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DECLINES IN FINFISH RESOURCES IN TARAWA LAGOON, KIRIBATI, EMPHASIZE THE NEED FOR INCREASED CONSERVATION EFFORT

BY

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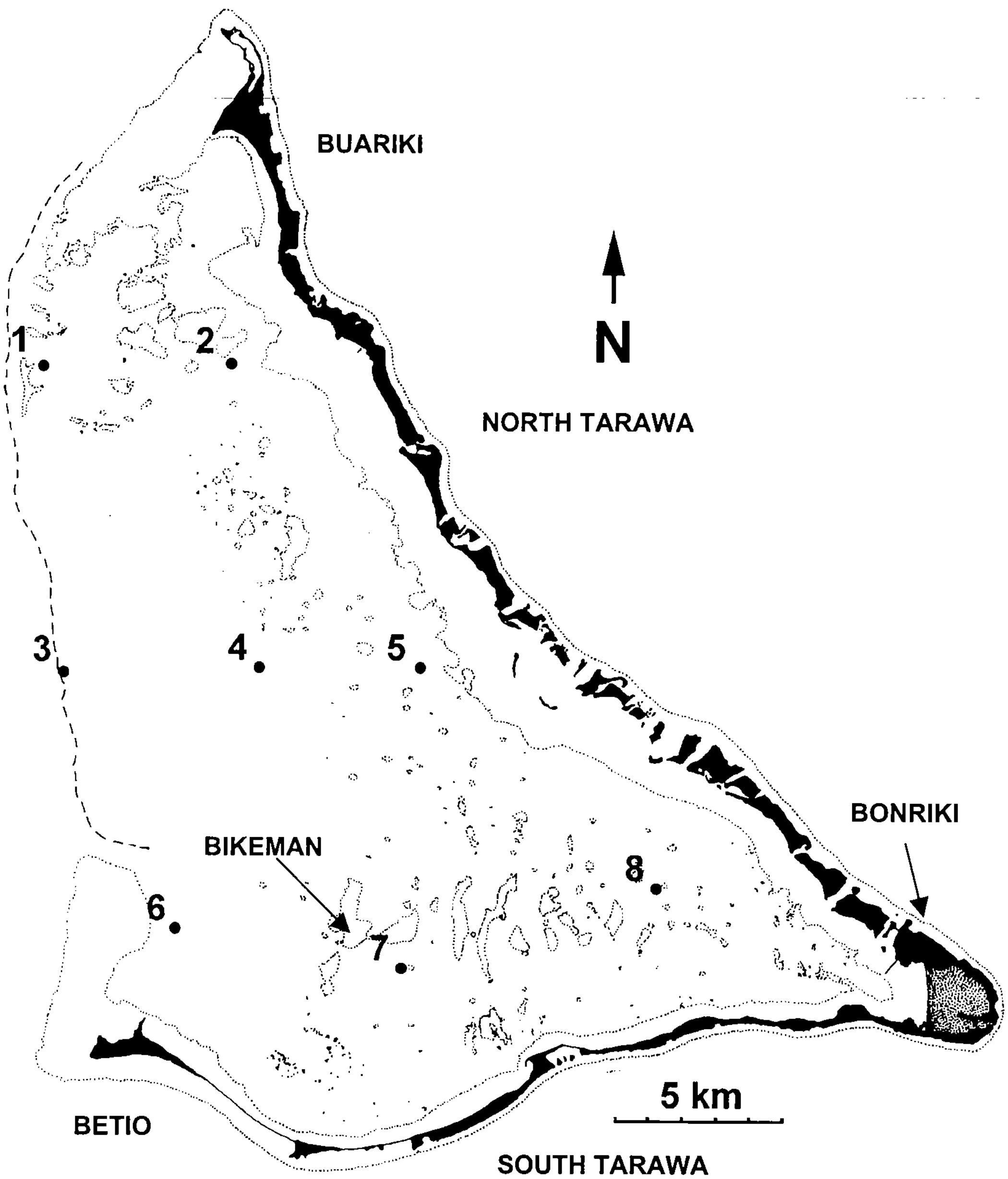

Figure 1. Map of Tarawa Lagoon, Kiribati, showing the eight fisheries-independent sampling sites used during the 1992-93 study. The center of the atoll (near station 5) lies at approximately $1^{O}27.5'N$, $173^{O}E$.

DECLINES IN FINFISH RESOURCES IN TARAWA LAGOON, KIRIBATI, EMPHASIZE THE NEED FOR INCREASED CONSERVATION EFFORT

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ABSTRACT

The very productive lagoon fisheries of Tarawa atoll changed greatly in recent decades as human development and intensive harvesting increased. Tarawa typifies the increasingly common condition of resource depletion and marine community structure change with expanding human activities and population growth. Fisheries-dependent reports have documented the change in fisher landings for nearly two decades. A comparison of fisheries-independent data collected during 1992-93 with data collected in 1977 allowed for documentation of large changes in important finfish resources in Tarawa Lagoon. The historically important bonefish (*Albula glossodonta*), like other important fishery species, demonstrated declines in catch-per-unit effort (CPUE), proportion of catch, mean length and weight (1977: 46.4 cm, 1.31 kg; 1992-93: 37.6 cm and 0.84 kg), and sex ratio (1977: 0.71:1 [F:M]; 1992-93: 0.15:1). Beach seine sampling of bait fishes demonstrated a major shift in species composition between 1977 and 1992-93, with severe depletion of some preferred species. These results suggest declining abundance in locally important fish species and large changes in species composition within Tarawa Lagoon.

INTRODUCTION

The marine resources of Tarawa atoll (the economic and political center of Kiribati) have been relatively well studied. The benthic invertebrate resources are very productive and are intensively harvested (Paulay, this volume). Traditional marine knowledge and management has been documented by Johannes and Yeeting (this volume). These studies and numerous earlier investigations documented the large changes in lagoon resources as development, exploitation, and human population growth expanded, especially along the southern portion of Tarawa atoll.

Fisheries data and analyses of Tarawa Lagoon resources have documented declines in abundance in some areas of Tarawa atoll and have presented generally negative trends in yield and CPUE (Cross 1978, Marriott 1984, Mees 1987, Mees 1988 a, b, Mees et al. 1988, Wright and Yeeting 1988). Several fish aggregations and migrations have ceased and/or changed migration patterns (Johannes and Yeeting, this volume). The predominant causes appear to be habitat alteration/loss and overfishing.

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The profile of the Tarawa Lagoon fishery greatly changed with an increase in the use of monofilament gill nets and boats with outboard engines, which coincided with the decline in use of traditional fishing methods. This resulted in an increased effort and landing of species selected by gill nets. With the high incidence of ciguatera on the outer reef of the atoll (McCarthy and Tebano 1988), fishing effort outside the lagoon has primarily targeted tuna or flying fish. Since offshore fishing around Tarawa is primarily a commercial effort using larger boats, most of the artisanal effort is on lagoon resources, although it is difficult to evaluate the proportion and importance of each from available statistics. In 1976, 87 outboards and 526 fishing boats were in use in Tarawa compared with 426 outboards and 1,312 boats in use in 1987 (Wright and Yeeting 1988). Although landings have continued at relatively high levels for Tarawa, CPUE of lagoon resources declined in recent years. Details of the fishery, such as declines of specific groups or species and changes in species composition of landings, are not provided in available reports; however, data analyses described a collapsing fishery in the lagoon.

The rapid human population growth on Tarawa atoll has placed increasing pressure on lagoon resources. The population is largely dependent on the lagoon resources for sustenance, and although lagoon resources have been traditionally used and preferred, a few investigations have evaluated the potential of other available resources. Two projects conducted by the South Pacific Commission, Outer Reef Artisanal Fisheries Project and Deep Sea Fisheries Development Project, demonstrated good catch rates for outer- and deep-reef resources (Crossland and Grandperrin 1980, Taumaia and Gentle 1983). These resources have incurred slight fishing pressure around Tarawa but are also susceptible to overfishing.

The presence of ciguatera has greatly restricted the use of outer-reef finfish resources around Tarawa atoll (McCarthy and Tebano 1988). There appears to be no incidence of ciguatera from fishes caught within the lagoon. The incidence of ciguatera around Tarawa atoll is apparently cyclic, not persistent. Use of outer-reef resources of the atoll could assist in removing fishing pressure from the lagoon; however, without rapid, inexpensive tissue tests, documentation of the decline of the incidence in ciguatera and identification of "safe" fish are not presently possible.

Additional resources and imports may become increasingly important for Tarawa, but, regardless, lagoon resources are important and preferred by Tarawans and thus require management. One goal should be the development of management strategies for sustainability of finfish resources within the lagoon. This goal requires adequate resource evaluation. This study component was designed to provide an evaluation of finfish resources in Tarawa Lagoon using historical data, fisheries-independent sampling, and fisher-landings surveys.

METHODS

An excellent description of Tarawa atoll, reasons for its high productivity, and documentation of benthic invertebrate resources have been presented by Paulay (this volume). The focus of this study was an evaluation of finfish resources of Tarawa lagoon; therefore, samples of fishers and fishes were restricted to the inner lagoon (Fig. 1). Data were obtained using two primary sampling methods: fisheries-independent sampling using gill nets, handlines, and seines, and fisheries-dependent sampling of fisher landings. Sampling for this study commenced in April, 1992 and terminated in February, 1994.

Gill-net and handline sampling

Fisheries-independent sampling was designed to assess finfish resources throughout the lagoon and for comparison with historical data collected in 1977. Gill-net sampling procedures were designed following those described by Cross (1978) to allow for statistical comparisons. Gill nets of the same mesh size and length were fished using the same set procedure and soak times. Only data from the same area fished in 1977 (Fig. 1, sites 6 and 7) and net mesh sizes (3.5 in [8.9 cm]) were used for the comparative analyses. Sampling was scheduled for three nights per month at one of eight permanent stations based on Global Positioning System (GPS) positions (Fig. 1). The randomized sampling schedule was devised based on eight sampling stations, four lunar phases, and four solar seasons. At each station, four gill nets were set at least 100 m apart, adjacent to shallow patch reefs or shoals that were present throughout the lagoon. Net dimensions were 50 m by 2 m, two nets with 6.4 cm stretch mesh and two nets with 8.9 cm stretch mesh. Each net was set from shallow water to deep (2-8 m) with lead lines along the bottom. Normally, two sets per night were made with soak times of three hours.

Handline fishing was conducted during gill-net sets with standard soak times. Each sampler used standard gear (30 lb. test monofilament, No. 9 hooks, leads) and fished in the same manner. Bait was standard juvenile milkfish (*Chanos chanos*) obtained from the Kiribati Fisheries Division fish farm.

During all sampling, parameters (date, time, site, lunar phase, climatic/physical conditions) were recorded by field technicians into field notebooks. Catch from each gear type was placed in separate, marked bags and processed in the laboratory. Data recorded on each specimen included fork length in cm, weight in grams, sex, and gonadal condition. Training and quick identification sheets for all species collected allowed for accurate species identification.

Seine sampling

Seine sampling followed the design of the previous study conducted by the Kiribati Fisheries Division (Cross 1978). The seine (50 m x 2 m x 10 mm stretch mesh) was hauled by four men from approximately 50 m offshore onto the beach. Fishes from each seine haul were labeled and returned to the laboratory for identification and measurements. Samples were taken in each of four major areas: North Tarawa, South Tarawa, Betio, and Bikeman. Bikeman later was eliminated from sampling due to the dramatic habitat alterations on that island since the last study. North Tarawa received low sampling effort (n = 4 seine hauls) and was not included in analysis.

Fisher Landings

The sampling design for finfish landings was randomized under given logistical and statistical constraints (Mackett 1973, Bazigos 1974, Ulltang 1977, Caddy and Bazigos 1985, Caddy and Sharp 1986). Fishers were sampled at randomized sites and dates, at least one day per week, with additional samples scheduled as possible. All samples were taken along the road which runs across the southern portion of the atoll (no road extended from the southeastern to northern portion of the lagoon). Samplers waited at a site to intercept all fishers landing within the defined time. Data were recorded on date/time, gear type and amount, boat type, fishing area, landing area, fishing/soak time, sample type (complete/partial catch), and climatic conditions. All fishes were identified by species, measured to the nearest 0.1 cm, and weighed to the nearest 0.5 g.

Bonefish (*Albula glossodonta*) was identified as a species of special concern and received additional sampling effort. Bonefish, greater than 35.0 cm (apparent size of maturity based on preliminary samples) in fisher landings, were separated for determination of sex and gonadal condition and for diet analysis.

RESULTS

Gill-net and handline sampling

During the fisheries-independent gill net sampling in 1992-93, 64 species were captured in 255 net sets. Paddletail snapper (*Lutjanus gibbus*) was the most commonly captured species (24.9% of total number of fish in gill-net sampling) followed by bonefish (*Albula glossodonta*, 7.5%; Table 1). Bonefish was the dominant fish captured in gill nets of the same mesh (3.5 in) during the 1977 investigation and represented a much larger proportion of the catch (44.6%; Table 1). Paddletail snapper was caught in similar proportion in both the 1977 and 1992-93 sampling. Several species, primarily snappers (Lutjanidae) and emperors (Lethrinidae), were common in 1992-93 gill-net sampling but absent in 1977 sampling (Table 1). Other taxa, especially squirrelfishes (Holocentridae) and trevallies/jacks (Carangidae), were abundant in 1992-93 gill net sampling (10.4% and 8.8%, respectively) but uncommon in 1977 samples (0% and 3.3%, respectively).

Table 1. Comparison of dominant taxa in fisheries-independent gill-net sampling, 1977 and 1992-93, and with fisher landings data. Data are percentages of total number of fish sampled. 1977 data from Cross (1978). Kiribati names are given beside common names.

	GILL-NET SAMPLING				**FISHER LANDINGS**	
	1977		**1992-3**		**1992-3**	
TAXON	**Number**	**Weight**	**Number**	**Weight**	**Number**	**Weight**
Albula glossodonta Bonefish - IKARI	44.6	66.5	7.5	12.9	41.0	61.3
Lutjanus gibbus Paddletail snapper - IKANIBONG	25.0	11.3	24.9	14.0	9.2	4.7
Gerres spp. Silverbiddy - AMORI	7.6	3.4	4.8	1.86	10.2	1.2
Lethrinus nebulosus Spangled emperor - MORIKOI	5.4	6.7	0.4	1.6	1.0	2.2
Lutjanus fulvus Flametail snapper - BAWE	0	0	6.6	3.4	6.2	2.7
Lethrinus obsoletus Orangestriped emperor - OKAOKA	0	0	4.4	2.4	6.6	3.5
Lethrinus olivaceus Longnose emperor -TAABOU/ROU	0	0	5.3	5.0	2.8	5.3
OTHERS	17.4	12.1	45.9	58.8	23.0	19.1

CPUE differed significantly between the two sampling periods, 1977 and 1992-93 (MW-U, $p = 0.002$). Average gill-net catch per net set (CPUE) for 3.5-inch stretch nets at the same location used in the 1977 study (Cross 1978) was 7.08 ± 5.45 (s.d.) fish per net set in 1977 and 1.57 ± 2.10 (s.d.) fish per net set in 1992-93 (Table 2). Large differences in CPUE were also noted for dominant species, especially for bonefish (MW-U, $p < 0.001$).

Table 2. Comparison of CPUE for total fishes and important species in fisheries-independent gill-net sampling in Tarawa Lagoon, 1977 and 1992-93. Data are mean CPUE (± s.d.) for 3.5-inch gill-net sets in 1977 (n=13) and 1992-93 (n=37) within the same area. 1977 data from Cross (1978). Kiribati names are given beside common names.

	1977		1992-93	
TAXON	**Number**	**Weight**	**Number**	**Weight**
TOTAL FISHES	7.08 ±5.45	6.20 ±5.50	1.57 ±2.10	0.92 ±1.52
Albula glossodonta Bonefish - IKARI	3.15 ±4.39	4.14 ±5.19	0.16 ±0.83	0.16 ±0.86
Lutjanus gibbus Paddletail snapper - IKANIBONG	1.77 ±2.77	0.70 ±1.15	0.78 ±1.70	0.31 ±0.67
Lethrinus nebulosus Spangled emperor - MORIKOI	0.38 ±0.65	0.42 ±0.76	0.03 ±0.16	0.07 ±0.41

Snappers (Lutjanidae), emperors (Lethrinidae), and groupers (Serrandae) dominated handline catches in the fisheries-independent sampling (as in the fisher landings) during 1992-93. A total of 54 species and 1,793 individuals were captured in 46 samples (approx. 560 fishing hours). Paddletail snapper (*Lutjanus gibbus*) was the most abundant species caught in handline sampling (39.8% of total number of fish caught), followed by orangestriped emperor (*Lethrinus obsoletus*, 17.6%; Table 3). Similar observations were made for the handline fisher landings. Trevellies/jacks and squirrelfishes were also important in landings; however, fisher catches of squirrelfishes may be much larger and not as apparent in landings since they are less preferred.

For both gill-net and handline sampling, catches were significantly greater in northern and western lagoon sampling sites (Sites 1, 3, and 4) than in southern and eastern sites (Sites 2, 5-8; KW tests, $p < 0.01$; Fig. 2 and 3).

Beach seine sampling

Thirty-eight species were sampled in 40 beach seine samples taken in Tarawa Lagoon in 1993, which was comparable to 40 species sampled in 176 seine samples taken in 1977. Comparison of the results between the two sampling periods demonstrated that the species composition and relative abundance of fishes captured using this method has greatly changed (Table 4). Several previously abundant species, primarily baitfishes, were not captured during seine samples in 1993. The second most abundant species captured in 1993, Dussumieri's halfbeak (*Hyporhamphis dussumieri*; greater than 20% of fishes captured), was rare in 1977.

Table 3. Comparison of six dominant species in fisheries-independent handline sampling with handline fisher landings data, 1992-93. Data are percentages of total number of fish sampled. Kiribati names are given beside common names.

	HANDLINE SAMPLING		FISHER LANDINGS	
SPECIES	Number	Weight	Number	Weight
Lutjanus gibbus Paddletail snapper - IKANIBONG	39.8	29.8	27.5	18.9
Lethrinus obsoletus Orangestriped emperor - OKAOKA	17.6	17.4	15.6	11.0
Lutjanus kasmira Bluestriped seaperch - TAKABE	8.8	3.3	4.5	1.0
Epinephelus merra Dwarf spotted rockcod - KUAU	7.3	3.3	2.9	1.7
Lethrinus olivaceus Longnose emperor -TAABOU/ROU	6.9	13.7	6.8	20.5
Lutjanus fulvus Flametail snapper - BAWE	5.0	2.5	8.6	3.2
OTHERS	14.6	30.1	34.1	43.7

Table 4. Comparison of results of inshore seine samples taken in Tarawa Lagoon, 1977 and 1993. Data are percentage of total fish captured for six dominant taxa in two areas, South Tarawa and Betio, 1977. Data from Cross (1978). Kiribati names are given beside common names.

	SOUTH TARAWA		BETIO	
SCIENTIFIC/COMMON NAME	1977	1993	1977	1993
Atherinomerus lacunosus hardyhead silverside - REREKOTI	33.14	1.36	15.79	0
Herklothsichthys quadrimaculatus gold-spot herring - TARABUTI	22.31	0.97	13.2	0
Gerres argyreus silverbiddy, mojarra - NINIMAI	14.62	32.61	1.07	7.93
Spratelloides delicatulus blue sprat - AUAN	13.07	0	8.37	0
Hypoatherina ovalaua Ovalaua silverside - REREKOTI	11.15	1.53	7.36	0.04
Mugilidae mullets - BAUA, BAUAMARAN	1.87	2.56	0.07	0.99
Number of samples	47	25	43	11

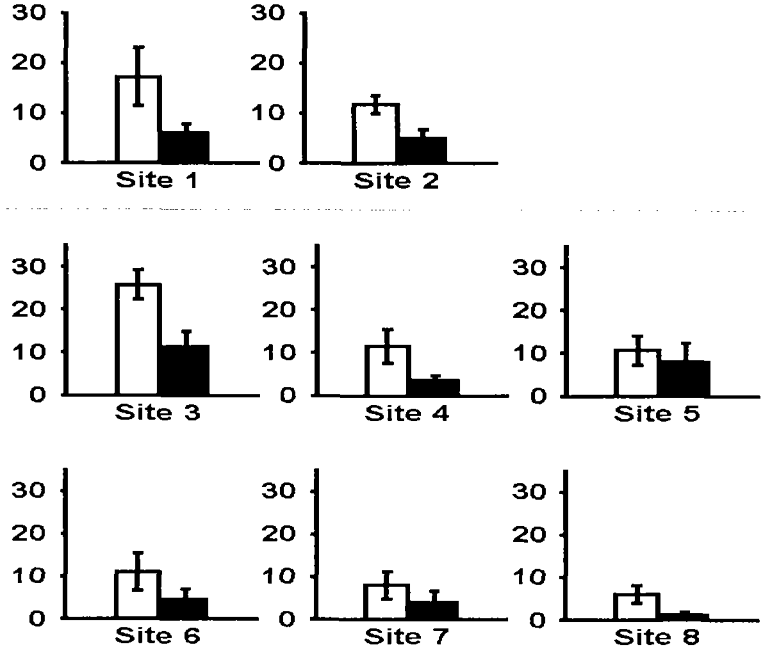

Figure 2. Mean number of fish (open bars) and mean weight in kg (solid bars) per gill-net sample for each sampling site in Tarawa Lagoon. Error bars are one standard deviation.

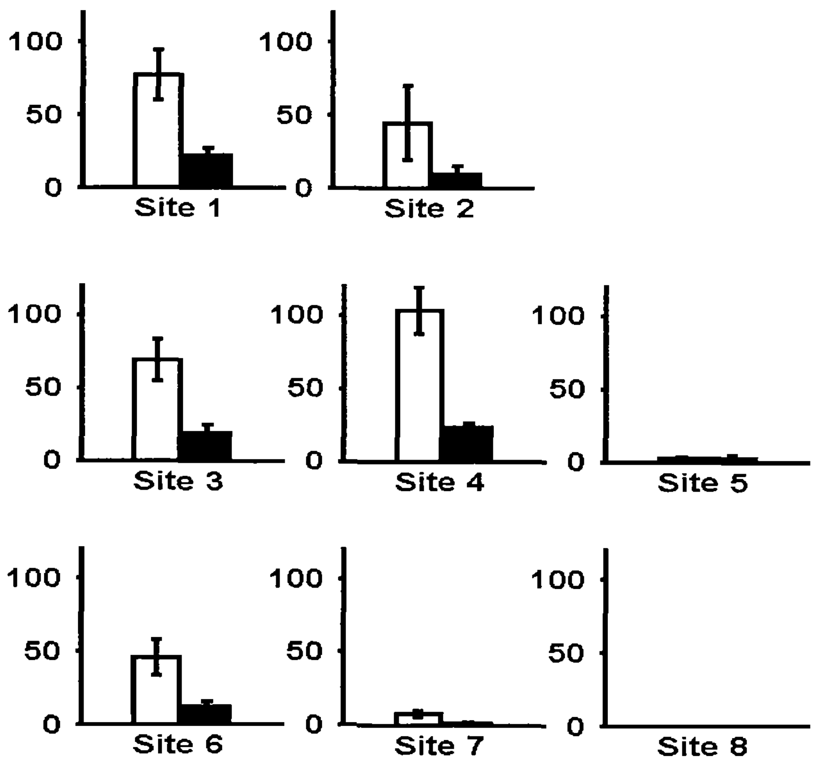

Figure 3. Mean number of fish (open bars) and mean weight in kg (solid bars) per handline sample for each sampling site in Tarawa Lagoon. Error bars are one standard deviation.

Fisher landings

Fisher landings surveys (n = 82) showed that bonefish dominated fisher landings (41.0%), followed by silverbiddies (*Gerres* spp.; Table 1). Bonefish landed by fishers were exclusively caught using gill nets. Fisher landings were reported for all gears because many fishers used several gear types per trip. Snappers (Lutjanidae), emperors (Lethrinidae), travallies/jacks (Carangidae), and goatfishes (Mullidae) followed bonefish and silverbiddies in abundance in fisher landings. The dominant fishes landed by handline were snappers and emperors (Table 3).

Gill-net fishers, who were sampled during landings surveys and target bonefish in Tarawa Lagoon, almost exclusively used the "splash method" of fishing gill nets (usually less than 100 m long) due to low catch rates using passive methods of fishing gill nets (see description of fishing methods in Johannes and Yeeting [this volume]). In the "splash method" fishers slap the water surface with long rods, which drives fish into the nets and enhances catches. Silverbiddies and goatfishes were also captured by gill net, whereas, reef species, such as snappers and emperors, were primarily taken by handline.

Bonefish data

At least two species of bonefish occur within this region of the Pacific (Shaklee and Tamaru 1981, Myers 1991). Meristic counts of bonefish obtained from fisher landings and fisheries-independent sampling were usually in the range of those given for *A. glossodonta* [although Cross (1978) listed *A. neoguinaica* for bonefish in Tarawa Lagoon]. Although two species may exist in Tarawa, for purpose of this report bonefish will be referred to a single species, *A. glossodonta*.

The mean length and weight of bonefish sampled in gill net sampling in 1992-93 (37.6 cm and 0.84 kg, respectively) were significantly smaller than those sampled in 1977 (36.4 cm, 1.31 kg), females (t-test, $p < 0.01$; Table 5). This was also true for the mean length of males and females (t-tests, $p < 0.01$; Table 5). The sex ratio was also greatly skewed between sampling periods (1977: 0.71:1 [F:M]; 1992-3: 0.15:1) Interestingly, the smallest reproductive individuals for both sexes sampled in 1992-93 were smaller than those sampled in 1977 (Table 5).

Comparison of length-frequency data for bonefish collected in 3.5-inch stretch gill nets during 1977 and 1992-93 demonstrated a large shift in size frequency of bonefish to smaller size classes in 1992-93 (Figure 4). The abundance of larger individuals was much lower in 1992-93 samples.

Bonefish sampled in fisher landings during 1992-93 had mean length and weight, 35.7 cm and 0.67 kg, respectively (Table 5). The average length of bonefish sampled in fisher landings during 1992-93 was lower than in gill-net samples (Table 5; Fig. 4). Although most fish in fisher landings were not sexed, a very conservative estimate of the percentage of nonreproductive bonefish taken by fishers would be 30% based on the smallest reproductive individual sampled in gill-net samples (male: 32.0 cm).

Results of the bonefish sampling of 100+ individuals greater than 35 cm provided data for additional comparisons. Since the sampling was exclusively for large individuals, larger-sized females should have been overrepresented. For this sample, the sex ratio was 42:67 (female:male), or 0.63:1, which was still biased towards males (Table 6). The mean length of males and females in this sample was 40.1 cm and 44.2 cm, respectively.

Table 5. Bonefish data (mean ± s.d.) from fisheries-independent sampling using gill nets in Tarawa lagoon, 1977 - 1992-93, and from fisheries-dependent sampling of fishers in South Tarawa, 1992-93.

	GILL NET SAMPLING 1977	1992-93	FISHERMEN LANDINGS 1992-93
TOTAL FISH			
Mean length (cm)	46.4 ±4.1	37.6 ±7.3	35.7 ±6.6
Mean weight (grams)	1313.4 ±317.8	835.2 ±260.3	666.0 ±428.4
Sample size	41	36	1831
Sex ratio (female:male)	17:24 (0.71:1)	4:27 (0.15:1)	
Males			
Mean length (cm)	44.6 ±4.1	37.4 ±7.9	
Mean weight (grams)	1170.4 ±322.1	825.9 ±236.7	
Females			
Mean length (cm)	49.1 ±3.0	37.8 ±6.2	
Mean weight (grams)	1515.3 ±228.1	935.8 ±416.0	
Smallest reproductive size (cm)			
Male	42.5	32.0	
Female	46.5	35.0	

Table 6. Results of bonefish sampling of individuals larger than 35 cm from fisher landings sampling in Tarawa Lagoon, 1992-93.

SEX	NUMBER	LENGTH (cm)	WEIGHT (g)
Male	67	40.1	959.1
std. dev.		4.0	275.0
range		23.4-51.3	500-2250
Female	42	44.2	1232.6
std. dev.		4.9	465.3
range		35.0-55.7	550-3000
SEX RATIO			
female:male	42:67 (0.63:1)		

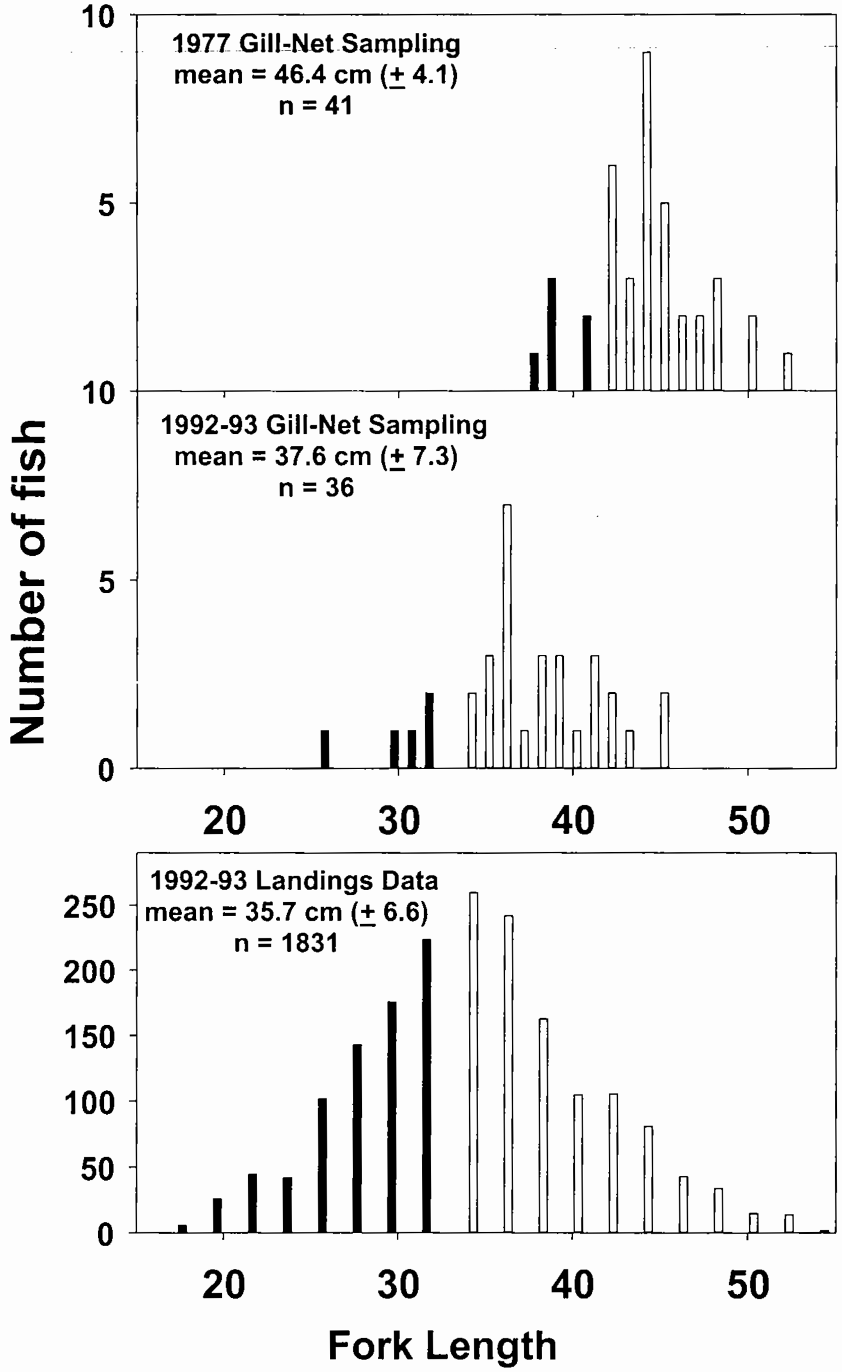

Figure 4. Comparison of length-frequency data for bonefish, *A. glossodonta*, caught during 1977 and 1992-93 gill net sampling and from 1992-93 fisher landings. Dark bars represent immature fishes; open bars represent fishes above size of first reproduction.

DISCUSSION

Review of existing literature and information from this investigation suggest that finfish resources of Tarawa Lagoon continue in a state of decline. Reports completed by the Kiribati Fisheries Division during the past two decades provided information on a declining lagoon fishery (Cross 1978, Marriott 1984, Mees 1987, Mees 1988 a&b, Mees et al. 1988, Wright and Yeeting 1988). Results from this investigation support and extend those conclusions.

Increased fishing pressure in Tarawa Lagoon is a response of increased population growth and the need for more fishery products. Unfortunately, many species in Tarawa Lagoon have experienced declines in abundance at least partially due to increased fishing pressure. Johannes and Yeeting (this volume) have provided important documentation from fishers on declining resources. Several conditions point to the condition of declining stocks. For example, fishers have increased use of the "splash method" of fishing gill nets in the lagoon due to low catch rates with gill nets alone. Such changes in fishing methods signal problems in lagoon fisheries.

Habitat alteration and loss, especially the construction of causeways, has caused a decline in fish migration to spawning sites (see discussion by Johannes and Yeeting, this volume). Channels are vital for the migrations of lagoon species which migrate to offshore sites during their spawning period. Additionally, causeways may block larval fish migration through channels into the lagoon following their early planktonic development offshore. Currents that develop during tidal exchange in the lagoon may provide the necessary cue for migration. Causeway construction obviously has resulted in loss of spawning migrations and may have contributed to declines in abundances of some species, particularly bonefish.

It would appear that the lagoon fishery has become overcapitalized. Considering the finite resources, the increase in use of monofilament gill nets and outboard engines has contributed to the overfished condition. Historically, Kiribati fishers were noted for using many fishing methods for a diversity of species (Kock 1986, Teiwaki 1988). The trend in recent years has been toward use of efficient gear, such as gill nets, and targeting fewer species. Such a trend has the inevitable consequences of declining stocks.

Bonefish (*Albula glossodonta*), the most important fish harvested in Tarawa Lagoon, demonstrated significant declines in CPUE effort and average size (for total individuals and both sexes) based on comparisons of the data from this study and the 1977 study (Cross 1978). Bonefish was the dominant species landed by fishers using gill nets in Tarawa Lagoon during this study. Of great concern is the shift in sex ratio from 0.71:1 (F:M; 1977) to 0.15:1 (1992-3). Shifts in sex ratio may be indicative of stressed populations, although much variability exists among samples, populations, and species, and differences should be cautiously interpreted (Sadovy 1996). Since male bonefish mature at smaller size than females, the intensive fishing effort, especially for larger fish, may have resulted in females being underrepresented in the population. Loss of large females for egg production could result in spawning failure for the population.

Fisher-landings data collected during 1992-93, suggested that a large percentage of bonefish caught in Tarawa Lagoon were prespawning individuals and that females, which have a larger mean size, have been selectively depleted. The conservative estimate of the number of bonefish landed by fishers that were below reproductive size was 30% (based on the smallest reproductive individual captured during fisheries-independent sampling). Since the greatest proportion of mature fish were males, the spawning stock of females within Tarawa Lagoon was apparently low. These results, in combination with the information obtained on spawning migration failure, indicate a critical condition for bonefish in Tarawa Lagoon with great potential for spawning failure in this species throughout the lagoon (see Johannes and Yeeting, this volume).

Analyses of other species demonstrated similar differences as those observed for bonefish. An example is the spangled emperor (*Lethrinus nebulosus*), which is one of the most preferred lagoon species. This species was much lower in proportion of catch and had lower CPUE in fisheries-independent samples taken in the lagoon in 1992-93 than in 1977. Spangled emperor ranked fourth in abundance in gill-net samples in 1977 but were uncommon in 1992-93 samples.

CPUE in fisheries-independent samples was significantly lower in 1992-93 than in 1977. This suggested that fisher catch rates were lower than in previous years and that increases in the amount of gear and fishing farther from previous fishing areas has been necessary to land the same amount of fish. As habitat is degraded and overfishing increases in areas, fishers are forced to fish more intensively for increasing limited resources in Tarawa Lagoon.

Distribution of catch in fisheries-independent sampling was not even throughout Tarawa Lagoon. Lower CPUE was observed in the southern and eastern portions of Tarawa Lagoon than in other areas for both gill-net and handline sampling. This same trend was documented for coral abundance, whereas deposit-feeding and suspension-feeding invertebrate distribution was reversed (Paulay, this volume). Most lagoon fishes are dependent on coral structure for shelter; therefore, the distribution of coral abundance should be closely correlated with fish abundance. Lower fish abundance in the eastern and southern portions of the lagoon could be influenced by habitat alteration/loss in addition to the intense fishing pressure.

Beach seine sampling demonstrated large changes in fish assemblage structure between the 1977 and 1992-93 studies. Several previously abundant species, primarily baitfishes, were not captured during 1992-93 seine samples. This supports information from fishers who stated that baitfishes have declined dramatically since the Betio-Bairiki causeway was constructed and intensive baitfishing was initiated to support the tuna fleet.

The results of this investigation suggest declining finfish resources in Tarawa Lagoon. Several management strategies should be considered to improve conditions and resources in the lagoon. A combination of strategies ultimately should be adopted to ensure resource maintenance or improvement. Johannes and Yeeting (this volume) recommend the reestablishment of community management (traditional marine tenure) and protection of prespawning aggregations for Tarawa. The central government should adopt strategies which would conserve resources for the entire atoll (and nation). Two management strategies with great potential for long-term benefit are: 1) the establishment of marine reserves; and 2) the protection of spawning (and prespawning) aggregations. Numerous publications provide the theoretical benefits of reserves and closed spawning areas and empirical improvements within them (Bohnsack 1989, 1996, Beets and Friedlander 1999, Johannes et al. 1999). These strategies allow improved population and community structures, increased biomass, and potentially greater reproductive output, which could act as "sources" for surrounding fishing grounds. Success of these management strategies requires important considerations such as adequate location and size, and fisher compliance. Other available resources, such as tuna, would possibly allow for lower fishing effort on lagoon resources but would require government incentives. Ultimately, management success will be based on resource user and community support, especially in smaller and remote locations.

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