

catch of 3500 t tuna, the requirement of baitfish would be 236 t (or 94 400 buckets) per year. This figure is almost double the maximum annual baitfish catch made in Kiribati (1984), and four times greater than that of 1989.

Using the estimates of potential yields from the backgrounds in Table 14, this requirement of baitfish would be difficult to meet from the natural stocks of pelagic baitfish from the lagoons of Abaiang, Abemama, Butaritari and Tarawa. But in order to approach these catch levels, increased nightly fishing effort by each vessel would be required. The effort required would be even greater if most of the fishing effort were to take place away from Tarawa. Due to the variation in catch rates in Kiribati, it may not be possible to achieve this average annual requirement from natural stocks, and so it will be necessary to supplement from the cultured milkfish farms.

As these estimated yields have been produced from methods whose underlying assumptions are rarely met, it cannot be assumed that the natural baitfish stocks can sustain the increased fishing effort this analysis suggests is possible. It will

therefore be vital to monitor on a regular nightly basis the catch and effort made by the pole-and-line boats. Such information can quickly indicate whether overfishing may be occurring. Due to the nature of baitfishing (and the relocation of fishing effort when declining catch rates occur), the fact that recruitment of the major baitfish species comes from an ocean-based pool and that the species are relatively short-lived (Milton et al. 1992a) and highly fecund (Milton et al. 1992b), it is unlikely that stocks could be completely decimated. The increased use of cultured baitfish could also take a considerable amount of fishing pressure away from the natural stocks.

It would therefore be unwise to increase the size of the present fishing fleet until increased catches by existing vessels are achieved. Extremely careful thought and consideration needs to be given to any increase in fleet size by Te Mautari Limited, and a lot of these decisions must be based on economic factors. However, once these have been taken into consideration and target catch rates have been set, the figures above should assist in assessing the amounts of baitfish required.

Table 15. Annual baitfish and tuna catches in Kiribati from 1982 to 1989 and their tuna-to-baitfish ratios (bu = buckets).

Year	Bait catch (bu) ¹	Tuna catch (t)	Tuna per unit of baitfish (kg)
1982a	16 913	549.89	13.01
1983a	45 513	1 868.52	16.42
1984b	50 586	2 252.00	17.81
1985b	35 329	826.00	9.35
1986c	29 636	1 360.00	18.36
1987d	32 896	584.00	7.10
1988e	24 274	875.70	14.43
1989f	23 241	1 242.80	21.30
Total	258 288	9 558.91	14.79

¹ 1 bu \approx 2.5 kg

Sources of tuna catch data: a. Dalley 1984; b. Lawson 1991; c. Mees 1987; d. Mees 1988; e. raw data from South Pacific Commission; f. Kiribati Fisheries Division 1989.

Table 16. Monthly tuna fishing effort, tuna and baitfish catch, tuna-to- bait ratio and the amount of baitfish used daily by the pole-and-line fleet during 1988 (N = number of vessels; bkts = buckets).

Month	N	Fishing days	Bait catch (bu) ¹	Tuna catch (t)	Tuna to bait (kg)	Bait/day (bu)
January	2	42	1 560	26.4	6.77	37.1
February	2	42	1 535	20.8	5.41	36.6
March	1	25	1 149	26.0	9.05	46.0
April	1	22	735	18.9	10.29	33.4
May	1	26	788	16.1	8.15	30.3
June	3	59	2 283	23.0	4.03	38.7
July	3	60	2 682	105.2	15.69	44.7
August	3	65	3 182	156.6	19.68	49.0
September	3	80	3 939	165.5	16.81	49.2
October	3	64	2 592	122.6	18.92	40.5
November	4	74	2 250	137.4	24.41	30.4
December	4	64	1 579	70.1	17.77	24.7

¹ 1 bu \approx 2.5 kg

Baitfish Biology

Summary

The main conclusions from this section are:

- the three main baitfish species spawn throughout the year with periods of more intense activity;
- *Amblygaster sirm* of effective baitfish size are absent from the lagoon and baitfishing catches only spawning adults;
- *Herklotsichthys quadrimaculatus* disperse from daytime aggregations after dark to feed and spawn and this may be the reason that this species is not attracted to the underwater lights in large numbers;
- predation of baitfish around underwater lights was higher than under natural conditions and there was an increase in the number of species preying on baitfish;
- there was some overlap in the predatory fish by-catch and the artisanal reef-fish fishery, but the effect of the interaction appears to be small.

Aspects of the biology that affect the catch rates of the three main baitfish species, *Amblygaster sirm*, *Herklotsichthys quadrimaculatus* and *Spratelloides delicatulus* are presented in this section.

Growth and Recruitment

As shown in the previous section on the size composition of the catch, most *A. sirm* and *S. delicatulus* in baitfish catches are too small or too large to be effective baitfish for skipjack tuna. The seasonal changes in the length-frequency

distribution of these species are influenced by the time at which fish recruit to the fishery. By having a better understanding of their recruitment patterns, the fishermen may be able better to predict when most fish of desirable size are in the population. They could also target areas where that species occurs in order to catch more bait of the most effective size.

The reproductive cycle of the three main species in Kiribati involves almost continuous spawning throughout the year (Milton et al. 1992b). However, the number of eggs produced each month varies in relation to food availability. The distribution of birthdates of each of the three species back-calculated from length-frequency samples (Figs 25–27) shows that some fish are born each month.

In 1989, *Amblygaster sirm* had a protracted spawning season during the middle of the year and most fish were born between March and October. These fish would reach the minimum preferred length for bait (5 cm) in 2–3 months (Fig. 25). Yet they rarely enter baitfish catches (Fig. 22). Most of the commercial catches of *A. sirm* were large adults involved in spawning (Milton et al. 1992b).

The distribution of birthdates back-calculated from length-frequency samples of *H. quadrimaculatus* from the four years examined was more even than for other species. Fish were fully selected by bouke-ami nets at five months of age (Table 2), when they approach sexual maturity (Milton et al. 1992b). Continuous spawning throughout the year by *H. quadrimaculatus* means that most of the *H. quadrimaculatus* population should be of a suitable length for baitfishing.

Herklotsichthys quadrimaculatus is not attracted to underwater lights as effectively as the other two species and does not form a significant part of the catch (Tables 7–10). During the day they form dense schools in shallow water where they are caught for local consumption. Their poor representation in baitfish catches may be because *H. quadrimaculatus* disperse during the night to feed (Milton et al., unpublished data). Density in baitlighting areas may be quite low and so few would be attracted to the lights. Both *A. sirm* and *S. delicatulus* feed during the day (Milton et al. 1990) and baitlights are probably attracting spawning fish (Milton et al., 1992b) that are aggregating in these areas.

The distribution of back-calculated birthdates of *Spratelloides delicatulus* varied among the four years examined (Fig. 27). Fish spawned throughout the year, but in each year there were two periods of increased activity. A similar pattern was found for this species in Solomon Islands (Milton and Blaber 1991). Only a small fraction of the length distribution of *S. delicatulus* is in the effective length range for skipjack tuna bait. This makes it difficult to predict at which time of the year these fish will be more prevalent. In 1989 and 1990, the largest length-classes were collected during the peak spawning period in June to August. This suggests that larger *S. delicatulus* may be more catchable at these times.

Predation on Baitfish

Previous work by the CSIRO–ACIAR baitfish research project in Solomon Islands and Maldives (Blaber et al. 1990a, b) addresses the question of biological interactions between baitfish and reef fish and the potential effects of baitfishing on artisanal and subsistence reef fisheries. Nothing is known of such interactions in Kiribati and hence as a first step predation by larger fish on baitfish was investigated. This predation takes two forms; firstly, natural predation by larger species, and, secondly, intense predation around baitlights at night. Information on both is necessary if we are to understand the trophic effects of baitfishing on reef fish communities.

Methods

During the course of sampling baitfish around the islands of Abemama, Abaiang, Butaritari and Tarawa, other fish were captured with a number of different types of fishing gear:

- (a) monofilament gill-nets of varying mesh sizes: 25 mm, 33 mm, 50 mm, 75 mm and 100 mm;
- (b) the bouke-ami net (as by-catch of the baitfishing operations);
- (c) trolling lines and lures towed from behind a small skiff;
- (d) handlines (or droplines) (these operations took place around the underwater light used to aggregate baitfish as well as under natural conditions when no light was operating); and
- (e) other methods including beach-seine, cast-net and fishing poles.

Most of the fishing gears were being used for the collection of baitfish samples or were incidental fishing operations while undertaking other activities. However, on one occasion a fishing competition was arranged specifically to sample non-baitfish species from Tarawa Lagoon (see Appendix 1).

After fish had been captured they were identified, measured (standard length) and weighed and the stomachs removed and preserved in 10% formalin. In the laboratory, the stomach contents were sorted, as far as possible, by species, and dried to constant weight at 60°C. The diets of each species are expressed in terms of the percentage contribution of each prey category to the total dry weight of stomach contents and its percentage frequency of occurrence.

Results

Species collected

A list of the different species that were collected from each site and examined for their stomach contents is given in Table 17. The numbers of each species and how they were caught are shown in Table 18.

Table 17. Species list of fish collected for dietary analysis during sampling in the Republic of Kiribati, September 1989–February 1991 (Ab = Abemama; Ag = Abaiang; Bu = Butaritari; Ta = Tarawa).

Species	Sites			
	Ab	Ag	Bu	Ta
BALISTIDAE				
<i>Balistipus undulatus</i>				*
<i>Pseudobalistes flavimarginatus</i>				*
<i>Rhinecanthus aculeatus</i>				*
<i>Sufflamen chrysopterus</i>				*
BELONIDAE				
<i>Ablennes hians</i>				*
<i>Strongylura incisa</i>	*	*	*	*
<i>Tylosurus acus</i>		*		
<i>Tylosurus crocodilus</i>			*	
<i>Tylosurus</i> sp.		*		
CAESIONIDAE				
<i>Caesio caerulaureus</i>			*	
CARANGIDAE				
<i>Alectis indicus</i>		*		
<i>Carangoides ferdau</i>				*
<i>Caranx ignobilis</i>			*	*
<i>Caranx melampygus</i>		*	*	*
<i>Caranx papuensis</i>			*	*
<i>Caranx sexfasciatus</i>			*	*
<i>Decapterus macarellus</i>				*
<i>Decapterus macrosoma</i>			*	
<i>Scomberoides lysan</i>	*	*	*	*
<i>Selar crumenophthalmus</i>		*	*	*
DUSSUMIERIIDAE				
<i>Dussumieria</i> sp. A		*		
ECHENEIDAE				
<i>Echeneis naucrates</i>	*			*
GERREIDAE				
<i>Gerres argyreus</i>				*
HOLOCENTRIDAE				
<i>Myripristis murdjan</i>		*		
<i>Sargocentron spiniferum</i>				*
LABRIDAE				
<i>Choerodon anchorago</i>				*
<i>Thalassoma lunare</i>				*

(Table continued on next page.)

Table 17. Cont'd

Species	Sites			
	Ab	Ag	Bu	Ta
LETHRINIDAE				
<i>Lethrinus elongatus</i>			*	*
<i>Lethrinus nebulosus</i>			*	
<i>Lethrinus ramak</i>				*
<i>Monotaxis grandoculus</i>				*
LUTJANIDAE				
<i>Aprion virescens</i>		*		
<i>Lutjanus bohar</i>			*	*
<i>Lutjanus fulvus</i>			*	*
<i>Lutjanus gibbus</i>			*	*
<i>Lutjanus kasmira</i>			*	*
<i>Lutjanus monostigma</i>			*	
<i>Lutjanus russelli</i>			*	
<i>Lutjanus semicinctus</i>				*
MULLIDAE				
<i>Upeneus vittatus</i>		*		
NEMIPTERIDAE				
<i>Nemipterus peronii</i>			*	
SCOMBRIDAE				
<i>Euthynnus affinis</i>		*	*	
<i>Grammatorcynus bilineatus</i>			*	
<i>Rastrelliger brachysoma</i>			*	
SERRANIDAE				
<i>Aethaloperca rogae</i>			*	
<i>Cephalopholis argus</i>				*
<i>Cephalopholis cyanostigma</i>			*	
<i>Epinephelus cyanopodus</i>			*	
<i>Epinephelus fuscoguttatus</i>				*
<i>Epinephelus merra</i>				*
<i>Epinephelus tauvina</i>			*	
<i>Plectropomus areolatus</i>			*	*
SPHYRAENIDAE				
<i>Sphyræna barracuda</i>				*
<i>Sphyræna flavicauda</i>		*	*	
<i>Sphyræna forsteri</i>	*	*	*	*
<i>Sphyræna novaehollandiae</i>				*

Table 18. Number of fish collected for dietary analysis by method and species during sampling in the Republic of Kiribati, September 1989–March 1991 (BOU = bouke-ami catch; DLL = drop-line fishing around artificial light at night; DL = drop-line fishing away from artificial light; NET = gill-nets; TRL = trolling lures; OTH = other methods including beach-seine, cast-net, fishing pole; TOT = total numbers sampled).

Species	BOU	DLL	DL	NET	TRL	OTH	TOT
BALISTIDAE							
<i>Balistipus undulatus</i>	–	–	1	–	–	–	1
<i>Pseudobalistes flavimarginatus</i>	–	–	1	–	–	–	1
<i>Rhinecanthus aculeatus</i>	–	–	1	–	–	–	1
<i>Sufflamen chrysopterus</i>	–	–	2	–	–	–	2
BELONIDAE							
<i>Ablennes hians</i>	–	–	–	1	–	–	1
<i>Strongylura incisa</i>	–	–	–	21	–	–	21
<i>Tylosurus acus</i>	–	–	–	2	–	–	2
<i>Tylosurus crocodilus</i>	–	–	–	1	–	–	1
<i>Tylosurus</i> sp.	2	–	–	–	–	–	2
CAESIONIDAE							
<i>Caesio caeruleus</i>	–	–	–	2	–	–	2
CARANGIDAE							
<i>Alectis indicus</i>	1	–	–	–	–	–	1
<i>Carangoides ferdau</i>	1	–	–	–	–	–	1
<i>Caranx ignobilis</i>	–	–	–	1	3	–	4
<i>Caranx melampygus</i>	21	–	–	29	52	1	103
<i>Caranx papuensis</i>	1	–	–	1	3	–	5
<i>Caranx sexfasciatus</i>	23	1	–	23	2	1	50
<i>Decapterus macarellus</i>	5	–	–	–	–	–	5
<i>Decapterus macrosoma</i>	–	–	–	1	–	–	1
<i>Scomberoides lysan</i>	2	1	–	128	–	–	131
<i>Selar crumenophthalmus</i>	5	1	–	7	–	–	13
DUSSUMIERIIDAE							
<i>Dussumieria</i> sp. A	4	–	–	–	–	–	4
ECHENEIDAE							
<i>Echeneis naucrates</i>	5	–	–	–	–	–	5
GERREIDAE							
<i>Gerres argyreus</i>	–	–	1	–	–	–	1
HOLOCENTRIDAE							
<i>Myripristis murdjan</i>	–	–	–	–	1	–	1
<i>Sargocentron spiniferum</i>	–	–	3	–	–	–	3
LABRIDAE							
<i>Choerodon anchorago</i>	–	–	1	–	–	–	1
<i>Thalassoma lunare</i>	–	–	1	–	–	–	1

(Table continued on next page.)

Table 18. Cont'd

Species	Method	BOU	DLL	DL	NET	TRL	OTH	TOT
LETHRINIDAE								
<i>Lethrinus elongatus</i>		–	–	4	–	2	–	6
<i>Lethrinus nebulosus</i>		–	–	–	5	–	–	5
<i>Lethrinus obsoletus</i> (ramak)		–	–	3	–	–	–	3
<i>Monotaxis grandoculus</i>		–	–	1	–	–	–	1
LUTJANIDAE								
<i>Aprion virescens</i>		–	–	–	–	1	–	1
<i>Lutjanus bohar</i>		–	–	–	–	6	–	6
<i>Lutjanus fulvus</i>		–	–	–	13	–	–	13
<i>Lutjanus gibbus</i>		–	–	5	8	2	–	15
<i>Lutjanus kasmira</i>		–	–	17	17	–	–	34
<i>Lutjanus monostigma</i>		–	–	–	1	–	–	1
<i>Lutjanus russelli</i>		–	–	–	1	–	–	1
<i>Lutjanus semicinctus</i>		–	–	1	–	–	–	1
MULLIDAE								
<i>Upeneus vittatus</i>		1	–	–	–	–	–	1
NEMIPTERIDAE								
<i>Nemipterus peronii</i>		–	–	–	1	–	–	1
SCOMBRIDAE								
<i>Euthynnus affinis</i>		1	–	–	–	4	–	5
<i>Grammatorcynus bilineatus</i>		–	–	–	2	7	–	9
<i>Rastrelliger brachysoma</i>		–	–	–	37	–	–	37
SERRANIDAE								
<i>Aethaloperca rogae</i>		–	–	–	–	1	–	1
<i>Cephalopholis argus</i>		–	–	4	–	–	–	4
<i>Cephalopholis cyanostigma</i>		–	–	–	–	1	–	1
<i>Epinephelus cyanopodus</i>		–	–	–	–	5	–	5
<i>Epinephelus fuscoguttatus</i>		–	–	–	–	2	–	2
<i>Epinephelus merra</i>		–	–	6	–	–	–	6
<i>Epinephelus tauvina</i>		–	–	–	1	–	–	1
<i>Plectropomus areolatus</i>		–	–	–	–	8	–	8
SPHYRAENIDAE								
<i>Sphyraena barracuda</i>		–	–	–	–	2	1	3
<i>Sphyraena flavicauda</i>		3	–	–	2	–	–	5
<i>Sphyraena forsteri</i>		123	1	–	20	4	–	148
<i>Sphyraena novaehollandiae</i>		31	–	–	–	–	–	31

Table 19. Percentage dry weight of prey consumed (Wt%) and percentage frequency of fish consuming prey type (F%) by species under natural conditions (no light) and artificially illuminated conditions (light) during sampling in the Republic of Kiribati, September 1989–March 1991.

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
BALISTIDAE					
<i>Balistipus undulatus</i>	Empty	–	100.00	–	–
<i>Pseudobalistes flavimarginatus</i>	Empty	–	100.00	–	–
<i>Rhinecanthus aculeatus</i>	Empty	–	100.00	–	–
<i>Sufflamen chrysopterus</i>	Empty	–	100.00	–	–
BELONIDAE					
<i>Ablennes hians</i>	Empty	–	100.00	–	–
<i>Strongylura incisa</i>	Atherinidae Unid. sp.	28.13	16.67	–	–
	Clupeidae Unid. sp.	38.86	16.67	–	–
	Empty	–	71.00	–	–
	<i>Spratelloides delicatulus</i>	11.88	16.67	–	–
	<i>Spratelloides</i> sp.	3.23	16.67	–	–
	Teleost remains	17.90	16.67	–	–
Total prey weight		5.453 g	–	–	–

<i>Tylosurus acus</i>	Empty	–	50.00	–	–
	Teleost remains	100.00	50.00	–	–
Total prey weight		0.026 g	–	–	–

<i>Tylosurus crocodilus</i>	Empty	–	100.00	–	–
<i>Tylosurus</i> sp.	Carid	–	–	0.46	50.00
	Empty	–	–	–	0.00
	Holocentridae Unid. sp.	–	–	59.09	50.00
	<i>Myripristis</i> sp.	–	–	4.58	50.00
	Ophichthiid Eel	–	–	10.95	5.00
	<i>Spratelloides delicatulus</i>	–	–	2.18	50.00
	<i>Spratelloides</i> sp.	–	–	8.97	50.00
	Teleost remains	–	–	13.77	100.00
Total prey weight		–	–	4.960 g	–

CAESIONIDAE					
<i>Caesio caeruleus</i>	Empty	–	100.00	–	–
CARANGIDAE					
<i>Alectis indicus</i>	Carid	–	–	11.54	100.00
Crab		–	–	53.85	100.00
Empty		–	–	–	0.00
Teleost remains		–	–	34.62	100.00
Total prey weight		–	–	0.260 g	–

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
<i>Carangoides ferdau</i>	<i>Apogon</i> sp.	—	—	100.00	100.00
	Empty	—	—	—	0.00
Total prey weight		—	—	0.478 g	—
<i>Caranx ignobilis</i>	Empty	—	50.00	—	—
	Teleost remains	100.00	50.00	—	—
Total prey weight		1.034 g	—	—	—
<i>Caranx papuensis</i>	Carid	—	—	24.36	100.00
	Clupeidae Unid. sp.	—	—	34.62	100.00
	Crab	19.96	25.00	—	—
	Decapoda	0.57	25.00	—	—
	Digested remains	1.00	25.00	—	—
	Empty	—	25.00	—	0.00
	Gerreidae Unid. sp.	78.47	25.00	—	—
Sergestidae Unid. sp.	—	—	41.02	100.00	
Total prey weight		18.080 g	—	0.078 g	—
<i>Caranx melampyus</i>	<i>Apogon</i> sp.	7.04	7.84	—	—
	<i>Atherinomorus lacunosus</i>	—	—	0.71	4.76
	Blenniidae Unid. sp.	0.07	1.96	—	—
	Brachyuran	—	—	0.10	4.76
	Caesionidae Unid. sp.	0.37	1.96	—	—
	Callionymidae Unid. sp.	0.03	1.96	—	—
	Carid	0.04	9.80	0.30	14.29
	Coral	7.72	1.96	4.18	4.76
	Crab	6.90	13.73	0.02	4.76
	Crustacea	0.04	1.96	<0.01	4.76
	Digested remains	0.10	1.96	—	—
	Empty	—	37.80	—	0.00
	<i>Gerres oblongus</i>	0.11	1.96	—	—
	Gobiidae Unid. sp.	0.74	1.96	—	—
	<i>Hypoatherina ovalaua</i>	—	—	2.97	14.29
	Isopod	—	—	0.11	4.76
	Monacanthidae Unid. sp.	—	—	0.11	4.76
	Myctophidae Unid. sp.	—	—	0.30	4.76
	<i>Myripristis</i> sp.	—	—	9.70	4.76
	Mysids	0.02	1.96	—	—
Natantid	0.01	1.96	—	—	
<i>Octopus</i> sp.	—	—	0.04	4.76	

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
	Pebbles	0.44	1.96	–	–
	Penaeid Prawn	0.03	1.96	–	–
	<i>Penaeus</i> sp.	1.09	1.96	–	–
	Plant matter	<0.01	1.96	–	–
	Pomacentridae Unid. sp.	0.54	1.96	–	–
	Priacanthidae Unid. sp.	–	–	0.75	4.76
	<i>Rhabdamia</i> sp.	0.41	1.96	–	–
	Scyllaridae Unid. sp.	–	–	0.64	14.29
	Sergestidae Unid. sp.	–	–	0.03	4.76
	<i>Spratelloides delicatulus</i>	6.55	7.84	13.03	14.29
	<i>Spratelloides</i> sp.	8.84	9.80	–	–
	<i>Squilla</i> sp.	–	–	0.18	14.29
	<i>Stegastes nigricans</i>	12.66	1.96	–	–
	<i>Encrasicholina punctifer</i>	1.13	5.88	66.20	71.43
	<i>E. punctifer</i> larvae	–	–	0.34	9.52
	Stomatopod	–	–	0.05	4.76
	Teleost larvae	–	–	2.02	4.76
	Teleost remains	45.13	84.31	6.94	4.76
Total prey weight		87.396 g		193.327 g	
<i>Caranx sexfasciatus</i>	Acanthuridae Unid. sp.	–	–	5.57	29.17
	Alphacid	–	–	0.08	4.17
	<i>Apogon</i> sp.	–	–	1.08	4.17
	Balistidae Unid. sp.	–	–	1.04	16.67
	Crab	–	–	0.15	4.17
	Crustacea	–	–	0.02	8.33
	Empty	–	84.62	–	0.00
	Gerreidae Unid. sp.	52.56	25.00	–	–
	<i>Herklotsichthys quadrim.</i>	–	–	4.44	8.33
	<i>Hypoatherina ovalaua</i>	17.83	25.00	0.84	4.17
	Isopod	–	–	0.06	4.17
	Myctophidae Unid. sp.	–	–	2.37	20.83
	<i>Myripristis</i> sp.	9.61	25.00	9.44	33.33
	<i>Panilurus</i> sp.	–	–	0.04	4.17
	Pomacentridae Unid. sp.	–	–	0.29	4.17
	<i>Priacanthus</i> sp.	–	–	5.18	33.33
	<i>Sargocentron</i> sp.	–	–	0.34	4.17
	Scyllaridae Unid. sp.	–	–	0.42	4.17
	Sea grass	–	–	0.02	4.17
	<i>Spratelloides</i> sp.	6.65	25.00	–	–
	Squid	–	–	0.07	4.17
	<i>Squilla</i> sp.	–	–	0.38	4.17
	<i>Encrasicholina punctifer</i>	–	–	38.05	66.67

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
	<i>E. punctifer</i> larvae	–	–	0.08	4.17
	Teleost remains	12.38	75.00	29.78	83.33
	Tetraodontidae Unid. sp.	–	–	0.26	4.17
	Unknown	0.98	25.00	–	–
Total prey weight		5.430 g		123.283 g	
<i>Decapterus macarellus</i>	Empty	–	–	–	0.00
	Fish scales	–	–	23.00	20.00
	<i>Spratelloides delicatulus</i>	–	–	75.05	80.00
	<i>E. punctifer</i> larvae	–	–	1.94	20.00
Total prey weight		–	–	0.926 g	–
<i>Decapterus macrosoma</i>	Empty	–	100.00	–	–
<i>Scomberoides lysan</i>	Atherinidae Unid. sp.	0.52	2.04	–	–
	Carid	–	–	0.18	33.33
	Copepods	0.34	2.04	–	–
	Crab	0.02	2.04	–	–
	Crustacea	5.79	12.24	–	–
	Empty	–	61.72	–	0.00
	Fish scales	0.12	4.08	–	–
	<i>Hypoatherina ovalaua</i>	12.05	4.08	–	–
	Mysid	39.08	55.10	–	2.26
	Natantid	0.25	2.04	–	–
	<i>Spratelloides delicatulus</i>	–	–	97.56	66.66
	<i>Spratelloides</i> sp.	4.84	2.04	–	–
	<i>Squilla</i> sp.	3.23	6.12	–	–
	Stomatopod larvae	13.69	6.12	–	–
	Teleost remains	13.97	12.24	–	–
	Teleost larvae	0.69	2.04	–	–
	Zooplankton	5.41	8.16	–	–
Total prey weight		6.523 g		4.387 g	
<i>Selar crumenophthalmus</i>	<i>Apogon</i> sp.	–	–	8.40	33.33
	Carid	100.00	100.00	–	–
	<i>Chaetodon</i> sp.	–	–	4.58	33.33
	Crustacea	–	–	49.75	33.33
	Empty	–	85.71	–	50.00
	Mysid	–	–	37.27	33.33
Total prey weight		0.003 g		1.202 g	

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
DUSSUMIERIIDAE					
<i>Dussumieria</i> Sp. A	Carid	—	—	82.05	100.00
	Crab megalopa	—	—	15.90	100.00
	Empty	—	—	—	0.00
	<i>Squilla</i> sp.	—	—	1.03	25.00
	Stomatopod	—	—	1.03	25.00

Total prey weight		—	0.195 g		

ECHENEIDAE					
<i>Echeneis naucrates</i>	<i>Amblygaster sirm</i>	—	—	23.91	20.00
	<i>Atherinomorus lacunosus</i>	—	—	1.93	20.00
	<i>Bregmaceros</i> sp.	—	—	0.88	40.00
	Carid	—	—	3.38	100.00
	Empty	—	—	—	0.00
	Gobiidae Unid. sp.	—	—	4.92	40.00
	<i>Hypoatherina ovalaua</i>	—	—	4.81	40.00
	Crab megalopa	—	—	0.21	40.00
	<i>Myripristis</i> sp.	—	—	0.93	40.00
	<i>Octopus</i> sp.	—	—	2.64	20.00
	Plant matter	—	—	6.92	60.00
	Pomacentridae Unid. sp.	—	—	1.15	20.00
	<i>Pomacentrus pavo</i>	—	—	1.86	40.00
	Sergestidae Unid. sp.	—	—	0.66	40.00
	<i>Spratelloides delicatulus</i>	—	—	38.67	40.00
	<i>Squilla</i> sp.	—	—	2.85	20.00
	<i>Encrasicholina punctifer</i>	—	—	1.69	40.00
	<i>E. punctifer</i> larvae	—	—	0.95	40.00
Teleost remains	—	—	0.29	40.00	
Teleost larvae	—	—	1.19	40.00	

Total prey weight		—	30.255 g		

GERREIDAE					
<i>Gerres argyreus</i>	Empty	—	100.00	—	—
HOLOCENTRIDAE					
<i>Myripristis murdjan</i>	Brachyuran larvae	100.00	100.00	—	—
	Empty	—	0.00	—	—

Total prey weight		0.003 g	—		

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
<i>Sargocentron spiniferum</i>	Alphacaid	0.57	33.33	–	–
	Crab	4.39	66.66	–	–
	Digested remains	4.01	66.66	–	–
	Empty	–	0.00	–	–
	Gastropod	38.74	66.66	–	–
	Green algae	0.19	33.33	–	–
	Portunid crab	52.10	33.33	–	–
Total prey weight		0.524 g	–		
LABRIDAE					
<i>Choerodon anchorago</i>	Empty	–	100.00	–	–
<i>Thalassoma lunare</i>	Empty	–	100.00	–	–
LETHRINIDAE					
<i>Lethrinus elongatus</i>	Blennidae Unid. sp.	12.80	20.00	–	–
	Crab	2.96	20.00	–	–
	Crustacea	1.98	20.00	–	–
	Digested remains	4.01	60.00	–	–
	Empty	–	16.67	–	–
	Holothurian	3.29	20.00	–	–
	Natanid	0.16	20.00	–	–
	Pebbles	14.24	40.00	–	–
	Portunid crab	1.98	20.00	–	–
	Teleost remains	53.56	60.00	–	–
	Xanthid crab	1.48	20.00	–	–
Total prey weight		2.429 g	–		
<i>Lethrinus nebulosus</i>	Bivalve	48.58	50.00	–	–
	Empty	–	60.00	–	–
	Gastropod	51.42	50.00	–	–
Total prey weight		0.212 g	–		
<i>Lethrinus ramak</i>	Bivalve	20.83	100.00	–	–
	Crab	2.60	100.00	–	–
	Digested remains	61.98	100.00	–	–
	Empty	–	60.00	–	–
	Polychaeta	14.58	100.00	–	–
Total prey weight		0.384 g	–		

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
<i>Monotaxis grandoculus</i>	Empty	–	100.00	–	–
LUTJANIDAE					
<i>Aprion virescens</i>	Empty	–	100.00	–	–
<i>Lutjanus bohar</i>	Crab	100.00	100.00	–	–
	Empty	–	83.33	–	–
Total prey weight		2.914 g	–		
<i>Lutjanus fulvus</i>	Carid	4.74	16.67	–	–
	Crab	62.38	50.00	–	–
	Crustacea	19.77	16.67	–	–
	Empty	–	53.85	–	–
	Teleost remains	13.10	33.33	–	–
Total prey weight		1.244 g	–		
<i>Lutjanus gibbus</i>	Anomuran	6.66	11.11	–	–
	Crab	49.29	55.56	–	–
	Empty	–	40.00	–	–
	Gastropod	27.62	44.44	–	–
	Portunid crab	2.69	11.11	–	–
	Sea grass	0.64	11.11	–	–
	Seed pod	0.21	33.33	–	–
	Teleost remains	0.14	–	–	–
	Vegetable matter	0.07	11.11	–	–
	Xanthid crab	12.68	11.11	–	–
Total prey weight		1.412 g	–		
<i>Lutjanus kasmira</i>	Carid	0.31	10.53	–	–
	Crab	31.89	42.11	–	–
	Crustacea	12.46	26.32	–	–
	Digested remains	1.39	21.05	–	–
	Empty	–	44.12	–	–
	Fish scales	3.02	15.79	–	–
	Gobiidae Unid. sp.	10.53	5.26	–	–
	Isopod	0.23	5.26	–	–
	Hermit crab	0.54	5.26	–	–
	Stomatopod	3.25	5.26	–	–
	Teleost remains	28.64	–	–	–
	Unknown	7.74	10.53	–	–
Total prey weight		1.292 g	–		

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
<i>Lutjanus monostigma</i>	Empty	—	100.00	—	—
<i>Lutjanus russelli</i>	Crab	6.58	100.00	—	—
	Empty	—	0.00	—	—
	Teleost remains	94.67	100.00	—	—
Total prey weight		0.076 g	—		
<i>Lutjanus semicinctus</i>	Empty	—	100.00	—	—
MULLIDAE					
<i>Upeneus vittatus</i>	Empty	—	—	—	0.00
	Mysid	—	—	6.50	100.00
	<i>Spratelloides delicatulus</i>	—	—	93.50	100.00
Total prey weight		—	0.200 g		
NEMIPTERIDAE					
<i>Nemipterus peronii</i>	Alpheid	22.49	100.00	—	—
	Carid	1.78	100.00	—	—
	Crab	18.34	100.00	—	—
	Crustacea	31.95	100.00	—	—
	Empty	—	0.00	—	—
	Teleost remains	24.44	100.00	—	—
Total prey weight		0.169 g	—		
SCOMBRIDAE					
<i>Euthynnus affinis</i>	<i>Apogon</i> sp.	—	—	2.27	100.00
	Empty	—	25.00	—	0.00
	<i>Herklotsichthys</i> sp.	—	—	9.58	100.00
	<i>Spratelloides delicatulus</i>	—	—	88.15	100.00
	<i>Spratelloides</i> sp.	48.89	33.33	—	—
	Teleost remains	51.11	66.66	—	—
Total prey weight		9.457 g	7.922 g		
<i>Grammatorcynnus bilineatus</i>	Anomurans	0.05	14.29	—	—
	Empty	—	22.22	—	—
	Gobiidae Unid. sp.	10.08	14.29	—	—
	<i>Spratelloides</i> sp.	38.95	42.86	—	—
	Teleost remains	50.20	42.86	—	—
Total prey weight		3.807 g	—		

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
<i>Rastrelliger brachysoma</i>	Amphipod	0.34	18.18	—	—
	Digested remains	9.66	90.91	—	—
	Empty	—	70.27	—	—
Total prey weight		2.040 g	—		
SERRANIDAE					
<i>Aethaloperca rogae</i>	Empty	—	0.00	—	—
	Teleost	100.00	100.00	—	—
Total prey weight		0.196 g	—		
<i>Cephalopholis argus</i>	Digested remains	33.33	66.66	—	—
	Empty	—	25.00	—	—
	Fish scales	66.66	33.33	—	—
Total prey weight		0.012 g	—		
<i>Cephalopholis cyanostigma</i>	Empty	—	100.00	—	—
<i>Epinephelus cyanopodus</i>	Empty	—	100.00	—	—
<i>Epinephelus fuscogutatus</i>	Empty	—	100.00	—	—
<i>Epinephelus merra</i>	Empty	—	100.00	—	—
<i>Epinephelus tauvina</i>	Empty	—	100.00	—	—
<i>Plectropomus areolatus</i>	Empty	—	87.50	—	—
	Teleost	100.00	100.00	—	—
Total prey weight		2.540 g	—		
SPHYRAENIDAE					
<i>Sphyraena barracuda</i>	Empty	—	66.66	—	—
	Teleost remains	100.00	100.00	—	—
Total prey weight		0.710 g	—		
<i>Sphyraena flavicauda</i>	Acanthuridae Unid sp.	10.27	50.00	—	—
	Empty	—	0.00	—	0.00
	<i>Hypoatherina ovalaua</i>	49.30	50.00	—	—
	<i>Spratelloides delicatulus</i>	—	—	79.75	33.33
	Teleost remains	40.43	100.00	20.25	66.66
Total prey weight		2.347 g	0.237 g		

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
<i>Sphyraena forsteri</i>	Acanthuridae Unid. sp.	—	—	4.83	19.17
	<i>Acanthurus triostegus</i>	—	—	0.07	1.67
	Alphaeid	0.30	10.00	0.01	0.83
	Anguilliform	—	—	0.13	0.83
	<i>Ariomma indica</i>	—	—	0.26	10.00
	Balistidae Unid. sp.	—	—	0.26	4.17
	<i>Caranx sexfasciatus</i>	—	—	0.26	0.83
	<i>Caranx</i> sp.	36.12	10.00	0.12	0.83
	Carid	—	—	0.21	12.50
	Chaetodontidae Unid. sp.	—	—	0.14	0.83
	Crab	—	—	0.03	2.50
	Digested remains	—	—	<0.01	0.83
	Eel	—	—	0.75	5.83
	Empty	—	58.33	—	2.44
	<i>Epinephelus</i> sp.	—	—	0.23	0.83
	<i>Herklotsichthys</i> sp.	—	—	0.04	0.83
	<i>Herklotsichthys quadrim.</i>	—	—	6.24	9.17
	Insect	—	—	<0.01	0.83
	<i>Mulloides flavolineatus</i>	14.33	10.00	—	—
	Mullidae Unid. sp.	—	—	1.28	2.50
	<i>Myripristis</i> sp.	—	—	4.64	24.17
	<i>Octopus</i> sp.	—	—	0.02	0.83
	<i>Panilurus</i> sp.	—	—	0.05	1.67
	<i>Priacanthus</i> sp.	—	—	2.41	9.17
	<i>Rhabdamia cypselurus</i>	—	—	0.05	0.83
	<i>Sargocentron</i> sp.	—	—	0.98	6.67
	<i>Scyllaridae</i> sp.	—	—	0.48	4.17
	<i>Spratelloides delicatulus</i>	1.13	10.00	0.01	0.83
	<i>Spratelloides</i> sp.	1.16	10.00	—	—
	Squid	—	—	0.16	1.67
	<i>Squilla</i> sp.	—	—	0.64	26.67
	<i>Encrasicholina punctifer</i>	—	—	61.30	80.83
	<i>E. punctifer</i> larvae	—	—	0.05	4.17
Stomatopod	—	—	0.04	2.50	
Teleost remains	46.96	50.00	14.29	55.00	
Tetraodontidae Unid. sp.	—	—	0.02	0.83	
Total prey weight		10.376 g	431.652 g		
<i>Sphyraena novaehollandiae</i>	Acanthuridae Unid. sp.	—	—	0.09	3.23
	<i>Apogon</i> sp.	—	—	0.66	3.23
	<i>Ariomma indica</i>	—	—	2.69	25.81
	Balistidae Unid. sp.	—	—	0.63	6.45

(Table continued on next page.)

Table 19. Cont'd

Species	Prey type	No light		Light	
		Wt%	F%	Wt%	F%
	Carid	—	—	0.03	3.23
	Crab	—	—	0.03	3.23
	Crustacea	—	—	0.02	3.23
	Myctophidae Unid. sp.	—	—	7.00	12.90
	<i>Myripristis</i> sp.	—	—	6.70	19.35
	<i>Priacanthus</i> sp.	—	—	1.13	3.23
	Squid	—	—	0.17	3.23
	<i>Squilla</i> sp.	—	—	0.10	6.45
	<i>Encrasicholina punctifer</i>	—	—	65.82	96.77
	<i>E. punctifer</i> larvae	—	—	0.04	3.23
	Teleost remains	—	—	14.89	58.06

Total prey weight		—	—	102.656 g	

The stomach contents of 719 fish of 56 taxa were analysed. The prey items consumed by each species are given in Table 19, which has been arranged to show those prey types consumed from fish collected under natural conditions (No light) and from those collected from around artificially illuminated conditions (Light), i.e. while using lights to attract baitfish.

Predation on Baitfish

The prey taxa considered as baitfish for this analysis are those from the families Clupeidae, Dussumieriidae, Atherinidae, Apogonidae and Engraulidae.

Predators of baitfish under natural conditions

From a total of 486 fish that were caught under natural conditions 254 (52.2%) had empty stomachs. Fish species identified as predators of baitfish collected under natural conditions and the percentage contribution by dry weight of baitfish species in their diets are shown in Table 20.

Under natural conditions no species in this study preyed on the sardine, *Amblygaster sirm*, or the

herring, *Herklotsichthys quadrimaculatus*. The primary baitfish species in the diets were the sprat, *Spratelloides delicatulus*, and the hardyhead, *Hypoatherina ovalaua* (Table 19).

In a similar study in Solomon Islands (Blaber et al. 1990a) fish were classed as major predators (>10% baitfish in diet) and minor predators (<10% baitfish in diet). Using this method, *Strongylura incisa*, *Sphyraena flavicauda*, *Euthynnus affinis*, *Caranx melampygus* and *Scomberoides lysan* would all be classed as major predators of baitfish, with *Caranx sexfasciatus* and *Sphyraena* being classified as minor predators. In the Solomon Islands study, only two specimens of *Grammatocynnus bilineatus* were collected and they showed no signs of baitfish in their diets. Other species in the Solomon Islands study that were classed as baitfish predators, which were also analysed in this study, were *Tylosurus acus* (minor), *Tylosurus crocodilus* (major), *Caranx ignoblis* (minor), *Caranx papuensis* (minor), *Selar crumenophthalmus* (major), *Lutjanus fulvus* (major), *Lutjanus gibbus* (minor) and *Sphyraena barracuda* (major). In this study either the sample sizes of these species were small, or their stomach contents contained teleost fish remains which could

Table 20. The percentage of baitfish (by weight) in the natural diet of major predators in Kiribati.

Species	Baitfish in diet (%)
<i>Strongylura incisa</i>	82.11
<i>Sphyraena flavicauda</i>	49.30
<i>Euthynnus affinis</i>	48.89
<i>Grammatocynnus bilineatus</i>	38.95
<i>Caranx sexfasciatus</i>	24.48
<i>Caranx melampygus</i>	22.80
<i>Scomberoides lysan</i>	17.05
<i>Sphyraena forsteri</i>	2.29

not be identified to species level, or their stomachs were empty. It is therefore conceivable that these species may well be predators of baitfish in Kiribati but could not be identified as such from this study.

One point of interest was the appearance of the oceanic anchovy, *Encrasicholina punctifer*, in the diets of three individuals of the blue-fin trevally, *Caranx melampygus*. As the anchovy has never been recorded in baitfish catches made inside the lagoons of Kiribati it must be assumed that they do not enter them and were consumed on the ocean side of the islands. The trevallies that had eaten the anchovy were caught inside the lagoons which suggests movement of this predator into and out of the lagoons.

Predators of baitfish under artificial conditions

A total of 233 fish was caught around the artificial light. Only six (2.6%) had empty stomachs.

It should be noted that the sample sizes of some of the predators were small or consisted of only one specimen, e.g. *Carangoides ferdau* (Table 19).

Many of the above predators were captured in bouke-ami operations that took place on the ocean side of Tarawa Lagoon (see section on

Improvements to Fishery) rather than inside the lagoon where commercial baitfishing operations usually take place. On this occasion, *Encrasicholina punctifer* were captured in large numbers and this species makes up a large component of the baitfish consumed by some of the predators, e.g. *Sphyraena forsteri*, *Sphyraena novaehollandiae*, *Caranx melampygus* and *Caranx sexfasciatus* (Table 21).

Another important point to note from fish caught under artificial conditions is the numbers of juvenile reef-associated fish species that are consumed. Juveniles of taxa from the families Acanthuridae, Holocentridae, Pomacentridae, Priacanthidae, Balistidae, Chaetodontidae, Serranidae and Mullidae were all found in the stomach contents of fish caught around the lights (Table 19).

Natural conditions versus artificial conditions

The percentage of empty stomachs in fish caught under natural conditions is far greater than in those caught under artificial conditions (52.2% and 2.6%) respectively. The underwater lights set up a situation where fish are attracted to the baitfish and other animals that have been aggregated and feed upon them voraciously.

Table 21. The predator species of baitfish collected under artificial light conditions and the percentage contribution by dry weight of baitfish species in their diets.

Species	Baitfish in diet (%)
<i>Euthynnus affinis</i>	100.00
<i>Carangoides ferdau</i>	100.00
<i>Scomberoides lysan</i>	96.60
<i>Upeneus vittatus</i>	93.50
<i>Caranx melampygus</i>	83.25
<i>Sphyraena flavicauda</i>	79.95
<i>Decapterus macruellus</i>	76.99
<i>Echeneis naucrates</i>	71.96
<i>Sphyraena forsteri</i>	66.57
<i>Sphyraena novaehollandiae</i>	66.52
<i>Selar crumenophthalmus</i>	61.70
<i>Caranx sexfasciatus</i>	44.44
<i>Caranx papuensis</i>	34.62
<i>Tylosurus</i> sp.	11.15

Although only a few species were caught under both natural and artificial conditions, comparison of the quantities of food taken under both conditions indicates the increased consumption of food that takes place around baitlights. The mean amount of food taken per species, calculated as total dry weight of food consumed divided by the number of fish sampled minus the number of fish with empty stomachs, from around light and from natural conditions, is shown in Table 22.

Table 22. Mean dry weight food items from stomach contents in fish from natural and baitlight feeding situations.

Species	Natural mean dry wt (g)	Baitlight mean dry wt (g)
<i>Caranx melampygus</i>	1.710	9.210
<i>Caranx sexfasciatus</i>	1.360	5.150
<i>Scomberoides lysan</i>	0.130	1.740
<i>Selar crumenophthalmus</i>	0.003	0.480
<i>Euthynnus affinis</i>	3.150	7.922
<i>Sphyraena forsteri</i>	1.038	3.630
<i>Caranx papuensis</i>	6.030	0.078
<i>Sphyraena flavicauda</i>	1.170	0.079

There was no significant difference in the size of fish sampled for each species between natural and artificial conditions. Apart from *Caranx papuensis* and *Sphyræna flavicauda*, for which sample sizes were small, the mean amount of food consumed around baitlights is at least two times greater than under natural conditions.

Possible effects of baitfishing on subsistence fisheries

The concern that commercial baitfishing causes a reduction in the amount of forage available for desirable predatory species is one that has been frequently voiced in Pacific Island countries where there have been active pole-and-line fisheries (Lewis et al 1983; Nichols and Rawlinson 1990). Te Mautari Limited encountered considerable antagonism while collecting wild tuna baitfish on many atolls and has been forced to pay fees (Zann 1983). One of the main concerns voiced by the outer island councils was that the commercial baitfishing activities deplete the source of food for larger species, thereby indirectly reducing the abundance of the larger species (Ianelli 1988).

From this study (although not comprehensive), the major predators of baitfish species, under natural conditions, are those from the families Carangidae, Sphyrænidae, Scombridae and Belonidae. Only the mackerel tuna, *Euthynnus affinis*, fed exclusively on baitfish; all other fish consumed other prey types in addition to baitfish. The general assumption and concern of local people are that if there is a reduction in baitfish numbers caused by baitfishing then predatory species might find a shortage of food and move to other areas in search of prey. This could have an effect on the subsistence fishery if these species were an important component of it. However, most piscivorous fish are essentially opportunistic (Lowe-McConnell 1987) and their diets are largely determined by prey availability and the size relationship between predator and prey (Alexander 1967; Kakuda and Matsumoto 1978; Davis 1985).

A number of fisheries surveys have been carried out in Kiribati to assess the levels of fishing, the composition of the fish catch, the areas fished, etc. A comprehensive list of these reports can be found in Gillett et al. (1991) under the Statistics section.

In a review of fisheries surveys carried out in South Tarawa from 1976 to 1987, Mees (1987) found that the species compositions of catches of marine resources by local fishermen and fisherwomen over this time period were similar. Mollusca (approximately 30%) tend to make up the single most important taxa, with species from the family Scombridae (approximately 20%). The scombrid catch primarily consists of skipjack tuna, *Katsuwonis pelamis*, and yellowfin tuna, *Thunnus albacares*, caught in oceanic waters. From the lagoon, species from the family Albulidae (bonefish) are the most important, followed by snappers and emperors (lutjanids and lethrins) which each represent about 10% of the catch. Of the families of baitfish predators Carangidae made up less than 4% of the catches (except in one survey carried out in November 1986, when its contribution was estimated to be 12.1%); Sphyrænidae made up 0.1% of the catch at the very most; and Belonidae were not recorded making a contribution to the catches. More recent surveys of South Tarawa (Kiribati Fisheries Division 1989) concur with the fact that species from the families Belonidae, Carangidae and Sphyrænidae make up only a small proportion of the catch. Baitfish predator families are also only a small component of the local catches in the other important baitfishing sites: Butaritari (Mees 1985; Kiribati Fisheries Division 1989), Abaiang (Taniera 1988) and Abemama (Mees 1986; Kiribati Fisheries Division 1989).

From the evidence available it would seem that a reduction in the numbers of baitfish caused by commercial fishing operations, even allowing for a pre-conceived movement of predatory fish to other areas for forage, is going to have little effect on subsistence fishermen. The adult fish removed as a direct result of baitfishing as by-catch of the bouke-ami operations are also primarily from the same families. Therefore any reported reduction in catches of fish within the lagoons, unless directly referring to species from the families Carangidae, Sphyrænidae and Belonidae, and the species *Euthynnus affinis*, are likely to be more attributable to direct fishing effort or changes in physical conditions in the lagoons than to the extraction of baitfish or predatory fish by commercial pole-and-line vessels.

During the period of the survey large amounts of *Spratelloides delicatulus* were present in Butaritari lagoon. At the same time many large schools of fish were observed actively feeding on these sprats. The schools were primarily of *Euthynnus affinis* that proved extremely difficult to catch as the schools would dive as soon as the boat approached. Local fishermen in the area also reported problems in catching this species despite their abundance in the lagoon. At the same time schools of carangids (particularly *Caranx melampygus*) were observed feeding on baitfish and they were much more easily caught on trolling lines.

From a similar study in Solomon Islands (Blaber et al. 1990a), it was concluded that unless there is a marked increase in trolling (the towing of lures or baits on a line behind a boat) among subsistence fishermen, there is little likelihood of a significant direct trophic interaction between the subsistence fishery and the commercial tuna baitfishery. A 'snap-shot' of the relevance of this conclusion to the situation in Tarawa is shown in the results of a fishing competition held during the course of the project (see Appendix 1). Fish from the families Carangidae and Sphyraenidae, which have been identified as predators of baitfish in Kiribati, were also only taken using trolling lines.

Appendix 1

Tarawa Lagoon Fishing Competition

A fishing competition was held in Tarawa Lagoon on Saturday, 2 March 1991. The competition was arranged so that fish could be landed to a weighing-in area where they were identified, measured and weighed, and their stomachs removed and preserved for later analysis.

Methods

Advertisements of the competition were posted around Tarawa in banks, supermarkets and other public areas. Radio messages were also announced over Radio Kiribati. Every effort was made to encourage as many people as possible to join in the competition and make them aware of the prizes to be won.

Ten prizes of \$25 worth of fishing gear were put on offer. Each prize was for a different section. The sections were divided by fishing method, sex of fishermen and age of fishermen, in an attempt to attract men, women and children to join the competition.

Entry forms were also left in banks, shops, etc. and included rules for the competition. Prospective competitors were encouraged to complete these forms before the event in order to assess the number of fishermen expected so that the appropriate manpower required to process fish at the weigh-in could be estimated. Entry forms were typed onto one sheet of A4 paper, one side written in English and the other in I-Kiribati.

The competition started at 06.00 hours on Saturday, 2 March 1991 and finished at 15.00 hours on the same day, by which time all fish were to be weighed-in at a central landing area, the Ambo Lagoon Club. Fishermen were trusted not to start before the given time and were to confine their fishing effort to Tarawa Lagoon itself and not go out into the ocean. The rules of the competition also stated that the only fishing methods allowed were hook and line, i.e. droplining and trolling. The use of gill-nets, longlines, etc. was prohibited.

Every fish landed was identified to species level, measured and weighed, and stomachs removed and preserved in 10% formaldehyde. Fish weighed-in after 15.00 hours were also processed in this way.

Results

A total of four motorised boats carrying fourteen men and one boy, and two paddle canoes with one man each were entered in the competition. Those fishermen in the motorised boats used both droplining and trolling techniques, whereas the men in the paddle canoes restricted themselves to dropline fishing. Seventy-five per cent of the entrants were I-Kiribati and the remainder expatriates.

The total number of fish caught was 132 with a total weight of 106.837 kg. Droplining accounted for 84.4% by numbers and 29.2% by weight of the catch (Table 23) with trolling accounting for the remaining 15.2% and 70.8% by number and weight respectively. *Lethrinus obsoletus* (ramak) and *Epinephelus merra* were the most dominant species caught by droplining and *Caranx melampygus* was the most numerous species caught by trolling.

Conclusions

The competition was successful because it encouraged fishermen to return their catch to a location for a weigh-in where stomachs could be removed for later analysis in an attempt to identify baitfish predators in Tarawa Lagoon. The number of entrants in the competition was, however, very disappointing and therefore the number of fish samples collected was limited. Although effort was made through posters and radio messages to advertise the competition this was obviously not sufficient to encourage large numbers of fishermen to enter. If the exercise is to be repeated then additional methods to publicise the event should be undertaken, e.g. announcements through the church, invitations to scout groups, etc. With larger numbers of entrants larger quantities of fish could be expected. Not only could this provide samples for dietary analysis but data from such an event would give a good indication of the importance of different species caught by the different fishing methods. Such details would be very useful to supplement the information collected through the questionnaire surveys carried out by Fisheries Division.

Table 23. The number and weight of each species caught during a fishing competition in Tarawa Lagoon on 2 March 1991 (Wt = weight in g).

Species	Dropline		Trolling		Total	
	N	Wt (g)	N	Wt (g)	N	Wt (g)
BALISTIDAE						
<i>B. undulatus</i>	1	1 460	—	—	1	1 460
<i>P. flavimarginatus</i>	1	360	—	—	1	360
<i>R. aculeatus</i>	120	—	—	1	120	—
<i>S. chryopterus</i>	2	191	—	—	2	191
CARANGIDAE						
<i>C. melampygus</i>	—	—	12	28 380	12	28 380
GERREIDAE						
<i>G. argyreus</i>	1	350	—	—	1	350
HOLOCENTRIDAE						
<i>S. spiniferum</i>	4	685	—	—	4	685
LABRIDAE						
<i>C. anchorago</i>	1	76	—	—	1	76
<i>T. lunare</i>	1	50	—	—	1	50
LETHRINIDAE						
<i>L. elongatus</i>	6	7 555	—	—	6	7 555
<i>L. obsoletus (ramak)</i>	39	12 075	—	—	12	12 075
<i>M. grandoculus</i>	1	1 160	—	—	1	1 160
LUTJANIDAE						
<i>A. virescens</i>	—	—	1	1 250	1	1 250
<i>L. bohar</i>	—	—	1	4 850	1	4 850
<i>L. gibbus</i>	7	2 185	—	—	7	2 185
<i>L. kasmira</i>	18	1 300	—	—	18	1 300
<i>L. semicinctus</i>	1	240	—	—	1	240
SERRANIDAE						
<i>C. argus</i>	5	1 425	—	—	5	1 425
<i>E. fuscoguttatus</i>	—	—	2	15 950	2	15 950
<i>E. merra</i>	23	1 915	—	—	23	1 915
<i>P. areolatus</i>	—	—	2	2 460	2	2 460
SPHYRAENIDAE						
<i>S. barracuda</i>	—	—	2	22 800	2	22 800
Total	112	31 147	20	75 690	132	106 837
Percentage by method	84.4	29.2	15.2	70.8		

Improvements to the Fishery

Summary

The major areas where significant improvements in baitfishing are possible:

- major sources of lost fishing time are identified, including late arrival at fishing grounds due to navigational difficulties and lack of or poor survival of bait (ways to reduce these effects are suggested);
- suggested improvements to the baitfishing technique, including the use of generator boats, echo-sounders and improved baitfish handling (methods to achieve these aims are outlined); and
- a method involving artisanal fishermen to increase the catch of tuna is proposed, the current state of its development outlined, and future research directions suggested.

During the course of the Baitfish project fieldwork a number of trips were undertaken on board pole-and-line vessels operating for Te Mautari Limited as well as a vessel carrying out tuna tagging work for the South Pacific Commission in Kiribati waters. From observations made during these trips and from experience on commercial vessels operating in Solomon Islands and Fiji, some suggestions are made for the improvement of the operations of Te Mautari Limited vessels in Kiribati.

Timing of Fishing Activities

Fishing ground arrival times

Following a trip on the South Pacific Commission research vessel *Te Tautai*, 6–12 October 1990, records were compiled of the number of tuna

caught at different times of day during the cruise (Fig. 28). The results showed that fish were caught throughout daylight hours. Most fish were caught between 15.00 and 16.00 hours but this was from one school which responded well to the chum and relatively large numbers of tuna were caught. The next most productive time was in the early hours of the morning between 06.00 and 08.00. Fishing success, measured by the number of schools spotted compared to number of schools from which fish were caught, was also greater at this time of day (Fig. 29).

The results of time of day fished versus mean catch per school during the two years of the survey undertaken by FAO on *Nei Manganibuka* showed that catches in Kiribati waters are not governed greatly by the time of day (Walczak 1982). The one exception is from 08.00 to 10.00, when there is a slightly higher per cent total catch compared to the per cent total effort. The mean catch per school chummed during both years of the survey was remarkably constant at 250 kg. Mean catches per school chummed remained close to this average during all the time intervals except during 08.00–10.00 when the mean catch per school averaged 326 kg. It is interesting to note that during this survey, greater fishing success depended neither on dawn nor sundown schools. In fact, the results obtained fishing the former were lowest with a resulting catch rate of 202 kg/school and sundown schools where the average was 252 kg/school.

It can be concluded, therefore, that as long as a vessel is carrying suitable amounts of live baitfish it is possible to catch tuna during any of the daylight hours. This implies that the more time spent on the fishing grounds, the greater the chance of catching fish. The early hours of the morning seem to hold better chance of success than later in the day.

From observations made during the course of the Baitfish Project, Te Mautari Limited vessels did not reach the fishing grounds until after 08.00, primarily due to difficulties of navigating out of the lagoons during darkness after completing baitfishing operations. The vessels usually completed their tuna fishing activities so that they were anchored back in the baitground by mid-afternoon. This was sometimes due to the fact that all the baitfish had been used or because there were no schools of tuna present in the area.

This loss of fishing time could be reduced by the following changes.

Early departure from baiting grounds

If vessels were able to navigate out of the lagoon during darkness then they could be on the fishing grounds at dawn and therefore maximise utilisation of daylight hours for searching and catching tuna. The navigation problem could be alleviated in two ways. Firstly, good navigational beacons could be placed to mark the passages of the lagoon as well as between the most commonly used baiting positions and the entrances/exits to the lagoons. All the passages to the lagoons commonly used for baitfishing were not clearly marked and the captains all expressed reluctance to pass through them in darkness. The positioning of beacons which could be picked up on radar or illuminated by the use of powerful searchlights on the boats would facilitate the movement of vessels in and out of lagoons during the night.

Secondly, advanced navigational equipment could be installed on the vessels. None of the Te Mautari vessels had operating radar systems during the trips undertaken so there were no operational electronic navigational aids to assist movement through the passages of the lagoons. A properly working system would obviously assist this situation. The Global Positioning Systems (GPS) that utilise satellite technology are now so accurate, if set up and used correctly in conjunction with normal navigational procedures, they would enable the captains to navigate through the passages of the lagoon during the night.

In conjunction with the optimisation of the use of the daylight hours for searching and fishing, not enough effort was expended in looking for schools of fish from the flying bridge of the Te Mautari

vessels. During the cruise on the *Te Tautai* two men were employed looking for schools with the aid of binoculars. In Solomon Islands this was always the case and it was not uncommon for four or five men to be searching at any one time. Te Mautari vessels seemed to have only one man undertaking this duty, usually the captain, and this was not on a full-time basis. The use of more men over longer periods of time can only increase the chances of locating schools of fish.

Increasing the survival times of the baitfish in the bait wells

If baitfish can be kept alive for two to three days inside the vessel bait wells then there may not be the need to return to the lagoon every night to collect baitfish. This will mean that the vessel can either drift or anchor on the ocean side of the lagoon, weather permitting. This will allow the vessel to move to the fishing ground at first light, especially if fishing around fish aggregating devices. Increased survival of baitfish could be achieved by the use of the hardy milkfish bait or, not as easily, conditioning of the wild bait species as mentioned earlier. These methods could be employed as alternative strategies to the normal practices of the pole-and-line vessels of the Te Mautari fleet.

Alternative Baitfish Species and Sites

Use of milkfish as bait

Te Mautari pole-and-line vessels have used milkfish as bait on only a few occasions during the last two seasons primarily because (a) milkfish are considered not to survive well in baitfish tanks, (b) milkfish are not considered an effective bait as tuna are not attracted to the boat by them, and (c) milkfish are expensive to purchase.

The results of previous studies on the use of milkfish in Kiribati (FAO 1983) and observations during the current project show that milkfish will survive well in bait wells for in excess of 3–4 days and act as an effective baitfish for tuna.

During a trip on the *Nei Kaneati* in 1989 milkfish were carried on board the vessel from Tarawa to Abemama. These milkfish survived in the bait

wells for over 4 days. These fish were too large (20–30 cm) and did not act as effective bait as they swam away from the boat and the tuna were seen following them.

Small milkfish (5–15 cm) were loaded onto the *Te Tautai* during the trip in October 1990. These fish could be seen swimming back towards the boat and acted as effective chum by attracting and inducing the tuna into a feeding frenzy. When the stomach contents of some of the tuna caught were examined, the size of chum eaten was in the length range of 6–9 cm. These smaller-size milkfish also survived well in the bait wells when handled correctly.

During a second visit of *Te Tautai* to Kiribati a total of 350 buckets of milkfish was loaded on the vessel at Tarawa on 19 August 1991. The vessel then proceeded south, fishing on the way, and on 22 August was able to tag and catch in excess of 1000 individual skipjack tuna, south of Arorae Island. This position is well to the south of the normal fishing grounds of the Te Mautari fleet. During two further uses of milkfish in September 1991, fishing was successfully carried out on one occasion south of Arorae, and on the other west of Banaba. During the trip to Banaba the milkfish bait was used to catch tuna six days after it had been loaded at Tarawa (SPC, pers. comm.). The milkfish bait in these instances was used successfully to increase the operational range of the vessel.

The recent experiences of the South Pacific Commission with the use of milkfish in Kiribati waters (Itano, pers. comm.) are that (a) the milkfish can be effective if delivered in graded sizes less than 15 cm, but are best between 8 and 12 cm, (b) their habit of running away from the boat when chummed can be limited if the bait is squeezed by the chummer prior to broadcast into the sea, (c) they are extremely hardy and lasted over one week on the vessel, (d) a majority of the bait from the fish farm appeared starved, skinny and in a very weakened condition (some were big-headed, cadaverous runts which may have been starved — if milkfish were to be used on a regular basis the quality of these fish would need to be improved), and (e) dead milkfish were effective if pinned onto the hooks of the fibreglass poles during

times when the tuna were not actively biting the artificial lures. This was especially effective for the capture of large yellowfin. All dead milkfish bait was kept and utilised when this situation arose.

In conclusion it was considered that milkfish should be able to realise a profit for Te Mautari vessels during times when wild baitfish are scarce, as long as correct and careful handling procedures are carried out, both during transport and delivery to the boat, and once the fish are in the bait wells.

These results indicate that milkfish can be an effective baitfish species, both in terms of survival and attractiveness to tuna, if the right size fish are used and handled correctly. If milkfish 5–15 cm can be produced at an affordable price, then the production of milkfish of the optimal size should be encouraged in order to provide an alternate source of baitfish for the Te Mautari fleet when any of the following conditions arise: (a) there are limited amounts of natural bait available, (b) when natural baitfish are difficult to catch during the full moon, and (c) when tuna schools cannot be found at the usual fishing grounds and the vessels need to increase their range.

Capture of anchovies

During the trip on the SPC research vessel *Te Tautai*, the vessel anchored in 40 m outside the entrance to Tarawa Lagoon when deck-lights were seen to attract schools of *Herklotsichthys quadrimaculatus*. Underwater lights were lowered and normal baitfishing operations started. When the net was hauled, the catch comprised approximately 80 buckets of *H. quadrimaculatus* and *Encrasicholina punctifer*. Two further hauls were made that night for a total catch of 200 buckets.

Encrasicholina punctifer have been found in the diet of skipjack tuna from Kiribati (Kleiber and Kearney 1983) and were found in the natural diet of 36% of the tuna caught during the SPC trip. These anchovies are highly prized as one of the most effective baitfish species. They work well as chum and during the SPC cruise lasted 2–3 days in the bait wells, indicating that they are hardier species than some of the coral reef lagoon baitfish species.

Encrasicholina punctifer are oceanic, do not enter the lagoons in Kiribati and little is known of their distribution in open waters. However, as lack of suitable baitfish is one of the prime causes of lost fishing time (MacInnes 1990) further effort under certain circumstances could be expended in trying to catch this species.

If a vessel has enough bait to carry out fishing operations the next day but the capacity to hold more bait, it may be worthwhile for it to anchor on the ocean side of the closest island and operate the baitlights. If baitfish aggregate then a haul of the net may allow the capture of extra bait which may make a significant difference to the success of operations next day. This situation could arise if milkfish bait is being used and schools of tuna are in close proximity to a lagoon that cannot be entered for baitfishing, e.g. the southern-most islands of the Kiribati group. If catches of *E. punctifer*, or another baitfish species, were possible, this could significantly extend the period of time available for fishing a productive school of fish.

Baitfishing effort should not be concentrated in these areas, rather, they should be considered as alternative sites. It must be remembered that bait may not be present at all at certain times in these ocean-side positions, as was the case when an underwater light was set from the fisheries research vessel *Nei Tewenei* during one of the baitfish sampling trips to Butaritari.

Technical Improvements to Baitfishing Techniques

Use of generator boats

One of the major limitations to successful pole-and-line fishing in Kiribati has been the lack of baitfish for the following day's fishing. One of the current inefficiencies of baitfishing in Kiribati is that each vessel hauls on average less than twice each night (Table 4). If the number of hauls each night could be increased, the number of days fishing lost due to inadequate baitfish supplies may be significantly reduced.

In Solomon Islands, vessels have generator boats which operate additional underwater lights that attract fish at the same time that the pole-and-line vessel is catching bait. This enables the vessel to move to the site where the generator boat is lighting, after hauling its own net, and quickly make an additional haul of the bait aggregated there. The use of generator boats enables up to five hauls per night to be made when necessary. The pole-and-line vessels in that country rarely have less than a full complement of bait.

The use of a generator boat was trialled on three occasions in Kiribati during July and August 1990. The generator boat was a small (5 m) dinghy with a Yamaha EF2500 generator which powered a one kilowatt underwater light similar to that routinely used on Te Mautari vessels. A marine plywood cover was constructed to house the generator and protect it from the rain.

Method

The generator boat was towed to the baitfishing grounds in Butaritari and Abaiang for each trial. It was anchored in a good location chosen by the fishing master and then the pole-and-line vessel chose its own fishing position and both started lighting as darkness fell. While the generator boat had only the single underwater light, the pole-and-line vessel also had two powerful overhead lights illuminated as well.

After the lights had been working for sufficient time to attract baitfish, the pole-and-line vessel would haul its bouke-ami net. When this was completed, the pole-and-line vessel moved toward the generator boat, dropped anchor ahead of it and then went astern until both vessels came into contact. The stern underwater light on the pole-and-line vessel was then lowered and turned on. When this light was in position and operating, the generator boat's light was turned off and the bait moved and aggregated around the new light source. The pole-and-line vessel was then able to use its own light and net as for normal operations. Once the net had been hauled, both boats were repositioned and the operation repeated. In this way four hauls a night were made compared with the usual maximum of two.

Results

The results of the three trials are given in Table 24. They show that the use of a generator boat can be used to double baitfish effort with a corresponding increase in catches. Where baitfish were abundant during the trials (in Butaritari), the generator boat attracted similar amounts of bait to the main light on the pole-and-line vessel and the species composition attracted to both lights was similar.

The increase in effort is especially important in Kiribati during the nights of the month the catcher vessel is limited to making only one haul a night. A typical fishing pattern for pole-and-line boats in Kiribati is that after the full moon they are able to undertake two or maybe three hauls of the bait net because of the long dark nights. However, as the month progresses the number of moonlight hours increases and the haul of the bait net has to be delayed until later each morning. This comes to the stage where, around its first quarter, the moon does not set until 05.00 hours. If there is any moonlight there is little evidence of baitfish schooling around the light. It is not until after the moon sets that baitfish aggregate around the light in any numbers. Due to the limited hours of darkness bait hauls are

restricted to an hour or two before dawn, during this period of the month, which only leaves time for one operation. A generator boat would allow a second haul to be made during this phase of the moon prior to it becoming full, instead of the one which often barely produces enough baitfish to allow for tuna fishing that day.

Another advantage of using generator boats is that baitfishing effort can be spread over a larger area of the lagoon. On occasions, large catches of baitfish were taken on one night but the following night from the same position were caught in low numbers. This indicates that the schools of baitfish have moved to another area in the lagoon. A similar situation was witnessed during the course of the project when large samples of sardines were caught in gill nets set at the eastern end of Tarawa Lagoon whereas pole-and-line catches at the western end of the lagoon on the same night were negligible. Schools of baitfish are found in different parts of the lagoon at different times, and with the use of a generator boat two separate positions would be tested at the same time, increasing the chances of locating baitfish schools. This situation is only useful if the pole-and-line boat is able to navigate to the generator boat during darkness.

Table 24. The catch rate per set and species composition of baitfish caught during three trials of a generator boat in Kiribati during July and August 1990 (*catches from Butaritari; rest of hauls from Abaiang).

Trial	Haul	Catch from main boat (buckets)	Catch from generator boat (buckets)
1	1*	>100 mainly <i>S. delicatulus</i>	>100 mainly <i>S. delicatulus</i>
2	1	11 <i>A. sirm</i>	22 <i>A. sirm</i>
	2	15 <i>A. sirm/S. delicatulus</i>	9 <i>A. sirm/S. delicatulus</i>
	3	35 <i>A. sirm</i>	40 <i>A. sirm</i>
3	1	~25 <i>A. sirm</i>	1 <i>A. sirm</i>
	2*	>100 <i>S. delicatulus/H. quadrimaculatus</i>	>100 <i>S. delicatulus/H. quadrimaculatus</i>

Other points to note from the trials include the following.

- (1) Transfer of bait from around the generator boat's light to the main light was not a smooth operation due to difficulties in manoeuvring the pole-and-line vessel alongside the generator boat. If the generator boat attached two large floats along the anchor line the crew could use a grapple from the front of the pole-and-line vessel to pull the two boats together. This would ensure that all baitfish aggregated around the generator boat's light are close to the pole-and-line vessel before the lights are changed.
- (2) The generator boat should be fitted with a transformer to regulate the brightness of its underwater light so that there would be no need for the pole-and-line vessel to turn on its light. The generator boat could raise and dim its light and move inside the bouke-ami net and the baitfish would follow the light. The net could then be hauled around the generator boat. This would speed up the operation and ensure no baitfish were lost during the turning off and on of the two lights.
- (3) A small two-way radio should be installed in the generator boat to enable the crew to talk with the fishing master on the pole-and-line vessel. On one occasion during the trials (trial 3, haul 1, Table 24), large quantities of bait were around the light of the generator boat for 4–5 hours but had dispersed by the time the pole-and-line vessel arrived.
- (4) The generator boat used 10–12 litres of petrol to power the one kilowatt light for the whole night, making it a cost-efficient way to increase catches.

Use of echo-sounders

A technique used on the SPC research vessel *Te Tautai* reduced the time needed to haul the baitnet and allowed the movement of the bait to be monitored. This method could be used on Te Mautari vessels. It involved the use of two echo-sounders to monitor the movement of baitfish into

the net. The echo-sounder connected to the transducer on the hull was used to monitor the build-up of baitfish during the lighting operation. Once it was considered that there was sufficient bait aggregated around the light, the bouke-ami net was set.

A long bamboo boom was extended out over the starboard side of the vessel with its end stretching above the middle of the baitnet. A baitlight was suspended from this boom. This light could be manoeuvred by a person standing next to the flying bridge using a series of pulleys and ropes. A similar arrangement was set up for a transducer to hang from the boom with the echo-sounder located in the wheel-house. After the light had been lowered to the desired depth in the middle of the net, it was turned on and all other baitlights extinguished. The transducer was set at the surface and the echo-sounder turned on. The movement of fish towards the light could be monitored by the disappearance of marks from around the vessel's main echo-sounder and the appearance of marks on the sounder above the light. The light could be raised and dimmed in order to maximise the amount of bait close to the light. When the fishing-master was sure that all bait had moved to the light, the command to haul the net was made.

This method worked well and the transfer of bait from the light under the vessel to that in the middle of the net could be closely monitored. The use of a skiff to manoeuvre the light was not required, which speeded up the operation. It also had the advantage that the baitfish deep underwater could be monitored coming to the light and only when all the bait had risen was the net hauled. This cannot be seen with the naked eye, especially if underwater viewfinders are not being used, as was the situation on Te Mautari vessels.

Conditions during the hauling of the baitnet are often very rough, making the movement of the light difficult using a skiff. The operation described above would be of great assistance during rough conditions. The time saved during the hauling operation would be especially important during those periods of the month when a generator boat is used and an increase in the number of hauls is required.

Baitfish handling

Bait mortality in the bait wells is one of the major problems of the pole-and-line tuna fishery in Kiribati (McInnes 1990). Part of this problem is due to the weak bait species such as *S. delicatulus*. This species has been documented in Kiribati as dying quickly after capture. However, a significant proportion of the bait mortality is due to fish losing scales during capture and transfer to the bait wells. The number of fish dying due to this cause could be reduced by several methods.

- (1) Regularly mending all holes in the baitnet. Baitnets on Te Mautari vessels were observed to have many small holes which were large enough for fish to gill themselves causing terminal damage or at least increasing their stress. Basic net maintenance would ensure fewer fish died or were damaged by this method.
- (2) At present, crowding of the fish prior to transfer to the bait wells is done in a haphazard manner. Crew members often retrieve too much net, causing it to dry, leaving baitfish struggling against the net. This increases scale-loss and decreases their chance of survival. A more coordinated approach is required to the drying of the net to ensure baitfish remain in water and are gently herded to the centre of the net prior to bucketing into bait wells.
- (3) The overhead light positioned over the middle of the baitnet is the same one-kilowatt light used to attract bait. It illuminates an area much larger than the dried-up baitnet, which causes the bait to struggle wildly against the sides of the net. A smaller, dimmer light positioned over the centre of the net would get the baitfish to swim quietly around the centre of the net reducing abrasion and scale-loss.
- (4) Te Mautari vessels use only small metal buckets for transfer of bait from the net to the baitwell. This not only slows down the procedure but the small buckets mean that the volume of water per fish is small, increasing scale-loss and further reducing chances of survival. A larger number of bigger-sized plastic buckets should be used, so that these difficulties are overcome.

Conclusions

All these technical modifications to the bouke-ami technique routinely used in Kiribati have the potential to increase the baitfish catch and the survival of the bait when caught. But as all are new concepts in Kiribati, the fishing masters will need to be encouraged to modify their practices so that the use of these methods becomes part of the regular baitfishing pattern.

The use of generator boats has the greatest potential to increase nightly catch rates. However, discussion with the fishing master following the trials showed that, while he agreed that there was great potential for increased catches, he would not start using a generator boat himself. His reluctance may stem from several reservations. As a new idea, it would take time to become familiar with the use of these boats to maximise the catches. The generator boat also had to be towed around during the trials and so was an extra burden for the captain above his normal duties. If the generator boat could be lifted on board, transferring the generator boat to new sites would be safer. Another reason for the reluctance to use the generator boat was the lack of shelter and place for a crew member to sleep. Future versions should try to include accommodation in their design so that the crew is adequately protected from the weather and can sleep, while watch is kept on the generator. The increased number of hauls will also reduce the amount of sleep crew may get and may meet some resistance.

The use of echo-sounders and improved baitfish handling will both improve the efficiency of the existing baitfishing operation and lead to improved catches per haul and better survival of the baitfish, once caught. These improvements will enable the pole-and-line vessels to range further looking for tuna schools, and to remain on the schools longer, once they have been located, as the amount of time spent catching bait will be reduced. Additionally, the number of days lost due to insufficient bait could be significantly reduced if generator boats are introduced.

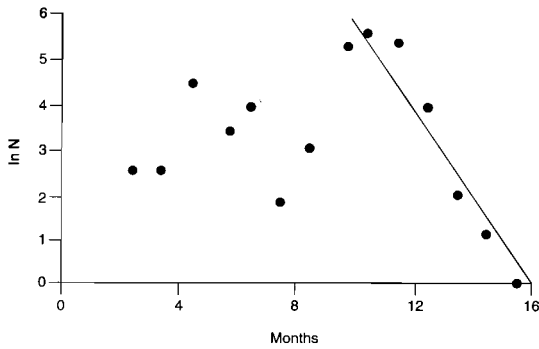


Fig. 1. The catch-at-age curve for *Amblygaster sirm* sampled from commercial baitfish catches during 1989 and 1990 (all sites combined).

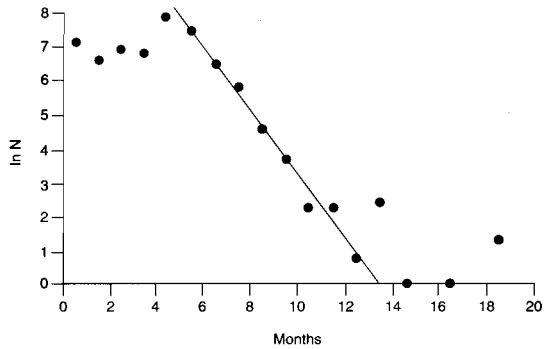


Fig. 2. The catch-at-age curve for *Herklosichthys quadrimaculatus* sampled from commercial baitfish catches during 1989 and 1990 (all sites combined).

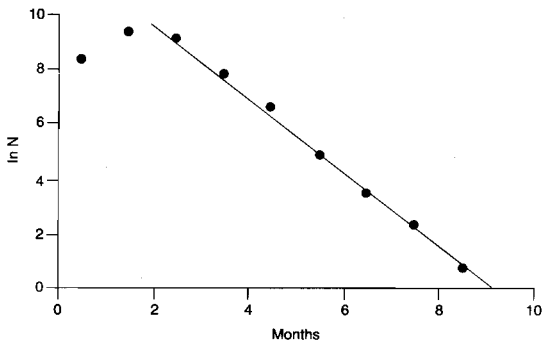


Fig. 3. The catch-at-age for *Spratelloides delicatulus* sampled from commercial baitfish catches during 1989 and 1990 (all sites combined).

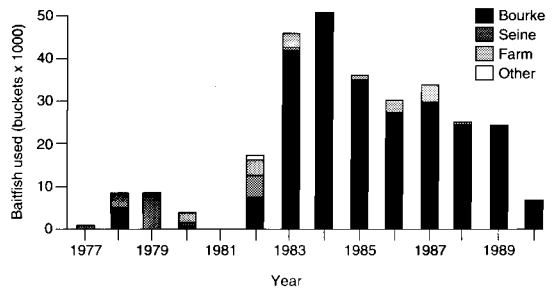


Fig. 4. Kiribati baitfishery 1977-1990, baitfish used per year by source.

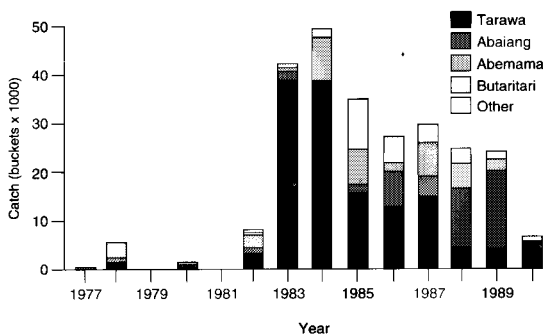


Fig. 5. Kiribati baitfishery 1977-1990, Bourke-ami catch by year by baitground.

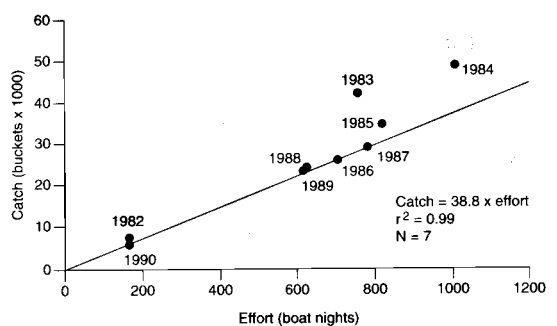


Fig. 6. Kiribati baitfishery, catch (buckets) vs effort (boat nights).

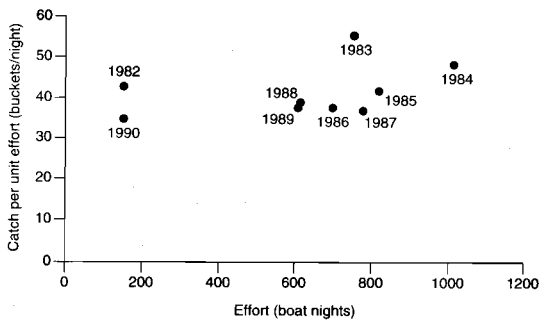


Fig. 7. Kiribati baitfishery, CPUE (buckets/night) vs effort (nights).

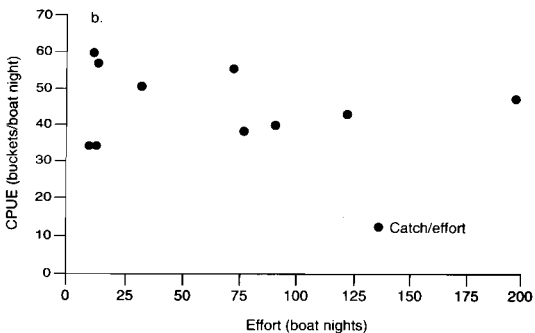
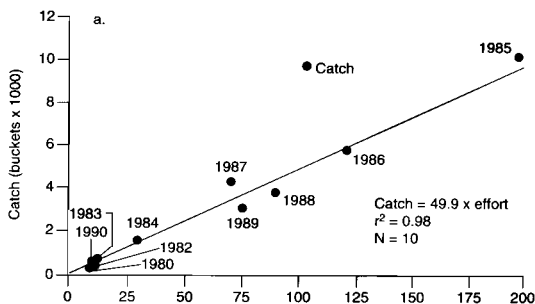


Fig. 8. Butaritari baitfish catch and effort (a) catch vs effort (b) catch per unit effort vs effort.

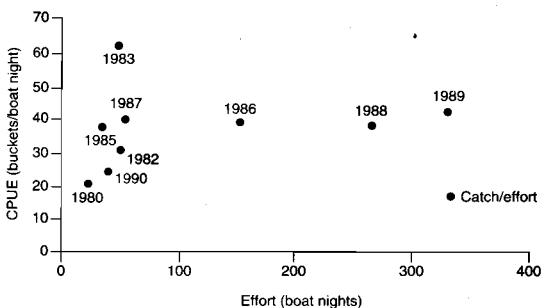
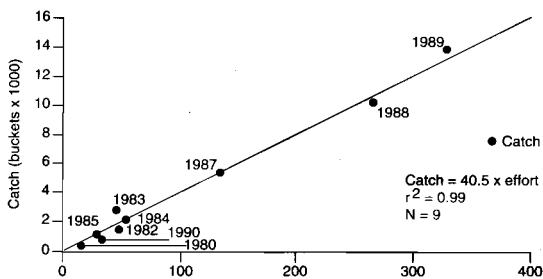


Fig. 9. Abaiang baitfish catch and effort, catch vs effort.

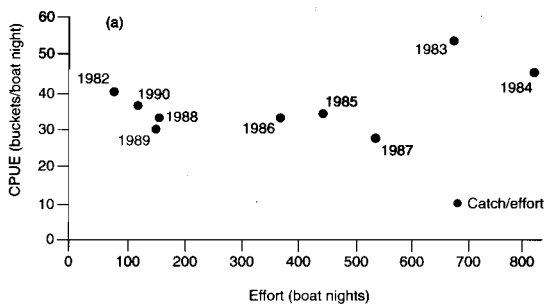
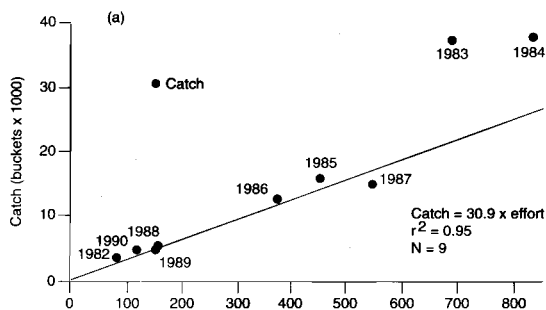


Fig. 10. Tarawa baitfish catch and effort (a) catch vs effort (b) catch per unit effort vs effort.

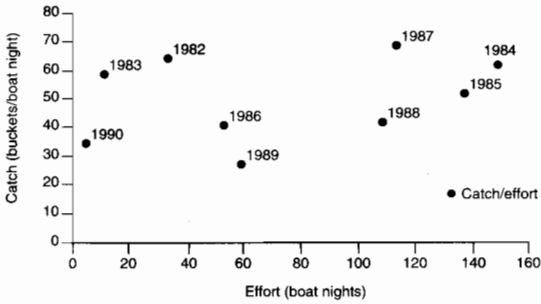
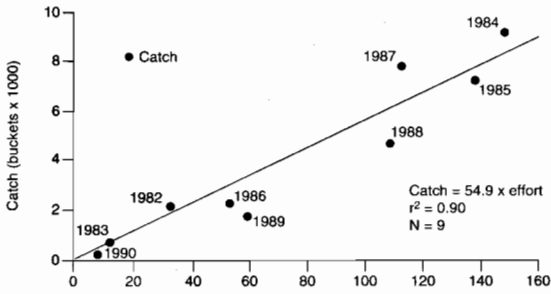


Fig. 11. Abemama baitfish catch and effort (a) catch vs effort (b) catch per unit effort vs effort.

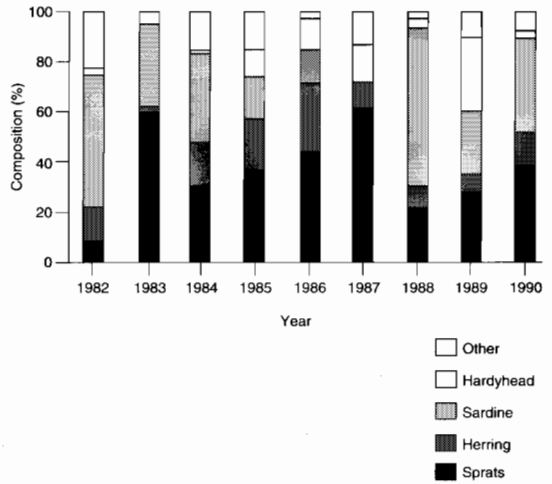


Fig. 12. Republic of Kiribati 1982–1990, baitfish species composition.

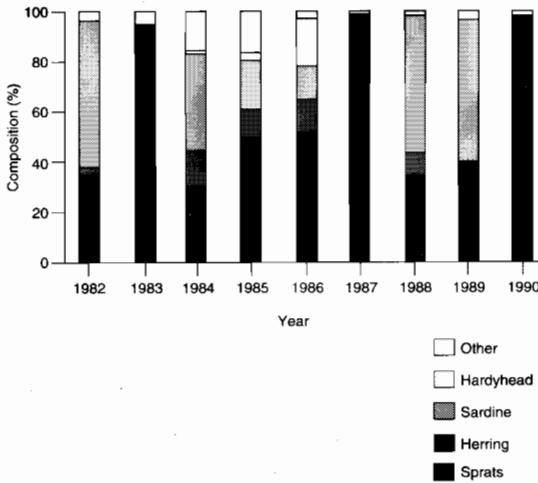


Fig. 13. Butaritari Lagoon 1982–1990, baitfish species composition.

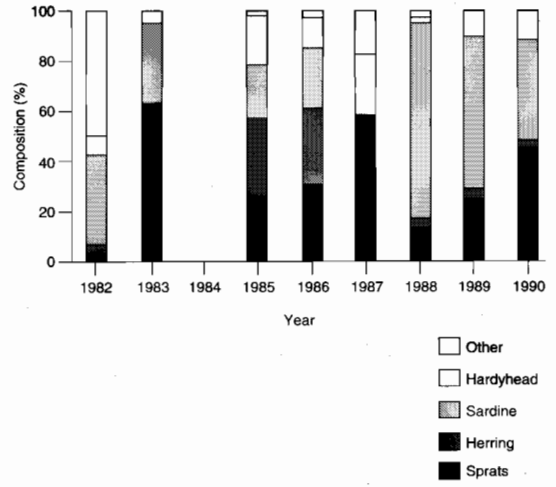


Fig. 14. Abaiang Lagoon 1982–1990, baitfish species composition.

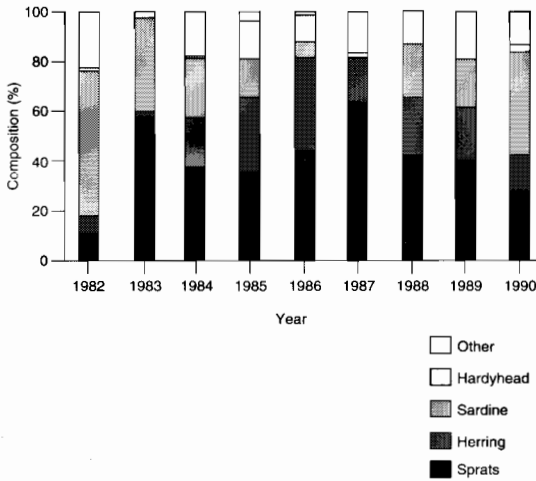


Fig. 15. Tarawa Lagoon 1982–1990, baitfish species composition.

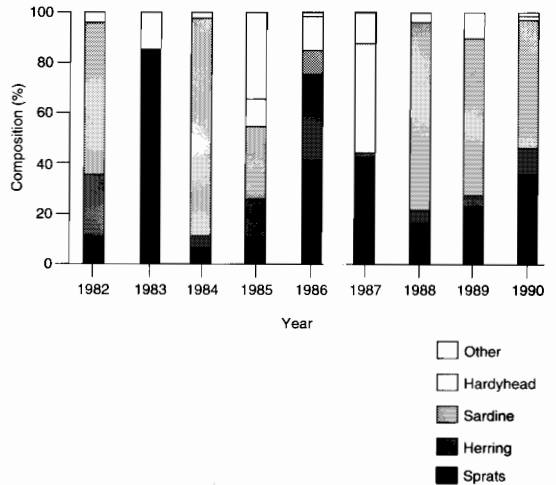


Fig. 16. Abemama Lagoon 1982–1990, baitfish species composition.

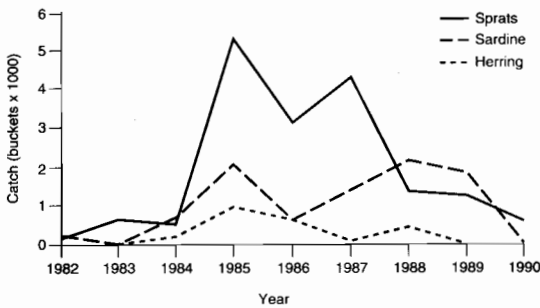


Fig. 17. Butaritari baitfish catch and effort, species catch by year.

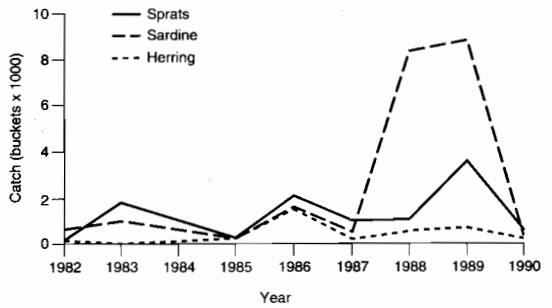


Fig. 18. Abaiang baitfish catch and effort, species catch by year.

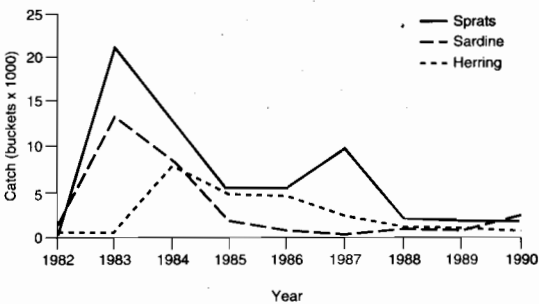


Fig. 19. Tarawa baitfish catch and effort, species catch by year.

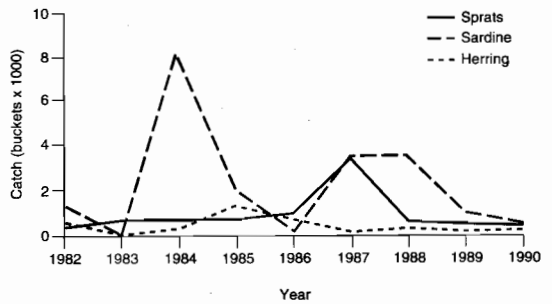
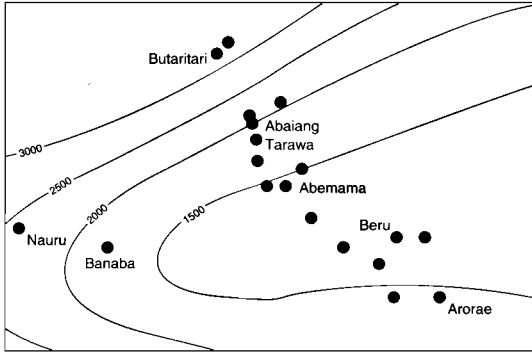
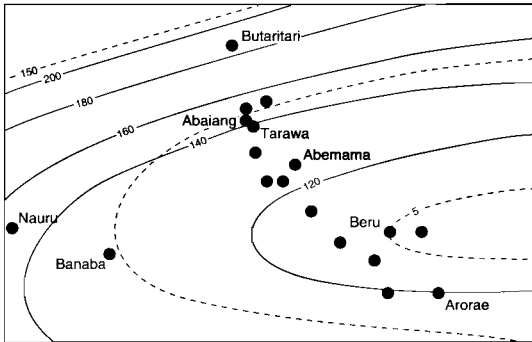


Fig. 20. Abemama baitfish catch and effort, species catch by year.

(a) Mean annual rainfall (mm)



(b) Raindays of at least --- >50 mm — >1 mm



(c) Co-efficient of variation of annual rainfall (%)

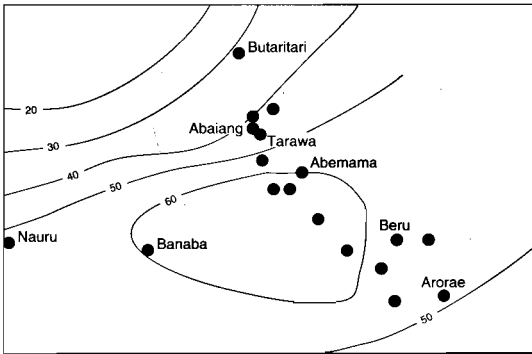


Fig. 21. Selected features of annual rainfall over Western Kiribati (1951–1980).

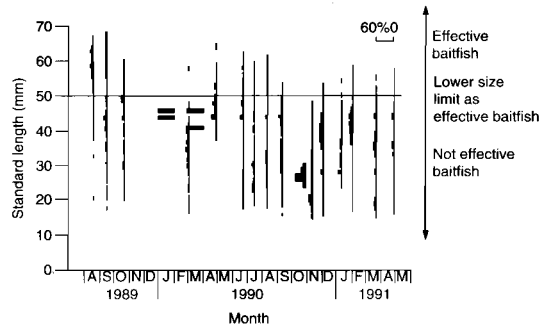


Fig. 22. The length-frequency distributions of *Spratelloides delicatulus* sampled from commercial baitfish catches at all sites in Kiribati between 1989 and 1991.

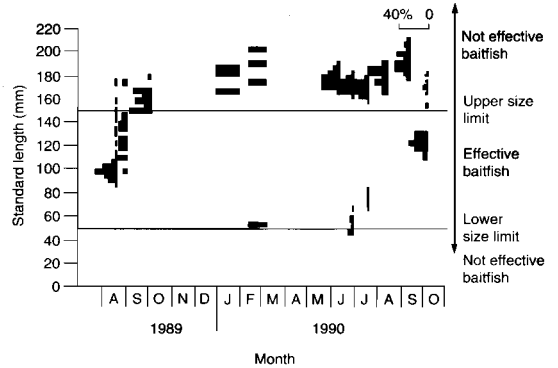


Fig. 23. The length-frequency distributions of *Amblygaster sirm* sampled from commercial baitfish catches at all sites in Kiribati during 1989 and 1990.

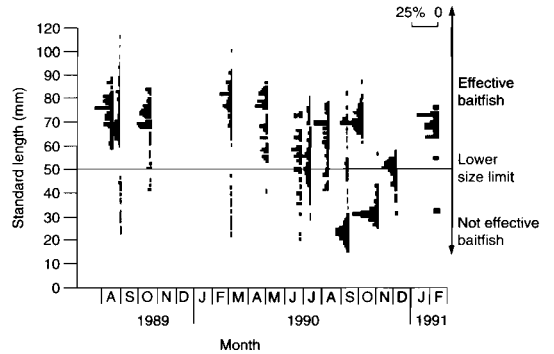


Fig. 24. The length-frequency distributions of *Herklotsichthys quadrimaculatus* sampled from commercial baitfish catches at all sites in Kiribati during 1989 and 1990.

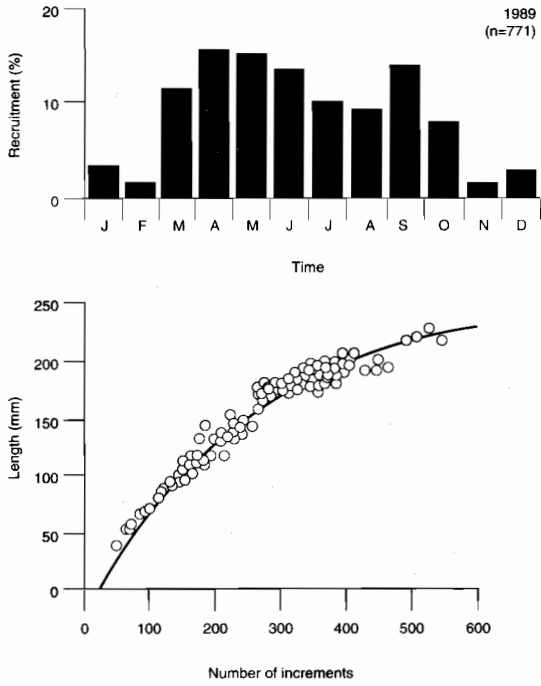


Fig. 25. The proportion of *A. sirm* born each month during 1989 (a) back-calculated from length-frequency samples, (b) assuming growth according to the relationship of Milton *et al.* (1992a).

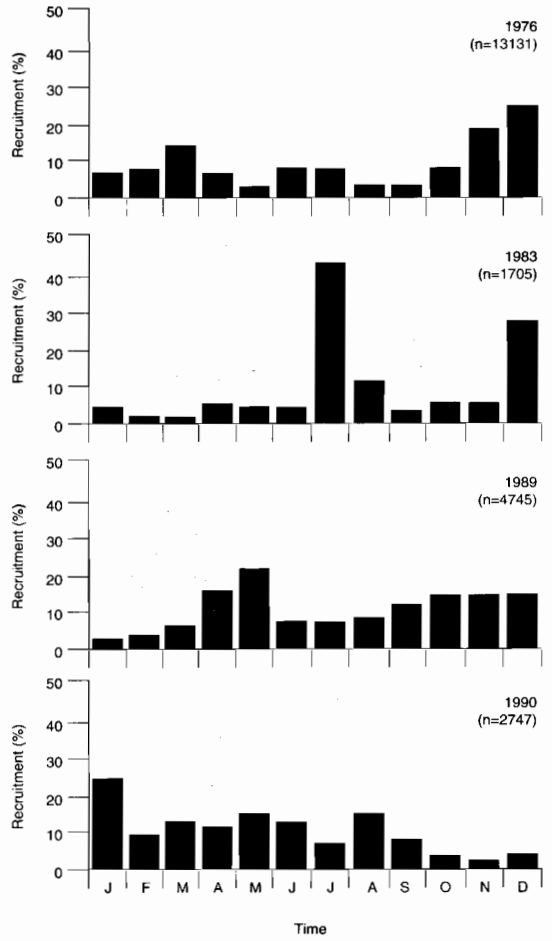


Fig. 26. The proportion of *H. quadrimaculatus* born each month in 1976, 1983, 1989 and 1990 (1976–Cross (1978); 1983 McCarthy (1985); 1989, 1990–present study).

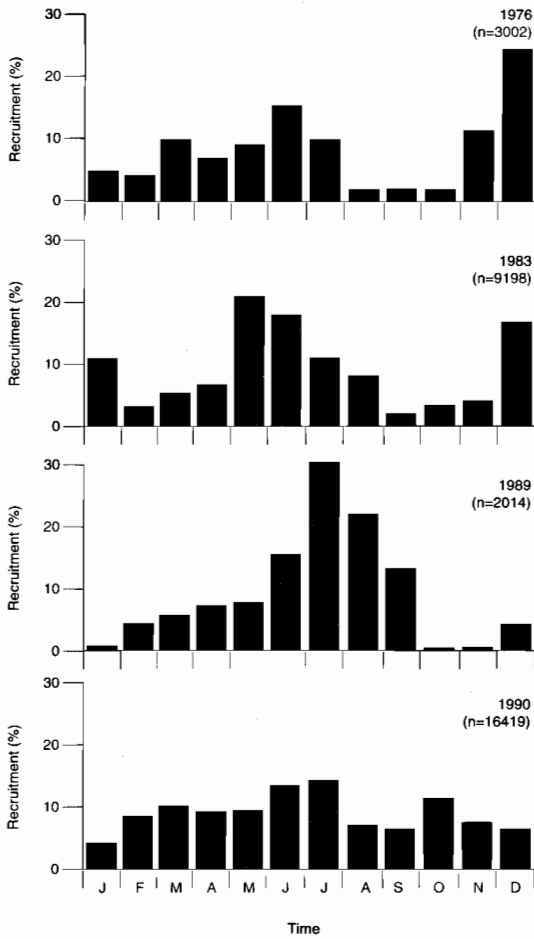


Fig. 27. The proportion of *S. delicatulus* born each month in 1976, 1983, 1989 and 1990 back-calculated from length-frequency samples (1976–Cross (1978); 1983 McCarthy (1985); 1989, 1990–present study).

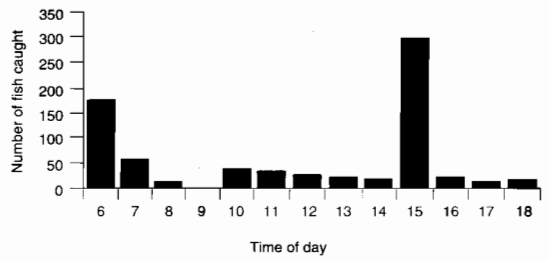


Fig. 28. The number of tuna caught throughout the day during the South Pacific Commission research cruise in early October 1990.

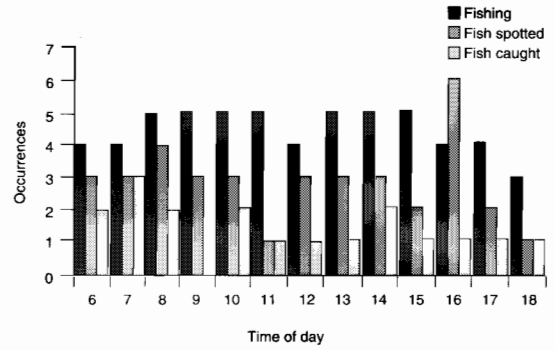
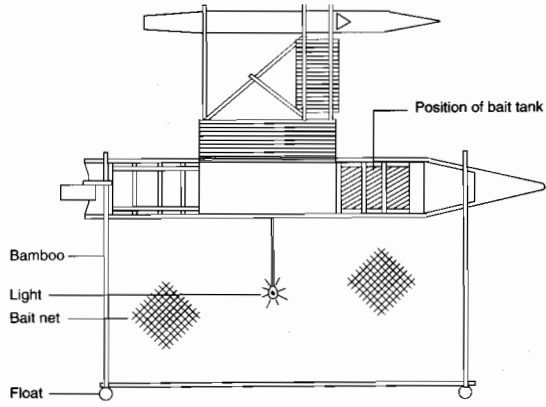


Fig. 29. The number of times that tuna schools were sighted, the vessel was fishing and tuna were caught at a particular time during the South Pacific Commission research cruise in early October 1990.

Plan view



End elevation

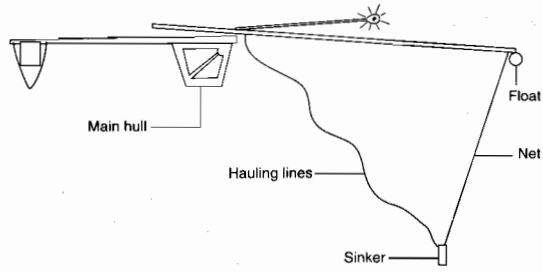


Fig. 30. The experimental baitfishing set-up of the 'PNG 11' outrigger canoe trialed in Butaritari.

An Alternative Tuna and Baitfishing Strategy

Artisanal fishing

The history of commercial pole-and-line fishing in Kiribati since its development in 1981 has been chequered (MacInnes 1990) and the continuing problems of quantity and survival of baitfish have limited its economic returns. In order to supplement catches of tuna made by the pole-and-line vessels, the Outer Island Project was initiated in 1987. The aim of this project was to encourage artisanal fishermen to catch tuna and supply them to Te Mautari Limited. Boats were built and supplied to fishermen at a reduced price and collection centres with blast freezers and cold storage were set up on the two outer islands of Abemama and Butaritari. Although tuna have been caught and preserved and supplied to Te Mautari, the operation has never been economic. A major problem is that the trolling technique used by the artisanal fishermen requires a large amount of fuel. The rising costs of fuel, decreasing prices of fish and generally poor catches of tuna, due primarily to the unpredictable nature of the occurrence of schools around the islands, have all played a part in the difficulties this project has faced.

Kearney (1975) considered that much smaller pole-and-line vessels (e.g. 8–10 metres) with smaller crews (e.g. 4–8) could operate economically with smaller bait quantities. If smaller vessels using greatly reduced quantities of bait can make economic catches of skipjack then the prospects of increasing local tuna production from a limited natural live-bait resource or some other supply of bait are greatly improved.

The use of small boats and live baitfish has been well established in the pole-and-line skipjack fishery in the Maldives in the Indian Ocean. The fishery relies on each boat collecting bait during the early daylight hours prior to the day's fishing operations. Each boat catches about 320 kg of tuna a day and the total annual catch for the country by boats using this method is over 52 000 t, which is well in excess of the largest industrial pole-and-line fishery in the Pacific (Maniku et al. 1990). The pole-and-line fishery in the Maldives relies on using about

5000 t of schooling reef fish species, especially cardinal fish (Apogonidae), fusiliers (Caesionidae) and sprats (*Spratelloides*) for baitfish.

As artisanal fishermen in Kiribati are traditionally used to using a pole-and-line technique which relies on pearl-shell lures, but no baitfish, and they are faced with economic problems carrying out their present fishing practices, the introduction of live baitfish into their operations might well improve their situation. However, for such an idea to be feasible it is necessary to develop a technique for catching the baitfish from a small boat. During extensive underwater surveys for the giant clam census during 1990 in Kiribati, only a few of any of the species used in the Maldives, except for *Spratelloides delicatulus*, were seen. Prevailing winds usually make conditions over the reefs of the margins of the lagoons, the areas in the Maldives where most of the baitfishing takes place, too rough to consider undertaking any form of fishing operation in Kiribati. Artisanal fishermen would therefore need to use a night-lighting method similar to the industrial fishery.

Several methods were developed to catch baitfish at night from small boats as a part of the regular sampling of the Baitfish Research Programme. Taking these ideas further, an attempt was made to catch baitfish from one of the boats used by the outer island project. The design of boat was an 9.5 m outrigger canoe which can be powered by both outboard engine and sail. The dimensions and general arrangements of the boat are described in RFSP (1990).

After different styles of operation were tried, the most suitable net design was a scaled-down version of that used in bouke-ami operations. A net 10 m² constructed of disused baitfishing net was attached to a rigid wooden cross-frame. This cross-frame was pushed out from the boat, on the opposite side to the outrigger, with the use of bamboo poles locally available from the island of Butaritari where the trials were undertaken. The net then hung down from the cross-frame which had plastic floats attached to ensure that it did not go underwater. Four hauling lines were attached to the bottom of the net which was weighted with cement-filled beer cans in order to sink it adequately. The hauling lines were attached to four points at equal

distances along the length of the boat (Fig. 30). The bamboo poles were tied tightly to the boat in order to ensure the whole structure remained rigid. The operation of shooting and hauling the net could be comfortably carried out by four people, and on occasions was operated by only three people. After baiting operations were completed, the net, bamboos and remainder of the gear could be neatly stowed and did not interfere with other fishing activities on the boat.

This method was effective at catching bait that had aggregated around an underwater light driven by a portable generator. As there were large quantities of sprats available during the course of the trial, catch rates were generally high. Catches in excess of 40 kg were made on one night.

However, it is not feasible for each artisanal boat to possess an underwater light and a portable generator. Therefore, on a number of occasions a kerosene lamp as the light source was tested. The use of such lamps for fishing in Kiribati is common practice for the capture of flying-fish at night. Although not as effective as the one-kilowatt underwater light, the kerosene lamp did succeed in attracting reasonable quantities of baitfish, which were easily caught using the arrangement described above.

The baitfish species taken during these trials were mainly *Spratelloides delicatulus* with some *Herklotsichthys quadrimaculatus* and atherinids. Schools of *Amblygaster sirm* were not observed attracted to the lights during the course of the trials so it is not known whether they could be caught using such gear. Because of their habit of swimming fast and erratically around lights in normal situations they would probably be difficult to capture using such a method.

The trials were taken a step further by trying to keep the baitfish alive on the boat. A marine plywood bait box was constructed. Its dimensions were 50 cm square at its base, 95 cm high, and 70 cm by 92 cm at the top. An outlet pipe was fitted near the top of the tank on the starboard side so it could hang just over the gunwale. This box fitted

neatly in the bow section of the boat just ahead of the forward cross-beam of the outrigger (Fig. 30). The box had sections added to it in each corner to give some curvature to its inside. The inside of the box was painted a light blue colour.

During the first use of this bait tank the bait died after a couple of hours due to overcrowding and limited water exchange. Before its second use a hand-operated whaler gusher pump was fitted to the boat. The inlet pipe to the pump was long enough to reach over the side of the boat into the sea and the outlet into the bait tank. After bait had been loaded it was possible to exchange the water in the tank at regular intervals. During this trial a total of approximately 10 kg of sprats was loaded into the tank before going in search of tuna. Unfortunately no tuna schools were seen so it was not possible to try and get a positive feeding response to the baitfish. However, on the boat's return to base in the middle of the afternoon the bait was still alive and could have been used for fishing. During one other attempt at using the live baitfish for catching *Euthynnus affinis*, present in vast numbers in the lagoon, a positive feeding response was achieved, and the boat at one stage was surrounded by a school of fish, although it was not possible to catch any.

As time available for these trials was limited the development of this technique could not be taken further. However, there were enough positive points coming from this experimental fishing to warrant further development in this area. Alternative light sources for catching bait at night (e.g. solar-powered), the formation of a dedicated baitfishing unit to supply boats with baitfish; work with boat designers on how best to optimise bait-holding capacity on the boats available, the use of cultured bait to assess whether the use of baitfish can produce better daily catch rates of tuna than those methods currently employed, the addition of a simple sprinkler system when fishing for tuna and other developments to increase the efficiency of the artisanal fishing fleet are all areas worth investigating.

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