MINISTRY OF FISHERIES
THE KINGDOM OF TONGA

BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR CONSTRUCTION OF TUNA FISHING RESEARCH AND TRAINING VESSEL
IN
THE KINGDOM OF TONGA

March, 1997

JAPAN INTERNATIONAL COOPERATION AGENCY
MARUHA CORPORATION

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PREFACE

In response to a request from the Government of the Kingdom of Tonga, the Government of Japan decided to conduct a basic design study on the Project for Construction of Tuna Fishing Research and Training Vessel and entrusted the study to the Japan International Cooperation Agency (JICA).

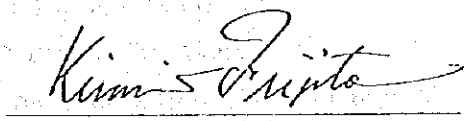
JICA sent to Tonga a study team from November 14 to December 12, 1996.

The team held discussions with the officials concerned of the Government of Tonga, and conducted a field study at the study area. After the team returned to Japan, further studies were made, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Tonga for their close cooperation extended to the team.

March, 1997



Kimio Fujita
President
Japan International Cooperation Agency

March, 1997

Letter of Transmittal

We are pleased to submit to you the basic design study report on the Project for Construction of Tuna Fishing Research and Training Vessel in the Kingdom of Tonga.

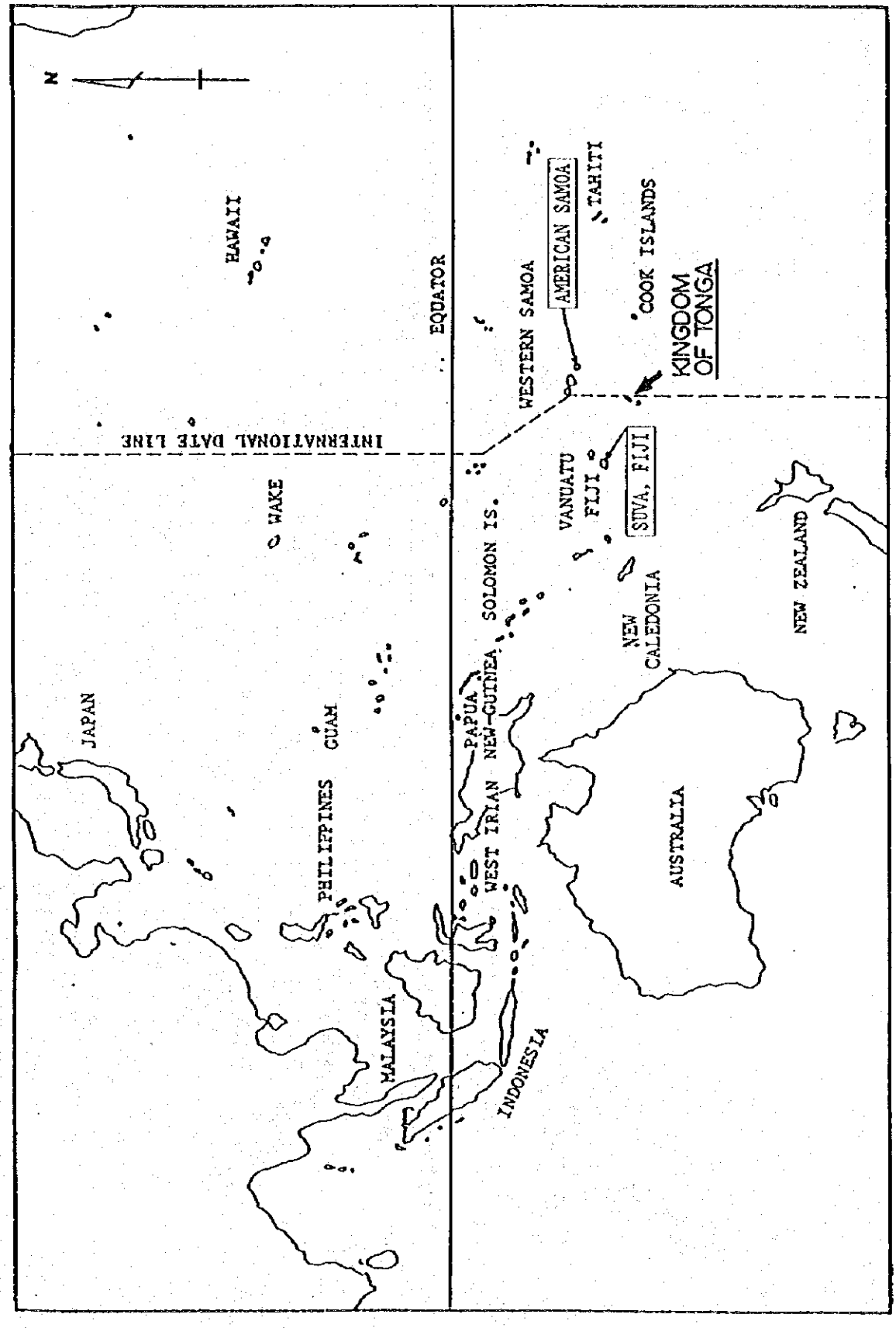
This study was conducted by Maruha Corporation, under a contract to JICA, during the period from November 1, 1996 to March 31, 1997. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Tonga and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

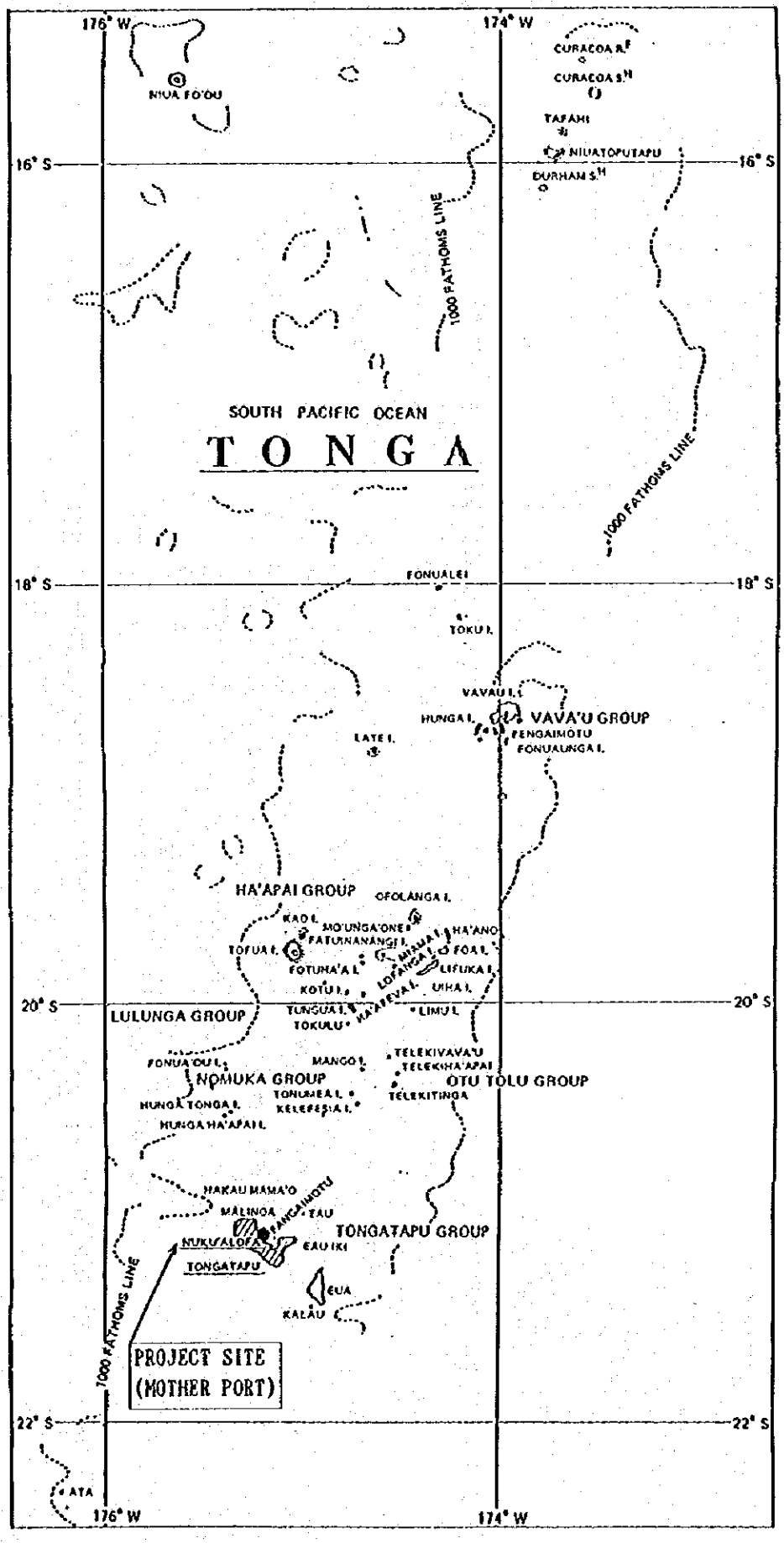
Very truly yours,

Toshio Hosonuma
Project manager,
Basic design study team on
the Project for Construction of Tuna
Fishing Research and Training Vessel
Maruha Corporation

LOCATION OF THE KINGDOM OF TONGA



LOCATION OF THE PROJECT SITE



Abbreviations

AIDAB:	Australian International Development Assistant Bureau
ADB:	Asian Development Bank
CPUE:	Catch Per Unit Effort
EEZ:	200 miles Exclusive Economic Zone
FFA:	South Pacific Forum Fisheries Agency
MSY:	Maximum Sustainable Yield
SPC:	South Pacific Commission
SPF:	South Pacific Forum
SSFCL:	Sea Star Fishing Co., Ltd.
USAID:	United States Agency for International Development
T$:	Tongan Dollar (1T$ = 93.70 yen)

Contents

[Appendices]

Chapter 1 Background of the Project

Chapter 1 Background of the Project

The Kingdom of Tonga consists of all sizes of approximately 150 islands located in the middle part of southern Pacific Ocean scattered in an area of 15°00' – 23°30' S and 173° – 177°W. These islands can be divided into three groups, from the south, Tongatapu Islands, Ha'apai Islands and Vava'u Islands. The total area of land is approx. 697km^2 and the surrounding sea area of these islands of the EEZ (200 sea miles Exclusive Economic Zone) as large as approx. 700,000 km^2 forms a good fishing ground of tuna species mostly of albacore tuna.

The total amount of GDP for FY 1995 was T$79,310,000 and the proportions of agriculture, sightseeing and fishery industries which are the three pillars supporting the Tongan economy were 30.0%, 13.5% and 10.6% respectively. With regard to the GDP growth rate, 6.3% was recorded in FY1990 thanks to the export of squash for the winter solstice demand in Japan started in 1989, but the growth rate declined to 1.7% in FY1995 as the amount of the export of squash decreased in and after 1993. Turning our eyes to the trend of respective proportions of these three major industries in the GDP, the agricultural industry decreased from 37.1% to 30.0%, the sightseeing industry flattened from 13.8% to 13.5% and the fishery industry from 3.4 to 10.6%. Such a substantial increase in the fishery industry is attributable to the promotion of the commercialized tuna fishing industry. The Tonga government wishes to develop its economy in coming years by further promoting said industry.

Meanwhile, the amount of exports in 1995 was T$18,020,000 while that of imports was T$98,050,000, thus showing a sizable excess of imports. Out of the exports, the primary products occupied 92.5% of the total exports consisting of agricultural products for 68.4% and fishery products for 24.1% respectively. The representatives of the agricultural products are squash and vanilla. The export of squash which started in 1989 recorded 60.4% of the total exports in 1991 but declined to 46.6% in 1995 due to the dropped market price associated with the decreased amount of production. As to vanilla, it also decreased from 19.2% in 1990 to 15.5% in 1995. On the other hand, fishery products increased substantially from 7.3% to 24.1% in 1995. The increase in export of fishery products was attributed to the export of tuna by the SSFCL which started business in 1991 and

the private fishermen who started business in 1993 in addition to the export of sea cucumber which was started in 1991. The Tonga government intends to further encourage the commercialized tuna fishing industry from the viewpoint of improving Tonga's balance of trade, too.

The Tonga government has given the priority to the promotion of commercialized fishing industry with an aim of promoting export of fishery products, expansion of their domestic supply as well as enlarging the employment opportunities, particularly the promotion of the tuna fishing industry which has plentiful unused natural resources as the development target of the fishery sector in the 6th Development Plan (1991 – 1995). In this regard, the Tonga government has decided, as its national policy, to develop the tuna resource in the EEZ by Tongan fishing vessels themselves, without relying upon the fishing operations in that area by foreign fishing vessels, based on the fostering of the crew provided by the M.V. LOFA, a tuna fishing training vessel which was included in the grant aid scheme of the Japanese government for FY1980, and on the good results of exploring of the fishing grounds as well. In line with this policy, the Tongan cabinet decided to establish the SSFCL as a model company of the tuna fishing industry in 1990. The SSFCL has started business by using the M.V. LOFA which was transferred from the Ministry of Fisheries in 1991. In addition, the government is making efforts in fostering the private fishermen, too, by giving the licence for tuna fishing to them in and after 1993.

Furthermore, the Tonga government has established the tuna longliner increasing plan by giving consideration to the maximum sustainable yield (MSY) based on the results of the tuna resource evaluation research study conducted by the USAID for a period from 1991 to 1994 and intends to develop the tuna fishing industry in a sustainable manner. According to this plan, they intend to increase the number of the vessels owned by the SSFCL from the present five to fifteen and that of the vessels owned by the private fishermen from the present three to fifteen during the period of coming ten years with an aim of increasing the annual haul of fish in the EEZ from the present approx. 650 tons to approx. 3,000 tons as the MSY. For achieving the above target, the government encourages to increase the number of vessels owned by the SSFCL as well as the private fishermen through various measures including the tax holiday and providing low-interest

loans.

For materializing the tuna longliner increasing plan established by the Tonga government, it is said, first of all, that it would require training of approx. 240 new crew for the coming ten years. With regard to the training of the new crew of the SSFCL, it is expected that the requirements will almost be satisfied by fully utilizing the training capacity of the M.V. LOFA which is being operated by the SSFCL. However, as to the training of the new crew of the private fishermen, the M.V. LOFA will have no excess capacity for that purpose and no other appropriate training vessel is available thus posing a problem. The second issue would be the expansion of the fishing operations area in order to avoid the expected overcrowded fishing operations in the present fishing ground of the middle area in the EEZ due to the increased number of longliners by means of implementing fishing ground research in the north and south areas in the EEZ which have not been fully utilized yet. Furthermore, they say that it would not be too early to implement a new fishing ground research in the southern area out of the EEZ, too, in preparation for future entering into the distant water fishing which would obviously become necessary. However, unfortunately the M.V. LOFA does not have such research capacity.

From the above viewpoints, the Tonga government has established the "Project for Construction of Tuna Fishing Research and Training Vessel" and requested the Japanese Government to grant an aid scheme for the purpose of training of the crew of the tuna fishing vessel and exploring new fishing grounds.

Details of the request:
One tuna fishing research and training vessel including fishing gears and relevant spares

Chapter 2 Contents of the Project

Chapter 2 Contents of the Project

2-1 Objectives of the Project

In view of the present unfavorable situation of the stagnant agricultural industry coupled with the depressed sightseeing industry, the Tonga government is making its efforts to promote the tuna fishing industry which has a plentiful unused resource as a major industry and which would play an important roll in acquiring foreign currencies as well as securing employment by replacing itself with the above-mentioned two industries. And, the Tonga government holds a persistent national policy which would encourage the initiative to increase the number of the longliners of its own so that the tuna resource in its EEZ would be effectively utilized rather than allowing foreign vessels coming into its EEZ.

This Project has the particular objectives of "training of the crew" and "making research of new fishing grounds" which are essential for the tuna longliner increasing plan aiming at expanding the annual haul of tuna to the maximum sustainable yield (MSY) of approx. 3,000 tons through increasing the number of the tuna longliners to 30 vessels during the coming ten years.

In connection with the training of the crew, the training focuses mostly on the new crew of the private fishermen who would play an important roll in the future development of the tuna fishing industry, with the objectives of guiding proper method of fishing and processing of the fish caught as well as efficient and effective fishing operations. Further, with regard to the research activities, the objectives include making research in the north and south sea areas within the EEZ where the fishing operations will be conducted by the tuna longliners the number of which will be increased in the coming ten years and providing the information so obtained to the SSFCL as well as the private fishermen in addition to conducting the fishing research in the southern open sea out of the EEZ, too, so that infrastructure-oriented information will be gathered in preparation for entering into the distant water fishing in the future.

2-2 Basic Concept of the Project

2-2-1 Training Program

(1) Objectives of the training

The objectives of the training is fostering the tuna longliner crew who would be required in Tonga in the future from the national standpoint whether they are of the SSFCL and the private fishermen or not. Therefore, the trainees to be covered by this Project are mostly the new crew of private fishermen but those new crew of the SSFCL who would not be covered by the training to be provided by the M.V. LOFA, will also be included in the training.

(2) Expected demands for the training

According to the investigations conducted with regard to the gross tonnage, number of vessels and number of crew per vessel of the longliners to be increased in accordance with the tuna longliner increasing plan, the number of new crew who will be required for the coming ten years are given below:

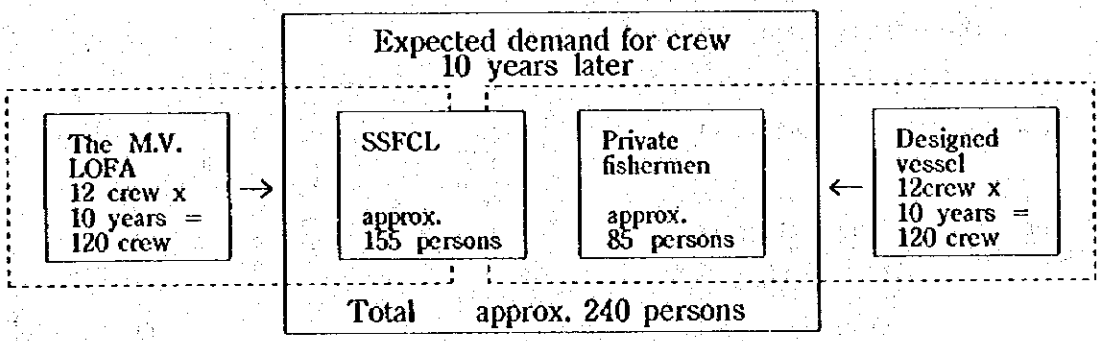
Type of corporation	Gross tonnage	Converted to Int. gross tonnage	No. of vessels increased	No. of crew per vessel	No. of new crew required	Type of longline
SSFCL	19 tons	30 tons	5	10	50	Monifilament type
	69 tons	110 tons	3	17	51	Conventional type
	120 tons	190 tons	2	17	34	Conventional type
Sub-total	--	--	10	--	135	--
Private fishermen	15 tons in average	25 tons	12	6	72	Monifilament type
Sub-total	--	--	12	--	72	--
Total	--	--	22	--	207	--

Against the actual number of the crew, 207, the number of the crew to be fostered through the training is expected as follows when giving considerations to the 5% of the ratio of reserve hands and 10% of the

ratio of separated crew based on the results of the SSFCL: 207 x 1.05 x 1.10 = approx. 240.

(3) Training period

The annual training period of four voyages can be divided into the first half and the second half each of which will be about half a year (two voyages) respectively and the number of the trainees to embark for one training will be 6 as same as for the case of the M.V. LOFA. On this basis, 12 crew for a year and 120 crew for ten years will be fostered on the same assumption for the M.V. LOFA. Accordingly, as shown in the Figure below, the expected number of crew required ten years later by the SSFCL and the private fishermen, approx. 240, will be supplied under the two-vessel system consisting of the Designed Vessel and the M.V. LOFA.



(4) Training of fishing method

In consideration of the fact that the monofilament type longline is employed by the small-sized longliner while the conventional type longline by the medium- and large-sized longliner, the training will be given to the trainees to conform to both of the fishing methods, i.e. the training for the conventional type longline and the monofilament type longline for one voyage each for the first half and the second half respectively.

Item	Training for 1st half of the term	Training for 2nd half of the term	Remarks
No. of trainees	6 persons	6 persons	Total 12 persons/year
Conventional type longline			2 voyages (approx. 160 days)
Monofilament type longline			2 voyages (approx. 160 days)

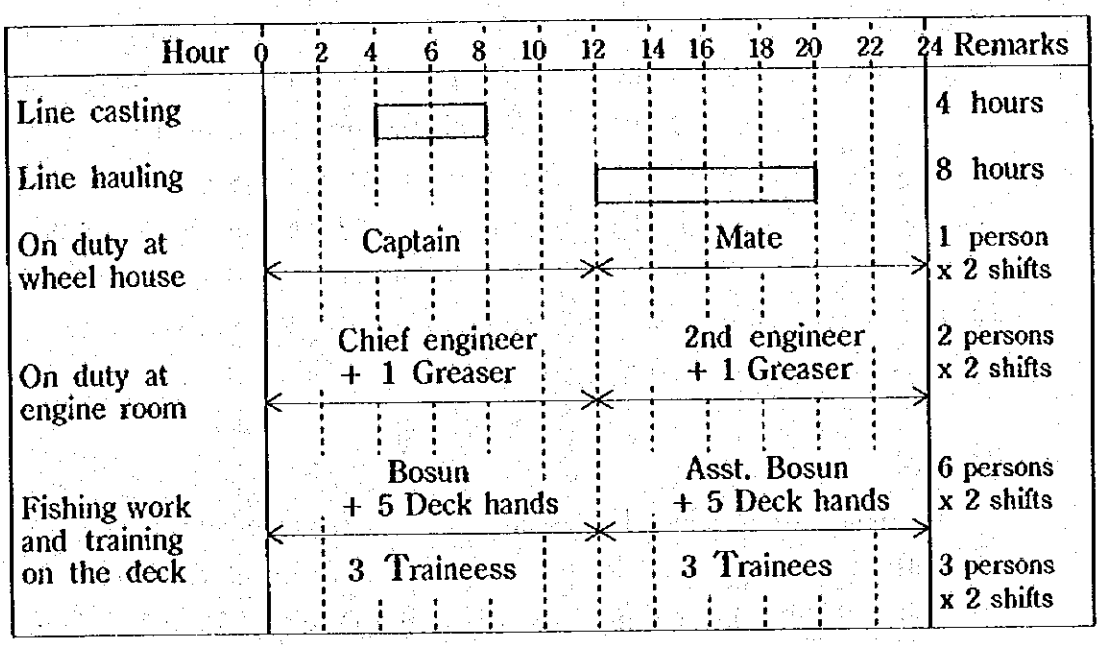
(5) Contents of training

The contents of the training will include that linked directly with the actual needs such as for the fishing work on deck and disposing and processing of the fish caught so that those crew will be fostered who can be used immediately after their embarkation. The detailed contents of the training are given below:

Classification	Details of training	Fishing method	
		Conventional type longline	Monofilament type longline
Fishing work on deck	Line casting work	O	O
	Line hauling work	O	O
	Operation of fishing machinery	O	O
	Production and repairing of fishing gear	O	O
	Control of bait	Common	
	Safety measures	Common	
Disposition and processing of fish	Taking fish onto the deck	Common	
	Cutting off heads and giblets from fish	Common	
	Blood washing off and cleaning	Common	
	Ice packing work	Common	
	Freezing work	Common	
	Quality control	Common	
	Stow fish in the fish hold	Common	
	Unloading fish on the pier	Common	

(6) Training method

From the viewpoint of fostering those crew who can be used immediately after their embarkation, the training method will introduce the same actual fishing operation method, which would involve the casting and hauling of lines one each a day providing Sunday as a holiday. The training schedule of a day is given below:



2-2-2 Research Program

(1) Objectives of research

Although the Tonga government intends for the time being to develop all of the fishing grounds located in its own EEZ for the coming ten years, it plans to go into the distant water fishing in the southern open sea after the annual haul of tuna in the relevant sea area reaches the maximum sustainable yield of approx. 3,000 tons. Such being the intention, the objectives of the research are to conduct the test fishing operations in these areas and to provide the information so gathered to the private fishermen and the SPC so that it will be used for the effective fishing operations and fishing resource control as well as for establishing the infrastructure-oriented foundation for the development of the tuna fishing in the future.

(2) Kinds of fishes and fishing periods covered by the research

The southern Pacific temperate water areas including Tonga's EEZ are well known as a fishing ground of albacore tuna. According to the results of the fish haul of the M.V. LOFA, the proportion of albacore tuna reached approx. 70%. Although albacore tuna can be caught through the year in this sea area, its prime fishing period is the winter in the southern hemisphere centering in August. Big eye tuna and yellow fin tuna inhabit widely from the tropical water area around the equator to the cold water area around 40°S. Although the proportion of their haul is small in the sea area of Tonga, it is expected that the proportion of their haul will be increased in the southern open sea located from 25° to 40°S out of the EEZ of Tonga. The prime fishing period of big eye tuna and yellow fin tuna is from December to February, the summer season in the southern hemisphere.

(3) Research sea area

The policy to establish the research sea area is given below:

1) With regard to the middle sea area (18°–23°S) in the EEZ, it will be excluded from the research sea area of the Designed Vessel since we already have the results of the test fishing operations conducted by the M.V. LOFA.
2) With regard to the north sea area (15°–18°S) and south sea area (23°–25°S) located in the EEZ as well as the open sea area out of the EEZ adjacent to the south sea area, these areas will be covered by the research since no sufficient research has not been conducted yet.
3) The area in the south down to around 35°S out of the EEZ is to be included in the research sea area since it is deemed to be a hopeful good fishing ground in the future as there are many ocean deeps and sea mounts on the east side of New Zealand.

(4) Research program

Based on the above results of study, the research program to be conducted is as follows:

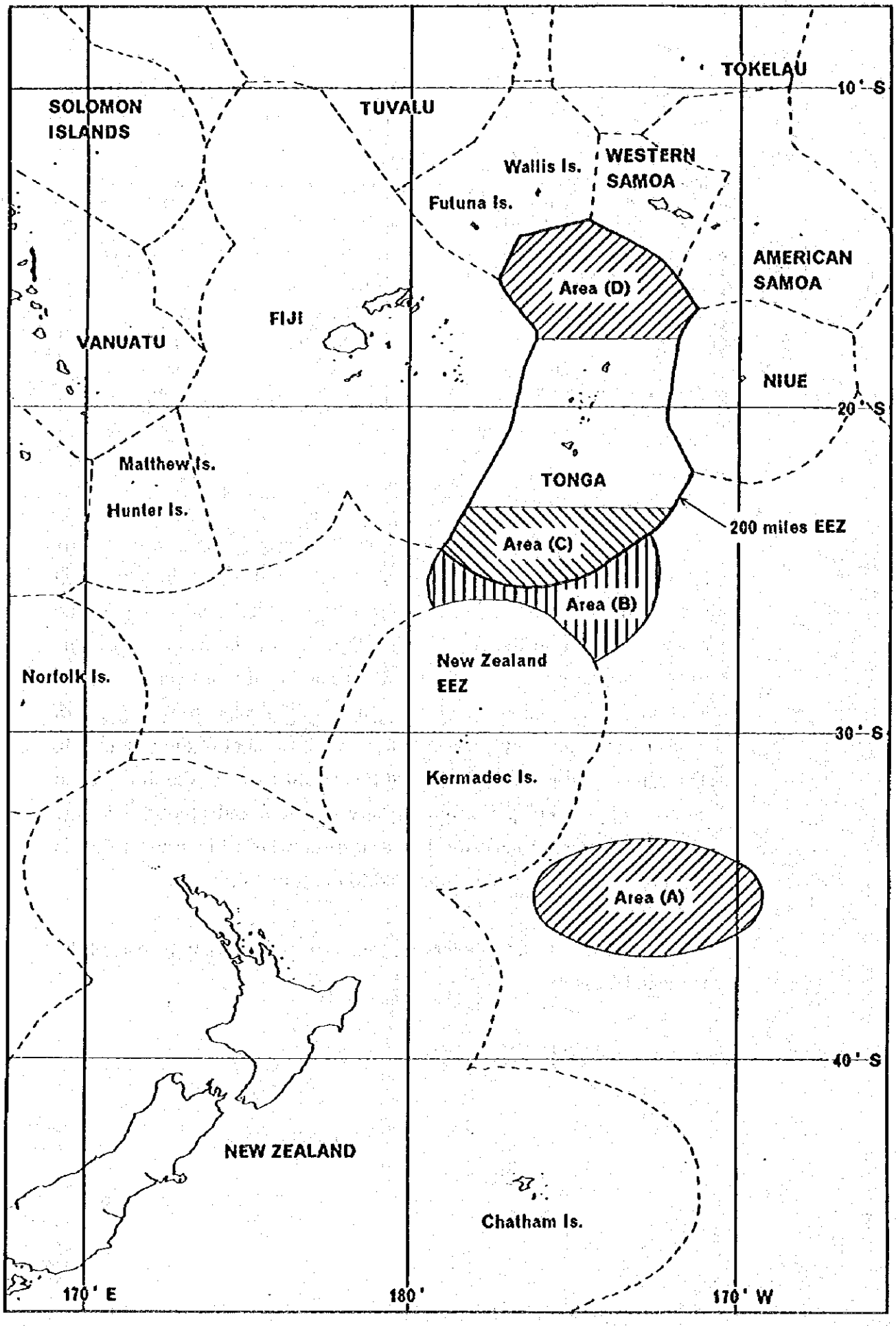
Sea area mark	Researh area	Researh period	Fishing gear used
(A)	Vicinity of 35°S off EEZ (approx. 900 sea miles from the home port)	Summer in south hemisphere (Jan. – Mar.)	Conventional type longline
(B)	Southern open sea adjacent to EEZ (mid-point between EEZs of Tonga and New Zealand)	Autumn in south hemisphere (Apr. – Jun.)	Monofilament type longline
(C)	Southern area within EEZ (23° – 25°S)	Winter in south hemisphere (Jul. – Sept.)	Monofilament type longline
(D)	Northern area within EEZ (15° – 18°S)	Spring in south hemisphere (Oct. – Dec.)	Conventional type longline

(5) Method of research

The research to be conducted by the Designed Vessel, differently from the pure scientific research to be conducted by a fishery research vessel, includes performing the actual fishing work and recording the results obtained on the record paper provided by the SPC. The items to be recorded include the time of the fishing operations conducted, the location of the fishing operations, number of hooks used, number of heads of fish caught by species of fish and the weight of the haul of fish. The Ministry of Fisheries will send the record paper to the SPC for the purpose of controlling the tuna fishery resource and prepare a fishing ground map which indicates the sea areas where big haul of fish is expected. The map will be provided to the tuna fishermen.

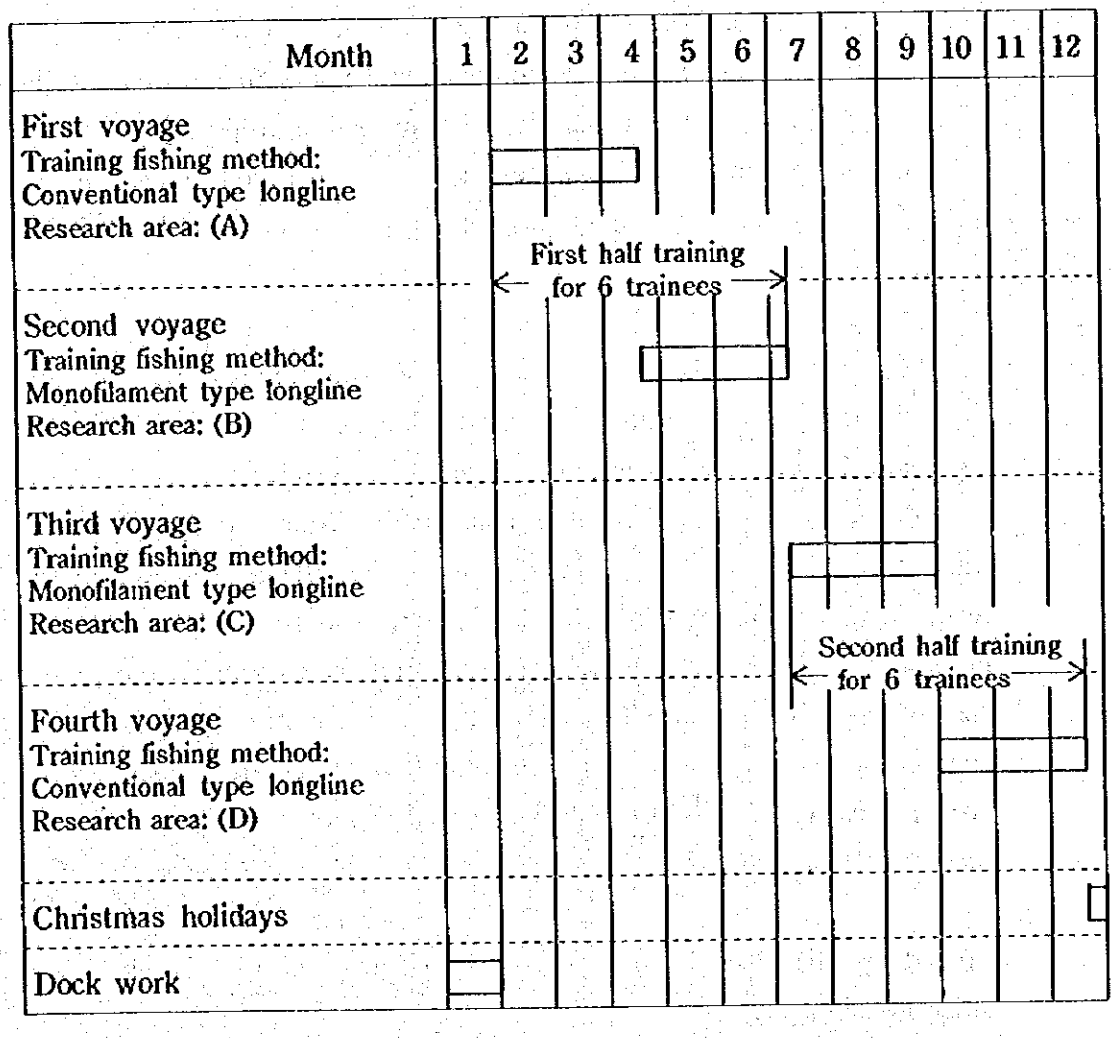
The Figure-1 on the following page shows the research areas of the Designed Vessel.

Figure – 1 Research Areas of the Designed Vessel



2-2-3 Voyage Program

Based on the training program and the research program studies in the preceding item, the annual voyage program of the Designed Vessel is as follows:



2-3 Basic Design

2-3-1 Design Concept

(1) Design concept of the size of the Vessel

Based on the procedures given below, make a plan of the vessel which has the proper service speed, capacity of the fuel tank, capacity of the fish hold, etc. as well as the stability and economy adequately matched with the research and training program.

Procedure– I : Establishment of proper speed and horsepower of the main engine

In view of the fact that the service speed of the M.V. LOFA is 8 knots while that of the tuna longliner of Japan is approx. 10 knots, estimate provisionally the income and expenditures of the service sailing by every 0.5 knots within the range between 8 knots and 10 knots of the service speed and then establish the most profitable proper speed for the service sailing among these estimations. In addition, establish the horsepower of the main engine required for obtaining this optimum speed.

Procedure– II: Provisional estimation of the annual income and expenditures of service sailing, and establishment of proper size of fishing gear as well as proper capacity of fuel tank

Obtain the amount of the fuel consumption from the annual service sailing program based on the proper speed and the horsepower of the main engine established in Procedure– I and the research and training program, estimate the fuel expenses, etc. and then establish the proper size of the fishing gear whose annual service sailing expenses can be covered by the sales income of the haul of fish. In addition, establish the proper capacity of the fuel tank based on the fuel consumption amount required for one voyage.

Procedure– III: Establishment of proper capacity of the fish hold and quick freezing capacity

Estimate the amount of haul of fish per voyage from the size of the fishing gear established in Procedure– II, number of days of the research fishing operations, CPUE (Catch Per Unit Effort), weight of fish body, etc. and then establish the proper capacity of the fish hold based on the above. In addition, establish the proper quick freezing capacity from the amount of the haul of fish per day.

Procedure– IV: Establishment of the proper rooming accommodations and fresh water– related facilities

Establish the proper rooming accommodations by giving

considerations to the limited number of the crew and trainees as well as the problems involved in the rooming accommodations of the M.V. LOFA. Also establish the fresh water-related facilities required from the number of the service sailing days and that of the research fishing operations days established earlier.

Procedure- V : Establishment of the principal dimensions

Study the established conditions under Procedures- I through VI above comprehensively, further study the enough stability and then establish the proper principal dimensions.

(2) Design concept of the machinery/equipment furnished

1) Minimize the quantity and capacity of the machinery/equipment as necessary avoiding any excessive ones.
2) Select such machinery/equipment whose structure is simple and which is easy to handle.
3) Select such machinery/equipment whose maintenance expenses are little as much as possible.
4) Select such machinery/equipment whose parts are relatively easy to get in Tonga or in neighbouring countries as much as possible.
5) Select such machinery/equipment whose parts are compatible with those of other existing vessels as much as possible.

2-3-2 Basic Design

(1) Basic design of the size of the Vessel

Based on the design concept in connection with the size of the Vessel, the basic design of the size of the Vessel is given from the next page to page 68.

Procedure– I : Establishment of proper speed and horsepower of the main engine

1. Method of studying and steps to be followed

Establish the proper speed and horsepower of the main engine of the Designed Vessel under the following procedures based on the research and training program and referring to the values/figures of the results of the M.V. LOFA. Meanwhile, the number of annual voyages will be four a year in accordance with the training and research program under four cycles each of which being starting from Tonga → fishing ground →Tonga (for unloading/loading, holidays and replenishment of water) → Pago Pago (for unloading/loading and replenishment of fuel oil) → Tonga (for holidays and replenishment of water) combined with one docking at Suva, Fiji, in a year. The following provides the step of studying and the methods of studying and calculation by step.

Step – 1 : Establishment of annual non–operating days

Establish the non–operating days consisting of the docking period at Suva, Christmas holidays, wharfing period when returned to Tonga port, unloading period at the time of calling Pago Pago port and holiday period of Sundays on the sea by referring to the results of the service operations of the M.V. LOFA in the past. Since the Designed Vessel is a newly built one, the number of days for docking is assumed one (1) day shorter than that of the M.V. LOFA.

Step – 2 : Calculation of annual total number of days distributable for the round voyage to the fishing ground and research fishing operations

On the assumption of five(5) speeds, 8.0, 8.5, 9.0, 9.5 and 10.0 knots, obtain the number of service operations days required for the round voyage between Tonga and Suva and the four (4) round voyages between Tonga and Pago Pago a year for the time of unloading, and obtain annual total number of days distributable for the research operations and the round voyage between Tonga and the fishing ground out of the annual 365 days under the following formula:

365 days – (Number of non–operating days obtained through "Step–1" + Number of service sailing days obtained through this "Step – 2")

The number of the service sailing days can be obtained under the following formula:

Number of the service sailing days = Number of annual voyages x 2 (round trip) x Distance between ports (in sea miles)/(Speed(knots) x 24 hours)

Distance between ports : Tonga – Suva 420 sea miles (one way),
Tonga – Pago Pago 540 sea miles (one way)

Step – 3 : Calculation of the number of days required for the service sailing between Tonga and fishing ground

The M.V. LOFA was mostly engaging in the research fishing operations in the middle area (approx. days for making round voyages: 4 days x 24 hours x 8 knots ÷ 2 = approx. 384 sea miles one way) in the Tonga's EEZ. Meanwhile, the Designed Vessel will research the southern open sea area near 35°S out of the EEZ ("A" sea area), southern open sea area adjacent to the EEZ ("B" sea area) and southern and northern sea areas in the EEZ ("C" and "D" sea areas). Therefore, obtain the number of days required for one way service operations per one voyage between Tonga and the respective fishing grounds concerned for approx. 900 sea miles one way in the case of research of "A" sea area and approx. 450 sea miles one way in the case of research of "B", "C" or "D" sea area and respectively for each speed mentioned above.

Step – 4 : Calculation of the annual total number of days for round voyages to the fishing grounds and annual total number of days distributable for the research fishing operations

According to the research and training program, they plan to make a research of the "A" sea area (900 sea miles away) once a year and three researches of "B", "C" and/or "D" sea area (450 sea miles away) a year, but in this study we would assume that all of the four researches will be made in the sea areas 450 sea miles away and study the following two cases:

a) Research fishing operations 900 sea miles away x 1 time + Research fishing operations 450 miles away x 3 times
b) Research fishing operations 450 sea miles away x 4 times

For the above two cases, calculate the number of annual service operations days required for making round voyage to the fishing ground at each speed given. Then, the annual total number of days distributable for the research fishing operations at each speed given can be obtained by subtracting the above number of days from the number of days obtained in "Step – 2."

Step – 5 : Establishment of horsepower of the main engine

Assume the horsepower of the main engine (= corresponds to maximum horsepower x 85% after giving considerations to the sea–margin, 15%) required for obtaining the respective service speeds at each five speed given. Next, obtain the average horsepower of the main engine during the research fishing operations on the basis of the horsepower obtained in the above and by giving considerations to the load factor based on the data obtained from the actual fishing operations of the vessel in the past. For making assumptions of the horsepower of the main engine, follow the following methods since no precise calculation can be made at this step.

1) For a vessel of 8 knots type, the speed is the same as of the M.V. LOFA (with the max. horsepower of 500PS). However, the expansion of the size of the hull is expected due to the increase in the capacity of the fuel tank required by the expansion of the sea area to be studied coupled with the expected expansion of the deck area due to the application of both of the conventional type longline and monofilament type longline. Such being the situation, assume the maximum horsepower as 500PS x 1.1 = 550PS, a 10% increase of that of the M.V. LOFA and set the horsepower required as 550PS x 0.85 = 467.5PS → approx. 465PS.
2) For a vessel of 10 knots type and for a case of a vessel built in Japan, it is said that the maximum horsepower required for the similar type of a fishing vessel of this size is 650 – 700 horsepower. In addition, it is necessary to make the vessel stoutish to some extent for securing the enough space of the fuel tank just as the case of a vessel of 8 knots type described in the above. Therefore, assume the maximum horsepower as 550PS x 1.2 = 660PS, a 20% increase of that of a vessel of 8 knots type and set the horsepower required as 660PS x 0.85 = 561PS → approx. 560PS.
3) With regard to the horsepower required for obtaining the other three kinds of speeds, obtain such horsepower by combining these points of the speed and

horsepower with a smooth curve having in mind that the horsepower is in proportion to the cube of the speed generally.

Calculate the horsepower of the main engine required during the time of service sailing and research fishing operations as follows:

Horsepower required during the time of service sailing = Follow the above method
Max. horsepower of the main engine = Horsepower required during the time of service sailing/0.85
Horsepower required during the time of research fishing operations
= Max. horsepower x 0.35 (load ratio according to the data obtained from the actual commercial fishing vessels)

Step – 6 : Establishment of horsepower of the electric generator

Although the M.V. LOFA has two electric generators, 170PS x 2, assume the electric generators to be furnished with for the Designed Vessel as approx. 200PS x 2 since air conditioners and heated water showers which have not been furnished with in the M.V. LOFA will be required due to the requested improvement in the living environment associated with the expansion of areas of the research fishing operations and consequently, the electric consumption will be increased by approx. 20KW. With regard to the horsepower required during the time of service sailing and research fishing operations, assume it as follows by using the load factor obtained by referring to the trial calculation amount of electric consumption and the data of actual fishing operations of a vessel in the past:

Horsepower required during the time of service sailing
= 1 generator x 200PS x 0.50 = 100PS
Horsepower required during the time of research fishing operations
= 2 generators x 200PS x 0.45 = 180PS

The horsepower required given in the above can be commonly used for any of the speed pattern of five kinds.

Step – 7 : Calculation of fuel consumption per day

Calculate the amount of the fuel consumption (by the main engine + electric

generator) for both of during the time of service sailing and during the time of research fishing operations at each speed pattern. Obtain the amount of the fuel consumption using the following formulas by giving considerations to the facts that the fuel consumption rate becomes the smallest at around 85% of the load factor both for the main engine and electric generator, approx. 150g/PS/hour for the main engine of the latest model and approx. 160g/PS/hour for the electric generator and that the fuel consumption rates deteriorates when the load factor becomes small:

During the time of service sailing:

Fuel consumption amount by main engine(KL)

= Horsepower required x 150g x 24 hours/(0.85 x 1,000,000)

Fuel consumption amount by electric generator(KL)

= Horsepower required x 165g x 24 hours/(0.85 x 1,000,000)

During the time of research fishing operations:

Fuel consumption amount by main engine(KL)

= Horsepower required x 160g x 24 hours/(0.85 x 1,000,000)

Fuel consumption amount by electric generator(KL)

= Horsepower required x 165g x 24 hours/(0.85 x 1,000,000)

Step – 8 : Calculation of annual fuel consumption during the time of service sailing and during the time of research fishing operations

The amount of the fuel consumption during the non-operations time established by "Step-1" is that of consumed by the electric generator only and the amount obtained can be applied commonly to each speed pattern. Therefore, disregard it in this step and calculate the annual amount of fuel consumption during the time of service sailing and during the time of research fishing operations only.

Fuel consumption amount during the time of service sailing(KL)

= [Number of service sailing days obtained in "Step-2" + Number of service sailing days obtained in "Step-4"] x [Fuel consumption amount per day during the time of service sailing obtained in "Step-7"]

Fuel consumption amount during the time of research fishing operations(KL)

= [Number of research fishing operation days obtained in "Step-4"] x [Fuel consumption amount per day during the time of research fishing operations obtained in "Step-7"]

Step – 9 : Calculation of annual fuel cost during the time of service sailing and during the time of research fishing operations

Calculate the annual fuel cost required during the time of service sailing and during the time of research fishing operations excluding the non-operations period. For making calculations, assume the unit fuel cost as T$300/KL at Pago Pago based on the materials obtained from the SSFCL and use the following formula:

Annual fuel cost = [Fuel consumption amount(KL) obtained in "Step-8"] x T$300

Step – 10 : Assumption of annual bait cost

With regard to the unit price of bait, we will describe it in other item in detail but assume it as T$0.13823/head. Do not include in this calculation the reserve bait such as the waste bait in this step and obtain the annual bait cost from the number of annual heads of the bait required by multiplying the unit price thereof as follows:

In connection with the number of hooks, in case of the research fishing operations 900 sea miles away, use the conventional type longline fishing gear which has more hooks than those of the monofilament type longline in order to avoid any deterioration in the balance of income and expenditures due to the increase in the number of service sailing days, i.e. the decrease in the number of research fishing operations days. Set the average number of hooks as 2,400/day(approx. 96% of the maximum assumed number of hooks, 2,500) as described in other item and set the average number of hooks as 2,200/day(approx. 88% of the maximum assumed number of hooks) for other research fishing operations under the conventional type longline method. In the case of research fishing operations under the monofilament type longline method, set the average number of hooks as 1,300/day(approx. 87% of the maximum assumed number of hooks). Further, with regard to the type of research fishing operations, assume that the conventional type longline and the monofilament type longline are used two times each a year and the line casting is performed once a day. Therefore, one head of bait will be required per hook and give "N" as the annual number of research fishing operations days. Thus, the annual number of heads of bait and the annual bait cost required can be calculated as follows on the assumption that the number of the research fishing operations days per voyage is to be simply dividing it by 4:

1) In the case of research fishing operations of 900 sea miles x 1 time + 450 sea miles x 3 times:

Annual number of bait required

= 2,400 heads x N/4 + 2,200 heads x N/4 + 1,300 heads x N/4 x 2 times

= 1,800 heads x N

Annual bait cost = T$0.13823 x 1,800 heads x N = 248.814 x N (T$)

2) In the case of research fishing operations of 450 sea miles x 4 times:

Annual number of bait required

= 2,200 heads x N/4 x 2 times + 1,300 heads x N/4 x 2 times

= 1,750 heads x N

Annual bait cost = T$0.13823 x 1,750 heads x N = 241.903 x N (T$)

Step – 11 : Calculation of annual variable expenses according to the changing speed

The sailing operations expenses of the Designed Vessel include those relating to crew, fishing gear expenses, foods and water expenses, maintenance and repairing expenses, agent commissions, ground administration expenses, warehouse charges, customs expenses, insurance premiums and miscellaneous expenses in addition to the above mentioned fuel expenses and bait cost. All of these expenses other than the last two items are fixed expenses commonly incurring to the respective speed patterns. Therefore, the expenses covered by the "Step–11" are the fuel expenses and bait cost only. In other words, the annual total amount of expenses variable subject to the respective speeds will be the total amount obtained in "Step–9" and "Step–10."

Step – 12 : Calculation of annual amount of haul of fish

Although we will discuss on this subjects later, the annual amount of haul of fish can be calculated as follows on the assumption that CPUE (Catch Per Unit Effort; number of heads of fish caught per 100 hooks) is 3.0/100, average fish weight is 19.5kg/head and the number of hooks is the same as that of annual bait obtained in "Step–10" based on the result obtained by the M.V. LOFA.

Annual amount of haul of fish (tons)

= Annual number of hooks x 0.03 x 19.5 kg /1,000kg.

Step – 13 : Calculation of annual amount of income

According to the results of the M.V. LOFA and the materials obtained from SSFCL, the export sales amount of the fish caught as the materials for canned goods at Pago Pago occupies 70% of the whole haul of fish and its unit price is T$2,670/ton. The rest of 30% is directed to the domestic sales whose unit price is T$2,500/ton. On this basis, the annual amount of income can be calculated as follows:

Annual amount of sales(T$)

= Annual haul of fish(tons) x (0.70 x T$2,670 + 0.30 x T$2,500)

Step – 14 : Calculation of difference between the annual amount of income and the annual expenses of fuel and bait

Calculate the difference from the amount of income obtained in "Step–13" by deducting the amount of expenses obtained in "Step–11."

Step – 15 : Consideration. And, establishment of the proper speed and horsepower of the main engine and electric generator.

At the respective five patterns of speed, the sailing operations expenses other than those of fuel consumed at the time of service sailing and at the time of research fishing operations and those of bait (including the expenses of fuel which is consumed by the electric generator during the non–operations period) are certain common fixed amount. Therefore, the speed region in which the amount obtained in "Step–14" becomes the largest is the most optimum speed from the viewpoint of economical sailing operations. So, set this speed as the proper speed and set the horsepower required for obtaining this speed divided by 0.85 as the proper and maximum horsepower of the main engine.

2. Results of the M.V. LOFA pertaining to the annual number of days by type of operations

1) Results of analysis of materials obtained from the Ministry of Fisheries and SSFCL

	Results between 1982 – 1992	Results of 1994	Results of 1995
– Number of research fishing operations days	180 days in average (153 – 200 days)	188 days	190 days
– Number of service sailing days	30 days in average (12 – 54 days)		
– Holidays on the sea (Sundays)	30 days in average (26 – 35 days)		
– Waiting period due to stormy weather	1 day in average (0 – 8 days)		
– Anchorage in a port	124 days in average (100 – 158 days)		

2) Data heard from SSFCL

– 4 voyages a year. One cycle: Tonga→Fishing ground→Tonga→Pago Pago→Tonga

– Docking at Suva for about a month (including the number of round voyage days to Suva)

– The number of days required to go to the fishing ground is two days for one way and four days for a round voyage.

– The number of days required for going to Pago Pago is three days for one way and six days for a round voyage with anchorage for three days.

– When returned to Tonga, ten to fifteen days per voyage are taken for anchorage combined with pleasure.

– About fifteen days for Christmas holidays.

– The number of fishing operations days is approx. 50 days per voyage (targeting for 200 days a year). Meanwhile, Sundays on the sea are holidays and for drifting.

Indicate the results of the calculation in the order of the respective steps for each of the speed pattern by referring to the above information while also

indicating the contents of the standard service sailing assumed for the M.V. LOFA. However, the type of engine of the M.V. LOFA is old and its fuel consumption rate is no good. Therefore, the following formulas must be applied for obtaining the amount of the fuel consumption per day.

[Amount of fuel consumption/day of the M.V. LOFA]

During the time of service sailing :

Main engine (KL/day) = 500PS x 0.85 x 157g x 24h/(0.85 x 1,000,000)

Electric generator(KL/day)

= 1 unit x 170PS x 0.50 x 170g x 24h/(0.85 x 1,000,000)

During the time of research fishing operations :

Main engine (KL)= 500PS x 0.35 x 167g x 24h/(0.85 x 1,000,000)

Electric generator (KL)

= 2 units x 170PS x 0.45 x 172g x 24h/(0.85 x 1,000,000)

3. Establishment of number of days by operations("Steps 1 – 4")

Item	M.V. LOFA 8 knots	Designed Vessel 8.0 knots	8.5 knots	9.0 knots	9.5 knots	10.0 knots
① Number of non-operating days						
Docking period at Suva port (days)	25			24		
Christmas holidays (days)	15			15		
When returning to Tonga port (days)	48			12 x 4 = 48		
When calling at Pago Pago port (days)	12			3 x 4 = 12		
Holidays on the sea (days)	28			7 x 4 = 28		
Total number of non-operating days (days)	128			127		
② Number of sailing days between ports						
Round voyage between Tonga and Suva (days)	4.4 (2.2x2)	4.4 (2.2x2)	4.2 (2.1x2)	4.0 (2.0x2)	3.8 (1.9x2)	3.6 (1.8x2)
Round voyage between Tonga and Pago Pago (days)	23.2 (2.9x8)	23.2 (2.9x8)	21.6 (2.7x8)	20.0 (2.5x8)	19.2 (2.4x8)	18.4 (2.3x8)
Total number of sailing days betweens these ports (days)	27.6	27.6	25.8	24.0	23.0	22.0
③ Number of days available for making round voyages and fishing operations = (365 days – (① + ②)) (days)	209.4	210.4	212.2	214.0	215.0	216.0
④ Number of sailing days between Tonga and fishing ground						
Fishing ground 450 sea miles away (one way) (days)	2.4	2.4	2.2	2.1	2.0	1.9
Fishing ground 900 sea miles away (one way) (days)	4.7	4.7	4.5	4.2	4.0	3.8
⑤ Number of annual sailing days for making round trips to fishing grounds						
a) 900 sea miles x 1 + 450 sea miles x 3 (days)	23.8	23.8	22.2	21.0	20.0	19.0
b) 450 sea miles x 4 (days)	19.2	19.2	17.6	16.8	16.0	15.2
⑥ Number of annual available research operations days = (③ – ⑤)						
a) 900 sea miles x 1 + 450 sea miles x 3 (days)	185.6	186.6	190.0	193.0	195.0	197.0
b) 450 sea miles x 4 (days)	190.2	191.2	194.6	197.2	199.0	200.8

4. Establishment of horsepower of main engine and electric generator, and calculation of fuel consumption amount ("Steps 5 – 8")

Item	M.V. LOFA 8 knots	Designed Vessel 8.0 knots	8.5 knots	9.0 knots	9.5 knots	10.0 knots
① Horsepower required for main engine	425PS	465PS	470PS	480PS	505PS	560PS
② Max. horsepower of main engine	500PS	550PS	555PS	565PS	595PS	660PS
③ Main engine horsepower at the time of research operations	175PS	193PS	195PS	198PS	208PS	231PS
④ Electric generator horsepower						
1) At the time of service sailing	85PS	100PS				
2) At the time of research operations	153PS	180PS				
⑤ Fuel consumption per day						
1) At the time of service sailing						
Main engine	1.834KL	1.969	1.991	2.033	2.139	2.372
Electric generator	0.403KL	0.466KL				
Fuel consumption at the time of service sailing/day	2.292KL	2.435	2.457	2.499	2.605	2.838
2) At the time of research operations						
Main engine	0.852KL	0.872	0.881	0.894	0.940	1.044
Electric generator	0.743KL	0.839KL				
Fuel consumption at the time of research operations/day	1.568KL	1.711	1.720	1.733	1.779	1.883
⑥ Annual fuel consumption (excluding non-operations period)						
a) 900 sea miles x 1 + 450 sea miles x3						
Number of annual sailing days (days)	51.4	51.4	48.0	45.0	43.0	41.0
Number of research operations days available (days)	185.6	186.6	190.0	193.0	195.0	197.0
Fuel consumption at the time of service sailing	117.809 KL	125.159 KL	117.936 KL	112.455 KL	112.015 KL	116.358 KL
Fuel consumption at the time of research operations	291.021 KL	319.273 KL	326.800 KL	334.469 KL	346.905 KL	370.951 KL
Total fuel consumption	408.830	444.432	444.736	446.924	458.920	487.309
b) 450 sea miles x 4						
Number of annual sailing days (days)	46.8	46.8	43.4	40.8	39.0	37.2
Number of research operations days available (days)	190.2	191.2	194.6	197.2	199.0	200.8
Fuel consumption at the time of service sailing	107.266 KL	113.958 KL	106.634 KL	101.959 KL	101.595 KL	105.574 KL
Fuel consumption at the time of research operations	298.234 KL	327.143 KL	334.712 KL	341.748 KL	354.021 KL	378.106 KL
Total fuel consumption	405.500	441.101	441.346	443.707	455.616	483.680

(Note) The fuel tank of the M.V. LOFA is 126.63m3 (loading capacity: 126.65 x 0.93 = 117.785KL, annual usable amount: 117.785KL x 0.90 x 4 times = 424.026KL). Therefore, if considerations are given to the fuel to be used

during the time of anchorage and holidays on the sea, the required amount will exceed the usable amount. So, the comparison between both vessels is discontinued at this stage.

5. Calculation of annual sailing operations expenses (expenses for fuel and bait only)("Steps 9 – 11")

Unit: T$(Tongan Dollar)

Item	8.0 knots	8.5 knots	9.0 knots	9.5 knots	10.0 knots
① Annual fuel cost					
a) 900 sea miles x 1 + 450 sea miles x 3	133,329.6	133,420.8	134,077.2	137,676.0	146,192.7
b) 450 sea miles x 4	132,330.3	132,403.8	133,112.1	136,684.8	145,104.0
② Annual bait cost					
a) 900 sea miles x 1 + 450 sea miles x 3	46,428.7	47,274.7	48,021.0	48,518.7	49,016.4
b) 450 sea miles x 4	46,251.9	47,074.3	47,703.3	48,138.7	48,574.1
③ Total annual cost (①+②)					
a) 900 sea miles x 1 + 450 sea miles x 3	179,758.3	180,695.5	182,098.2	186,194.7	195,209.1
b) 450 sea miles x 4	178,582.2	179,478.1	180,815.4	184,823.5	193,678.1

6. Calculation of the amount of annual haul of fish, annual income and difference between annual income and expenses ("Steps 12 – 14")

Unit: T$(Tongan Dollar)

Item	8.0 knots	8.5 knots	9.0 knots	9.5 knots	10.0 knots
① Annual haul of fish					
a) 900 sea miles x 1 + 450 sea miles x 3	196.490 t	200.070 t	203.229 t	205.335 t	207.441 t
b) 450 sea miles x 4	195.741 t	199.222 t	201.884 t	203.726 t	205.569 t
② Annual income					
a) 900 sea miles x 1 + 450 sea miles x 3	514,607.3	523,983.3	532,256.8	537,772.4	543,288.0
b) 450 sea miles x 4	512,645.7	521,762.4	528,734.2	533,558.4	538,385.2
③ Difference between annual income and annual expenses					
a) 900 sea miles x 1 + 450 sea miles x 3	+334,894.0	+343,287.8	+350,158.6	+351,577.7	+348,078.9
b) 450 sea miles x 4	+334,063.5	+342,284.3	+347,918.8	+348,734.9	+344,707.1

7. Considerations. And establishment of proper speed and horsepower of the main engine and electric generator ("Step – 15")

According to the results of calculation in the above, in both cases of (a) in case where one research fishing operations 900 sea miles away and three research fishing operations 450 sea miles away respectively are conducted in the four voyages a year and (b) in case of conducting research fishing operations in all of the four voyages a year, the difference between the annual income and annual expenses (expenses for fuel and bait) increases gradually in line with the increasing speed from 8.0 knots to 9.5 knots but when the speed reaches 10.0 knots, the profit suddenly turns to a loss. This is a phenomenon which occurs due to the fact that it becomes necessary to make the vessel somewhat stoutish compared with the standard type of vessel of Japan in order to provide a space for a sufficient size of fuel tank capacity associated with the expanding sea areas to be studied coupled with the fact that the rapid increase in the horsepower of the main engine required in order to obtain 10 knots of speed which necessitates consequent increase in the amount of fuel consumption.

Such being the situation, it is appropriate for the Designed Vessel to establish the proper service sailing speed at about 9.5 knots and the maximum horsepower of the main engine at about 600PS (capacity during the time of service sailing = 600PS x 0.85 = 510PS; according to the calculation in the above, 505PS) from the profitability–oriented viewpoint of the sailing operations by checking any further increase in the number of service sailing days associated with the expanding sea areas to be studied as much as possible so that the number of the research fishing operations days can be secured and so that the income will also be increased and further by checking the increase in the fuel expenses accompanied by the increased fuel consumption.

With regard to the electric generator, it is appropriate to set the maximum horsepower at about 200PS x 2 generators in consideration of the power consumption and the load factors of the respective operations conditions.

The conclusion in this section is given below:

1) Proper service sailing speed: approx. 9.5 knots
2) Proper horsepower of the main engine: max. output approx. 600PS
3) Proper horsepower of the electric generator: max. output approx. 200PS x 2

Procedure – II : Trial calculation of annual profitability of sailing operations and establishment of size of proper fishing gear and capacity of fuel tank

1. Method of study and steps to be taken

With regard to the annual sailing operations, the number of voyages is four with a cycle starting from Tonga→Fishing ground→Tonga→Pago Pago→Tonga combined with one docking at Suva as used in the "Establishment of proper speed." In addition, the same formula being used in the calculation, load factor of the engine, fuel consumption rate, etc. as used in the "Establishment of proper speed" unless otherwise prescribed. However, with regard to the number of service sailing days and the number of research fishing operations days, although we calculated it below decimal point in the "Establishment of proper speed" in order to make a precise comparison of figures obtained, we will use those figure rounded up any fractions for calculating the number of respective sailing operations days under this study as used in the calculation of sailing operations days of the ships and fishing vessels in general.

For making the relative comparison of the figures obtained in the respective steps of the study easier, we will study the following five cases including the vessel indicated in the request (hereinafter referred to as the "Requested Vessel") and the M.V. LOFA in addition to the Designed Vessel:

1) For the Designed Vessel (9.5 knots of speed, main engine of 600 horsepower and two electric generators of 200 horsepower each)
   a) One research fishing operations 900 sea miles away and three research fishing operations 450 sea miles away a year
   b) Four research fishing operations a year
2) For the Requested Vessel (8.0 knits of speed, main engine of 500 horsepower and two electric generators of 200 horsepower each)
   a) One Research fishing operations 900 sea miles away and three research fishing operations 450 miles away a year
   b) Four research fishing operations 450 sea miles away a year
3) For the M.V. LOFA (8.0 knots of speed, main engine of 500 horsepower and two electric generators of 170 horsepower each)
   a) Four research fishing operations 380 sea miles away a year

(Note) Although no indication is given as to the electric generator with regard to the Requested Vessel, the horsepower of the electric generator is assumed as same as that of the Designed Vessel since the same increase in the power consumption is expected as the Designed Vessel.

The following shows the steps to be followed for the study as well as the methods of study and calculation:

Step – 1 : Calculation of the fuel consumption per day by type of operations

With regard to the load factor of the main engine and electric generator by type of operations, use the figures used at the time of "Establishment of the proper speed" during the time of service sailing and during the time of research fishing operations. Meanwhile, with regard to the load factor of the electric generator during the time of anchorage in a port and during the time of drifting on the sea(holidays), use the figures obtained at the trial calculation of the power consumption and those figures obtained by referring to the data of a vessel at the time of its actual operations in the past.

Step – 2 : Establishment of the number of annual operations days by type of operations

Use the same calculation conditions as used for the "Establishment of proper speed." However, with regard to the Requested Vessel, its fuel tank capacity is approx. 126m^3 and, therefore, the usable fuel amount is restricted but the number of service sailing days cannot be changed. Such being the situation, reduce the number of research fishing operations days and increase the number of days for anchorage at Tonga so that the fuel consumption amount per voyage will correspond to the capacity of the fuel tank.

Step – 3 : Establishment of the largest number of operations days per voyage by type of operations and calculation of the fuel consumption

With regard to the fuel supply, make a plan to supply fuel four times a year at Pago Pago where its unit price is cheap. With regard to the M.V. LOFA and the Requested Vessel, calculate the consumable fuel amount per voyage from the capacity of the fuel tank, fuel stowage factor and required residual fuel amount and

then obtain the largest number of operations days per voyage by type of operations within this framework. With regard to the Designed Vessel, establish the largest number of operations days per voyage by type of operations which is obtainable based on the contents of "Step – 2," and then obtain the fuel amount required for the longest one voyage based on the above.

Further, with regard to the tank stowage factor, use 0.93 instead of 0.95 – 0.96 which is used usually, since a decline in the stowage factor is expected due to the larger trim in the stern to be required. In addition, as to the amount of residual fuel, leave the equivalent amount of 10% of the fuel at full load before the fuel supply is made from the safety viewpoint.

Step – 4 : Calculation of annual fuel consumption and fuel expenses

Use the same calculation conditions including the fuel unit price as used for the "Establishment of proper speed." The comparison with the M.V. LOFA is to be discontinued at this Step.

Step – 5 : Estimation of the annual sailing operations expenses excluding bait cost

Sum up the annual fuel expenses obtained in "Step – 4" and other expenses (excluding bait cost) estimated based on the results of the M.V. LOFA and materials obtained from the SSFCL and calculate the annual service operations expenses. As to the basis for calculation of the respective expenses, we will describe them in detail in the relevant Step.

Step – 6 : Assumption of the correlation formula between the size of fishing gear/bait cost and annual haul of fish/income

Estimate the unit price of bait cost, CPUE, average fish weight, and unit sales price of fish caught based on the results of the M.V. LOFA and the materials obtained from SSFCL, set them as the fixed figures and then assume a formula for obtaining the total number of hooks for a year and average number of hooks per day for obtaining the income amount which would exceed the annual gross sailing operations expenses including those expenses obtained in "Step–5" and bait cost. With regard to the basis of the calculation of the respective expenses, we will describe them in detail in the relevant Step.

Step – 7 : Establishment of proper size of fishing gear and trial calculation of annual sailing operations expenses

From the formula assumed in "Step–6", establish the proper size of fishing gear which can cover the annual sailing operations expenses, calculate the annual bait cost and then obtain the annual gross sailing operations expenses.

Step –8 : Annual haul of fish based on the proper size of fishing gear and trial calculation of income amount

Obtain the annual haul of fish and income amount by using the CPUE assumed in "Step–6", average fish weight and the sales unit price of fish caught.

Step – 9 : Summary of annual sailing operations profitability

Assume the annual sailing operations profitability of the Designed Vessel from the annual gross sailing expenses and income amount obtained in "Step–7" and "Step–8" respectively.

Step – 10 : Establishment of proper fuel tank capacity

Establish the proper fuel tank capacity based on the fuel consumption amount of the longest one voyage of the Designed Vessel obtained in "Step–3." With regard to the stowage factor and residual fuel amount, use those figures stated in "Step–3."

Step – 11 : Consideration and conclusion

According to the proper size of fishing gears and fuel tank capacity established through the above steps, investigate the annual expenses and income.

2. Calculation of fuel consumption amount per day by type of sailing operations ("Step – 1")

Conditions of the vessel	M.V. LOFA (8.0 knots)	Designed Vessel (9.5 knots)	Requested Vessel (8.0 knots)
1) At the time of service sailing Main engine Electric generator	500x0.85x157x24/0.85 =1.884KL/day 1x170x0.50x170x24/0.85 =0.408KL/day	600x0.85x150x24/0.85 =2.160KL/day 1x200x0.50x165x24/0.85 =0.466KL/day	500x0.85x150x24/0.85 =1.800KL/day 1x200x0.50x165x24/0.85 =0.466KL/day
Total	2.292KL/day	2.626KL/day	2.266KL/day
2) At the time of research operations Main engine Electric generator	500x0.35x167x24/0.85 =0.825KL/day 2x170x0.45x172x24/0.85 =0.743KL/day	600x0.35x160x24/0.85 =0.949KL/day 2x200x0.45x165x24/0.85 =0.839KL/day	500x0.35x160x24/0.85 =0.791KL/day 2x200x0.45x165x24/0.85 =0.839KL/day
Total	1.568KL/day	1.788KL/day	1.630KL/day
3) At the time of drifting on the sea Main engine Electric generator	0 1x170x0.30x175x24/0.85 =0.252KL/day	0 1x200x0.30x170x24/0.85 =0.288KL/day	0 1x200x0.30x170x24/0.85 =0.288KL/day
Total	0.252KL/day	0.288KL/day	0.288KL/day
4) At the time of anchorage in a port Main engine Electric generator	0 1x170x0.25x180x24/0.85 =0.216KL/day	0 1x200x0.25x175x24/0.85 =0.247KL/day	0 1x200x0.25x175x24/0.85 =0.247KL/day
Total	0.216KL/day	0.247KL/day	0.247KL/day
5) At the time of docking Main engine Electric generator	0 0	0 0	0 0
Total	0	0	0

3. Establishment of number of annual operations days by type of operations ("Step – 2")

Item	M.V. LOFA (8.0 knots)	Designed Vessel (9.5 knots)		Requested Vessel (8.0 knots)	
	380 sea miles x 4 times	900 sea miles x 1 time + 450 sea miles x 3 times	450 sea miles x 4 times	900 sea miles x 1 time + 450 sea miles x 3 times	450 sea miles x 4 times
①Period requiring no fuel 1)Docking period at Suva port	25days	24days	24days	24days	24days
②Anchorage period in a port 1)Christmas holidays	15days	15days	15days	15days	15days
2)Anchorage period at Pago Pago port	3day x 4 = 12days	3day x 4 = 12days	3day x 4 = 12days	3day x 4 = 12days	3day x 4 = 12days
3)Anchorage period at Tonga port					
After research operations for 900 sea miles	–	13days x 1 =13days	–	17days x 1 =17days	–
After research operations for 450 sea miles	12days x 4 =48days	12days x 3 =36days	12days x 4 =48days	15days x 3 =45days	15days x 1+ 14days x 3 =57days
Total	75days	76days	75days	89days	84days
③Number of sailing days 1)Round voyage between Tonga and Suva	5daysx1=5days (Same as for the Requested Vessel)	4daysx1=4days (420/(9.5x24))=1.84 →2.0days x 2)	4daysx1=4days	5daysx1=5days (420/(8.0x24))=2.19 →2.5days x 2)	5daysx1=5days
2)Round voyage between Tonga and Pago Pago	6daysx4=24days (Same as for the Requested Vessel)	5daysx4=20days (540/(9.5x24))=2.36 →2.5days x 2)	5daysx4=20days	6daysx4=24days (540/(8.0x24))=2.81 →3.0days x 2)	6daysx4=24days
3)Round voyage to the fishing ground 900 sea miles away	–	8days x1 =8days (900/(9.5x24))=3.95 →4.0days x 2)	–	10daysx1 =10days (900/(8.0x24))=4.69 →5.0days x 2)	–
4)Round voyage to the fishing ground 450 sea miles away	4days x4 =16days (Round voyage of 380 sea miles)	4days x3 =12days (450/(9.5x24))=1.97	4days x4 =16days →2.0days x 2)	5days x3 =15days (450/(8.0x24))=2.34	5days x4 =20days →2.5days x 2)
Total	45days	44days	40days	54days	49days
④Number of drifting days on the sea	7days x4 =28days	7days x4 =28days	7days x4 =28days	7days x4 =28days	7days x4 =28days
⑤Number of research operations days 1)Research operations for 900 sea miles	–	45days x 1 =45days	–	38days x 1 =38days	–
2)Research operations for 450 sea miles	48days x 4 =192days	50days x 1 =50days 49days x 2 =98days	50days x 2 =100days 49days x 2 =98days	44days x 3 =132days	45days x 4 =180days
Total	192days	193days	198days	170days	180days

(Note) In the case of the Designed Vessel, give one more additional day for anchorage when returned to the Tonga port after completing the research fishing operations 900 sea miles away. In the case of the Requested Vessel, the number of the research fishing operations days will be decreased due to the limited capacity of its fuel tank and consequently the number of the anchorage days will be increased.

4. Establishment of the largest number of the fishing operations days by type of sailing operations in a voyage and calculation of the amount of fuel consumption ("Step–3")

Item	M.V. LOFA (8.0 knots) 380 sea miles x 4 times	Designed Vessel (9.5 knots)		Requested Vessel (8.0 knots)	
		900 sea miles x 1 time + 450 sea miles x 3 times	450 sea miles x 4 times	900 sea miles x 1 time + 450 sea miles x 3 times	450 sea miles x 4 times
①Fuel tank capacity and usable amount 1)Fuel tank capacity	126.65㎥	Unfixed		126㎥	
2)Usable amount (per voyage)	106.006KL (12.65x 0.93x0.9)	Assumed as infinity.		105.462KL (126.00x0.93x0.90)	
②The largest number of days by condition of vessel per voyage 1)Number of sailing days	(380 sea mile operations) 6+4 =10days	(900 sea mile operations) 5+8 =13days	(450 sea mile operations) 5+4 = 9days	(900 sea mile operations) 6+10 =16days	(450 sea mile operations) 6+5 =11days
2)Number of holidays on the sea	7days	7days	7days	7days	7days
3)Number of anchorage days at Pago Pago port	3days	3days	3days	3days	3days
4)Number of anchorage days at Tonga port	12days	13days	12days	17days	15days
5)Number of days of research operations	48days	45days	50days	38days	45days
Number of days per voyage	80days	81days	81days	81days	81days
③Fuel consumption for one voyage 1)At the time of service sailing	10days x 2.292KL= 22.920KL	13days x 2.626KL= 34.138KL	9days x 2.626KL= 23.634KL	16days x 2.266KL= 36.256KL	11days x 2.266KL= 24.926KL
2)At the time of drifting on the sea	7days x 0.252KL =1.764KL	7days x 0.288KL =2.016KL	7days x 0.288KL =2.016KL	7days x 0.288KL =2.016KL	7days x 0.288KL =2.016KL
3)At the time of anchorage at Pago Pago port	3days x 0.216KL =0.648KL	3days x 0.247KL =0.741KL	3days x 0.247KL =0.741KL	3days x 0.247KL =0.741KL	3days x 0.247KL =0.741KL
4)At the time of anchorage at Tonga port	12days x 0.216KL =2.592KL	13days x 0.247KL =3.211KL	12days x 0.247KL =2.964KL	17days x 0.247KL =4.199KL	15days x 0.247KL =3.705KL
5)At the time of research operations	48days x 1.568KL= 75.264KL	45days x 1.788KL= 80.460KL	50days x 1.788KL= 89.400KL	38days x 1.630KL= 61.940KL	45days x 1.630KL= 73.350KL
Total fuel consumption	103.188KL	120.566KL	118.755KL	105.152KL	104.738KL

(Note) In the types of sailing operations, the Christmas holidays and the docking one time each a year are not included although the round voyage is to be included.