. For example, the use of an ice-seawater slurry for rapid chilling, once believed to be a critical element of proper tuna handling, has been discontinued by the long-range Japanese *"sashimi"* longline fleet in favor of pressurized bleeding with sea water pumped through tuna arteries.

The immediate priorities after capturing tuna are rapid chilling and thorough bleeding of the fish, while the primary objective is to capture. According to Japanese technicians, the first 30 minutes to one hour on deck is the most critical period. If body temperature remains above 26 C for more than one hour after capture, there is a greatly increased risk of flesh deterioration.

In PIMAR/Tonga horizontal longline trials, all export-size tuna were bled, gilled, gutted, and submerged in ice as soon as possible. Fishermen were trained to handle fish gently, without throwing or dragging by the tail. A cushioned cradle was installed on the fishing vessel to hold fish for evisceration.

The best method for icing tuna at sea is in a compartmentalized and refrigerated hold below the deck of the vessel. Fish can be separated and well packed in ice without chafing and bruising. The vessel used for horizontal longline experiments lacked a compartmentalized or refrigerated hold during 1993 fishing trials. Fish were subject to damage from contact with other fish, as well as contact with water from melted ice. Most of the export-size tuna were iced in deck boxes with plugs opened to drain off ice melt, rather than in the holds.

Rapid chilling of tuna catches can be enhanced by submerging the fish in an ice slurry for up to 24 hours before repacking in ice. This treatment was abandoned during the fishing trials because of vessel limitations which agitated the slurry and severely bruised the fish. Export-size tuna had to be wrapped in cheesecloth "socks" or plastic bags and packed tightly in ice to prevent damage to their bodies.

The internal temperatures of the catch were checked as the fishing vessel unloaded in Vava'u. If temperatures were above 0 C, the fish were submerged in a saltwater-ice slurry to reduce core temperatures before shipping. Due to limited air transportation from Vava'u, the 18-hour ferry ride to Nuku'alofa was the most practical means of delivering fish to Nuku'alofa for trans-shipment overseas by air freight. Fish traveled on the ferry in iced bins, with drain plugs open to remove water.

Private seafood exporters in Nuku'alofa received the tuna from the ferry and arranged overseas sales. They rechecked fish core temperatures, maintained or returned temperatures to 0 C in a saltwater-ice slurry, and completed processing by removing fish heads and cleaning up the bodies.

Fish were air shipped to overseas markets in waxed shipping cartons insulated with styrofoam or with a thermal barrier material known as "insufoil". Frozen coolant was enclosed in the boxes to shield the fish from heat transfer while in transit. The coolant consisted of dry ice, wet ice, frozen gel ice or a combination of these materials.

Core temperatures and grades of fish shipped to Hawaii were checked by the PIMAR/Tonga marketing consultant upon arrival. Core temperatures were not recorded for tuna arriving in Japan, but the buyers indicated that they were satisfactory and provided comments on fish quality and packing. Core temperatures and grades were not generally recorded for tuna arriving in Australia.

4.2.6 Evaluation of Fish Quality

A few markets for cooking-grade tuna were tested during the 1993 PIMAR/Tonga marketing trials but the *"sashimi"* tuna market was more economically attractive. Therefore, the quality of fish produced during the project was, evaluated against the standards of the *sashimi* tuna industry.

4.2.6.1 Freshness and shelf life

The freshness and shelf life of tuna exported to Hawaii during the PIMAR/Tonga marketing trials were better than average because of short fishing trips. The time between capture and marketing is compared with other longline fisheries in Table 8. The results of the trial exports were generally favorable, although three shipments were considered substandard.

Table 8. Time elapsed between capture of tuna and delivery to Hawaii market, various longline fishing fleets

Longline Fishing Fleet	Time Elapsed Between Fish Capture and Marketing (Days)
Hawaii	10-14
Federated States of Micronesia and Guam	14-21
Marshall Islands	6-8
PIMAR/Tonga	8
Tahiti	6-8

One small shipment to Australia had to be marketed at a large price discount because of a severe deterioration in freshness. The buyer observed that the Australian market is accustomed to tuna no older than 5-7 days from capture. Tuna exports from Vava'u cannot meet this timetable because of limited ferry and airline service. A large shipment to Hawaii was not iced properly on board the fishing vessel, when the crew caught an exceptional amount of fish. A second shipment to Hawaii lost quality during a five-day holding period in Vava'u when the ice facility was partially inoperable. The core temperatures of the second and third substandard shipments were noted to be above the acceptable range at the time of trans-shipment and the fish would not normally have been exported. The purpose of sending the substandard shipments was to demonstrate to the crew and exporters that proper procedures must be followed throughout the harvesting, handling, and shipping chain.

The PIMAR/Tonga Marketing Consultant viewed two shipments at the time of vessel off-loading in Vava'u and inspected all shipments to Hawaii upon arrival. Fish were in good condition at the time of offloading but lost some quality during the trans-shipment process. A primary reason for this was the poor quality of ice available in Vava'u during 1993 fishing and marketing trials. Also, sharp-edged ice caused

bruising and chafing of fish bodies during ferry transport. This problem proved to be controllable by bagging fish in cheesecloth "socks" and in plastic.

4.2.6.2 Grade

Fresh tuna entering the Hawaii *"sashimi"* market are graded accordingly to a qualitative scale: grade 1 is prime *"sashimi"*, grade 2 is acceptable for *"sashimi"*, grade 3 is marginally acceptable for *"sashimi"*, and grade 4 is unacceptable. Each tuna buyer keeps records of tuna purchases by grade of fish, but summarized statistics for the entire *"sashimi"* industry are unavailable.

Approximately 70% of the tuna exported to Hawaii during the PIMAR/Tonga marketing trials were grade 1 or 2 *sashimi* quality. This percentage compares favorably with imports from areas (Marshall Islands, Fiji) with a reputation for producing high-quality tuna.

4.2.6.3 Internal Temperature Control

Tuna landed in Vava'u by the project fishing vessels were chilled to 0 C before transport by ferry. When received in Nuku'alofa, the fish still had core temperatures of 0-2 C. This temperature was maintained until the tuna were boxed for air shipment.

Hawaii tuna buyers, as well as the U.S. Food and Drug Administration, are presently using a guideline of 7.2 C as the core temperature that should not be exceeded in tuna imports. Core temperatures of fish received in Hawaii ranged from 2.2 C to 10 C but were mostly satisfactory to marginally satisfactory. Two shipments contained fish with core temperatures higher than the guideline. Fish exported from Vava'u on Sept. 30, 1993, arrived in Hawaii with elevated core temperatures (7.8-10 C). This shipment occurred during a heat wave in Hawaii.

Another shipment of fish, exported from Vava'u on Dec. 2, 1993, arrived in Hawaii with core temperatures of 10-11.7 C. This shipment was not iced properly on-board the fishing vessel. Subsequently, fish core temperatures were noted to be above acceptable limits at the time of surface shipment. Furthermore, the exporter failed to include frozen gel packs in the shipping cartons. This shipment was treated as a training exercise, demonstrating to the fishing crew and exporters the loss of market valued from poor handling and packing of tuna exports.

4.2.7 Evaluation of Packing

The objective in packing fresh tuna for overseas export is to deliver fish with core temperatures below 7.2 C (45 F), the current guideline of Hawaii tuna importers and the U.S. Food and Drug Administration (FDA). Most of the tuna exports to Hawaii during the 1993 marketing trials arrived with temperatures between 4.4 C and 7.2 C. Fish were shipped inside standard waxed cartons insulated with pre-cut styrofoam or with thermal barrier (insufoil) material and cooled with frozen gel material. Typically, the fish weight (frozen coolant weight ratio) in a shipping carton was 12:1.

Packing of the tuna exports was generally satisfactory for all overseas markets tests. The FDA is proposing more rigorous temperature controls for U.S. imports of scombroid fish. Without improvements in shipping carton insulation and coolant to control fish temperatures while in transit, the risk of product rejection could increase for future exports to the U.S.

4.2.8 Evaluation of Transportation System

Air transportation links from Vava'u do not allow for direct shipment of chilled tuna by air freight to major market destinations overseas. The freight compartments of the small aircraft flying from Vava'u to Nuku'alofa and to American Samoa cannot accommodate large tuna boxes. It is possible to make special arrangements for chartering small aircraft but only at high cost. Therefore, for the tuna to reach overseas markets, it must be trans-shipped via Nuku'alofa. Various methods can be used to deliver fish to Nuku'alofa:

* Direct delivery by Vava'u-based harvester vessels;

* Transfer by Vava'u-based harvesters vessels to Nuku'alofa-based vessels; or

* Surface shipment via ferry boat.

All methods require double handling of the fish, with potential for loss of quality at each transfer point. The ferry is the most practical and least expensive option, especially when time lost from fishing is considered. Limited ferry service forces Vava'u-based fishing boats to adhere to the ferry schedule or risk loss of export opportunities. An additional problem associated with ferry transport is that fish iced in insulated containers are subject to bruising and chafing through contact with ice and with other fish. Damage to fish bodies while in transit was a major problem at the beginning of PIMAR/Tonga marketing trials. The only remedy was to bag fish individually in cheesecloth "socks" or in plastic before shipping. This problem has been greatly reduced with the opening of a private ice plant in Vava'u in February 1994.

4.2.9 Evaluation of Markets

Trans-shipment of fresh tuna from Vava'u to overseas markets is costly. For fish exported to Hawaii, the cost of trans-shipment, which includes ice, handling, packing materials, freight and U.S. Customs clearance, is estimated to range from US$2.50/kg (for 1,000 kg or more per shipment) to over US$3.20/kg (for 500 kg - 800 kg per shipment). To obtain a net return of at least US$2.50/kg, tuna exported from Vava'u should sell for a minimum of US$5.70/kg overseas. Only tuna that is grade 1 or 2 *sashimi* will generate sufficient sales revenue.

A critical element of tuna marketing is recognizing and rejecting lower-grade fish which are unprofitable to export. Tuna grading skills develop with years of experience and only the most rudimentary level of grading can be taught through short-term

training. Nevertheless, every opportunity was taken during the PIMAR/Tonga marketing consultancy to train government and private fisheries personnel in tuna grading techniques.

4.2.10 Evaluation of Processing Facilities

The Government of Tonga (GOT) operates fish marketing facilities in Nuku'alofa and Vava'u. Neither would meet the sanitation requirements that the U.S. FDA has proposed for overseas facilities where seafood is processed for export to the U.S. The primary shortcoming of the Nuku'alofa facility is its open-air construction and lack of insect guards. Private operators rent space at the facility for processing, marketing and freezing seafood. Fresh fish is stored in iced containers.

The GOT facility in Vava'u is enclosed but the door is not protected by insect guards. The major sanitation problem is the accumulation of dirt and mud on the floor. Fortunately, fishermen have discontinued the practice of placing fish on the floor while weighing their catches. This facility was used by the PIMAR/Tonga project but fish was always stored in iced containers and processing was done according to approved sanitary practices.

The water available for ice-making and fish processing at the Nuku'alofa and Vava'u facilities does not meet U.S. drinking water standards. Water and ice samples taken at both facilities in May 1993 were tested at a Hawaii laboratory for total and fecal coliform. Total coliform were present in the water and ice at concentrations of 4-6 coliform/100 ml. Fecal coliform were not detected, indicating that there is no contamination by sewage. The PIMAR/Tonga project used seawater exclusively for fish processing and for brining. The make-up water used by a private ice plant which opened in Vava'u in February 1994, has not been tested.

4.3 Economic Analyses of Project Results

4.3.1 Economics of Horizontal Longlining

Assessing the economic, financial, or commercial feasibility of the potential of small-scale tuna horizontal longlining in the Vava'u group is faced with several obstacles. The main problem is that the cost and revenue data derived from the tuna trials are not representative of what can be expected under truly commercial fishing and marketing conditions. The vessel employed in the fishing trials was not appropriate for small-scale horizontal longlining. The crew members were government employees rather than fishermen and they were not experienced in longlining or in fish handling for export. The ice available for preserving the fish catch was inappropriate in quality and insufficient in quantity throughout most of the project, ferry transport service from Vava'u to Nuku'alofa was limited, and the tuna export trial shipment costs were relatively high and the prices received were relatively low, as shipments were small, irregular, and infrequent and buyers were inexperienced with the source. Thus, the data generated by the project's fishing and marketing trials are, by themselves, a marginal basis for evaluating the commercial feasibility of small-scale tuna longlining in Tonga.

The initial project results were so successful at catching and exporting tuna, that several commercial operations, seeing the potential profits to be made in small-scale horizontal longlining, entered the industry and sought to exploit commercially the potential proven by the project. Fortunately, one of these operations, which began tuna fishing in January 1994 and which employed project fishing techniques, shared with us all of its catch, cost, and revenue data from its first three months of operation. The fact that commercial operators have already entered the industry shows that the project's results on the prospect of small-scale horizontal longlining in Tonga are very promising. More importantly for the economic and commercial assessment of small-scale horizontal longlining in Tonga, however, is the fact that this report can incorporate some actual commercial experience in making the assessment.

4.3.1.1 Total Sales

The total project longline catch on Capricorn Seamount was 27,863 kg, of which 65% was marketable, as compared to the total project longline catch on non-seamount areas of 9,786 kg, of which only 28% was marketable. The total project handline catch was 5,890 kg, of which, by contrast, 100% was marketable. Out of the total project catch of 41,445 kg, 27,809 kg, (67%) of the total, was marketable. Out of the 27,809 kg of marketable fish, almost 82%, or 22,738 kg was actually sold. Some of the waste was due to loss when the ice machine was malfunctioning and the project simply did not have sufficient ice to preserve the catch. In addition, probably about half of the waste of marketable fish was due to gutting and heading at the time of sale and to a portion which was shared with the crew following each fishing trial.

Table 9 summarizes the total project fish sales. A total of 8,885 kg were sold locally in Vava'u at an average price of T$2.04, for total sales revenues of T$18,108. Another 5,975 kg were (shipped to and)sold in Nuku'alofa at an average price of $2.00, for total sales revenues of T$11,924. Finally, the project exported a total of 7,879 kg at an average return (net to the project) of T$1.40 per kg, for total export revenues of T$11,034. However, these sales revenues require some explanation.

The price of tuna in Tonga is essentially determined by the tuna distribution and pricing policies of Sea Star Fishing Co. Although most of Sea Star's catch is sold to the canneries, the company now sells tuna locally when the ships are in port, and has set a ceiling of T$2.50/kg. Allowing for waste and the selling of the heads and other lower valued cuts at lower prices, the whole tuna is averaging about T$2.00/kg.

4.3 1.2 Export Trial Results

The project conducted 36 export marketing trials. However, five of these export marketing trials were either intentional trials of smaller or of lower quality tuna. Thus, the following analysis of the export marketing trial results includes only 31 of the 36 actual trials conducted.

Table 9. Total project fish sales

Fishing Trials	Longline Catch	Handline Catch	Total Catch	Total Sales		Local Sales, Vava'u [a]		Local Sales, Nuku'alofa [a]		Export Sales [b]		Export Trials
#	Kg	Kg	Kg	Kg	T$	Kg	T$	Kg	T$	Kg	T$	#
1	39	0	39	39	$71	39	$71	0	$0	0	$0	0
2	50	0	50	50	$121	50	$121	0	$0	0	$0	0
3	103	0	103	103	$88	103	$88	0	$0	0	$0	0
4	29	0	29	29	$55	29	$55	0	$0	0	$0	0
5	20	0	20	20	$43	20	$43	0	$0	0	$0	0
6	510	0	510	125	$242	125	$242	0	$0	0	$0	0
7	637	0	637	0	$0	0	$0	0	$0	0	$0	0
8	2327	0	2327	535	$1,045	268	$378	206	$515	61	$153	1
9	462	0	462	105	$261	105	$261	0	$0	0	$0	0
10	169	0	169	54	$131	54	$54	0	$0	0	$0	0
11	2699	0	2699	715	$1,634	177	$427	359	$688	179	$519	2
12	2881	0	2881	81	$173	81	$173	0	$0	0	$0	0
13	675	0	675	366	$914	366	$914	0	$0	0	$0	0
14	745	0	745	235	$586	235	$586	0	$0	0	$0	0
15	1568	0	1568	158	$384	158	$384	0	$0	0	$0	0
16	1374	0	1374	327	$758	327	$758	0	$0	0	$0	0
17	1831	0	1831	1516	$3,231	958	$2,075	558	$1,156	0	$0	0
18	228	0	228	242	$475	242	$475	0	$0	0	$0	0
19	515	0	515	170	$340	170	$340	0	$0	0	$0	0
20	693	0	693	194	$337	194	$337	0	$0	0	$0	0
21	247	0	247	217	$382	217	$382	0	$0	0	$0	0
22	2202	0	2202	1004	$1,383	189	$473	440	$910	375	($38)	4
23	2438	0	2438	1686	$3,940	818	$1,787	387	$734	481	$1,419	2
24	1207	0	1207	187	$417	187	$417	0	$0	0	$0	0
25	3009	981	3990	1964	$4,307	640	$1,529	566	$1,095	758	$1,683	4
26	1874	0	1874	945	$1,866	0	$0	367	$759	578	$1,107	3
27	613	0	613	209	$528	116	$251	93	$277	0	$0	0
28	1000	739	1739	1137	$2,290	390	$897	459	$867	288	$525	3
29	2030	493	2523	1155	$2,353	314	$779	305	$625	536	$949	6
30	3019	411	3430	2255	$4,648	243	$578	991	$1,876	1022	$2,195	3
31	817	0	817	72	$166	72	$166	0	$0	0	$0	0
32	880	0	880	673	$1,240	7	$18	62	$124	604	$1,099	3
33	3257	1726	4983	3910	$5,060	1993	$3,051	609	$1,150	1308	$859	3
34	1297	1540	2837	2262	$1,713	0	$0	573	$1,147	1689	$566	2
Total, all trials	41445	5890	47335	22738	$41,182	8885	$18,108	5975	$11,924	7879	$11,034	36
Average, all trials	1219	982	1392	669	$1,211	261	$533	176	$351	232	$325	1
Average T$/Kg					$1.81		$2.04		$2.00		$1.40	

[a] Landed value. [b] Net return after deducting all packing, shipping, and marketing costs.

Table 9 shows the results of the export marketing trials. The results are organized to show the distribution of exports by country and by species. Out of the total 31 successful export marketing trials, there were 9 successful export marketing trials to New Zealand, 15 to Hawaii, 6 to Australia, and only one to Japan. There were 14 of the export marketing trials, totaling 3,308 kg, or 71% of the exported fish by weight, containing bigeye tuna. Another 15 trials, containing 1,217 kg, or about 26% of the exported fish by weight, were of yellowfin tuna. There were only two small export trials with albacore tuna.

The net return to the project for the exported fish in these 31 trials averaged T$2.26 per kg. The returns ranged from T$1.95 and T$1.96 per kg for exports to Australia and New Zealand, respectively, to T$2.50 per kg for exports to Hawaii and T$5.26 per kg for shipments to Japan. The two albacore shipments reaped only T$2.05 per kg, while the 15 yellowfin export trials yielded an average T$2.21 per kg and the 14 bigeye export trials yielded an average T$2.28 per kg.

Since these export shipments were project trials, the marketing arrangements do not reflect those that could be obtained by a commercial fishing operation. The project made an arrangement with a fish exporter in Tonga to front the funds necessary to pay for the packing materials and to share in the risk involved in the trial shipments. In return, the exporter received 50% of the net return over packing and shipping costs. For this reason, the net returns received by the project for the exported tuna were artificially lower than those obtainable by a commercial operator. One current arrangement between a Tongan commercial fishing operation and a Tongan fish exporter is for the commercial fishing operator to pay up front for the packing and shipping (including labor) costs, to absorb the risk of the exporting, and to pay to the exporter only 15% of the net return over packing and shipping costs. Had the project used this type of commercial exporting arrangement in its export trials, it would have received approximately 70% more in net returns over packing and shipping costs than it did. While the project collected precise data on the net price per kg received on tuna shipments, the data collected on the gross price received on the shipments, packing costs, and shipping costs were insufficient to make detailed calculations of the intermediate costs and the average spread between gross and net revenues. However, some estimates on typical packing, shipping, and marketing costs on tuna exports are presented in Bartram 1992 and Bartram 1994.

In order to obtain a better assessment of the possible returns from exporting fresh tuna from Tonga, the net revenues in Table 10 were adjusted to the expected yield. If the commercial exporting arrangement described above had been used instead of the arrangement actually used by the project. The adjusted net revenues on tuna exports, shown in Table 10 as "Adjusted T$/KG", averaged $3.84 per kg. The adjusted net return ranged from T$3.32 per kg for exports to Australia and New Zealand, to T$4.25 per kg on exports to Hawaii, and to T$8.94 per kg on the one shipment to Japan. The average adjusted net return on *albacore* tuna shipments was T$3.49 per kg, while that for yellowfin tuna was T$3.76 and that for bigeye tuna was T$3.88.

The average adjusted net return on all tuna shipped by the project during the 31 successful export marketing trials came to T$3.84 per kg. This is a particularly good result in view of the conditions under which the project operated. Throughout most of these trials, ice was not of a good quality flake ice, and it often bruised and dented the fish skin in shipment, thereby reducing the value. In addition, ice was often in short supply. The fish were transported from Vava'u to Nuku'alofa by ferry, so the tuna shipment schedule was at the mercy of the ferry schedule. This often meant that the time lag between catch and exporting was lengthened by 1-3 or more days, again reducing the quality and the price received at the final market destination. By improving the quality of the ice and coordinating catching and shipping schedules, net export revenues should reach T$5.00 per kg. As all parties learn how to catch, handle, pack, and ship a higher quality product, and as more attention is paid to current supply and price trends in particular markets so that shipments are timed and targeted more profitably, the annual net export revenues over packing and shipping costs could reach as much as T$7.00 or more per kg, a net return now being achieved by some fresh tuna exporters in neighboring South Pacific countries.

4.3.1.3 Costs

The project fishing trial expenses are presented in Table 11. The cost data of the project's fishing and export trials are even more problematical than were the revenue data. The project cost data cannot appropriately reflect the probable cost of a commercial venture largely because the *Ekiaki* was over-sized and used far more fuel than would be required by an appropriate vessel. Gear costs included only miscellaneous expenditures over the course of the half year during the project's fishing trials analyzed here, and do not represent actual gear replacement costs. Costs were not recorded for either the crew nor the provisions. The crew wages do not reflect ordinary fishing wages for there was twice the number of crew than an ordinary fishing crew. Also, the crew was composed of government workers, not experienced fishermen. All in all, only the bait and ice costs are a roughly appropriate value of the costs of a commercial operation.

As can be seen in Table 11, the project recorded fishing trial costs of T$39,804. This compares with the total project fish sales revenues of T$41,182, so that, with the limitations noted in the preceding paragraph, the project in its fishing trials brought in more revenues than it incurred in costs.

4.4 Baitfish Resource Assessment

The development of an artisanal fishery for baitfish is intended to complement, and provide bait for a proposed small-scale longline fishery for tuna.

Fishing was carried out from the government research vessel "Albacore" at nine different stations in Vava'u waters. Fishing began in April, 1992, with 93 fishing trips completed by the end of 1993. The fishing method involved the deployment of an anchored dinghy fitted with lights to attract baitfish during the hours of darkness. An 80 m circumference purse seine net with 20 mm meshes, set from the research vessel, was used to surround the schooling baitfish.

Table 10. Results of export trials

	No. of TRIALS	KG	T$	T$/KG	Adjusted T$	Adjusted T$/KG
EXPORTS BY COUNTRY						
EXPORTS TO NEW ZEALAND						
BIGEYE	4	215	$448.04	$2.08	$761.67	$3.54
YELLOWFIN	5	464	$880.00	$1.90	$1,496.00	$3.22
TOTAL	9	679	$1,328.04	$1.96	$2,257.67	$3.32
EXPORTS TO HAWAII						
BIGEYE	7	1748	$4,460.75	$2.55	$7,583.28	$4.34
YELLOWFIN	6	412	$993.01	$2.41	$1,688.12	$4.10
ALBACORE	2	125	$256.52	$2.05	$436.08	$3.49
TOTAL	15	2285	$5,710.28	$2.50	$9,707.48	$4.25
EXPORTS TO AUSTRALIA						
BIGEYE	3	1345	$2,647.36	$1.97	$4,500.51	$3.35
YELLOWFIN	3	290	$548.57	$1.89	$932.57	$3.22
TOTAL	6	1635	$3,195.93	$1.95	$5,433.08	$3.32
EXPORTS TO JAPAN						
YELLOWFIN	1	51	$268.31	$5.26	$456.13	$8.94
TOTAL	1	51	$268.31	$5.26	$456.13	$8.94
GRAND TOTAL	31	4650	$10,502.56	$2.26	$17,854.35	$3.84
EXPORTS BY SPECIES						
BIGEYE	14	3308	$7,556.15	$2.28	$12,845.46	$3.88
YELLOWFIN	15	1217	$2,689.89	$2.21	$4,572.81	$3.76
ALBACORE	2	125	$256.52	$2.05	$436.08	$3.49
GRAND TOTAL	31	4650	$10,502.56	$2.26	$17,854.35	$3.84

Table 11. Project fishing trial expenses

Fishing Trials	Longline Catch	Handline Catch	Total Catch	Expenses						
				Fuel	Oil	Ice	Bait	Gear	Marketing	Total
#	Kg	Kg	Kg	T$	T$	T$	T$	T$	T$	T$
1	39	0	39	$140	$14	$25	$60	$0	$0	$239
2	50	0	50	$114	$11	$25	$60	$0	$0	$210
3	103	0	103	$144	$14	$25	$100	$20	$0	$303
4	29	0	29	$129	$13	$25	$60	$0	$0	$227
5	20	0	20	$129	$13	$45	$100	$0	$0	$286
6	510	0	510	$478	$48	$145	$300	$40	$0	$1,010
7	637	0	637	$675	$68	$175	$400	$900	$0	$2,218
8	2327	0	2327	$627	$63	$163	$400	$100	$0	$1,352
9	462	0	462	$815	$81	$100	$160	$140	$0	$1,296
10	169	0	169	$501	$50	$75	$140	$0	$0	$767
11	2699	0	2699	$752	$75	$200	$280	$70	$0	$1,377
12	2881	0	2881	$382	$38	$75	$140	$50	$36	$721
13	675	0	675	$191	$19	$125	$140	$40	$17	$532
14	745	0	745	$191	$19	$125	$220	$25	$18	$598
15	1568	0	1568	$206	$21	$88	$200	$40	$0	$554
16	1374	0	1374	$213	$21	$81	$200	$20	$0	$535
17	1831	0	1831	$550	$55	$250	$240	$70	$80	$1,245
18	228	0	228	$208	$21	$75	$220	$20	$0	$543
19	515	0	515	$208	$21	$200	$220	$45	$0	$693
20	693	0	693	$208	$21	$125	$210	$20	$0	$583
21	247	0	247	$415	$41	$175	$400	$40	$0	$1,071
22	2202	0	2202	$830	$83	$280	$400	$60	$80	$1,733
23	2438	0	2438	$993	$99	$280	$400	$60	$120	$1,952
24	1207	0	1207	$204	$20	$100	$120	$40	$0	$484
25	3009	981	3990	$962	$96	$625	$400	$480	$150	$2,713
26	1874	0	1874	$205	$20	$375	$120	$40	$0	$760
27	613	0	613	$582	$58	$375	$280	$20	$0	$1,315
28	1000	739	1739	$1,091	$109	$500	$400	$210	$80	$2,390
29	2030	493	2523	$1,091	$109	$390	$620	$50	$120	$2,380
30	3019	411	3430	$1,164	$116	$293	$468	$120	$80	$2,241
31	817	0	817	$728	$73	$8	$280	$25	$0	$1,113
32	880	0	880	$1,310	$131	$325	$280	$40	$0	$2,085
33	3257	1726	4983	$1,091	$109	$450	$600	$0	$170	$2,420
34	1297	1540	2837	$873	$87	$369	$300	$25	$200	$1,854
Total, all trials	41445	5890	47335	$18,395	$1,840	$6,690	$8,918	$2,810	$1,151	$39,804
Average, all trials	1219	173	1392	$541	$54	$197	$262	$83	$34	$1,171
Average T$/Kg				$0.39	$0.04	$0.14	$0.19	$0.06	$0.02	$0.84

Although catches varied greatly, the mean catch rate over the survey period of all species combined was 475 kg per night (with a maximum of 2537 kg per night), and returns on fish sales were approximately T$2.00 per kg. A total catch of 16.4 tons was landed in 1992, and 27.8 tons in 1993. The mean catch rate was higher in 1992 (606 kg per haul) than in 1993 (402 kg per haul), and decreasing catch rates, particularly over 1993, were a cause for concern.

Four species accounted for 85% by weight of the total catch, including the sardine (Tongan = *satini*), Amblygaster sirm (39%), the scads (Tongan = *otule kau*), Decapteru macarellus (27%), and Decapterus macrosoma (15%), and the herring (Tongan = *ulukau*), Herklotsichthys (4%). The scads were the preferred bait for catching large tuna on longlines, the sardine for catching smaller (<10 kg) tuna around fish aggregating devices (FADs), and the herring was considered too small for use as tuna bait. All species caught were edible, except the herring, which is believed to be ciguatoxic causing ciguatera fish-poisoning at times.

Growth rates of the four major species were found to be high, suggesting lifespans of between two and three years. The sardine has a lower growth rate, and is therefore likely to be more susceptible to over- fishing. In all species, total mortality rates (from both fishing and natural causes) were correspondingly high (greater than 90% per year).

Two species, the sardine, A. Sirm, and the scad, D. macarellus, matured relatively late in their lifespans and spawned during March through April. Small individuals of these two species were recruited into the fished stock during the early months of the year, and in the scad, D. macrosoma, recruitment occurred over a more extended period beginning in September.

Intensive fishing in a small area showed that local stocks of baitfish are extremely vulnerable to the fishing method. This indicates that a commercial fishing strategy should involve targeting different fishing areas on a rotational basis.

Yield per recruit analyses indicated that baitfish resources are limited and the survey vessel alone imposed a fishing mortality of between 29% and 56% (depending on species) of that required to obtain the maximum sustainable yield.

The lack of infrastructure to enforce fisheries regulations in Vava'u means that any controls placed on the fishery would have to be direct and relatively easy to police. For these reasons, input controls on the amount of fishing effort are more appropriate than output controls on the quantity of fish caught (such as catch quotas).

It is assumed that a profit-driven commercial operation would be more efficient than that of the government vessel. A vessel of a similar size, and using gear similar to the "Albacore" would therefore make greater catches, and is likely to impose a fishing mortality close to the optimum level. However, the same catch could be taken, and the same level of fishing mortality imposed, by two or three smaller vessels using smaller gear. Smaller gear may include lift-nets, such as "boki-ami"(Japanese gear) would have to be determined by trials.

4.5 Manpower and Skill Levels

In general, Tongan commercial fishermen are good seamen and not afraid of hard work. The fleet of small snapper vessels routinely works 100 km from port and averages four days per trip. The level of technology tends to be very low, with only a few boats equipped with GPS and video echo sounders.

Except for the two project Master fishermen, all project fishing personnel were Tongan nationals. The captains and crews of the government vessels lacked commercial fishing experience, but all proved to be apt students of fishing technology. The deck crews were able to perform all required tasks within a month of start-up. Twenty different deck crew were trained aboard the *Ekiaki*, and fourteen subsequently worked on private vessels.

The major skills deficiency is the vessel maintenance and repair, both for government and private vessels. This was particularly noticeable in Vava'u, where repair facilities and parts supplies are minimal. In addition, the government captains did not take an active role in assuring that the vessels were ready for sea.

4.6 Constraints to Development

The primary production sector of Vava'u is extremely limited-- and with good reason. Because of numerous constraints, only products with relatively long shelf-life can be produced for export. Among these are vanilla, squash, and some root crops. Those factors which directly or indirectly constrain the development of fisheries in Vava'u are:

Trans-shipment: Air cargo space is not available and surface ferries run only twice weekly (mid-week). At least two days of shelf-life are lost during surface shipment, and further delays can be encountered because of limited air cargo space from Nuku'alofa. Compared to other regional services, air cargo rates from Tonga are quite high.

Communications: Telephone and fax services are inadequate.

Dockside: Dock space is limited, with no dockside power or water.

Vessel Maintenance: Repair services and parts supply are virtually non-existent.

Markets: Consumer demand for non-exportable fish is limited to the output of one or two vessels.

Nuku'alofa, Tonga's center of population and commerce, is relatively developed compared to Vava'u. Yet, there are still factors that will constrain increases in the fisheries sector. Among these are:

Dockside: Dock space is limited and generally without power and water.

Water Supplies: Town water is considered unpotable and may present quality problems in ice production.

Vessel Maintenance: Marine repair services and parts supplies are sub-standard.

Markets: While consumer demand can handle current supplies, any major increase in fish production will result in market over-supply.

Air Freight: Capacity is adequate for current fish exports, but will not be able to meet a major increase in tuna shipments. Air cargo rates from Tonga are roughly twice that of comparable sectors originating from Fiji, and represent about 50% of total fish production and shipment costs.

In addition to the largely infrastructural constraints listed above, there are two institutional factors that may affect development of the tuna industry . These are:

Financing: The private banks and Tonga Development Bank are largely in-experienced in providing loans for medium to large fishing vessels. This has resulted in unfavorable terms for entrants into the fishery.

Government Regulation: While the question concerning Sea Star's exclusivity in the tuna fishery has apparently been resolved, other companies are still wary of entering the fishery because of preceived competitive advantages accruing to the parastatal company. The government has been careful that Sea Star's policies do not hinder growth in the private sector. Further, Government has been given the task of overseeing grading of tuna exports. If not handled properly, government grading could become a burden rather than a help to the private sector.

4.7 Commercial Feasibility

One must be careful to separate technical feasibility from economic feasibility in assessing the prospects for tuna fishery development in Tonga. All of the techniques tested were technically feasible; i.e., they caught tuna. Further, the average daily catch rates were promising for four of the six techniques (or variations) even with limited inshore tuna resources. However, given the constraints reviewed above, only two methods would appear to have commercial application for Vava'u. These are, the use of a small-scale (8 km) monofilament longline around seamounts from a 40-45 foot vessel, and a night time handlining from smaller vessels such as the local snapper boat. A third technique not tested in this project, the capital-intensive 80 km

monofilament system from a 60 foot or larger vessel, would probably be commercially feasible from Nuku'alofa.

Since a great deal of time and effort were invested in both small-scale horizontal longlining and vertical longlining, the economic results of these techniques are discussed below in some detail. Because night time handlining will have limited export potential, the ensuing discussion is brief.

4.7.1 Economics of Small-Scale Horizontal Longlining

Since the *Ekiaki* is not an appropriate style or size of vessel, evaluating the commercial feasibility of small-scale tuna longlining would have been a matter of substantial guesswork but for the fortunate circumstance that, due to the success of the fishing and marketing trials, a commercial vessel recently began operating in Vava'u. The commercial operator shared his cost and revenue data with the project. This presented a unique opportunity to evaluate the commercial feasibility of small-scale tuna longlining in Tonga.

The commercial operation is employing a suitable 40 foot steel vessel equipped with a 6 km monofilament longline using 200 hooks per set, as compared with *Ekiaki's* 8 km of monofilament longline using an average of 249 hooks per set during the 25 fishing trials on Capricorn Seamount. In the first three months of 1994, with a relatively inexperienced crew, two different skippers and several expeditions with very bad weather, the commercial operator was successful in catching by longlining 55% as much fish by weight per fishing day as the *Ekiaki* did in its Capricorn Seamount trials--with only 76% as many hooks. In other words, the beginning commercial operation caught slightly more than 63% (by weight) of that caught in *Ekiaki's* trials. But the results are actually more impressive than the above suggests. When the fishing expeditions involving engine trouble, skipper changes, and extremely bad weather are excluded from the available data, so that only the "normal" 6 fishing trips with 18 days of actual fishing are examined, one finds that the commercial operator had catch rates comparable to those of the project's fishing trials with the *Ekiaki*. This newly formed commercial operation confirms the tuna longlining potential established by the *Ekiaki*, and provides the basis for better evaluating the commercial potential than would be feasible with project data only.

A review of the experience of the new commercial operation is appropriate here. The data was adapted to facilitate the presentation, but was firmly based on actual commercial experience. First, the investment and fixed costs will be examined. This will be followed by a brief discussion of the variable fishing costs, including fuel, ice, bait, crew, provisions, and marketing costs, comparing these with project trial experience where appropriate. Finally, an assessment of the commercial feasibility of small-scale horizontal longlining in Tonga will be made.

4.7.1.1 Investment and Fixed Costs

An overview of representative investment and fixed costs of small-scale horizontal longlining in Tonga is presented in Table 12. These data are based on the actual costs

of a commercial tuna fishing operation in Tonga. The vessel was purchased in the fall of 1993 and conducted tuna fishing out of Vava'u, Tonga during the first three months of 1994. The numbers have been rounded for clarity.

Initial investment costs included vessel and vessel acquisition capital. The vessel cost approximately T$105,000, but there were additional vessel acquisition costs of roughly T$25,000. The hydraulic reel and other equipment cost T$22,000; fishing lines, hooks, buoys, and other gear cost T$24,000; and approximately T$50,000 in operating capital was invested in the enterprise. This brought the total initial investment to T$226,000. The commercial operator obtained a development loan with a 5-year payback period from the Tonga Development Bank to finance the investment. Discussions with Tonga Development Bank officials suggested that there was likely to be some flexibility in the payback schedule. While a commercial loan would have cost in the vicinity of 12% or more interest, the development loan was obtained at the rate of 10.5%.

Based on these investment costs, a projection of annual capital and other overhead costs was made. The vessel is about 10 years old and probably can provide some 15-20 years more good service; however, for planning purposes, a 15 year life was assumed, with a roughly 20% salvage value at the end of the 15 year period. (Of course, when the expected rate of return on this investment was calculated, a separate annual depreciation cost was not included in the annual cash flow projections.) The operator must plan for annual equipment replacement at the rate of about 20% of the value of the equipment, annual gear replacement at the rate of about 33.3% of the value of the gear, annual vessel repair and maintenance costs of approximately 10% of the value of the vessel, and annual vessel insurance premiums of 6% of the value of the vessel. These annual capital costs come to approximately T$38,960 per year. In addition, Table 12 includes a modest estimate of other overhead expenses. Management expenses were estimated at T$1,000 per month and miscellaneous expenses were estimated at T$3,000, bringing the total other annual overhead expenses to T$15,000. While the management expenses of T$12,000 can hire a manager to tend to management and administrative affairs, there was no accounting for the expenses of a bookkeeper, rental on office space, and other ordinary business expenses. It was presumed that a single manager could tend to the affairs of at least two fishing vessels, so that if the fishing business expanded, there might be the need to hire a secretary and rent an office, but the T$15,000 in annual other overhead expenses is a fair estimate of the per vessel management expenses. Clearly, some of these expenses vary according to fishing effort, but since they are not directly related to particular fishing trips, it facilitated the analysis of categorizing these expenses as annual fixed costs.

Table 12. Representative Investment and Fixed Costs

Investment Costs	
Vessel	$105,000
Vessel Acquisition	$25,000
Equipment	$22,000
Gear	$24,000
Operating Capital	$50,000
Total investment Costs	$226,000
Annual Fixed Costs	
Annual Capital Costs	$7,000
Vessel Depreciation (15 yr. st. line dep.)	$4,400
Equipment Replacement (20% per yr.)	$8,000
Gear Replacement (33.3% per yr.)	$10,500
Repair & Maintenance (10% of value of vessel)	$9,060
Total Annual Capital Costs	$38,960
Other Annual Overheads	
Management Expenses	$12,000
Miscellaneous Expenses	$3,000
Total Other Annual Overheads	$15,000
Total Annual Fixed Costs	$53,960

4.7.1.2 Costs and Returns

Fishing costs vary with, among other factors, the fishing effort, the catch, and the average revenue received for the fish. For example, fuel requirements per day of fishing vary according to the number of days of fishing per fishing trip. Bait costs vary according to the number of hooks used per set. Wages vary because, in addition to a base wage for the crew, there are usually bonuses paid according to the value of the catch. Hence, any representative costs of fishing are based on the assumptions made regarding the amount of fishing, the catch, and the prices received for the catch.

The representative fishing operation examined here assumes that a commercial venture would experience catch rates similar to the project's results with the *Ekiaki*

and with those of the commercial operation discussed above. While the *Ekiaki* usually fished only one or two days per fishing trip, the commercial operation discussed above has been fishing three days (one set per day) per fishing trip. In order to develop a set of representative costs, it is assumed that a commercial venture would set one longline set per fishing day for a total of 108 fishing days per year. Conducting three fishing days per fishing trip, the venture would undertake 36 fishing trips per year. A commercial venture operating on Capricorn Seamount and using 200 hooks per set per fishing day, would catch, at project catch rates, roughly 625-650 kg of marketable fish per day. Supplemented by a modest amount of handline fishing, as demonstrated by the project trials, the results of which were shown in Table 7, roughly 2 hours of handline fishing per day on Capricorn Seamount would bring the total catch to roughly 1,000 kg of marketable fish per fishing day. In summary, a commercial venture, duplicating project catch rates while using 200 hooks per longline set and a modest amount of handline fishing, should be able to catch 108,000 kg of marketable fish per year.

While the project actually exported in trial shipments about 45% of its horizontal longline catch, it is assumed that under commercial conditions 60% of the longline catch would be exportable. The entire handline catch would be sold locally. Based on project marketing experience and presuming that the higher quality of ice now available to commercial operators in Vava'u continues to be available, it is reasonable to assume that fish sold locally would bring an average revenue of T$2.00 per kg and exported fish would yield an average revenue (net over packing and shipping costs) of between T$5.00 per kg and T$7.00 per kg.

Based on these assumptions regarding fishing effort, catch, marketing, and expected average revenues, the expected fishing costs for a commercial venture can be estimated. Based on the actual cost experience of the commercial operator, representative costs per fishing day were developed and are shown in Table 13, below:

Table 13. Representative costs per fishing day

Item	Cost
Fuel	$259
Ice	$200
Bait	$140
Provisions	$51
Base Wages	$204
Crew Bonus	$393
Miscellaneous	$18
Total	$1,265

Since the estimated fuel costs are based on the experience of a 40 foot fishing vessel rather than the *Ekiaki*, the fish carrier used in project trials, the estimate of fuel costs here is less than half that of the project average. The costs for ice and bait when adjusted for the number of hooks per set, are comparable to those experienced in the project trials. The cost of provisions is based on actual experience of the commercial operator in Vava'u; however, since the commercial operator is transporting the catch to Nuku'alofa, the actual fishing days per fishing trip are less than half of the sea going days. This makes the costs of crew provisions per fishing day more than twice the actual daily cost of provisions. The base wages vary from about T$4,000 per year for an ordinary crew member to twice that for the skipper. The base wages for a crew of 4, including the skipper, engineer, and two other crew members, comes to T$204 per fishing day. The bonus arrangements currently used by the commercial operator are to share among the crew 20% of the value of local fish sales and T$0.50 per kg for exported tuna. Based on catch and average revenue assumptions, the crew bonus comes to about $393 per fishing day. Finally, miscellaneous expenses are estimated at T$18 per fishing day. This brings the total representative costs of a commercial fishing operation to T$1,265 per fishing day. This is the cost framework which is used below in determining the expected rate of return from a tuna fishing venture in Tonga.

Representative annual costs and returns may now be calculated based on project catch rates, commercial investment and annual fixed costs as shown in Table 12 and operating costs per fishing day as shown in Table 13. The results, along with expected annual rates of return on investment are shown in Table 14. In the simplest terms, a commercial operator achieving project catch rates and continuing to export 60% of the longline tuna catch at expected prices for a whole year can expect to receive annually internal rate of return on investment over cost of 57.8%. This is a healthy rate of return, especially in view of the fact that one commercial tuna operator has already received a Tonga Development Bank loan at an interest rate of 10.5% and other operators should be able to obtain loans in the vicinity of 12%. Furthermore, this rate of return is based on continuing business as usual. There is every reason to believe that net revenues on export sales of up to T$7.00 per kg or more can be obtained as fish handling, packing, and shipping experience is gained, and as more careful monitoring and targeting of markets is done. Tonga has South Pacific neighbors who are currently achieving such net revenues on fresh tuna exports to Hawaii, so higher returns are certainly possible. If average net export sales revenues of T$7.00 per kg are obtained, the annual rate of return on investment rises to 94.6%.

It is worth noting that the expected annual rates of return on an investment in small-scale tuna horizontal longlining in Tonga are rather robust. A 25% increase in initial investment costs only reduce the expected annual rates of return to 75.6% and 46.1% at net export revenues of T$7.00 per kg and T$5.00 per kg, respectively. Alternatively, if the expected catch rates should fall to 75% of those proven possible by 6 months of project trials, the expected annual rate of return falls to 26.8% if export sales net revenues remains at T$5.00 per kg, and falls only to 55.1% if export sales net revenue rises to T$7.00 per kg.

While potential investors often decide whether an investment opportunity is attractive or not by comparing the rate of return on the investment with rate of interest at which

capital may be obtained, economic planners frequently prefer to assess the attractiveness of investment opportunities by examining the net present value of revenues over costs. These results are equally impressive. Given the representative fishing operation described above, the present net values of revenues over costs are T$597,563 at an assumed net export sales revenues of T$5.00 per kg and T$1,103,197 at an assumed net export sales revenues of T$7.00 per kg.

Table 14. Representative annual costs and returns based on project catch rates and commercial costs.

Annual Costs and Returns Based on 108 Fishing Days per Year

	@T$5.00/kg	@T$7.00/kg
Total Catch (kg)	108000	108000
Local Sales (kg)	54271	54271
Export Sales (kg)	41574	41574
Total Sales (kg)	95845	95845
Waste and Share (kg)	12155	12155
Total Revenues on Local Sales, T$	$108,541	$108,541
Average Revenue on Local Sales, T$/kg	$2.00	$2.00
Total Revenue on Total Sales, T$	$316,411	$399,599
Average Revenue on Total Sales, T$/kg	$3.30	$4.17
Total Operating Cost, T$	$136,647	$136,647
Margin on Total Operating Costs, T$	$179,764	$262,912
Less Total Annual Capital Costs, T$	$145,704	$$228,852
Less Total Other Annual Overheads, T$	$130,704	$213,852
Annual Rate of Return on Investment, %	57.8%	94.6%

4.7.1.3 Summary of Horizontal Longline Commercial Feasibility

The commercial feasibility of small-scale tuna horizontal longlining in Tonga has been demonstrated not only in the rate of return and the present net value calculations made above but also by the fact that several commercial operators, seeing the potential returns, have already begun fishing operations. The commercial operation which shared the cost and revenue data has already acquired a second fishing vessel.

There are several unknown factors which can positively or negatively affect the expected rates of return calculated above. On the positive side, as noted above, new tuna operators can be expected to learn from experience. Greater care with handling, packing, and shipping of exportable fish, which can be learned from experience, will gradually increase net export revenues. Improved targeting of export shipments can

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also substantially increase net export revenues. All things considered, the rates of return calculated above may be conservative estimates.

Because the 8 km longline is ideally suited for a 40 to 45 foot vessel, it made no sense to use expense data from the *Ekiaki* in calculating profitability. On the other hand, the *Ekiaki* expenses are representative of the class of vessel that could utilize the longer 32 km system. The per trip operating costs of the *Ekiaki* were T$1170 for the 8 km system and T$1474 for the 32 km system. This 25% increase came mostly from increased bait use (30 kgs for 250 hooks; 100 kgs for 800 hooks), and additional fuel used in setting and retrieving the longer line. Unfortunately, daily catches did not increase proportionally, but decreased. Only 3 of 11 trials with the 32 km system resulted in net profit. Clearly, this is not a favorable economic situation. Several vessels of roughly the same capabilities as *Ekiaki* are currently using 32 km systems in Tonga. We have not had access to their cost and revenue data, but these vessels are reportedly running at a loss.

There appears to be a specific pattern involving vessel size, number of hooks fished, fixed and operating expenses, and daily catches. The 8 km system (200 hooks) fished from a 40-45 foot vessel around seamounts has a favorable economic outcome. If this small-scale system is applied to a larger vessel, the operation becomes unprofitable as fixed and operating expenses increase. An upgrade to the 32 km system (800 hooks) results in even higher operating costs, but catch rates decrease as the longer system is inefficient around seamounts. Thus, it appears that any system within the limitations of a 46-55 foot vessel would have little chance of profitability. Although not tested in this project, the full-size 80 km longline (2000 hooks) has been successful in Fiji, Hawaii, and Australia. The larger system usually requires a vessel in the 55-75 foot range, and some of the Hawaiian longliners are as large as 120 feet. Apparently, profitability returns at open ocean catch rates when the number of hooks approaches or exceeds 2000.

4.7.2 Economics of Vertical Longlining

The project also conducted vertical longline trials with a 35 foot vessel, the *Dora Malia*. These trials were an effort to explore the advisability of using the Tongan snapper fleet in the developing tuna industry. It was thought that either some of the vessels could be effectively and economically redeployed from bottomfishing to tuna fishing, or that tuna fishing could serve as a source of supplemental catch and income for the fleet, assisting in reducing some of the fishing pressure on the bottomfish stocks.

Tables 15 and 16 show the vertical longline trials revenues and costs. The revenues and expenses are shown both for the total number of trips and for those trips during which actual fishing was undertaken. There is little reason for exploring implications of the specific expense line items, since it is obvious that the total revenues received from the catch from all 74 sea trials, when fishing was conducted, barely exceeded the total expenses. In fact, net revenues over expenses were positive for only 21 of those 74 sea trials which included actual fishing time. Furthermore, it can be noted that these expenses included neither allowances for crew wages or bonuses nor for capital costs.

Despite the discouraging results of the vertical longlining trials, an effort was made to explore a best case scenario. A hypothetical fishing operation was constructed from the catch, revenue, and cost data from the *Dora Malias* 21 sea trials (with 26 fishing days) in which net revenues exceeded expenses. A snapper vessel, like the *Dora Malia*, was assumed to cost T$60,000, fully equipped. The vessel was assumed to have a crew of three persons, with base wages similar to those assumed above in the case of the horizontal longlining and bonuses of 20% of the value of the catch. Each fishing trip was assumed to contain 3 fishing days. This exercise revealed that even under these favorable assumptions the expected revenues would barely cover the operating costs, leaving little or no surplus to cover the investment and annual fixed costs. Calculated net present values and annual rates of return were all negative. It was not possible to construct a fishing operation scenario from the *Dora Malia* fishing trial results which would yield positive returns. Accordingly, on the basis of the vertical longline trials with the *Dora Malia*, it is concluded that full-time vertical longlining with the Tonga snapper fleet is not an economically viable option. However, during periods of tuna abundance vertical longlining may be used to supplement catch and relieve pressure on the deep snapper resources.

4.7.3 Economics of Day and Night-Time Handlining

Like vertical longlining, the night-time handline technique can be easily fished from the local snapper boats, requires a low capital investment (T$500), and results in low operating costs. A direct comparison of the two handline techniques and vertical longlining was conducted during February-August 1994, Table 2 and Table 7. Given that the fixed and operating costs of all three techniques are virtually equal, it can be concluded that night-time handlining holds more promise for the current local fleet. However, during periods of tuna abundance, catches from vertical longlining and daytime handlining approach those of night-time handlining, and each of the three techniques has advantages under specific conditions.

It must be emphasized that the catch from night-time handlining around Vava'u, like that of vertical longlining, consists mostly of small to medium yellowfin tuna with little effort potential. Thus, the development of this fishery will be limited by local market conditions in Vava'u and Nuku'alofa.

Table 15. Vertical longline trials catch rates

	Sea Days	Fishing Days	Number of Sets	Number of Hooks	Total Catch		Yellowfin		Albacore		Bigeye		Mahi Mahi		Other Marketable		Unmarketable	
					#	Kg	#	Kg	#	Kg	#	Kg	#	Kg	#	Kg	#	Kg
Total	159	89	432	8390	547	8859	267	3975	112	2181	4	89	118	816	9	227	39	1600
Average Per Fishing Day			4.9	94.3	6.2	99.5	3	44.7	1.26	24.5	0	0.8	1.30	9.17	0.1	2.55	0.44	17.98
Catch Per Hundred Hooks					6.5		3.18		1.33		0		1.38		0.11		0.46	

Table 16. Vertical longline trials revenues and costs

	Trips	Catch	Sold	T$/Kg	Revenue	Fuel	Oil	Ice	Bait	Gear	Packing	Freight	Marketing	Expenses	Net
Total, all trips	107	8,859	7,002	$2.14	$15,010	$5,340	$525	$9,605	$1,572	$1,519	$40	$181	$8	$18,791	($3,781)
Average, all trips		83	65	$2.14	$140	$50	$5	$90	$15	$14	$0	$2	$0	$176	($35)
Total, fishing trips	74	8,859	7,002	$2.14	$15,010	$3,620	$353	$7,385	$1,490	$1,210	$40	$181	$8	$14,267	$743
Ave., fishing trips		120	95	$2.14	$203	$49	$5	$100	$20	$16	$1	$2	$0	$193	$10

5.0 RECOMMENDATIONS

5.1 Fleet Composition and Fishing Methods

The results of project fishing trials have clearly demonstrated the potential for small-scale tuna longlining from 40 to 45 foot vessels using an 8 km, 250 hook monofilament system. Conversely, the tests of a 32 km, 800 hook system to be operated from a 46 to 55 foot vessel were discouraging as far as economic feasibility. Tests of the smaller 28 to 35 foot snapper boats indicated that, because the nearshore tuna resource is productive only during short seasons, vertical longlining and daytime handlining can be used only to supplement snapper fishing. Night-time handlining holds the most promise for the local fleet, but will probably yield profits for only six months of the year.

Tests of larger vessels (>55 feet) with 80 km systems were not conducted, but it can be inferred from the development of the Fiji fleet that these vessels can be profitable if the marketing system and infrastructure are efficient.

There are several factors which point to the need for extreme caution in managing the development of the tuna fleet in Tonga.

First, the most promising opportunity involves seamount tuna fishing -- particularly at Capricorn Seamount. The remarkable catch rates at Capricorn currently produce a favorable economic return, but little is known of the sustainability of the resource at increased levels of fishing effort. Based on current catch rates, entrepreneurs may develop a "gold rush" mentality resulting in economic overfishing and over-capitalization. For this reason alone, growth of the seamount fishery (i.e., 40 to 45 foot vessels using the 8 km system) should proceed at a measured pace.

Secondly, the constraints described in Section 4.6 above make it very difficult for a commercial operator to be successful in Vava'u and moderately difficult in Nuku'alofa. The limitations imposed by inadequate trans-shipping, communications, repair services, etc are individually frustrating and collectively devastating to a commercial operation in Vava'u. Only above-average catch rates can sustain such an operation. The major problems at Nuku'alofa are dock space, air cargo space and rates, and lack of chill room capacity.

Thirdly, assuming growth in the medium and large vessel fleets, any increase in small-boat tuna fishing will be limited by the local market since vertical longlining and handlining produce fish too small for export.

Given these factors, it would be prudent for the government to carefully control the growth of the tuna fisheries. It is recommended that MOF adopt a plan of limited tuna licensing based on close monitoring of catch results. A possible scenario would be:

Seamount Fisheries (40-45 foot vessels with 8 km system)

Vava'u
Year 0: 2 current vessels
Add no more than 2 vessels per year until catch rates drop below optimum economic yield.
Probable future fleet is 5-10 vessels

Nuku'alofa

Year 0: no current vessels; fishing grounds unknown
Add no more than 2 vessels per year until catch rates drop below optimum economic yield.
Probable future fleet is 5-10 vessels

Open Ocean Fisheries (>45 foot vessels with 32-80 km systems)
Year 0: 4 current vessels
No limit on number of domestic vessels
No licenses for foreign vessels
Probable future fleet is 5-10 vessels

Small Boat Fishery
Limit entry to those boats already in the snapper fleet or replacements for those boats.
Probable future fleet is 10 part time vessels

The rationale for this scenario is:

- The seamount fishery is potentially the most profitable, but will be constrained by resource and infrastructure limitations.

- The open ocean fishery is not resource limited and the larger vessels would most probably operate from Nuku'alofa. However, licensing of foreign/joint venture vessels would severely tax the inadequate dock space and air cargo capacity. This would impede development by local entrepreneurs.

- The small boat fishery would not be a full-time operation. Any additional entrants would probably fish at least part time in the deep snapper fishery, adding pressure to the already heavily fished stocks. This would defeat the purpose of small-boat tuna development, which is to decrease fishing effort on the deep bottomfish resources.

5.2 Vessel Type and Layout

One of the important tasks of this project was to determine, after careful analysis of fishing trial results, the optimum fishing vessel(s) for tuna fleet development in Tonga. Factors to be taken into consideration were size, layout, hull materials, equipment, speed, and availability. Are suitable vessels and vessel designs currently available? If so, is it more economical to import vessels or construct in Tonga. If suitable vessels were not identified, then it was the project's task to design the optimal vessel.

The analyses in Section 3.7 indicate that the greatest economic opportunity lies in vessels of 40-45 feet. It is the considered opinion of project staff, drawn from a cumulative 80 years experience dealing with fishing vessels, that a number of production vessels meet the criteria listed below.

Vessel Length: 12.2 - 13.7m (40-45 feet)
Beam: 4.3 - 5.2m (14-17 feet)
Draft: 1.5 - 2.4m (5-8 feet)

Hull Material: aluminum or fiberglass preferred; steel as second choice; wood not recommended.

Hull Design: Can be forward or aft cabin; semi-displacement hull preferred, but efficient displacement hull is acceptable.

Vessel Speed: Minimum 8-10 kts, depending on hull type.

Sea-keeping Ability: Must be above average to withstand rough beam seas when hauling line. Requires either beamy semi-displacement hull or stabilizers on displacement hull.

Open deck space: Minimum 15 sq m (161 sq ft); can be forward (schooner design) or aft. Hydraulic reel situated so that line does not crisscross deck when shooting or hauling.

Gear Storage: Minimum 3 cu m (35 cu ft) hold for float lines and 8 cu m (282 cu ft) for floaters (can be atop cabin) is required.

Fish Hold: Two adjoining holds of 5 mt capacity each (roughly 10 cu m or 270 cu ft each); one for fish and one for ice. Insulation should be 3-4 inches thick, and well-protected. The fish hold must have vertical and horizontal pound boards. A single 10 mt hold is less desirable, but acceptable.

Refrigeration: Ice is preferred, but a refrigerated sea water system can be used. Mechanical refrigeration can only be used to maintain the ice (fish should not be frozen), and is an expensive and maintenance intensive feature. An ice maker is desirable but should only be considered if the vessel has exceptional deck space.

Engine(s): Twin diesel engines are preferred for maneuverability and safety, but one well maintained engine is acceptable. Total horsepower should be around 200-300hp, depending on engine make and hull configuration. Excess horsepower must be available to operate the hydraulic and battery charging systems. Because of standard parts and repair services, engines should be new, or at worst two years old. A small auxiliary engine is desirable for emergency battery charging. A larger auxiliary (>5 kw) could operate the hydraulics, but engine room space is a major consideration. The engine room should have easy access and working space for maintenance and frequent running checks.

Fuel Capacity: Enough for 10 running days (roughly 6,000 liters depending on specific engine fuel consumption rates).

Crew Comfort: 4-5 bunks in cabin or separate crew's quarters. Propane stove in well ventilated, sheltered area of cabin. Food refrigerator is nice, but ice coolers will work. Outside shower from deckwash system and separate fresh water hose. If deckwash is run from engine exhaust and if fresh water tanks are built close to engine, the crew will have hot showers.

Electronics: The following are mandatory: GPS Navigator, SSB radio, VHF radio, color echo sounder (>1 kw, 28 hz). Radar and radio direction finder are desirable, but not absolutely necessary.

Deck Gear: A hydraulic reel for the monofilament mainline is absolutely essential. Several manufacturers produce acceptable 10 km capacity reels of either aluminum or steel. It is crucial to have a good pressure relief system to avoid excess strain on the spool. A line shooter is not necessary if leaded swivels are used on the droppers. A deck winch and anchor winch are useful, but not necessary.

Figures 5 and 6 depict a common 40-45 foot vessel which combines all of the attributes discussed above. Similar vessels can be found in virtually all major fishing ports that harbor trawlers, seiners, or modern longliners. Because of over capitalization in a number of fisheries, vessels of this size and design are readily available, with a number of used boats currently advertised in the US, Australia, and New Zealand. With limited entry becoming the standard in most developed fishing countries, excess boats and shipyard capacity are the rule. This means that either new or used vessels can be purchased at reasonable prices (relative to the market of a few years ago).

Figure 5. Small-Scale Tuna Longliner - Composite Design

LOA	45'
Beam	16'
Draft	7'
Speed	10 kts
Hull	Aluminum or Fiberglass
Hold Cap	10 mt'
Fuel Cap	6000L

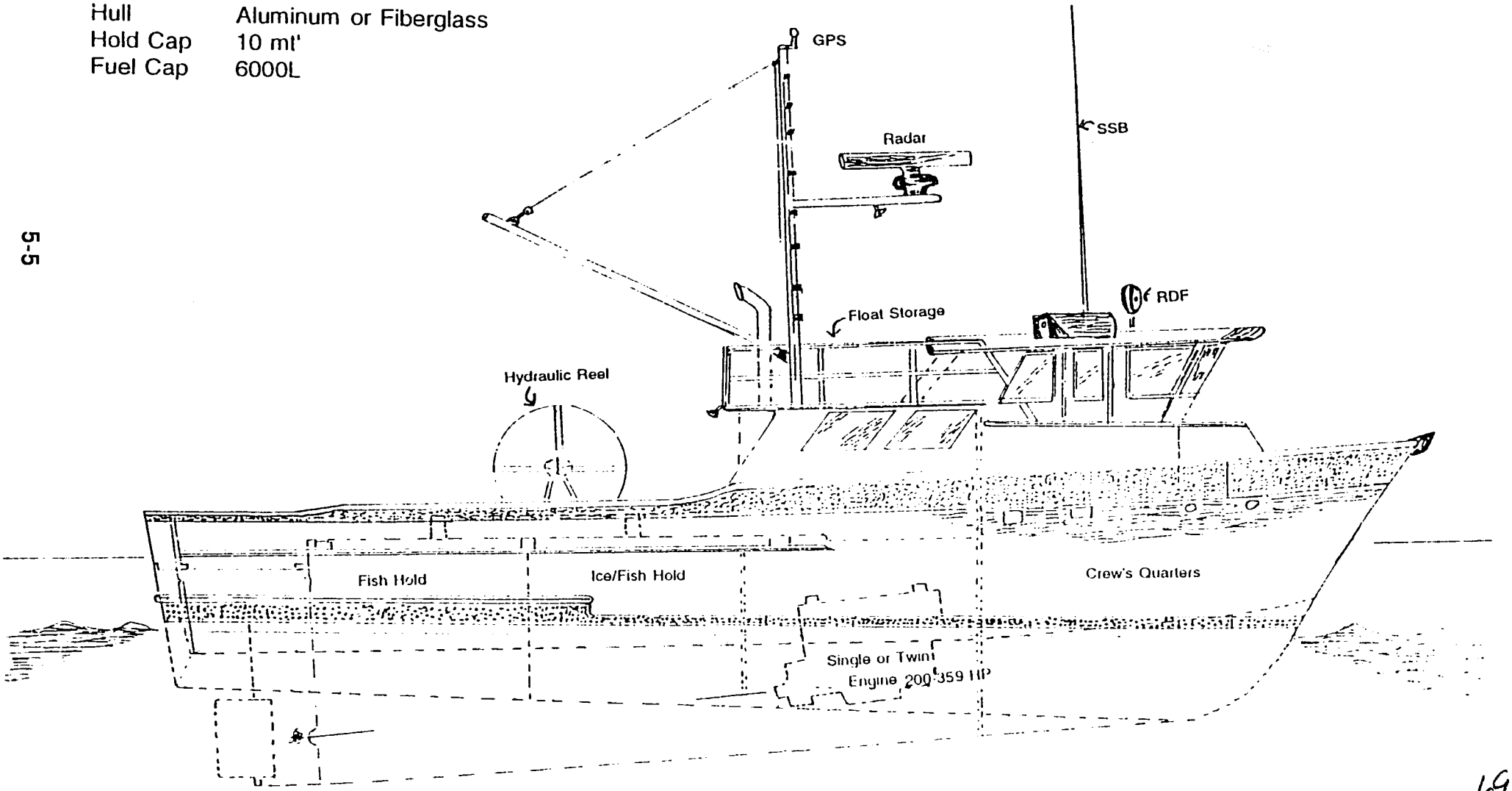
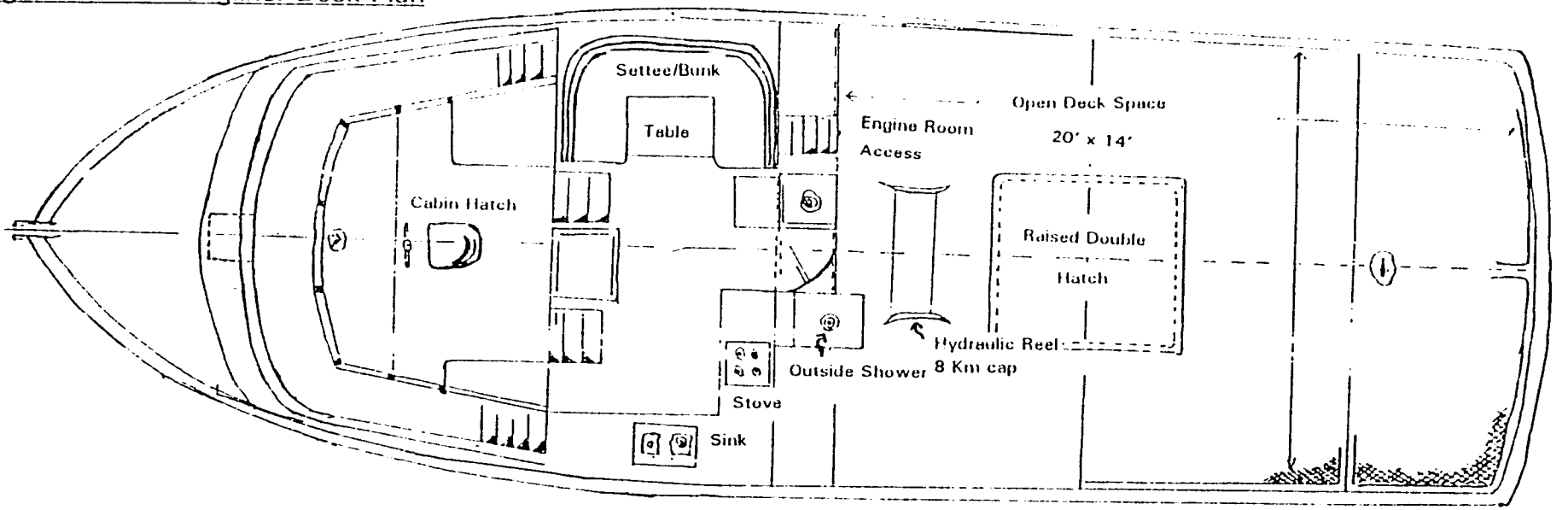
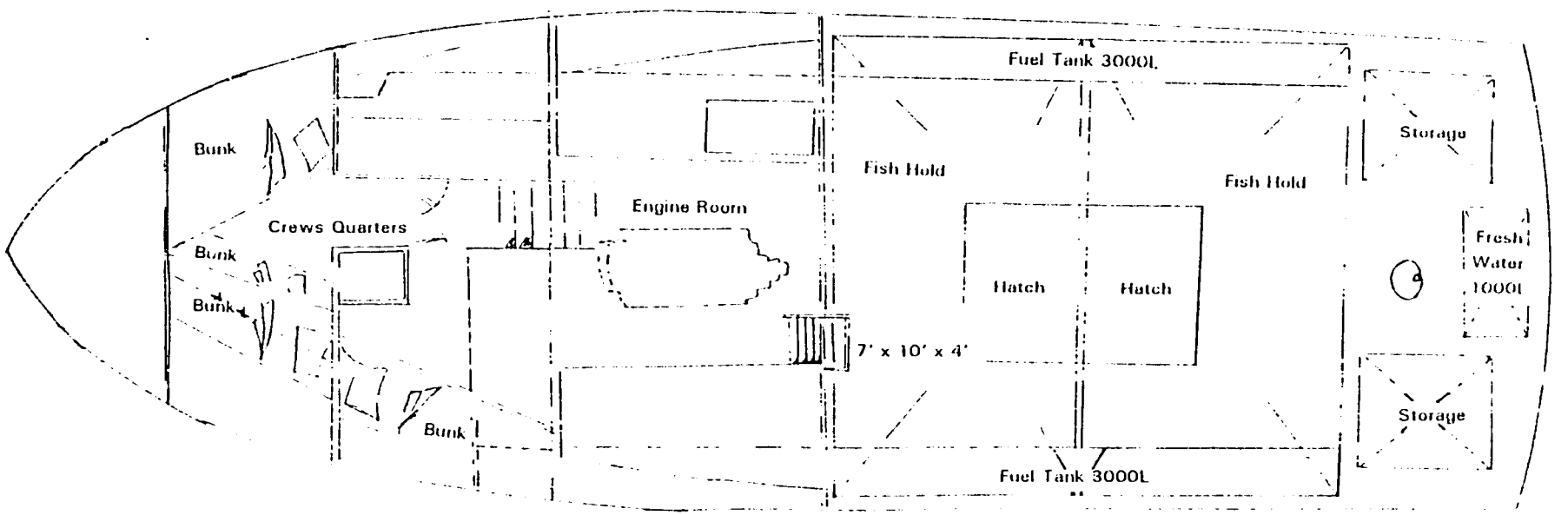


Figure 6. 45' Longliner Deck Plan





Below Decks View

The question of new versus used vessel is often a matter of personal preference, but should be dictated by economics. Our analysis indicates that the total investment for small-scale longlining should not exceed T$250,000, including vessel, gear, delivery costs, and capital reserve. A new vessel built in the US or Australia might exceed this limit, but prudent shopping at shipyards could result in a reasonably-priced new vessel. However, if the prospective owner is experienced in judging vessel condition, a used vessel is probably the more attractive alternative. A good aluminum, fiberglass, or steel hull should have a life of at least 20 years. Engine and machinery life is generally in the neighborhood of five years. Ideally, a vessel aged 0-2 years (or 5-7 years with new engine and machinery) should offer the best investment opportunity. Of course, the vessel maintenance history must be carefully examined as reliability of engines and equipment will be the single most important factor in establishing a successful fishing operation in Tonga.

In the past year, two used vessels in the 40-45 foot class were imported from New Zealand and Australia for the Tongan longline fishery. Each of these vessels met the investment criterion of total costs below T$250,000 (in fact, one of the vessels had total investment costs of less than T$150,000). However, the second vessel did not meet the machinery age criterion and has suffered major down time because of a defective engine. The two vessels are of completely different hull design, but both have effectively fished small monofilament longline systems. This demonstrates that a specially designed, purpose built vessel is not required for the developing longline fishery.

As noted earlier, economic results from fishing trials on 45-55 foot vessels using 32 km longline systems were negative. Since the investment costs would approach T$350,000 and operational costs would increase 25-40%, this size of vessel is not recommended.

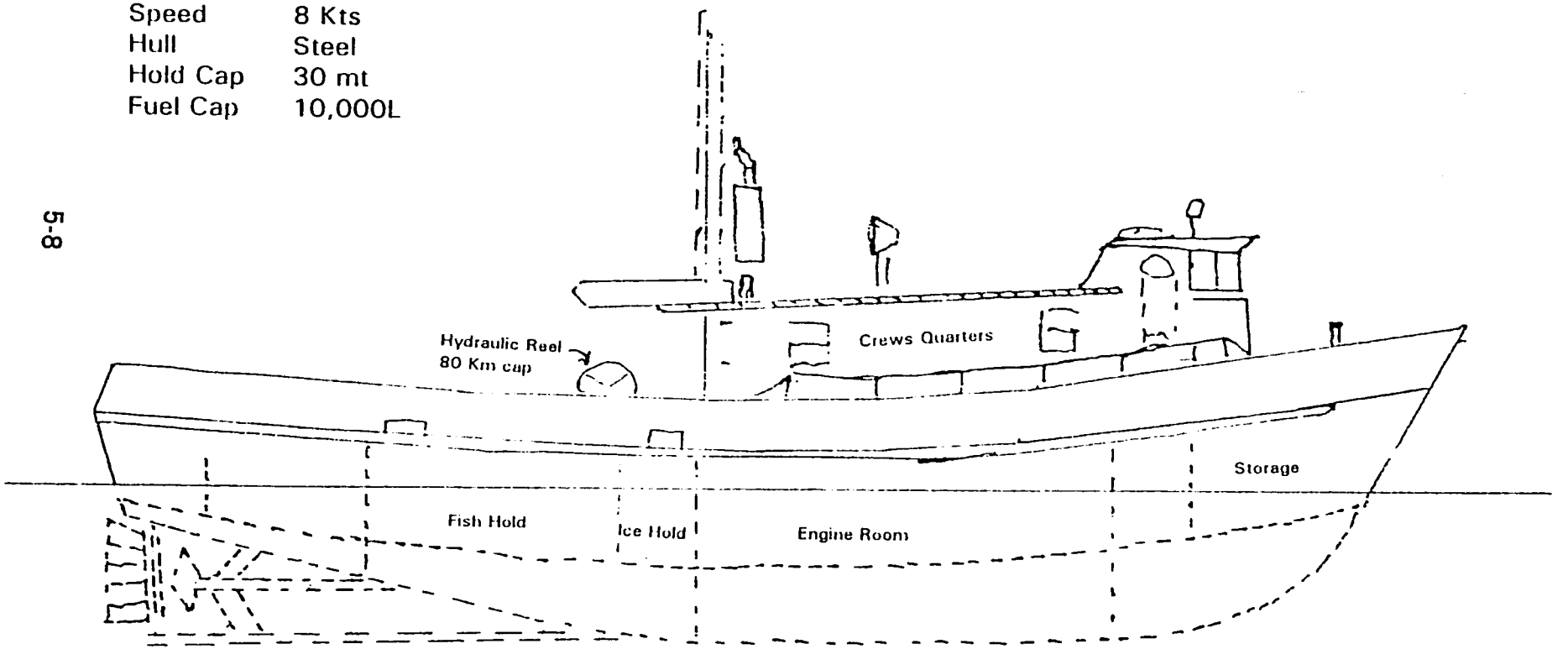
Figure 7 illustrates a trawler/seiner hull in the 60-75 foot range. This size and design of vessel is common in the Fiji and Hawaii longline fisheries, but must utilize maximum gear (80 km system) to be economically effective. Total investment costs would be in the neighborhood of T$450,000 for a used vessel, and T$750,000 for a new vessel. The investment costs are probably not within the reach of an individual entrepreneur, but may suit a larger corporation.

Sea Star has invested in two vessels of traditional Japanese longline design and has reportedly had trouble adapting the monofilament system to these vessels. Other than problems with vessel suitability, Sea Star is using 32 km systems which do not give enough fishing power for the size of vessel.

There are currently no boat yards in Tonga that are capable of building either 40-45 foot vessels or 60-75 foot vessels of aluminum, fiberglass, or steel. Further, it is questionable whether skill levels exist in Tonga to construct the hulls and install machinery, electric,and electronic components. As all materials and equipment have

Figure 7. Standard Trawler/Longliner

LOA	65'
Beam	18'
Draft	10'
Speed	8 Kts
Hull	Steel
Hold Cap	30 mt
Fuel Cap	10,000L



to be imported at relatively high cost, it is doubtful that low labor costs would provide a competitive advantage in the local and regional market. Several large, well established boat yards in Fiji have not been able to compete cost wise or quality wise with vessels built in Australia, New Zealand, or the US.

In summary, it is the project staff's conclusion that suitable vessels are readily available from overseas fisheries for the development of the Tongan longline fishery. This is not viewed as a constraint to the industry. However, if the prospective Tongan entrepreneur is not experienced with fishing vessels, he would be well-advised to hire the services of a qualified vessel consultant and marine surveyor. The costs of such consultants (T$5,000-10,000) would be returned many-fold in investment and downtime savings.

5.3 Transport

Inter-island transportation and international air cargo space and rates have been identified as major constraints to development of the Tongan longline industry. There are no easy solutions to these vexing problems, but the Government of Tonga may be able to at least ease the situation with a little coordination.

Both ferries that service Vava'u have mid-week arrivals and departures. It seems probable that one ferry could arrive and depart Vava'u on Tuesday, and the other on Friday. As the government is a major shareholder in the largest ferry, perhaps schedules could be adjusted. It is also possible that, with the upgraded Vava'u airport, larger aircraft with fish carrying capacity could be utilized in the future. Dialog with Royal Tongan Airlines may result in a more appropriate class of airplane for the Vava'u sector.

The problems associated with international air freight are two fold. Air cargo rates are high for the Tonga sector relative to other sectors in the region. As cargo rates are negotiable, and as Tonga has its own carrier, coordination between government ministries could result in a downward adjustment of rates. The potential shortage of air cargo space is not so easily handled as it is dependent on the number of flights servicing Tonga. However, dialog between government and the airlines could result in adequate planning to at least partially ameliorate future needs.

As the government agency responsible for fisheries development, it is within MOFs responsibilities to initiate discussions with other government agencies and the private sector to seek solutions to the transportation constraints.

5.4 Training

Development of manpower skills for the longline fleet is an important issue, but, if properly approached, should not be a critical constraint to development. There is no shortage of trainable deck crew in Tonga, and project experience showed that we could develop competent deck skills within one month. It is our considered opinion that no special program is required for the deck crew, they can be trained in a commercial operation by a competent vessel captain.

The training of competent captains is more complex. A limited vessel masters certificate is required by insurance companies for insured fishing vessels. Assuming that the investment in longliners would be insured, certified captains are mandatory. Training of seagoing personnel in Tonga is conducted by the Fokololo Polytechnic Maritime School. After a rigorous course of academics and sea experience, captains (and mates and engineers) can sit for Marine Department certificates. The number of qualified captains currently residing in Tonga is unknown, but is thought to be adequate for the developing fishing fleet. A masters certificate, of course, does not imply knowledge of fishing. This can only be gained by extensive experience in fishing operations and the adoption of a commercial fishing mentality.

It is felt that a special program to train fishing vessel captains is crucial to development of the longline fleet. However, the program should not be carried out initially in Tonga. The most practical and cost-effective method of training senior crew is by placing them on commercial vessels in an established fishery. This can be done through inter-governmental arrangements with the private sector. For example, MOF arranges with another countrys fisheries or education agency to place Tongan captains on a commercial longliner in that country for a period of six months to a year. The Tongan trainee works as a paid member of the crew while he is in training, thus earning income. The private foreign company benefits by paying a reduced share for the trainee (usually half-share) who works as a full-time member of the fishing crew. The cost to MOF is a round-trip air fare. This arrangement has worked successfully in Hawaii, and, assuming inter-governmental cooperation, could be done in regional countries that already have a modern longline fishery (such as Fiji, New Zealand, Australia, or Hawaii). Countries that still use the traditional longline methods (Japan, Korea, Taiwan) would not be a wise choice. In the long term, as the Tongan fleet develops, the on-board training could be conducted from local vessels.

The training of vessel engineers is not quite so complex. Engineering graduates from the maritime school should be competent in any of the systems found aboard a small longliner. Since the engineer usually participates in fishing operations by running the winch systems, this should not require any training other than supervision by a competent captain.

Since one of the major attributes of the monofilament longline system is reduced crew size (usually four or five total crew), there is no need for a mate or deck boss. The

captain should be able to personally supervise all fishing operations.

In summary, the only special training program required for development of the Tongan longline fleet is placing of captains on established commercial vessels in a cooperating country.

5.5 Markets and Handling

5.5.1 Fish Handling

The primary handling constraints faced by the project during 1993 fishing trials were the poor quality of ice and the inability to brine fish because of vessel limitations. The ice problem has been solved with the opening of a private ice facility in Vava'u in February 1994. Commercial longline operators would be well advised to consider installation of brining tanks on their vessels or, alternatively, to implement the pressurized tuna bleeding technique which has replaced brining on long-range Japanese *sashimi* boats. Proper care of tuna may not be as crucial in fisheries where tuna are off-loaded from the vessel and immediately air shipped, but the ferry ride and limited air service make fish shelf life a key issue for the Vava'u fishery.

5.5.2 Target the *Sashimi* Market

Considering the high cost of export, it is unprofitable to export lower-quality tuna. It is essential to differentiate lower-grade and higher-grade fish in each catch. When demand is strong in overseas *"sashimi"* tuna markets, grade 1 through grade 3 fish can be exported. When markets are weak, only grade 1 and grade 2 fish should be exported. Each export company should dedicate one person to the critical task of grading tuna. Recognition and rejection of lower-grade fish requires continual improvement of grading skills. The grader should receive feedback on every shipment and should communicate with Hawaii and Japanese tuna specialists whenever possible.

5.5.3 Develop Overseas Marketing Relationships

Fresh tuna is an internationally-traded commodity. Fish are usually sold on consignment, through auctions or wholesale distributors, and to final processors. The quantities and prices of tuna sold through auctions or wholesale distributors fluctuate widely with supply and demand. Final processors, on the other hand, have commitments to supply steady customers with regular amounts of fish. To obtain a steady supply, tuna is purchased from the spot market (auctions, wholesalers) and directly from fishing fleets and exporters. As they become more consistent in the production of export-size, *"sashimi"*-grade tuna, Tonga exporters can expect to develop steady relationships with processors in Hawaii and possibly in Japan. Such relationships are valuable to both parties. The importer can rely on a consistent supply of fish that can be blended into normal sales. The exporter, in contributing to a more stale business climate for the importer, can expect to receive a more consistent price than by selling in the volatile spot market. Small-scale longline operators in Tonga

should strive to develop mutually-advantageous relationships with Hawaii and Japanese tuna processors.

5.5.4 Improve Packing For Overseas Export

FDA has proposed new regulations for U.S. seafood processors and importers that could place scombroid fish species, including tuna, under stricter temperature control guidelines (4.4 C or 40 F). If the FDA proposal is implemented, Tongan tuna exporters will need to improve packing for better temperature control. The ratio of fish weight to frozen coolant weight in shipping cartons should be reduced to 8:1 or lower. A heavier grade of "insufoil" or one-piece styrofoam coffins with better insulating properties should be used. These improvements should allow fish to be delivered to Hawaii with core temperatures below 4.4 C (40 F).

5.5.5 Improve Water Quality

Tap water presently available at the GOT fish markets in Nuku'alofa and Vava'u does not meet U.S. drinking water standards. This water should not be used for ice make-up slurry make-up of fish processing unless it is treated. The preferred method of treatment would probably be ozonation, which can be accomplished with small-scale, relatively inexpensive equipment and without chemicals.

5.6 Financing

As noted earlier, the private banks and Tonga Development Bank have little experience in medium to large vessel loans. The short-duration terms offered by the banks put an unnecessary burden on vessel operators during the learning phase of fishing. We have found the Development Bank officials to be flexible, and believe that, with more complete information on the potential of the longline fishery, the bank will liberalize its terms. MOF and the Ministry of Commerce could assist by preparing a presentation to the banks which details expected catch rates, returns, vessel longevity, and costs.

5.7 Infrastructure

The primary infrastructural need for longline fishery development is additional dock space in Vava'u. Approximately 200 linear feet of new dock frontage will be necessary to accommodate growth in the northern fishery. Water and power facilities are needed in both Vava'u and Nuku'alofa. MOF should scope out these requirements and petition through normal channels for inclusion within the capital improvements budget.

Shoreside ice and fuel service will need to expand to meet the requirements of the expanded fleet. Since these services are carried out by the private sector, MOF should present information to the concerned companies estimating fleet usage over the next ten years.

The freezer facilities operated by MOF on a number of islands are adequate for bait processing and/or storage. However, at least one of the freezers at Nuku'alofa and one at Vava'u should be converted to chill boxes for the holding of fresh tuna prior to trans-shipment.

5.8 Institutional

Even though understaffed, the Department of Fisheries will play a critical role in the development of the Tongan longline fishery. The growth of the fishery must be carefully managed to avoid over capitalization, especially in the early stages. MOF will need to adopt a limited entry licensing scheme to ensure measured growth.

MOF must take the lead in disseminating information and coordinating with other governmental agencies and the private sector. At the very least, briefings should be prepared for Cabinet, Ministry of Finance, Ministry of Commerce and Labor, and the Tonga Development Bank. Areas which should be targeted are training, inter-island transportation, international air cargo, dock construction, water quality, and vessel financing.

Because of the import requirements of the US and Japan, MOF will need to adopt a certification program for exports. However, it is unrealistic to expect MOF to assign finite grades to the exported tuna. Simple certification as "fit for export" should suffice. It should be up to the individual exporters to assess and export by grade.

6.0 NATIONAL BENEFITS

Although the Tongan longline fleet could expand to as many as thirty vessels, the following benefits to Tonga have been calculated on the basis of modest growth to only ten vessels. By and large, all of the projections are based on conservative estimates. The total catch from ten vessels is estimated at 1000 mt, of which 500 mt would be exported.

For these ten vessels, the direct income from export and domestic tuna sales would increase by T$4.5 million, with net foreign exchange earnings of T$3.5 million. The direct income would generate a demand for associated services and goods. Using a conservative multiplier effect of 2.5, roughly T$11.25 million would circulate through Tongas economy.

In terms of direct employment, the fleet would require a minimum of 50 new fishing jobs and at least 20 new shoreside positions in fish handling, ice making, etc.

An indirect benefit will be nutritional improvement as more relatively low-priced tuna is placed on the domestic market and hopefully replaces such low-quality items as mutton flaps. It is estimated that perhaps T$0.5 million could be saved by import substitution.

There will be costs to the Government of Tonga, but these should not exceed T$1.0 million, and will be primarily in dock construction about five years in the future. These costs will easily be offset by company tax revenues over a five-year period.