CHANGES IN THE FIJIAN BAITFISHERY, 1974 - 1980

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1. INTRODUCTION

Since the existence of commercial quantities of skipjack (Katsuwonus pelamis) and adequate resources of suitable baitfish were demonstrated in the waters of Fiji (FAO, 1974), the pole-and-line tuna fishing industry has steadily increased in size to become an important primary industry. The IKA Corporation, set up by the Fijian Government as an autonomous body in 1975 to develop the tuna fishing industry, recorded its first catches in the 1976 season and is today the major tuna pole-and-line operator in Fiji. Since fishing commenced, the Fisheries Division of the Fiji Ministry of Agriculture and Fisheries has maintained detailed statistics on a monthly basis of tuna and baitfish catch and effort.

Fleet size, tuna landings and baitfish catches all tended to increase from 1976; however, the 1979/1980 season commenced with an apparent marked reduction in baitfish abundance. Poor catches of skipjack at the same time were thought to be largely a result of the inadequate bait supplies. In late January 1980 baitfish supplies improved, but still remained much lower than in previous years. This document examines trends in the baitfishery from 1976 to 1980 and investigates the poor season in 1979/1980. Alternative hypotheses to explain the 1979/1980 season include: decline in baitfish resources due to environmental phenomena (e.g. rainfall and temperature); a drop in the intensity of effort or efficiency of the fishing vessels; depletion of baitfish stocks by excessive fishing pressure; natural variability in the abundance and/or behaviour of baitfish; overstatement by the fishing fleet of the magnitude of the drop in baitfish abundance.

Analyses in this report are largely based on recorded bait catch and effort data. To assist in evaluating these data, the captains of the vessels were interviewed in April 1980 and their opinions of the reasons for the poor initial catches that year are examined.

2. THE SKIPJACK FISHERY

2.1 The Fleet

Only pole-and-line vessels have, to date, been used in the Fijian commercial skipjack fishery. The size of the fleet increased between 1974 and 1980 from one to nine vessels with a concomitant increase in total fishing days per year (Table 1). Vessels have varied in size between 57 and 245 tonnes, most being in the range of 57 to 81 tonnes (Table 2).

2.2 Tuna Landings

Following the completion of exploratory fishing in 1975, commercial catches of tuna increased steadily through 1979 (Table 1). Approximately 88 per cent of these catches have been skipjack with juvenile yellowfin tuna (Thunnus albacares) providing the bulk of the remainder. Processing of tuna landings is carried out at the local cannery at Levuka.

TABLE 1
The Development of Effort and Catch
in the Fijian Skipjack Fishery, 1974 to 1980
(Data from Fisheries Division,
Ministry of Agriculture & Fisheries, Fiji)

SEASON	MAXIMUM NO. VESSELS	USUAL NO. VESSEL	TOTAL BOAT DAYS	TUNA CATCH (tonnes)	AVERAGE TUNA CATCH PER DAY
1973/4	1	1	196	100*	0.51
1974/5	1	1	144	101*	0.70
1975/6	2	2	(300)	717	2.39
1976/7	3	3	(500)	1,706	3.41
1977/8	6	4 - 5	771	2,525	3.27
1978/9	7	5	863	3,495	4.04
1979/80	9	7	N.A.	1,399	-

Bracketed figures indicate authors' estimate.
* indicates exploratory fishing only.

TABLE 2
Classification of Pole-and-line Vessels Operating in Fiji in 1978-1980
(Data from Fisheries Division,
Ministry of Agriculture & Fisheries, Fiji)

VESSEL	LENGTH LOA (m)	WEIGHT (tonnes)	CREW	OWNER
Ika No.1	27.2	114	28	Ika Corporation
Ika No.2	26.0	69	22	Ika Corporation
Ika No.3	25.2	59	24	Ika Corporation
Tui-ni-Wasaliwa	22.8	173	23	Ika Corporation
Hatsutori Maru No.1	35.7	192	36	Japan (Joint Agreement)
Hatsutori Maru No.2	27.5	79	22	Japan (Joint Agreement)
Hatsutori Maru No.3	27.5	79	22	Japan (Joint Agreement)
Hatsutori Maru No.5	39.8	254	36	Japan (Joint Agreement)
Hatsutori Maru No.6	24.5	59	22	Japan (Joint Agreement)
Hatsutori Maru No.7	26.0	69	22	Japan (Joint Agreement)
J-Ann	23.0	81	16	USA (Joint Agreement)
Sunbird	19.0	57	20	Private Charter

2.3 Skipjack Fishing Areas

Fijian skipjack fishing grounds are considered by the fishermen to be grouped into northern, central and southern zones (Figure 1). The Koro Sea (central zone) provides the most proximate fishing grounds to the major fish

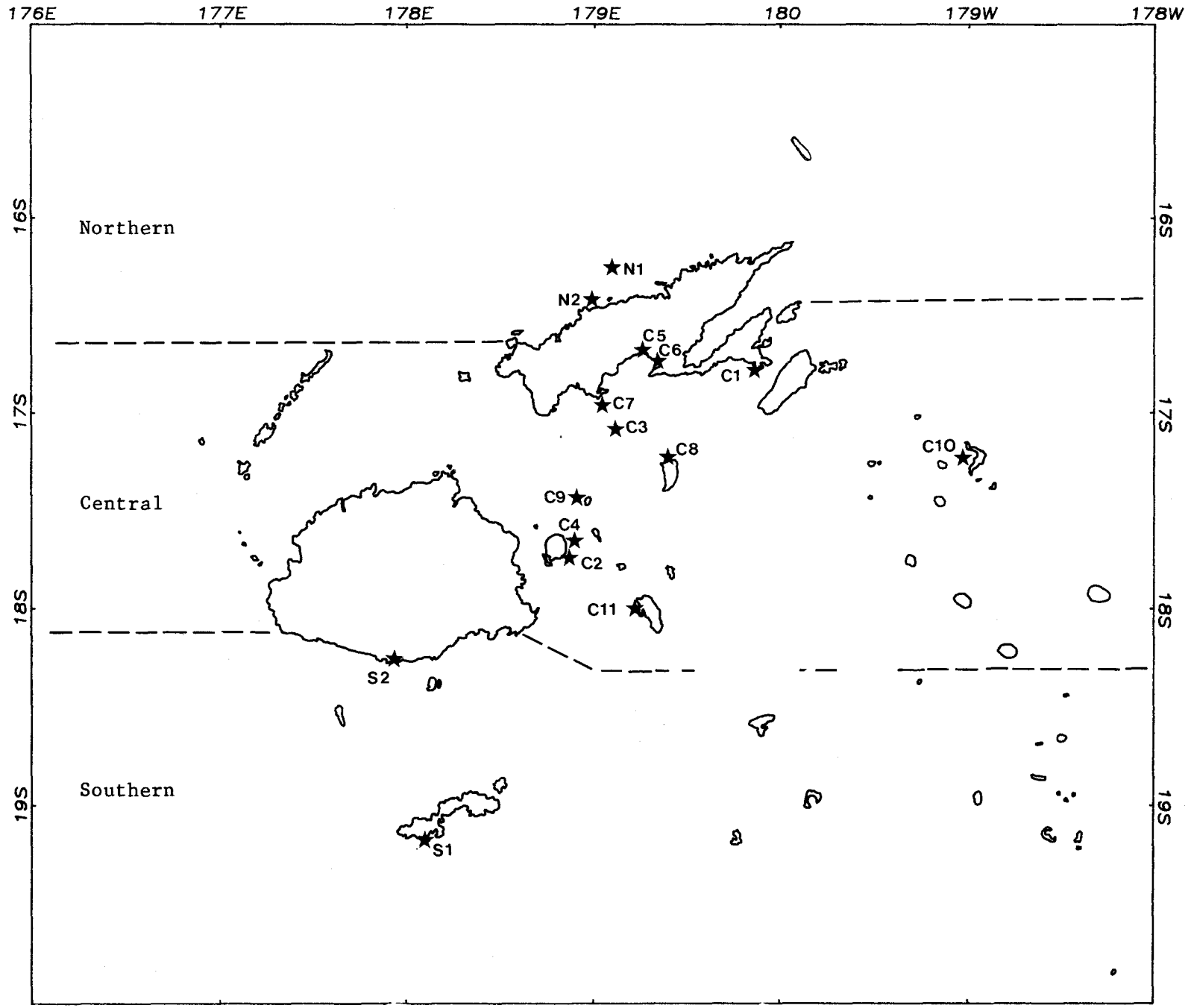

FIGURE 1: Major fishing zones in Fiji and location of principal baiting sites.

handling facilities at Levuka. Kia Island is the focus of the fishing grounds north of Vanua Levu. The southern fishing grounds encompass the waters south of Viti Levu and centre on Kandavu Island. Fishing intensity in each of these three areas coincides with spatial fluctuations in skipjack abundance.

2.4 Seasonality

The fishing season normally commences in October or November and is completed by July or August of the following year. The heaviest catches of skipjack are taken about March and most fish are taken in the period January-June each year.

The 1979/1980 season opened late and with very poor catches. Low catch rates prevailed until late January. Skipjack concentrations were reported to be reasonable early in the season, but in the absence of adequate bait, fishermen were unable to catch tuna in quantity.

3. THE BAITFISHERY

3.1 Statistics

Each vessel supplies information on daily tuna and baitfish catch and effort directly to the Fisheries Division. Baitfish data from each vessel includes date and location of each baitfishing site, number of net hauls, total catch and approximate species composition. Although this system works well there are occasional difficulties in compiling data due to form filling delays and variability in accuracy of some information. Completed data sheets are processed by hand and summaries produced by Fisheries Division staff.

All baitfish catches are reported by the fleet in buckets which is the unit used by the fishermen for loading and measuring baitfish. Throughout this report baitfish catches have been converted to kilograms by using a figure of 1.8 kg of bait per bucket. This figure is only an estimate by the Fisheries Division (Anon, 1980) and it is doubtful that it accurately represents the average contents of a bucket of bait under all fishing conditions. Nonetheless, its use does not seriously detract from analysis of seasonal fluctuations in baitfish catches and comparisons between years, as has been done in this report.

The Fisheries Division has noted that to avoid competition from other boats on the baiting grounds, some captains may declare bait catches which were lower than those actually taken. The 1978 Fisheries Report (Anon, 1979) suggests from trial experiments that the actual number of buckets transferred on board was 50 per cent higher than estimated by the fishermen. An error of this magnitude would lead to substantial underestimation of baitfish catches which could lead to serious inconsistencies in studies of the dynamics of the baitfish resources. The authors felt that the tendency to under-declare bait catches could be worse in seasons of low baitfish abundance when competition would be greater.

3.2 Bait Fishing Areas

There are 93 suitable baitfishing areas scattered widely through the Fiji group (Anon, 1980). The sites which are most frequently used are concentrated in three areas which broadly correspond to the three skipjack fishing grounds (Figure 1). Although there are a large number of baiting areas available, only a few sites close to the tuna fishing grounds are fished regularly. In 1979, one third of all bait caught originated from only three sites while a further third was captured at seven additional sites. The remaining third was distributed over 36 sites. In 1978 and 1979, approximately two-thirds (64 per cent and 63 per cent respectively) of the total bait was caught in the central zone.

With so many sites and a relatively small fleet, there is little sequential data which indicates within-site variability of total catch or species composition. Within each of the three zones, sequential data on a monthly basis are available for only a few grounds; these are recorded in Table 3.

3.3 Species Composition of Bait Catches

Estimates of species composition of baitfish catches contained in the catch returns from commercial vessels are considered questionable. Several research efforts have provided more accurate estimates, but for limited time periods; these are summarized in Table 4. Sardinella sirm and Spratelloides delicatulus are shown to be, by far, the two most abundant species particularly in the large samples of Lee (FAO, 1974) and the South Pacific Commission surveys (Kearney 1978, SPC manuscript).

3.4 Total Effort and Catch

With the exception of the J-Anne, which has a lampara net, all vessels (Table 2) use "bouki-ami" nets for baitfishing and all bait used by the commercial fleet is captured at night.

It is evident from Figures 2(a), 2(b) and 3 that there was a general increase in both total effort and catch from 1976 to 1978 after which a decline in total catch is apparent. In all years it can be seen that the highest catches occurred from January onwards.

Two measures of total baitfishing effort have been used in Fiji: nights fished per month and the number of net hauls (sets) per month. Availability of both these statistics for the Fiji fishery enables variations in effort and catch per unit effort to be investigated in greater depth.

The average number of sets per night is a measure of the intensity of effort: normally the higher the number of sets per night per vessel, the harder the crew are striving to catch bait. Variations may be due to greater (or lesser) abundance of skipjack or bait, phase of the moon, weather conditions and a variety of other variables such as abundance of predators. There is some variation in the number of sets that can be completed in a night, but at least two sets are normally possible but not always necessary. Changes in the pattern of sets per night since 1976 for the Fijian fishery are shown in Figure 4.

TABLE 3
Average Baitfish Catch (kilograms) and Effort in Number of Nights Fished (in brackets) for Major Baitfishing Sites in Northern (N), Central (C) and Southern (S) Waters of Fiji.

SITE	1978	1979			1980		
	Mean	Jan.	Feb.	Mar.	Jan.	Feb.	Mar.
N1	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	62.3 (15)
N2	243.7 (5)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	149.4 (2)	49.1 (3)
C1	159.8 (31)	129.6 (1)	124.4 (20)	114.5 (19)	7.2 (4)	0.0 (0)	48.1 (14)
C2	94.1 (52)	65.2 (4)	105.3 (12)	131.9 (15)	25.5 (14)	30.0 (19)	51.5 (10)
C3	136.8 (40)	276.3 (2)	144.5 (9)	231.8 (9)	54.2 (8)	36.0 (19)	40.5 (2)
C4	103.7 (16)	142.2 (5)	125.6 (8)	114.6 (4)	7.2 (2)	27.0 (9)	48.6 (4)
C5	103.7 (44)	169.4 (6)	58.5 (2)	0.0 (0)	0.0 (0)	12.5 (2)	0.0 (0)
C6	0.0 (0)	130.5 (2)	58.5 (2)	162.0 (1)	0.0 (0)	0.0 (0)	31.7 (5)
C7	0.0 (0)	0.0 (0)	124.7 (10)	157.5 (4)	43.2 (7)	50.0 (6)	50.4 (1)
C8	0.0 (0)	0.0 (0)	27.0 (1)	189.0 (6)	20.7 (2)	39.8 (18)	64.2 (27)
C9	110.7 (11)	235.1 (3)	63.7 (9)	139.5 (4)	0.0 (0)	0.0 (0)	27.0 (1)
C10	134.8 (8)	0.0 (0)	55.8 (3)	0.0 (0)	10.1 (3)	7.2 (1)	100.2 (7)
C11	0.0 (0)	163.8 (8)	378.0 (1)	209.2 (6)	18.9 (9)	48.6 (1)	48.6 (4)
S1	59.7 (37)	87.8 (24)	0.0 (0)	126.0 (6)	25.2 (24)	28.8 (2)	32.4 (2)
S2	175.5 (36)	53.5 (4)	0.0 (0)	0.0 (0)	18.0 (1)	94.8 (13)	48.6 (6)

Baiting Areas:

N1 = Kia Island
N2 = Cakau Tavea
C1 = Viani Bay
C2 = Levuka
C3 = Namena Island
C4 = Vagadaci
C5 = Savarekareka
C6 = Vataga Bay
C7 = Na Sonisoni
C8 = Vata Leile
C9 = Makagai Island
C10 = Vanua Mbalavu
C11 = Sawaieke
S1 = Yauravu Bay
S2 = Serua Harbour

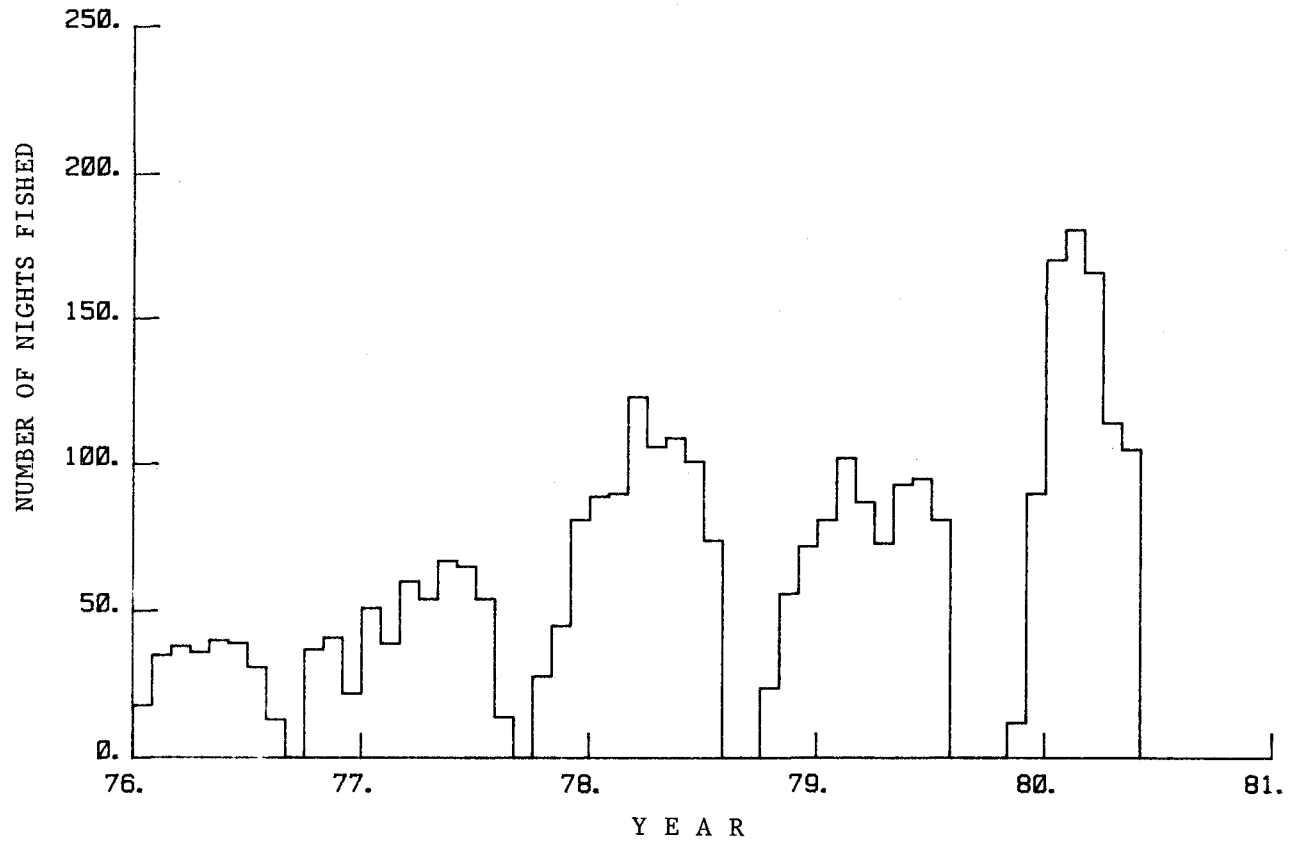

FIGURE 2(a): Combined monthly baitfishing effort (in nights) for all vessels in the Fijian fleet.

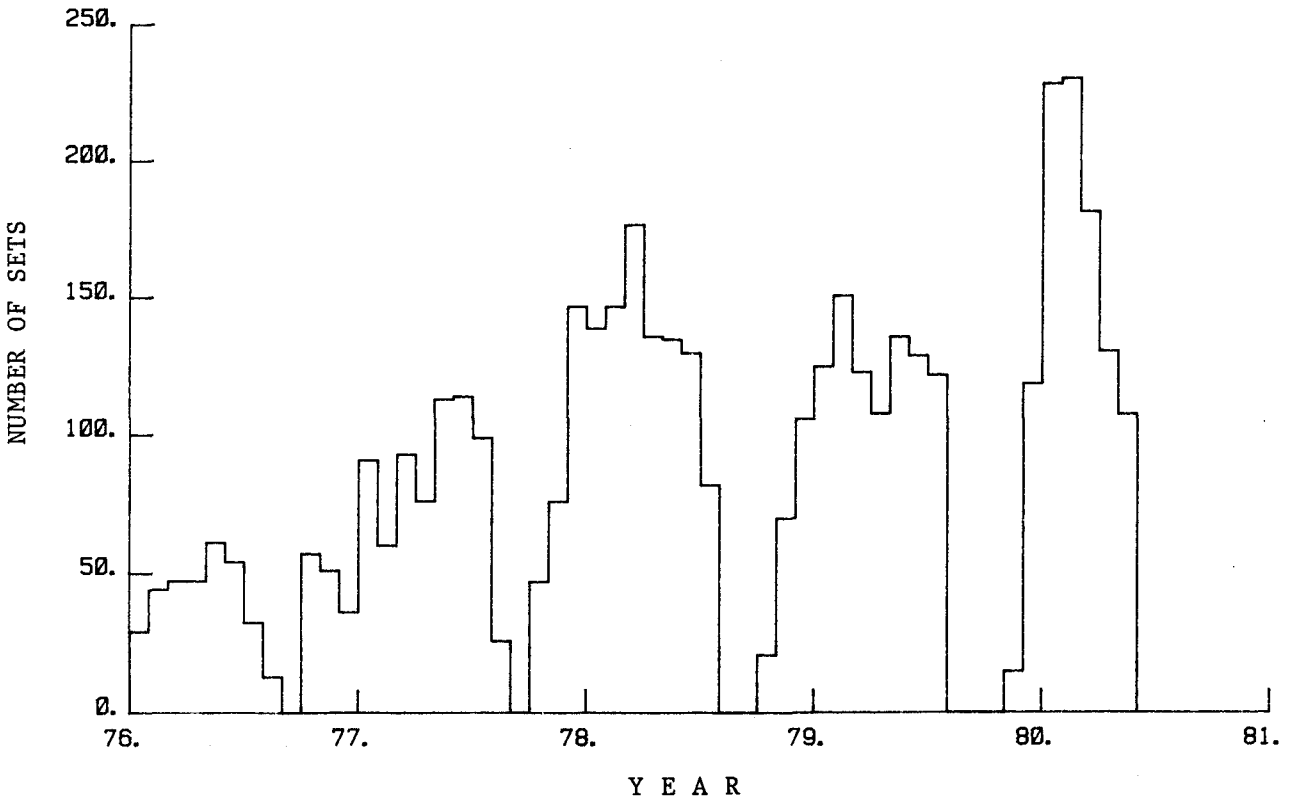

FIGURE 2(b): Combined monthly baitfishing effort (in sets) for all vessels in the Fijian fleet.

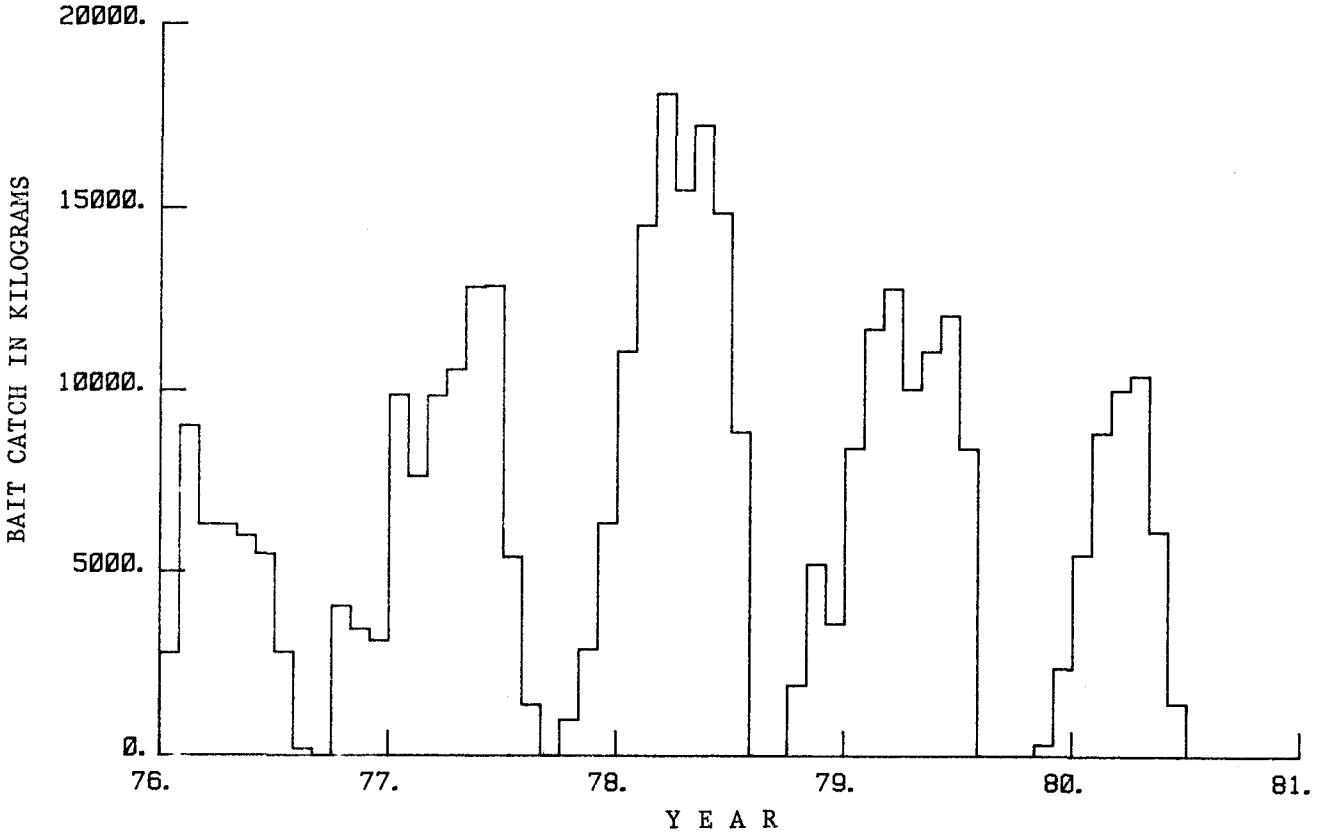

FIGURE 3: Combined monthly baitfish catch (in kilograms) for the Fijian fleet.

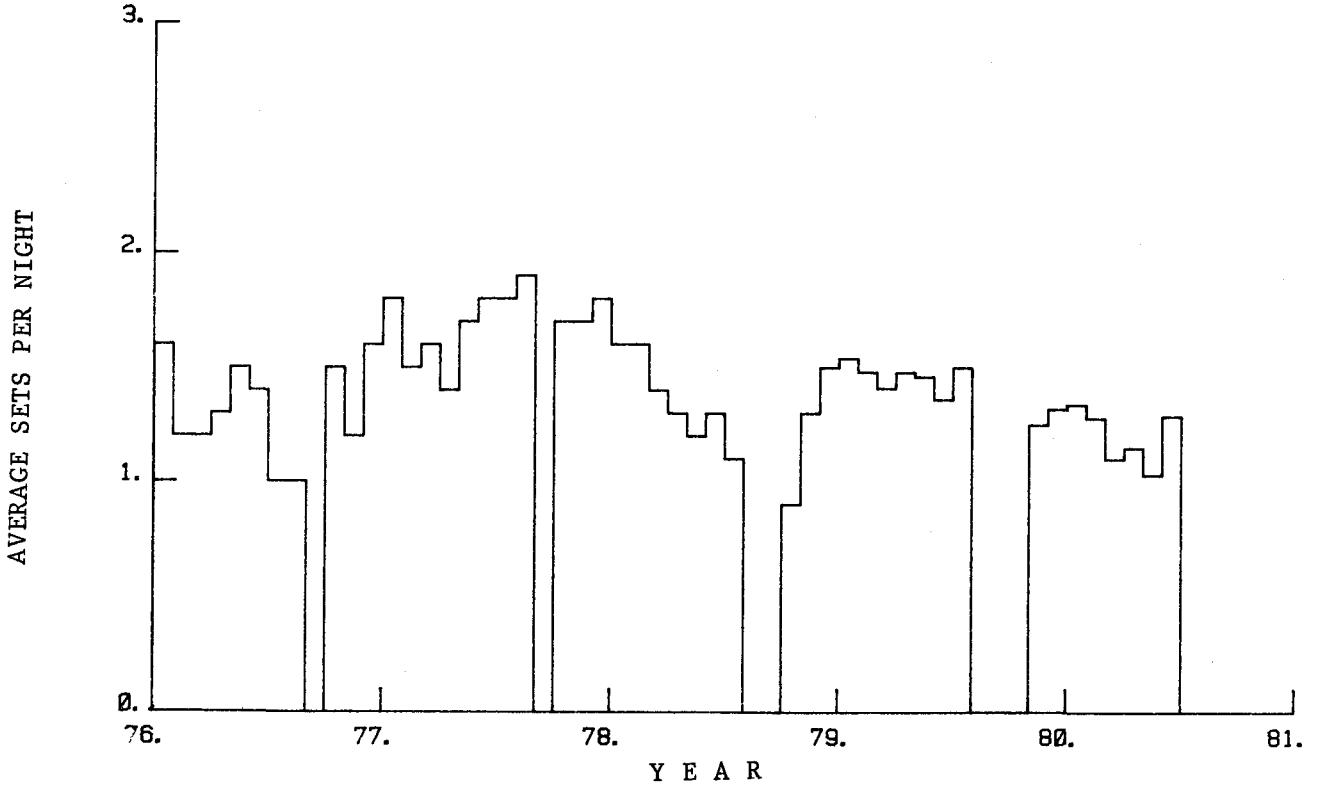

FIGURE 4: Fluctuations in the average number of sets per night for vessels in the Fijian fleet.

TABLE 4
Average Species Composition of Baitfish Catches Taken Throughout Fijian Waters by Various Surveys

SPECIES	FAO(1974) kg	FAO(1974) %	MAF(1978) kg	MAF(1978) %	SPC(1978) kg*	SPC(1978) %	SPC(1980) kg*	SPC(1980) %
Sardinella sirm	2,684	26.4	45.7	27.7	1,414	31.4	1,371	18.8
Spratelloides gracilis	107	1.1	0.0	0.0	123	2.7	653	9.0
Spratelloides delicatulus	2,297	22.6	21.1	12.8	1,735	38.6	975	13.4
Stolephorus buccaneeri	1,512	14.8	0.0	0.0	0	0.0	152	2.1
Stolephorus heterolobus/devisi	195	1.8	3.8	2.3	169	3.8	592	8.1
Stolephorus indicus	100	1.0	0.0	0.0	17	0.4	957	13.1
Thrissina baelama	331	3.3	0.0	0.0	57	1.2	774	10.6
Herklotsichthys punctatus	371	3.7	38.6	23.3	17	0.4	669	9.2
Dussumiera acuta	431	4.2	3.3	2.0	9	0.2	0	0.0
Pranesus pinguis	118	1.2	7.1	4.3	4	0.1	18	0.2
Hypoatherina ovalaua	1,265	12.6	32.8	19.8	139	3.1	250	3.4
Other species	741	7.3	21.0	9.0	817	18.1	865	11.9

* SPC data calculated from numerical composition of catches.

3.5 Catch Per Unit Effort

There are several measures which can be used to estimate catch per unit effort (CPUE). Two obvious ones are kilograms of bait caught per night and kilograms of bait caught per haul.

The CPUE in kilograms per night is most useful for studying relationships between bait availability and skipjack catch, while CPUE in kilograms per set probably more closely parallels relative abundance of bait (assuming stability in technique). Measures of abundance can only be indirectly related to the catch per night figures as these tend to underestimate abundance when bait is plentiful (baitwell capacity is often limiting) and overestimate it when scarce (large number of sets to achieve minimum bait for trip).

A comparison of Figures 5(a) and 5(b) shows CPUE as kilograms per night to be more variable than CPUE in kilograms per set. In both cases the CPUE appears to have steadily fallen since 1976.

4. REASONS FOR THE LOW APPARENT ABUNDANCE OF BAITFISH IN 1979/1980

The captains of eight vessels were interviewed after the poor catches of bait early in the 1979/1980 season. Most agreed that there was very little bait in November and December 1979 and what bait there was, was of small size, consisting mostly of fish larvae and juveniles. Through January 1980 the fishing improved and in February, bait catches were considered reasonable. Reasons given by the eight captains for a poor start to the season were varied and included a late baitfish breeding season (4), the influence of low water temperatures (3) and a large catch the previous season (1). Several thought there was a change in species composition. It should be noted that while most captains had at least one season's fishing experience in Fijian waters, this fishery is a relatively young one (4 seasons). It is therefore unlikely that fishing masters would be thoroughly familiar with the intricacies of the baitfishery. Five potential reasons for the poor 1979/1980 season are considered in sections 4.1 to 4.5.

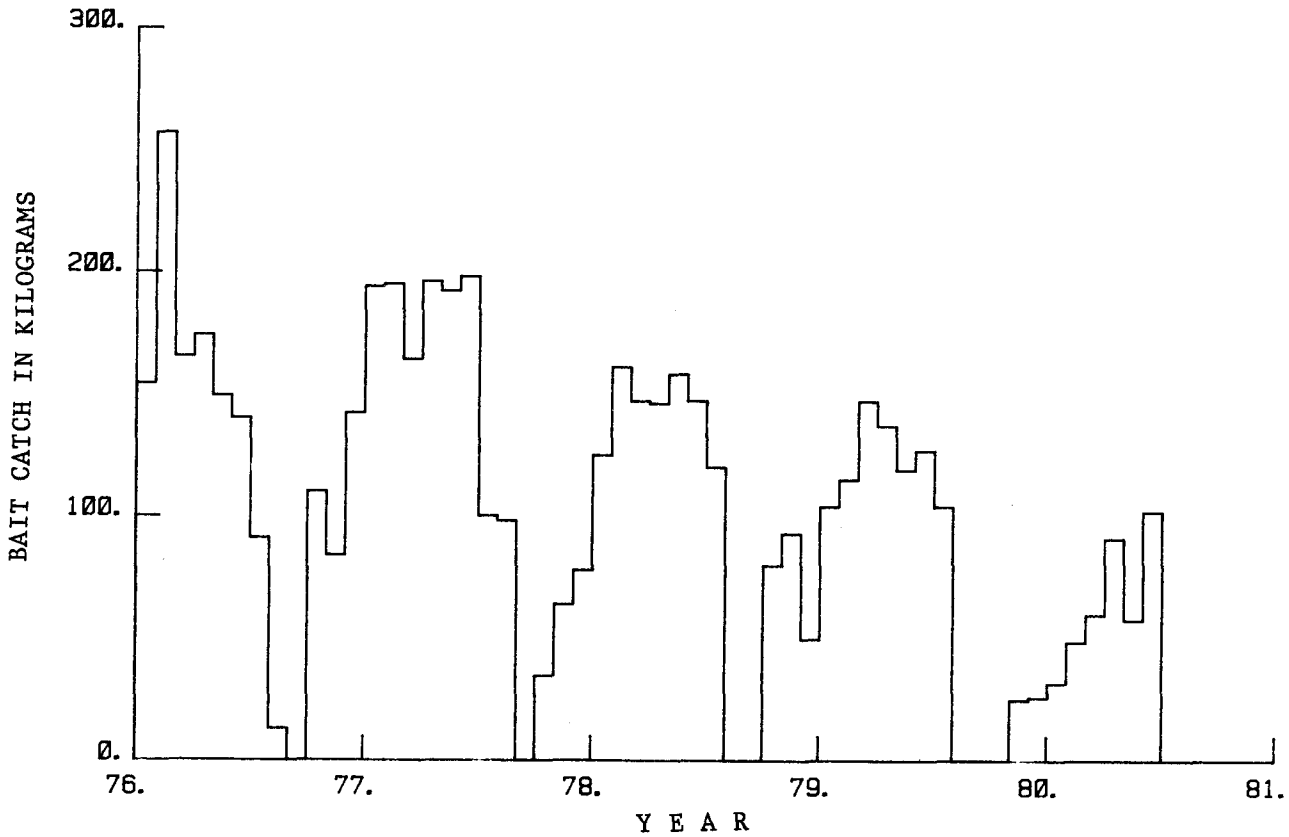

FIGURE 5(a): Average baitfish catch (in kilograms) per night per vessel for the combined Fijian fleet.

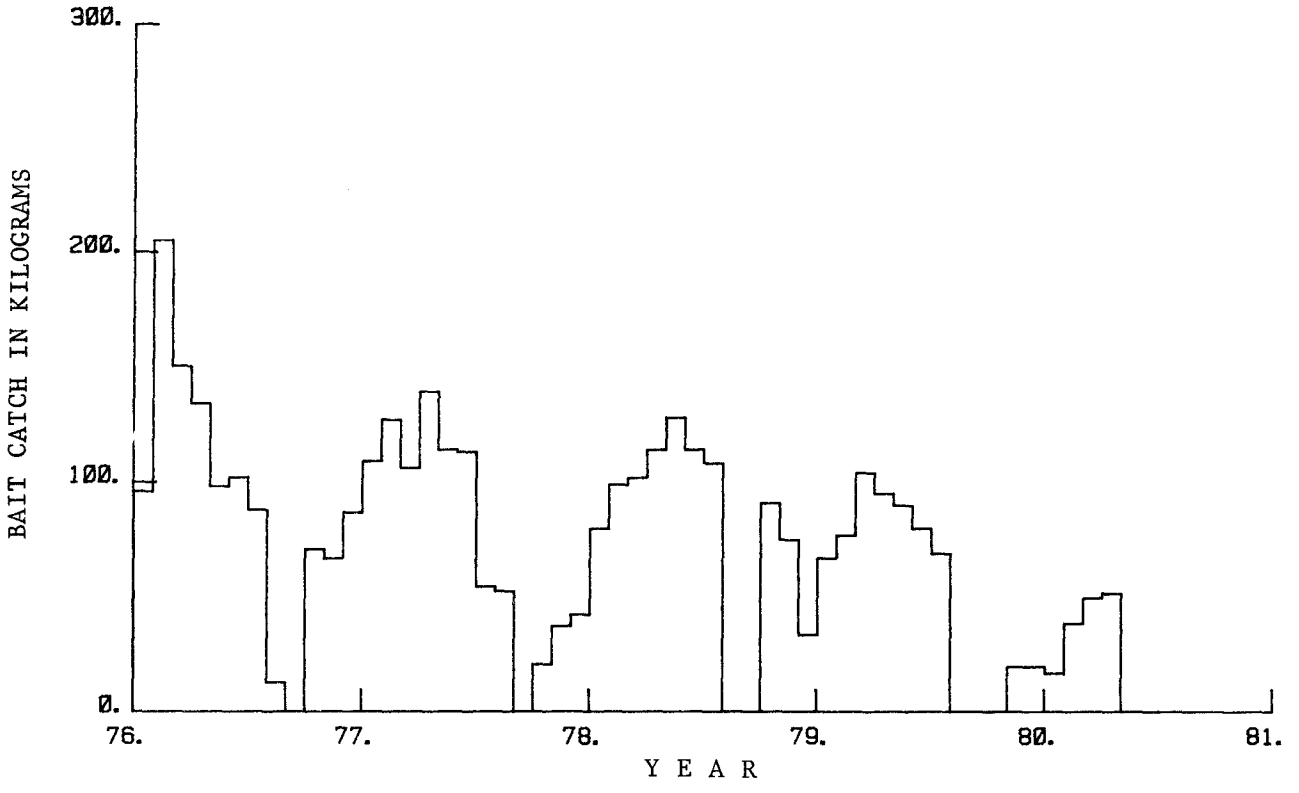

FIGURE 5(b): Average baitfish catch (in kilograms) per set per vessel for the combined Fijian fleet.

4.1 Environmental Influences

4.1.1 Water Temperature

Several of the captains interviewed thought that waters colder than 29.0°C were not conducive to good bait fishing and that the occurrence of water temperatures lower than this in 1979/1980 was responsible for the scarcity of bait. Temperature data averaged from pole-and-line fleet records for the 1976 to 1980 period are shown in Figure 6. These data are recorded in the vessel's logs as noon temperatures at the tuna fishing grounds, and therefore probably do not accurately mirror temperature fluctuations on the baitfishing grounds. Temperatures inside lagoons and estuaries might be expected to show much wider variation. Figure 6 does show that good bait catches were taken when sea surface temperatures on the tuna fishing grounds were well below 29°C.

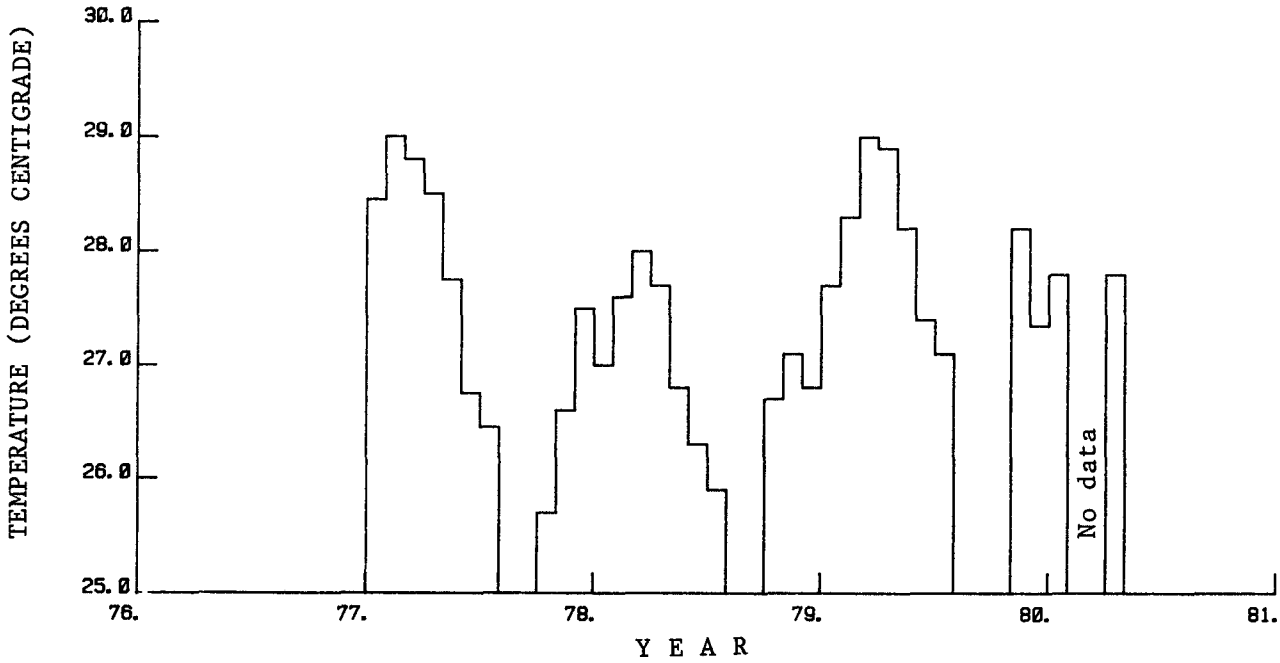

FIGURE 6: Mean monthly noon sea surface temperatures on the fishing grounds.

Similarity between histograms of noon temperature on the tuna fishing grounds (Figure 6) and total bait catches (Figure 3) and bait catch per unit effort (Figures 5(a) and 5(b)) is immediately apparent. It is probable that this correlation is merely indicative of seasonal variation in both temperature and baitfish abundance (similar fluctuations also occur in rainfall) and when plotted over a number of seasons a common cyclical pattern predominates. There is a suggestion that temperatures in 1980 may have been lower than 1979, but they were at least as high as in 1978 (the break in the 1980 data complicates interpretation). Air temperature data recorded by the Fiji Meterological Service were also considered for sites in northern, central and southern Fiji and, while the same seasonal pattern was of course apparent, no major inconsistency could be found in the 1978, 1979 or 1980 data.

The failure to find a correlation between temperature and the poor baitfish season in 1980 does not preclude some form of temperature fluctuation as the cause. It does suggest, that as the captains of the fishing vessels interviewed had access only to limited data, their opinion that lower temperature was responsible for the poor season is difficult to substantiate.

4.1.2 Rainfall

Researchers in other countries have correlated abundance of particular year classes of sardines with surface water temperatures and rainfall during the spawning period. In the Mediterranean Sea, Ben-Tuvia (1960) found a relationship between an exceptionally strong year class of *Sardinella*

aurita and a high level of precipitation in the spawning season. He theorised that rain-induced soil erosion increased the quantity of nutrient salts available for the development of plankton and hence enhanced the survival of the Sardinella brood. Similar work in India by Antony Raja (1964) shows a correlation between the abundance of juveniles of Sardinella longiceps and rainfall during the peak spawning period preceding the commercial season.

Rainfall in northern, central and southern Fiji exhibits a seasonal pattern with most rain in the months January through June and a drier period for July through December (Figures 7(a), 7(b) and 7(c)). 1979 has a rainfall pattern which does not markedly differ from that of preceding years. Therefore, even though there is a similarity between the seasonal rainfall pattern and seasonal baitfish abundance, no reason could be found to support the hypothesis that variability in rainfall accounted for a poor baitfish season in 1979/1980.

4.2 Intensity of Baitfish Effort

One measure of the intensity of baitfishing effort is the number of net hauls (sets) each vessel has per night. When the phase of the moon and the environmental variables are favourable, each vessel will have more than one net haul per night to catch the required quantities of bait. If bait is really abundant, only one haul is necessary. It is normal in other baitfisheries in the Pacific (e.g. Papua New Guinea) for vessels to have at least two hauls per night when baitfish abundance is low (Smith, personal communication). Under normal fishing conditions, a high average number of bait net hauls per night would be indicative of low baitfish abundance. If skipjack abundance was particularly low, fishermen would not bother to make the extra baitfishing effort.

From an examination of changes in the number of sets per night since the commencement of the commercial fishery in Fiji in 1976 (Figure 4), it is apparent that the sets per night ratio increased in 1977 over the 1976 figure, but then gradually declined through the end of the 1980 season, as did average baitfish catches (Table 5). This continued decline in intensity of baitfishing effort, even in the very poor 1979/1980 season, is most surprising. It suggests that fishermen could not be bothered to make the extra effort when bait was scarce. This lack of extra effort could perhaps be a response to low skipjack abundance at the time such that even reasonable bait catches produced uneconomical returns of skipjack. Another possible reason would be some form of industrial imbalance such that there was no incentive for fishermen to catch more fish.

The authors feel that the present systems of bonus payments for large catches by Ika and joint agreement vessels provide little, or no, incentive to fishermen in times of reduced skipjack abundance. As a result, there is a decline in effective bait and skipjack fishing effort in poor seasons when skipjack landings are low. This problem is exaggerated for Ika vessels in very poor seasons as no bonus payments are payable until total monthly landings by each vessel exceed 25 tonnes, a total which crews can sometimes see is unattainable even with maximum effort.

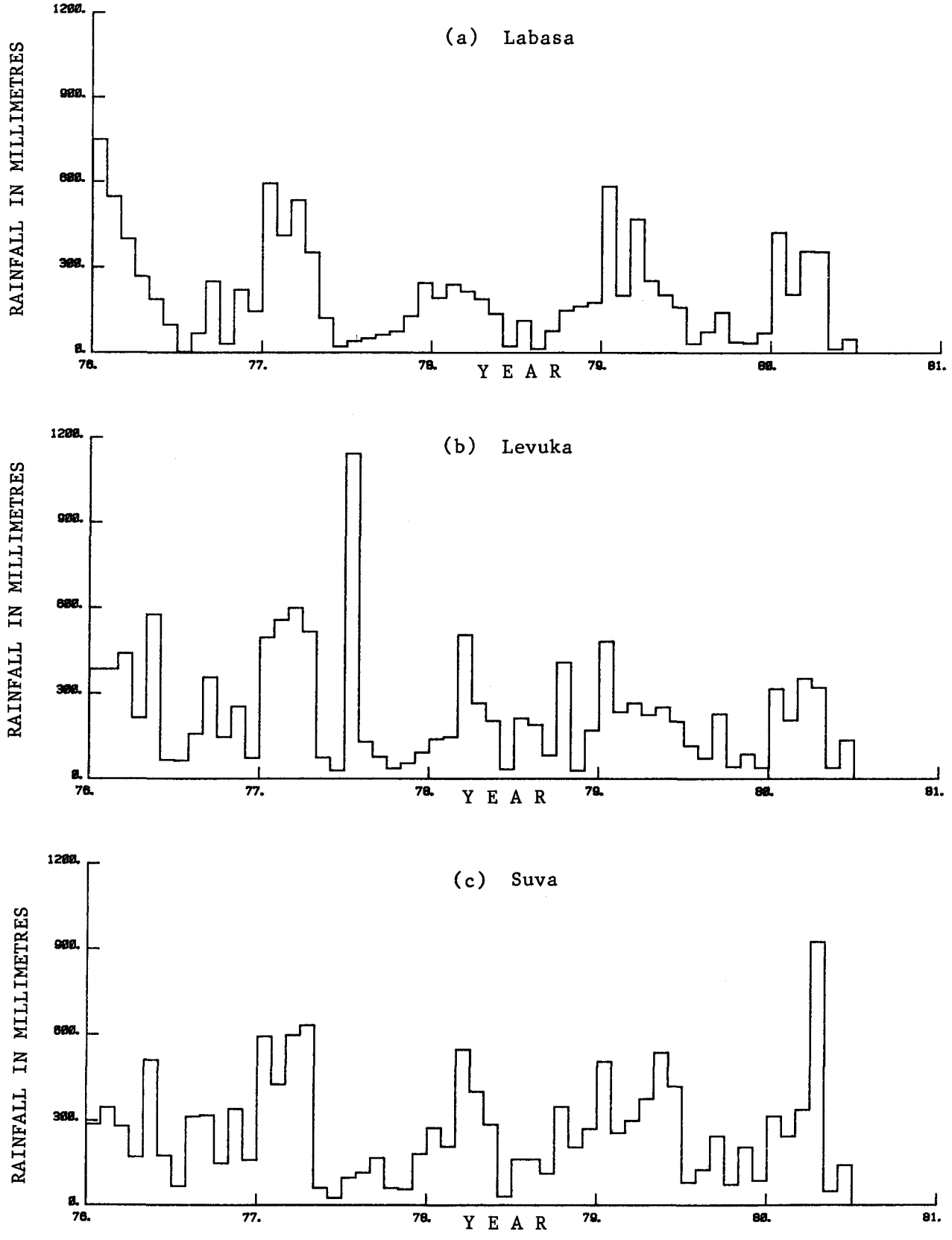

FIGURE 7: Fluctuations in monthly rainfall

TABLE 5
Comparison of Baitcatching Effectiveness of IKA Corporation and Joint Venture Vessels for Those Vessels for Which A Comparable Time Series is Available
(Data from Fisheries Division, Ministry of Agriculture & Fisheries, Fiji)

YEAR	MONTH	AVERAGE BAIT CATCHES EXPRESSED IN KILOGRAMS PER NIGHT FISHED				
		IKA NO.1	IKA NO.2	HATSUTORI MARU NO.2	HATSUTORI MARU NO.3	HATSUTORI MARU NO.6
1977	Dec.	-	-	68.4	-	38.1
1978	Jan.	-	-	113.4	-	138.9
	Feb.	-	-	157.7	-	165.2
	Mar.	113.9	-	144.7	-	117.7
	Apr.	142.0	-	129.2	-	173.5
	May.	152.6	-	112.8	-	135.4
	Jun.	156.6	-	-	-	141.1
	Jul.	146.9	-	-	-	91.4
	Aug.	273.6	-	-	-	-
	Sep.	-	-	-	-	-
	Oct.	-	-	-	-	-
	Nov.	-	-	-	-	-
	Dec.	-	-	-	-	-
1979	Jan.	179.3	-	85.7	88.6	141.6
	Feb.	171.4	-	119.5	95.4	106.9
	Mar.	219.9	-	130.3	92.0	147.2
	Apr.	162.7	-	134.5	102.4	132.8
	May.	157.7	-	114.1	103.8	107.3
	Jun.	-	-	127.3	80.1	122.6
	Jul.	109.8	154.6	103.5	75.8	97.5
	Aug.	-	-	-	-	-
	Sep.	-	-	-	-	-
	Oct.	-	-	-	-	-
	Nov.	-	25.4	-	-	-
	Dec.	-	48.9	15.3	20.5	25.2
1980	Jan.	-	51.5	41.9	30.8	26.5
	Feb.	154.8	27.0	44.5	79.6	40.8
	Mar.	91.6	63.7	59.4	68.0	51.5
	Apr.	-	-	70.9	61.2	-

During February and April 1978 and April and May of 1980, the South Pacific Commission's Skipjack Survey and Assessment Programme operated in Fijian waters. Two chartered Japanese pole-and-line vessels were used. Both vessels, the Hatsutori Maru No.1 and No.5, had at different times operated in the Fijian commercial fleet. The baitfish catches by the Hatsutori Maru No.1 during the 1978 tagging and survey work were very similar to those taken by the commercial vessels (Table 6) and skipjack catches were considered comparable, bearing in mind the greatly reduced catching efficiency of the Hatsutori Maru No.1 during tagging operations. In the 1980 survey, the Hatsutori Maru No.5 made baitfish catches which averaged approximately seven

times those of the commercial fleet (Table 6), and skipjack catches were at least equal to those of other vessels without any correction for the greatly reduced efficiency (Table 6). When the estimated conversion factor of 3.47 for survey to commercial conditions (Kearney, 1978) is applied, the Hatsutori Maru No.5's skipjack catches were at least three times those of the commercial vessels. Throughout the survey the Hatsutori Maru No.5 operated in the same general areas as other vessels.

TABLE 6
Comparison of Baitfish and Skipjack Catches of the SPC Chartered Vessels with Similar Vessels in the Fijian Fleet During Each of Three Survey Periods
(Data from Fisheries Division, Ministry of Agriculture & Fisheries, Fiji and Skipjack Survey & Assessment Programme, South Pacific Commission)

VESSEL	Average bait catch (kg) per night fished	Average Skipjack Catch (tonnes) per day fished
PERIOD: February 1 - 21,1978		
Hatsutori Maru No.2	152.5	3.65
Hatsutori Maru No.5	151.2	4.53
Hatsutori Maru No.6	154.4	4.66
Hatsutori Maru No.1 (SPC)	149.4	0.72* (2.72**)
PERIOD: March 28 - April 10,1978		
Hatsutori Maru No.2	129.3	5.23
Hatsutori Maru No.5	204.0	4.47
Hatsutori Maru No.6	135.9	5.48
Hatsutori Maru No.1 (SPC)	311.3	2.33* (8.10**)
PERIOD: April 9 - 27, 1980		
Hatsutori Maru No.2	58.7	2.21
Hatsutori Maru No.3	33.2	2.45
Hatsutori Maru No.7	51.5	1.69
Hatsutori Maru No.5 (SPC)	354.0	2.31* (8.02**)

* Survey catches including tagged fish.
** Raised estimate of commercial catch (survey catch x 3.47). (See sections 4.2 and 4.3)

The Hatsutori Maru No.5 is a larger vessel than others operating in Fiji in 1980 and it carries a larger "bouki-ami" net. Nonetheless, during previous years when the vessel had fished commercially in Fiji its performances had been only comparable to other vessels (Table 6). In 1980, it did have the benefit of a captain with considerable experience, but while this would undoubtedly improve its performance, it could not account for the

seven-fold difference in reported bait catches and was most probably not responsible for the more than three-fold difference in skipjack catching efficiency (see Section 4.3). The SPC vessel averaged 1.8 bait net hauls per night during the 1980 survey compared to approximately 1.2 sets by the fleet.

The startling difference between the catches of the SPC survey vessel and the commercial fleet in 1980 strongly suggests that the efficiency of the local vessels was greatly reduced at that time.

4.3 Fishery Induced Changes

Figures 5(a) and 5(b) suggest that baitfish catch per unit effort (both per night and per set) declined consistently on an annual basis from 1976 through the 1978-1980 season. This could, if considered in isolation, be taken to be a classical stock response to increasing effort. The very low apparent baitfish abundance in late 1979 and early 1980 could then perhaps be attributed to a stock collapse in this period. There are numerous reasons why this explanation could be incorrect.

Baitfishing effort in Fiji is distributed over 93 sites with approximately two-thirds of the annual catch coming from 10 sites (section 3.2). Areas which are fished heavily one season are often neglected the following season, particularly if the major skipjack fishing grounds change. Fluctuations in the fishing effort and resulting catch at principal sites in 1978 through 1980 (Table 3) demonstrate this variability and show that baitfish catches reported in early 1980 were much below average at every major site. This table also shows that the lowest declared catches in 1980 were common to even those sites which were infrequently fished.

Fluctuations in catches at frequently fished sites suggest that the drop in apparent abundance in 1980 was sudden (Table 3) and not in keeping with the more gradual decline one would expect for a response to fishing pressure in a multi-species fishery of this type.

Species composition of commercial baitfish catches taken in Fiji are estimated on each vessel, but as the ability of fishing masters to distinguish among the more similar genera is questionable, this information is of limited value. When interviewed, captains of vessels suggested that early in the 1979/1980 season there was an abnormal lack of sardines (Sardinella sirm and Herklosichthys punctatus) and that juvenile sprats (Spratelloides spp.) and anchovies (Stolephorus spp.) were dominant in what little bait was available.

Lee's analysis (FAO, 1974) of baitfish catches in 1971-1973 in kilograms of each species is compared with those of the Fisheries Division for 1978 and the two South Pacific Commission surveys of 1978 and 1980 in Table 4. These analyses show that the dominant baitfish species in Fiji are sardines, sprats and silversides (Hypoatherina ovalaua and Pranesus pinguis) and not anchovies, which are the mainstay of baitfisheries in most other Island countries in the western Pacific. The opinions of the fishing captains confirm these species compositions as being representative of overall catches. It should be noted that the 1980 SPC survey suggested that the captains' opinions were also correct in that there was a marked decrease in the abundance of Sardinella sirm and an increase in the proportion of Stolephorus anchovies in the catches in 1980 (Table 4). It could also be

significant that most of the Stolephorus anchovies taken by the SPC in 1980 were Stolephorus indicus, which is an extremely delicate species with which mortalities of 100 per cent within a few hours of capture are normal; it is therefore virtually worthless as live bait. A significant decrease in the abundance of Spratelloides delicatulus was also detected during the second SPC survey.

During the first SPC visit the chartered vessel, Hatsutori Maru No.1, recorded baitfish catches which averaged 149.4 and 311.3 kg per night in February 1978 and March-April 1978 respectively (Table 6). These catch rates were equal to 102.2 and 191.5 kg per set in the two periods. In April 1980 the SPC chartered vessel Hatsutori Maru No.5 achieved bait catches which averaged 354.0 kg per night (225 kg per set). While the Hatsutori Maru No.5 is 25 per cent larger than the No.1 and carries a slightly bigger bait net, its baitfishing efficiency would almost certainly not be more than 25 per cent greater than the No.1. Table 6 suggests that the Hatsutori Maru No.5 is on average only about 20 per cent more effective than the Hatsutori Maru No.2 and No.6, which are smaller than the No.1 (Table 2). The high catches by the SPC vessel in 1980 therefore suggest that baitfish abundance in Fiji was no lower in late April 1980 than it had been in early April 1978. The most conclusive argument against the hypothesis that 1980 was a poor fishing year because of overexploitation of the baitfish resources, is provided by the 1980/1981 skipjack and baitfish catches. Although no figures on the 1980/1981 season were available to the authors, it has been reported (Hunt, personal communication) that baitfish and skipjack catches in late 1980 and early 1981 were exceptionally good. As total baitfishing effort was higher in Fiji in the 1979/1980 season than in any preceding year (Figures 2(a) and 2(b)) this recovery would not be expected if the resources were in a state of collapse.

4.4 Normal Variability in the Behaviour and/or Abundance of Baitfish

In many fisheries poor catches in a given time period can result from decreased availability or vulnerability of the species taken, without any decrease in the underlying stocks. Variability in the distribution of stocks can often appreciably influence availability, while failure of some fish to school in catchable concentrations is the most common cause of decreased vulnerability. Adverse weather conditions can be a major factor in reducing catchability (either availability or vulnerability) by preventing fishermen from travelling to the best fishing grounds or from fishing efficiently.

The baitfishery in Fiji operates in many locations throughout the country and fishing is normally done in relatively sheltered anchorages. There is no evidence that weather caused any adverse redistribution of effort in the 1979/1980 season or abnormally disrupted fishing operations at major sites. Because the major species taken are inshore species with a relatively restricted habitat and because apparent abundance was low throughout the country in 1979/1980, it is most unlikely that change in availability was responsible for the poor season.

Reasons why baitfish are attracted to bright lights are not sufficiently well understood to evaluate if an abnormally low response is likely to occur in any one season. No other likely cause of a decrease in vulnerability of baitfish in Fiji in 1979/1980 could be identified.

A summary of studies in other countries of the reproductive characteristics of species found in Fiji reveals that many of these species have been shown to spawn year-round in other areas, while others spawn but once a year (Table 7) and have a life span of only a year or less. Much of the published information on these species has been generated from studies in equatorial areas where the seasonal variability in the environment is much less than in Fiji. Seasonal variations in the stocks, as indicated by CPUE (Figures 5(a) and 5(b)), are therefore much greater in Fiji. It is also probable that for some species, such as the dominant Sardinella sirm, spawning is only once annually and concentrated seasonally such that environmental factors on the spawning or nursery grounds over relatively limited time periods could significantly influence abundance in the following season. This is in agreement with the general hypothesis that where subtropical seasonal fisheries for small clupeoids exploit only a single year class, considerable variability in the magnitude of the resource can be anticipated.

It is also possible that the reported low baitfish abundance in the 1979/1980 season was a result of temporal variation in spawning and recruitment, rather than a change in overall abundance. Seasonality in apparent abundance, as indexed by changes in monthly catch rates from year to year, is well documented (Figures 5(a) and 5(b)) and if the 1979/1980 season was late for any reason, poor baitfishing early in the season would be anticipated. If spawning was late in this season, it would explain the large quantities of larval and juvenile baitfish observed by the vessel captains in late 1979.

If the lateness of the season was the only factor, a recovery in catch and CPUE to normal levels would be expected early in 1980. While a recovery certainly did occur, total reported catches and CPUE did not rise to levels of previous years (Figures 5(a) and 5(b)) during the 1980 season.

If it is accepted that the reported low abundance of suitable baitfish in Fiji in the 1979/1980 season was real, and that it was not a result of fishery induced changes (see section 4.3), then it is most likely that this low abundance was within the range of natural fluctuations in the size of the stocks. For tropical bait species, such as most of those taken in Fiji, wide variability from year to year in the magnitude of the standing stock is anticipated.

4.5 Overstatement by the Fishing Fleet of the Magnitude of the Drop in Baitfish Abundance

A tendency by crews to underestimate or understate by as much as 50 per cent the baitfish catch taken, has already been reported by the Fisheries Division (Anon, 1979). As fishing vessels will change fishing grounds in response to reports of good catches from other boats, a captain underdeclaring his catches is less likely to face increased competition from other boats at his baitfishing site. At times when baitfish are scarce, a report of a baitfish catch above the expected is more likely to attract attention. Hence it is probable that declared catches at such times give an even lower bias to apparent abundance. It is more than possible that declared baitfish catches in Fiji in the 1979/1980 season exaggerated the low apparent abundance of baitfish.

TABLE 7
Reproductive Characteristics Reported from Other Countries of Baitfish Species Dominant in the Fijian Fishery

SPECIES	LENGTH AT MATURITY	AGE AT MATURITY (days)	BREEDING TIMES
Sardinella sirm	-		Winter(1)
Spratelloides delicatulus	40mm(6) 50mm(1)	74(1)	-
Spratelloides gracilis	41mm(8),45mm(7)	35(7)	All year(7)
Stolephorus devisi	40mm(7),46mm(8),	36(7)	May-June(7)
Stolephorus heterolobus	50mm(7,9) 55mm(8),60mm(3)	42(7)	Winter(3) May-Jun(7) Sep-Dec(7) All year(3,8)
Stolephorus indicus	116-125mm(4)	43(5)	All year(3)
Herklotsichthys punctatus	73-90mm(2)	180(2)	Spring(2),
Pranesus pinguis	55mm(2)	180(2)	All year peak Aug(2)

(1) Li (1960)
(2) Hida & Uchiyama (1977)
(3) Tiews et al (1970)
(4) Hardenburg (1934)
(5) Tham (1967)
(6) Kearney,Lewis & Smith (1972)
(7) Wankowski & Dalzell (Manuscript)
(8) Lewis, Smith & Kearney (1974)
(9) Tham (1965)

5. COMPARISON WITH OTHER BAIT FISHERIES IN THE WESTERN PACIFIC

Substantial bait fisheries in the western tropical Pacific other than Fiji are those in Papua New Guinea, Solomon Islands and Palau. Minor fisheries exist in numerous other Island states. Each of the three fisheries mentioned above is much larger and has been in operation for longer than the Fijian fishery. It was hoped that the results from an examination of catch trends in these fisheries would be relevant to the assessment of the status of stocks in Fiji. This does not appear to be the case.

Bait fisheries in Palau and Solomon Islands rely predominantly upon catches of Stolephorus anchovies and, in Papua New Guinea on Stolephorus species and Spratelloides gracilis. These species are relatively short lived but do not exhibit the strong seasonal cycles of abundance typical of less tropical areas such as Fiji. Use of the knowledge on the dynamics of the bait resources in these three countries for assessment of the Fijian situation is therefore not considered appropriate.

6. CONCLUSIONS AND RECOMMENDATIONS

Five general factors were considered as possible explanations of the poor baitfish season in 1979-1980. One, depletion of resources as a result of fishing pressure, and part of another, change in the behaviour of the bait species, have been judged as unlikely causes. Furthermore, no correlation could be found between the environmental phenomena temperature and rainfall and the poor season. However, undetected short-term variations in these or other environmental factors, which could result in lower survival rates at some stage in the life cycle, are a likely cause or associate of a "natural" change in abundance. All of the remaining factors are incorporated below into a most likely explanation.

There seems little doubt that the abundance of suitable baitfish in late 1979 was well below normal for that time of the year. It is probable that this was due to a late 1979 spawning season for Sardinella sirm and Spratelloides delicatulus, which are the dominant species in the Fijian baitfishery. Quite possibly, the season for both these species was poor as well as late and this kept abundance of both species below normal well into 1980. Furthermore, as Sardinella sirm and Spratelloides delicatulus are both excellent skipjack bait, a decrease in their contribution to the catch would also almost certainly lower the effectiveness of the average unit of bait that was available. The marked increase in the catches of Stolephorus indicus, almost worthless as live bait, compounded this problem.

The initial impact of the poor baitfish season was to delay commencement of the skipjack fishery, which established uncertainties amongst the fishermen. It is probable that the skipjack abundance in this season was also below average and even when baitfish catches did begin to improve in January, returns were still only marginally economical. Certainly it was difficult for most vessels to achieve catch rates which resulted in a substantial bonus to fishermen. Incentives for extra effort were therefore minimal with the result that effective effort per vessel was less than in previous years. When fishermen were able to take good bait catches they were probably reluctant to declare them because of fear of competition at that particular baiting site. Overall, the magnitude of the reduction in total baitfish abundance was exaggerated and overemphasized and the poor, or perhaps only late, baitfish season was blamed for a generally bad year in the Fijian skipjack fishery.

The inadequacy of the available data for making more precise assessments of factors influencing the 1979-1980 season emphasizes the need to improve the data base. Steps likely to increase the understanding of the dynamics of the baitfish resources and the fishery on them include:

(1) More accurate estimates of bait catches. Underestimation or under-declaration of catches by the fleet should be urgently investigated and corrected. Improved estimates of the live weight of bait contained in buckets of different species are required.

(2) Increased accuracy in estimating species composition and average size distributions. More emphasis could be placed on the correct identification and declaration by the crews of the dominant bait species in each catch. This might necessitate some training of a few key personnel on each vessel in identification of the six or so important species.

(3) Life history studies on the dominant species. These should be undertaken to ascertain age and size at recruitment, spawning frequency and other parameters necessary for biologically accurate evaluation of the resources.

Steps which could lead to improvement in the overall bait catching efficiency of the fleet include a re-examination of the incentive systems operating within the industry and co-ordinated deployment of fishing effort. It is felt that centralized collation and analysis of daily fishing performances could enable direction of survey fishing trips to infrequently used baiting grounds in times of low baitfish abundance.

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