THE PALA LAGOON SUBSISTENCE FISHERY

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ABSTRACT

Pala Lagoon accommodates the largest remaining stand of mangroves in the Territory of American Samoa. To provide current data on fish harvests in Pala Lagoon, a year-long study on the human use was initiated in 1991. The results of the study showed that this predominantly subsistence/recreational fishery harvested a total of 23,800 lb of fish and invertebrates (excluding bivalve shells) from the lagoon. The annual catch, when converted to its market value, was worth approximately $66,000.

The catch was comprised of 45 species, or species groups, with fish contributing 62% to the total harvest and invertebrates contributing the remaining 38%. Leading contributors to the catch were two species of bivalves (23%), mullet (22%), mangrove crabs (14%), and jacks (11%).

The results of this study were compared to a similar study conducted on the nearby coastal reef flat. Nearly all of the species caught in the lagoon were also caught on the coastal reef. The notable exceptions were the mud clam (Gafrarium timidum), and mangrove crabs (Scylla serrata), both of which rely on mangrove habitat for all or part of their life history. Only approximately 50% of the fish caught on the reef were also caught in Pala Lagoon.

CPUE (catch per unit effort) in the lagoon ranged from 2.0 lb/gear-hour for throw netting to 0.02 lb/pot hour for crab pots. Although CPUE was an order of magnitude lower than on the nearby coastal reef flat for most fishing methods, people still chose to fish Pala Lagoon, because 1) it was a traditional fishing ground of the families that reside adjacent to the lagoon, 2) Lion's Park provides easy public access to the lagoon for people from outside the area, and 3) the lagoon provides access to many of the species prized by the Samoan people in an area that is placid compared to the often treacherous reef flat and front.

INTRODUCTION

The importance of mangroves as a nutrient source for fishery resources has been well documented in tropical and subtropical regions throughout the world (Lal et al. 1984, Davie 1985). Mangrove lagoons are also widely accepted as critical nursery habitat for a variety of coastal reef species. An estimated 80% of all marine species of commercial or recreational importance in Florida are dependent on mangrove estuarine areas for at least some stage of their life cycles. In Fiji, approximately 60% of the entire commercial catch is composed of species dependent upon mangrove estuarine areas (Hamilton and Snedaker 1984). In spite of this, mangrove habitat worldwide is being lost at an alarming rate.

Pala Lagoon in Nu'uuli, the largest enclosed bay in American Samoa, has the largest remaining stand of mangroves (123 acres) left in the Territory. However, that wetland is being lost at a rate of over 2 acres/year due to illegal filling (BioSystems Analysis, Inc. 1992). In addition to acreage lost to illicite activities, the lagoon has been the subject of several feasibility and impact studies for aquaculture and development projects, some of which revealed that proposed developments would have detrimental effects on the lagoon habitat.

It is important that decisions with respect to the wetland habitat of Pala Lagoon be made with as complete an understanding as possible of the value of the area in its present state. The present study was designed to quantify the human use of the Pala Lagoon in terms of fishery activities and harvests. Catch and effort data were collected over a 1-yr period to determine annual harvests of fish and shellfish. Sociological data were also collected to provide a profile of the fishery users.

In addition to the present study of fish harvests in Pala Lagoon, a complimentary study of the lagoon's fish resources was conducted by Knudsen (1992). Unfortunately, the results of that study were not yet available when the present study was written.

Study Area

Pala lagoon is a large, protected mangrove lagoon on the southern coastline of Tutuila Island (Fig 1). It is roughly circular, approximately 1 mile in diameter and has a surface area of about 1 square mile. The study area consisted of the entire lagoon to a line drawn from the end of the airport runway to the southeastern tip of Coconut Point.

The lagoon is bordered on the north shore by a mud-bottomed swamp vegetated with red (Rhizophora mangle) and oriental (Bruguiera gymnorrhiza) mangroves. Coconut Point, the sandy peninsula separating the lagoon from the coastal waters and forming the eastern shore, is vegetated with mangroves interspersed with houses. Lion's Park, a public park, established on landfill, borders the western side. The runway of the Pago Pago International Airport, also built on fill, makes up the southern shoreline. A 0.25-mile gap between the tip of Coconut and the runway provides entrance to the lagoon for coastal waters.

The lagoon is shallow, with depths generally ranging from 1 to 5 feet. The area adjacent to the airport has been extensively dredged for fill material, leaving a series of borrow pits up to 10 feet deep in that area. Bottom substrate is organic mud, gradually shifting to silty sand from the north to south shores. Overlying waters are generally turbid, and turbidity levels appear to vary with rainfall and tidal magnitude. Turbidity tends to be

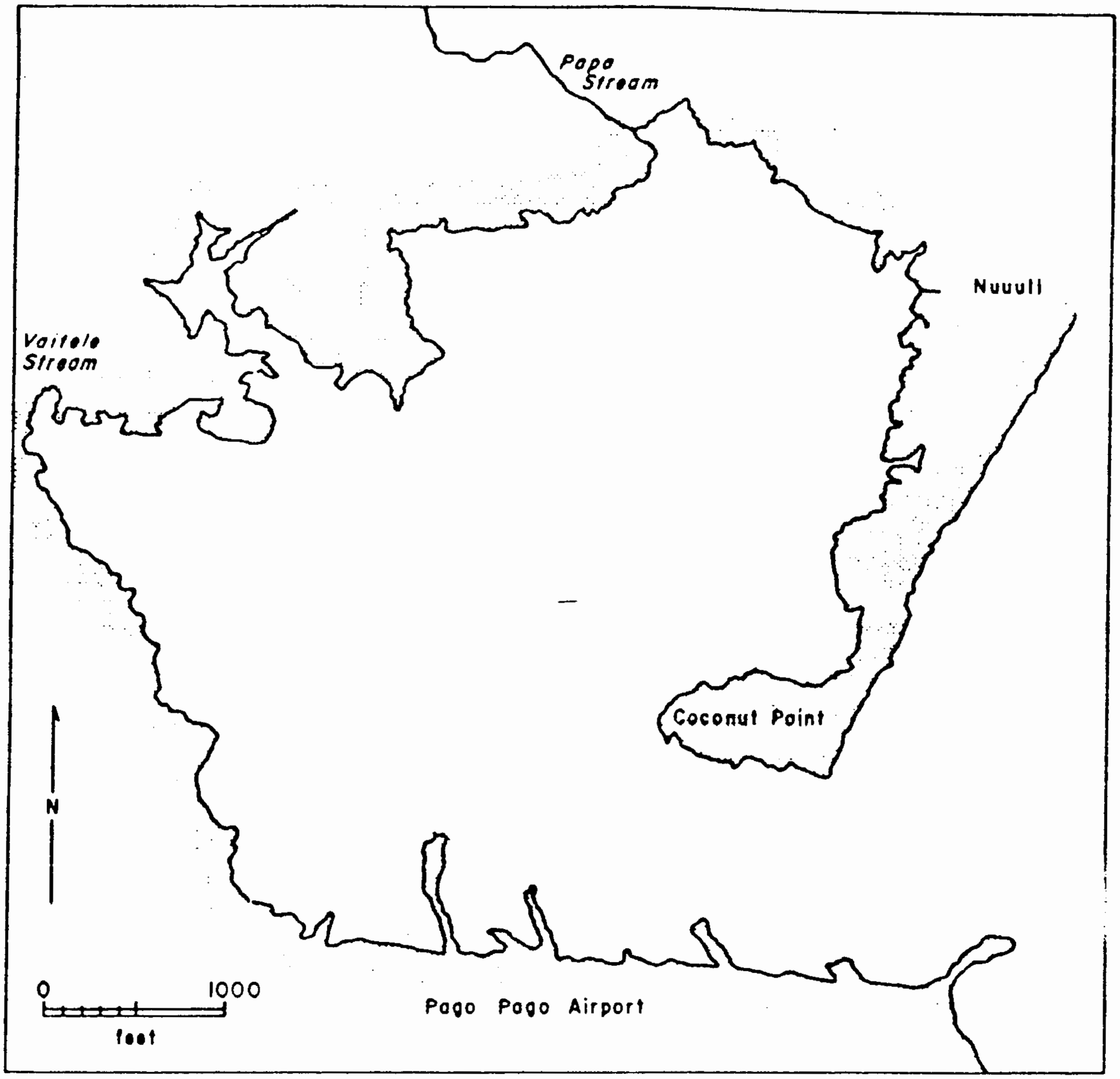

Figure 1. The study area for a 1-year survey to determine catch and effort levels for the subsistence fishery in Pala Lagoon in American Samoa.

higher along the north shoreline, with waters gradually becoming clearer toward the mouth of the lagoon.

Much of the fishing effort originated from Lion's Park, a public access point to the lagoon. Additionally, people entered the lagoon via private land with permission from the landowner. Although the rubble-fill shoreline along the airport taxiway was fenced off and posted with a no trespassing sign, the warnings were largely ignored. People walked around the fence to fish that stretch of the study area or to gain access to the reef front beyond the study area. On rare occasions, airport personnel drove out along the taxiway to evict people from the posted area.

METHODS

To estimate the amount of fishing effort and resultant catch for Pala Lagoon, data were collected over a 1-year period, January to December 1991. The study was designed was to systematically subsample the total time in the year, and to expand this subsample estimate the entire year's catch and effort.

Field Sampling

Sampling was conducted in 8-hr shifts which were stratified to sample the 24-hour-a-day, 7-day-a-week fishery. Typically, two sampling shifts were scheduled per week, during which a census was made of all fishing and swimming activity within the study area. At the beginning of a shift, a thorough search of the study area for fishing trips in progress and for passive gear such as gill nets and crab pots was conducted. After that, the lagoon was monitored from a vantage point at the south end of Lion's Park from which most of the lagoon could seen. The lagoon was circumnavigated by kayak once every 1 to 2 hours to account for activity in areas which were hard to see from there.

As each trip began, the start time, fishing method employed, number of gear units (e.g. number fishing rods, throw nets, number and length of gillnets etc.), number of people, and location within the study area were recorded. End times were recorded as each fishing trip was completed. Only the portion of the trip which occurred during the sampling shift was recorded for trips that were in progress at the onset and/or end of the shift.

As the study was monitored for the movement of fishing parties into and out of the lagoon, catch data were gathered from as many of the fishing parties as was physically possible, which ranged from 50 to 100% of the activity occurring during the shift. Ideally, interviews were conducted as the trip ended so that it would represent the entire extent of the fishing effort. However, some interviews were conducted while the trip was in progress to maximize the number of interviews conducted. In such a case, the fishing party was sampled as far into the trip as possible, and no interviews were conducted on trips that were shorter than half an hour.

Data recorded for each catch interview included start time, interview time and elapsed fishing time for the trip, fishing method, gear units, number of people by age and sex category (male adult, female adult, male child, female child), location within the study area, home village of the participants, and whether the catch was to be sold or kept. The catch was then sorted by species or species group, and weighed on a spring scale to the nearest ounce. Occasionally, a fishing party was sampled that could not wait for the catch to be sorted by species. Rather than discarding those data, the catch was weighed in aggregate and recorded as mixed fish.

Data Analysis

To clarify some of the analysis procedures, it is necessary to first introduce some of the assumptions, conventions and units of measurement used in the analysis. It has been observed that levels of fishing effort differ between day and night, and between weekends and weekdays (Wass 1980, Ponwith 1991). To allow comparisons to be made among these temporal groupings, data were stratified into four time periods, hereafter referred to as time strata: weekday day (Sunday-Friday 0600-1800), weekday night (Sunday-Thursday 1800-0600), weekend day (Saturday and non-religious holidays 0600-1800), and weekend nights (Friday, Saturday and non-religious holidays 1800-0600). Sundays were treated as weekdays because effort levels more closely resembled that of a weekday than a Saturday. Total estimates for catch and effort are therefore the sum of the weighted estimates for each strata.

Fishing methods used in Pala Lagoon were split into two categories: 1) active methods, where the participant worked the gear throughout the extent of the trip (rod and reel, bamboo pole, handline, clamming, diving, throw net, active gill net and crab lift net) and 2) passive methods, where the gear was set, left to fish for a period of time and then collected (gill net and crab pot).

Effort was expressed as lb/gear-hour, which differs from the more commonly used unit of lb/person-hour. In Samoa, it is common for a fishing party to include people who are not actively harvesting fish. For example, one person may fish with a throw net or rod and reel while another merely holds the bag containing the catch. In such a case the lb/gear-hour unit more closely describes the fishing power for that trip than pounds per person-hour.

One exception was made in the case of active gill net fishing. In this method, a gill net is set in a deep semi-circle and a number of people approach the open side of the semi-circle while flailing the water with palm fronds, sticks, or their arms, in an attempt to drive fish into the net. While the length of the net may have had some influence on the catch rate for this method, it seemed that the number of people pounding the water in front of the net had a greater influence. Therefore, effort for this method was expressed in terms of the number of people participating, i.e. lb/person-hour. Because the length of the net greatly influenced catch levels, passive gill net effort was expressed as lb/100 foot-hour.

Clamming was a popular harvest method used to collect two species of clams from two different areas in the lagoon. Rather than risk sampling the two types of clamming disproportionately (which would bias the species composition of the catch) clamming was split into two fishing methods based on the target species.

Four main steps were required to expand the sample data to represent the entire fishery: 1) participation expansion, 2) CPUE calculation, 3) catch expansion, and 4) species composition calculation. The first step was to expand the participation data to represent all hours in the year-long study period. To accomplish this, the total amount of participation observed was first divided by the number of hours of observation to calculate the mean amount of effort per hour for each of the four time strata by fishing method. The expansion was made by multiplying these mean values by the respective total number of hours within each of the time strata in the entire year. Recreational swimming was treated as method so observed person-hours of swimming could also be expanded to an annual estimate.

A preliminary analysis of participation data after 6 months of data collection showed that very little fishing effort took place on weeknights after 2200 hours. A decision was made to shift sampling effort away from that time period to increase sampling efficiency. Effort estimates for the period between 2200 and 0600 hours on weekday nights were made by multiplying the mean amount of effort per hour based on the data from the first six months by the total number of hours between those times in the entire year.

Next, CPUE values were calculated for each method by two time strata, day and night. Separate CPUE values for weekday and weekend time periods were not calculated because an assumption was made that CPUE was the same on weekdays as on weekends. The sum of the number of pounds caught was divided by the sum of the effort for each fishing method to give a mean CPUE value for each method by day and by night.

In the third step, catch expansions were produced by multiplying the expanded effort values by their respective CPUE values to get expanded pounds landed.

The last step was to break the expanded catch down into species composition estimates. Percent contribution for each species or species group in the observed catch was calculated for each fishing method by day and by night. The observed proportions were then expanded by multiplying them by the expanded catch for each strata.

Similar expansions of the raw data for the sociological data collected were not made because it would have resulted in an unwieldy number of strata. However, since interviews were collected randomly, the raw (unexpanded) data should be a fair representation of the fishing population. From the raw data, the age and sex composition of the participants, percent of the catch sold, and percent of the participants from villages adjacent to the Pala Lagoon were calculated.

RESULTS

Fishery Profile

A variety of fish and invertebrate species were harvested from the Pala Lagoon using several different fishing methods, which often were used in distinct areas of the lagoon (Fig. 2). Three hook-and-line methods were used (rod and reel, handline, and bamboo pole) to catch fish along the lagoon shoreline, primarily along Lion's Park, the runway and at the tip of Coconut Point. The rare fishing party that fished from a boat, fished the area between the runway and Coconut Point almost exclusively.

Clamming was a popular fishing method. In virtually all cases, the target species was either tugane (Gafrarium timidum) or pipi (Asaphis deflorata). Clamming for tugane took place primarily in the muddy substrate along the north shore of the lagoon but also along the northern end of Coconut Point in both sand and mud substrates. Clam were harvested from exposed sandy areas by probing suspected syphon holes with a knife. The mud, being too soft to show the syphon marks of the clams, was searched for clams with bare feet. Most clams were harvested while the mud was exposed at low tide, although some people preferred to avoid the difficult walk through the mud by clamming at mid to high tide. Their strategy was to float above the clam beds while feeling for the clams with bare feet and reaching down to collect them once located.

Size measurements were not taken on individual clams. However, when time allowed, both the count and weight of the catches were recorded, allowing for a rough estimate of average weight to be made. On the average, tugane ran 11 clams to the pound, including shell weight.

Clamming for pipi took place mainly at low tide in sandy areas along the south end of Lions Park and along the runway. A tool,

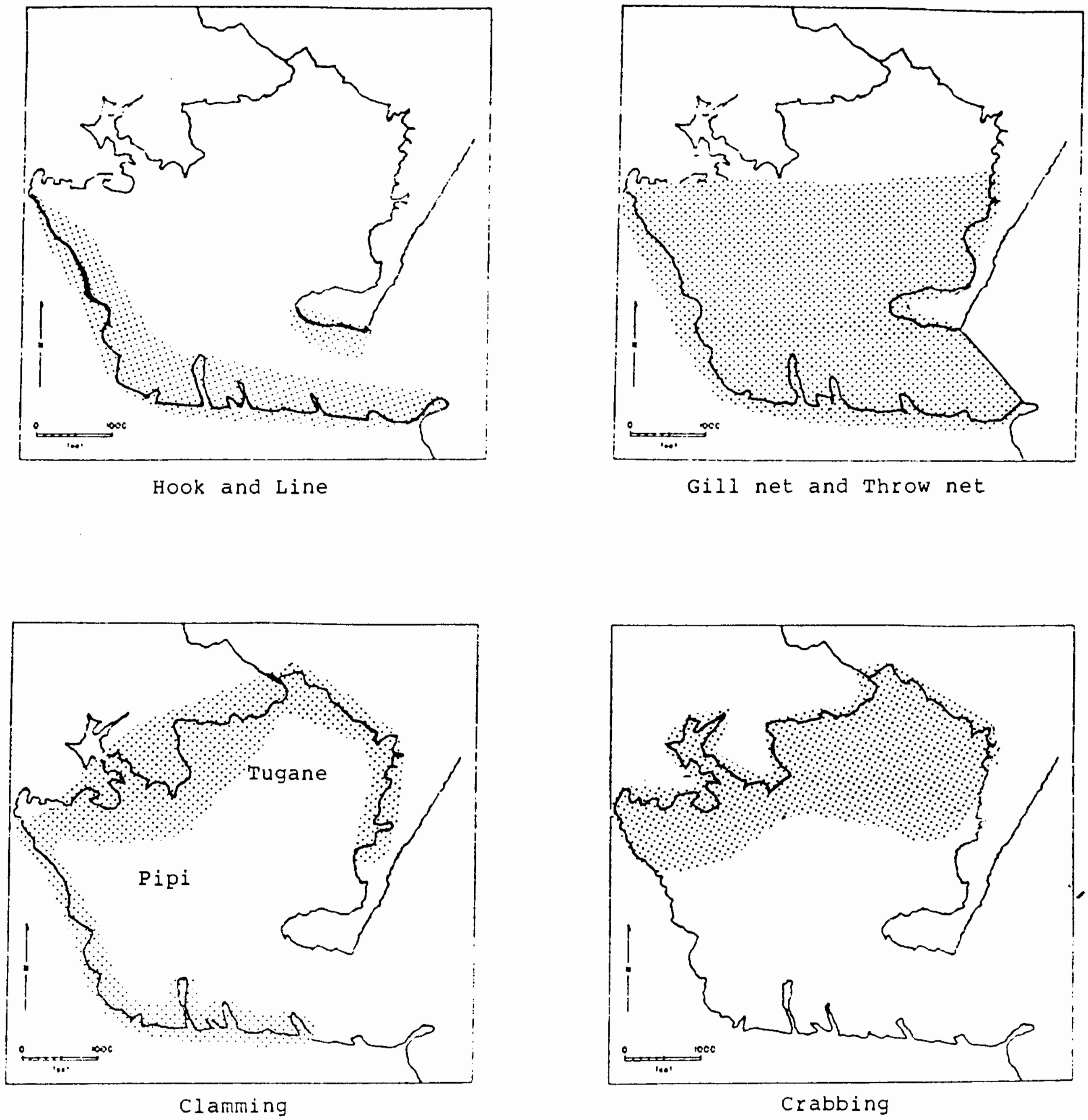

Figure 2. Areas of concentrated effort for different fishing methods in Pala Lagoon.

usually a knife, stick, or screw driver, was used to dig into the sand to expose the clams which were buried in 2 to 12 inches of sand. As was done for tugane, counts and weights were recorded when time allowed. Pipi ran 13 clams to the pound, including shells.

Three fishing methods involved the use of nets. Gill nets ranging from 50 to 300 feet in length, with stretched mesh ranging from 1.5 to 4.5 inches, were used in one of two ways. The more conventional use was as passive gear, where the net was set by anchoring it to the bottom and then checked intermittently for fish. This method was used throughout the lagoon. Gill nets were also used as active gear as was described earlier. The number of people in an active gill net fishing party ranged from 3 to 8 and these groups would cover large areas of the lagoon, moving to a new area for each set.

The other net method, throw netting, employed a circular net ranging from 5 to 8 feet in diameter, which was weighted around the perimeter and had a mesh size of 0.5 to 3 inches. The net was thrown out and then retrieved by a line secured at its center. Most throw netting was done from the shoreline around the perimeter of the study area although some individuals waded or boated into the center of the lagoon to fish that area as well.

Because of the lagoon's turbidity, only a limited amount of spear diving was observed within the study area. Divers were generally equipped with swimming goggles as eye protection and either a 3-pronged spear or a steel rod with which to spear fish. All of the dive activity was observed in the area between the runway and the end of Coconut Point where the water was clearer and coral cover was higher than in the inner region.

Two methods were used to harvest mangrove crabs from the lagoon. Crab pots, made from rat wire which was sewn in the shape of a pillow ranging from 2x1 ft to 3x2 ft in size, were used as passive gear (i.e., deployed and retrieved later). These were baited with partially decayed crabs hung in a corner of the trap. Crabs gained entrance through a hole, roughly 6 inches square, in the top panel of the pot. A collar around the hole, which extended nearly to the bottom panel of the pot enhanced retention of the crabs once they entered the pot, and a length of line extending from the pot to a small float served as a means of relocating the pot once deployed.

Crab pots were deployed using paopaos (outrigger canoes), several of which were va'a apa (boats made from a sheet of tin roofing material folded in half lengthwise and sealed at the ends with lengths of 2x4 lumber and tar, to which an outrigger was attached). The number of individuals who participated in crab pot fishing throughout the year ranged from 2 to 6. The number of pots used by a fisherman depended on the size of his pots and boat. The number of pots fished ranged from 4 to 13, with 10 being about the average.

The north shore area along the margin of the mangrove stands was fished the heaviest for crabs, but pots were deployed in the open water offshore of the mangroves as well. Generally, pots were checked between 0600 and 0700 and were pulled if they needed fresh bait. Pots were redeployed anywhere from 1400 to 1800 depending on the tide.

Active crab fishing also employed handmade lift nets quite different in design from the passive gear. Purse seine netting was attached to the perimeter of metal band approximately 1 ft in diameter and 4 in high so the netting hung like a basket below the band. A 3 to 5 ft stick was suspended just above the level of the lower edge of the band by heavy gauge wire which was secured to the top of the band. At the lower end of the stick, a bait bag made of screen material and containing small, partially decayed crabs was hung.

Crab fishermen loaded anywhere from 5 to 12 of these lift nets onto a paopao and deployed them within and along the edges of the mangrove stands. The fisherman then paddled among the lift nets, watching for movement at the top of the stick, an indication that a crab was tugging at the bait on the lower end. When motion was observed, the fisherman paddled to the net and lifted it abruptly from the water, causing the crab to drop into the basket below the level of the metal band. The crab was then dumped into the boat and the claws tied to its body with strands of inner tube rubber.

Catch, Effort and CPUE

Estimates of catch, effort and CPUE were based on 565 hours of observation which equates to 6% of all hours in the 1-year study. Sampling rates among the time strata ranged from 3% for weekday nights to 15% for weekend days. At total of 207 catch interviews were conducted which represented 849 gear-hours of active fishing effort, 3999 pot-hours of crab pot effort and 1220 100'-hours of passive gill net effort.

The 1991 annual harvest of fish and shellfish from Pala Lagoon was 23,800 lb without clam shells (Table 1) or 33,900 lb with the shells. Fish weights are expressed as whole fish. Clam shell weights were not weighed, but assumed to be 0.7 of the tugane total weight and 0.5 of the pipi weight. Hereafter, all bivalve shell weights will be excluded from all totals unless otherwise noted.

Catch and effort levels varied among the different fishing methods. The passive gill netting method had the highest contribution to total catch (Fig. 3), and the combined contribution of the two gill net methods, active and passive was 39% of the total catch. Clamming had the second highest contribution to catch, followed by throw net, crab pot, active gill net methods. Very little diving

Table 1. Catch and effort by method in the Pala Lagoon during 1991.

FISHING METHOD	CATCH (lb)	EFFORT ACTIVE (gear-hrs)	EFFORT PASSIVE (as noted)
Gill net	6,665		35,572 (100 ft-hrs)
Clamming	5,448	5,784	
Throw net	3,931	1,944	
Crab pot	2,998		198,566 (pot-hours)
Active gill net	2,625	2,545	
Rod and reel	1,298	4,328	
Handline	598	2,628	
Active crab pot	149	1,584	
Bamboo pole	64	155	
Diving	0	146	
GRAND TOTAL	23,776	19,116	(units not additive)

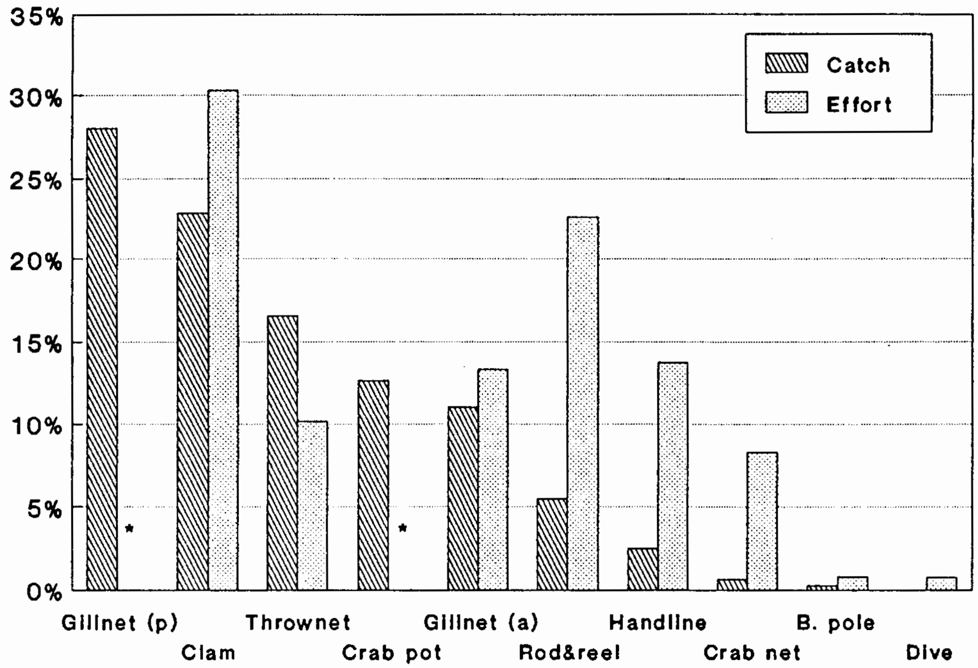

Figure 3. Contribution to total catch and effort for each fishing method used in the Pala Lagoon in 1991. The clam catch does not include the weight of the clam shells. Effort for passive gill net (35,572 ft-hours) and crab pots (198,556 pot-hours) are not shown because they are not directly comparable.

effort took place (146 gear-hours) during the year, and the expanded catch for that effort was zero, since the divers sampled had no catch.

Fishing effort was not evenly distributed among the four time strata:

TIME STRATA	PERCENT OF TOTAL TIME IN A WEEK	PERCENT OF TOTAL EFFORT EXPENDED IN A WEEK
Weekday day	43	56
Weekday night	36	13
Weekend day	7	23
Weekend night	14	8
TOTAL	100	100

The weekend day time strata was the hardest fished -- this strata accounts for only 7% of the total hours available in a week but 23% of the total fishing effort expended in a week.

CPUE varied greatly among the various fishing methods (Table 2). Only three methods, throw net and active gill net, and clamming caught a pound or more per gear-hour.

Species Composition

In total, 45 species or species groups were represented in the catch in Pala Lagoon (Table 3). Fish contributed 62% to the total catch of fish and invertebrates combined. Fish from the family mugilidae (mullets) comprised the greatest portion of the fish catch (18%), and carangids (jacks) were the only other species group that contributed greater than 10% to the total fish catch (Table 4). The fish catch was spread among numerous species with no major contributor (Table 3). Of the fish that were identified to species, the bluespot mullet (Valamugil seheli) was the only species to contribute more than 10% to the total fish catch.

Invertebrates, mainly clams and crabs, comprised 38% of the total catch (Table 3). Tugane (Gafrarium timidum) dominated the invertebrate catch, accounting for 51% of the total harvest.

Sociological Information

Sociological data were collected along with catch data for each interview taken to provide information on the people who fish in the Pala Lagoon. As stated in 'Methods', catch and effort data were not expanded on the basis of the sociological information, so all analyses were conducted on raw (unexpanded) data.

Table 2. CPUE by day and night for each fishing method used in the Pala Lagoon, 1991.

METHOD	CPUE (lb/gear-hour) 24 hr	DAY	NIGHT
Throw net	2.0	2.0	-
Gill net[a]	1.1	1.1	-
Clamming	0.9	0.9	-
Rod and reel	0.3	0.3	0.2
Bamboo pole	0.4	0.2	1.0
Handline	0.2	0.2	0.3
Gill net[b]	0.2	0.2	0.2
Crab lift net	0.1	0.1	-
Crab pot	0.02	0.006	0.02

DAY = 0600-1800
NIGHT = 1800-0600
[a] lb/person-hour
[b] lb/100' hour

Table 3. Catch and percent composition of fish and invertibrates (excluding shell weights of bivalves) for the Pala Lagoon fishery during 1991.

FISH NAMES SAMOAN	COMMON	SCIENTIFIC	CATCH (lbs)	PERCENT FISH CATCH	PERCENT TOTAL CATCH
Lupo, ulula	Jacks	*Caranx sp.*	2349	16	10
Anae	Bluespot mullet	*Valamugil seheli*	1926	13	8
Anae	Giantscale mullet	*Liza melinoptera*	1191	8	5
Ganue	Rudderfish	*Kyphosus sp.*	1160	8	5
Anae	General mullet	Mugilidae	987	7	4
Mata'ele'ele	Blackspot emperor	*Lethrinus harak*	980	7	4
Anae	Engel's mullet	*Valamugil engeli*	872	6	4
Ga	Striped mackeral	*Rastrelliger kanagurta*	468	3	2
Mumu	Ponyfish	*Leiognathus equula*	424	3	2
Apeape	Blacktip reef shark	*Carcharhinus melanopterus*	325	2	1
'Ava 'ava	Terapon perch	*Terapon jarbua*	297	2	1
Lai	Leatherback	*Scomberoides lysan*	287	2	1
Sapatu	Barracuda	*Sphyraena barracuda*	280	2	1
Anae	Yellowtail mullet	*Liza vaigiensis*	279	2	1
Mata'ele'ele	Unknown emperor	*Lethrinus sp.*	267	2	1
I'asina	Yellowfin goatfish	*Mulloides vanicolensis*	261	2	1
Ga	Mackeral	*Rastrelliger brachysoma*	226	2	1
Ta'uleia	Indian goatfish	*Parupeneus indicus*	224	2	1
Gataia	Honeycomb grouper	*Epinephelus merra*	218	1	1
Palagi	Yellowfin surgeonfish	*Acanthurus xanthopterus*	208	1	1
Ula'oa	Blackstriped goatfish	*Upeneus vittatus*	176	1	1
Manini	Convict tang	*Acanthurus triostegus*	171	1	1
Tamala	Flametail snapper	*Lutjanus fulvus*	143	1	1
Lo	Scribbled rabbitfish	*Siganus spinus*	140	1	1
Tusia	Dot-and-dash goatfish	*Parupeneus bifasciatus*	101	1	1
Sumu-uo'uo	Picassofish	*Rhinecanthus aculeatus*	98	1	<1
I'asina	Yellowstripe goatfish	*Mulloides flavolineatus*	97	1	<1
Nofu	Flasher scorpionfish	*Scorpaenopsis macrochir*	97	1	<1
Ise	Needlefish	*Strongylura incisa*	79	1	<1
Matu	Common mojarra	*Gerrus argyreus*	70	<1	<1
Malau	General Squirrelfish	Holocentridae	67	<1	<1
Avali'i	Milkfish	*Chanos chanos*	55	<1	<1
Apoa	Eel catfish	*Plotosus anquilaris*	40	<1	<1
Matulau	Multibarred goatfish	*Parupeneus multifasciatus*	29	<1	<1
Malau	Squirrelfish	*Sargocentron sp.*	19	<1	<1
Matu	General mojarra	*Gerrus sp.*	13	<1	<1
Atule	Bigeye scad	*Selar crumenophthalmus*	11	<1	<1
Sugale	Wrass	*Cheilinus sp.*	8	<1	<1
Fuga	Parrotfish	Scaridae	8	<1	<1
Malau	Bronze soldierfish	*Myripristis adustus*	6	<1	<1
Ali	Peacock flounder	*Bothus mancus*	6	<1	<1
Sumu-aimaunu	Orangestriped trigger	*Balastapus undulatus*	4	<1	<1
Pelupelu	Herring	Clupeidae	4	<1	<1
Matu	Oblong mojarra	*Gerrus oblongus*	2	<1	<1
Pusi	Morray eel	*Gymnothorax sp.*	2	<1	<1
TOTAL FISH			14676	100	62

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Table 3 cont.

INVERTEBRATE NAMES					
SAMOAN	COMMON	SCIENTIFIC	CATCH (lbs)	PERCENT INVERT. CATCH	PERCENT TOTAL CATCH
Tugane	Mud clam	*Gafrarium timidum*	4638	51	19
Pa'a le mago	Magrove crab	*Scylla serrata*	3421	38	14
Pipi	Clam	*Asaphis deflorata*	837	9	4
Sisi	Nerita	*Nerita sp.*	72	<1	<1
Loli	Sea cucumber	Holothuridae	76	<1	<1
Pa'a	Unknown crab		33	<1	<1
Valo	Mantis shrimp	*Lysiosquilla maculata*	23	1	<1
TOTAL INVERTEBRATES			9012	100	38
GRAND TOTAL			23776		100

Table 4. Composition of fish and invertebrate harvest (shell weight of bivalves excluded) in Pala Lagoon during 1991.

FISH	CATCH (lbs)	PERCENT OF FISH CATCH	PERCENT OF TOTAL CATCH
Mugilidae (mullet)	5255	36	22
Carangidae (jacks)	2647	18	11
Lethirinidae (emporers)	1247	8	5
Kyphosidae (rudderfish)	1160	8	5
Mullidae (goatfish)	888	6	4
Scombridae (mackeral)	694	5	3
Leiognathidae (ponyfish)	424	3	2
Acanthuridae (surgeonfish)	379	3	2
Carcharhinidae (requiem sharks)	325	2	1
Teraponidae (terapon perch)	297	2	1
Sphyraenidae (barracudas)	280	2	1
Serranidae (groupers)	216	1	1
Lutjanidae (snappers)	143	1	1
Siganidae (rabbitfish)	140	1	1
Balistidae (triggerfish)	102	1	<1
Holocentridae (soldierfish)	82	1	<1
Other	385	3	2
Total Fish	14676	100	62

INVERTEBRATES	CATCH (lbs)	PERCENT OF INVERTEBRATE CATCH	PERCENT OF TOTAL CATCH
Bivalves (meat only)	5475	61	23
Crabs	3477	38	14
Gastropods	72	1	<1
Holothurians	76	<1	<1
Total Invertebrates	9012	100	38
GRAND TOTAL	23776		100

An overall majority of the fish and invertebrates harvested were caught by people from the two villages adjacent to the lagoon (Nu'uuli and Tafuna) who intended to keep their catch rather than sell it. The percentage of the catch that was sold varied among fishing methods (Table 5).

Each of the three methods that had 100% of their catch landed by local villagers (tugane clamming, and crabbing) were ones where the prime fishing areas were adjacent to private property, i.e. the mangrove-lined north shore and Coconut Point. People using the other methods fished in those areas as well, but were not as restricted to them by the distribution of their desired species.

The proportion of the total catch by method intended for personal use ranged from 8% to 100%. The crab pot fishing method is clearly a commercial enterprise. While they may have occasionally kept crabs for home consumption, no trip was sampled during the study period which was purely recreational. Crabs were sold to restaurants and along the roadside at approximately $7.00/lb.

Clamming for pipi and tugane had the next highest proportions of the catch sold. Two women were responsible for a large portion of the commercial sale of pipi. They fished sandy shoreline nearly every day during the 2 to 3 hours at low tide. Commercial clamming for tugane was distributed among many individuals. In times past, clams were sold in woven baskets at a price of $1.00 per basket, which held an estimated 10 to 15 lb of clams in the shell (Glude 1972). The price quoted by present commercial clammers is $5.00 per "basket", but a basket is now a small plastic bag which holds an estimated 5 lb of clams in the shell.

Only two methods which harvest fish, active gill net and throw net, had a portion of their total catch sold. Nearshore fish were uniformly priced across all species and size groupings and were sold at an average price of $1.80/lb during the study period.

The age and sex of fishery participants varied among fishing the fishing methods (Fig. 4). Males dominated all fishing methods with the exception of clamming. Across all methods, 67% of the people encountered were males over 14 years of age, followed by females older than 14 years (17%), males 14 and younger (12%), and females 14 and younger (4%).

As an aside to the estimation of consumptive use in the Pala Lagoon, data were collected on the amount of recreational swimming activity which took place in the lagoon. A total of 2,501 person-hours were spent swimming during the 1-yr period, most of which took place along the sandy shoreline of Lion's Park.

Table 5. Percent of the people interviewed while fishing in Pala Lagoon who were 1) lived in one of the two villages adjacent to the lagoon, and 2) kept rather than sold their catch.

FISHING METHOD	PERCENT OF CATCH LANDED BY PEOPLE FROM NU'UULI AND TAFUNA	PERCENT OF CATCH KEPT RATHER THAN SOLD	SAMPLE SIZE
Clamming (tugane)	100	62	79
Crab lift nets	100	100	6
Crab pots (passive)	100	8	36
Throw net	97	94	27
Clamming (pipi)	93	78	45
Gill net (passive)	91	100	35
Rod and reel	88	100	61
Bamboo pole	67	100	3
Gill net (active)	50	93	53
Handline	45	100	33
TOTAL	92	75	387

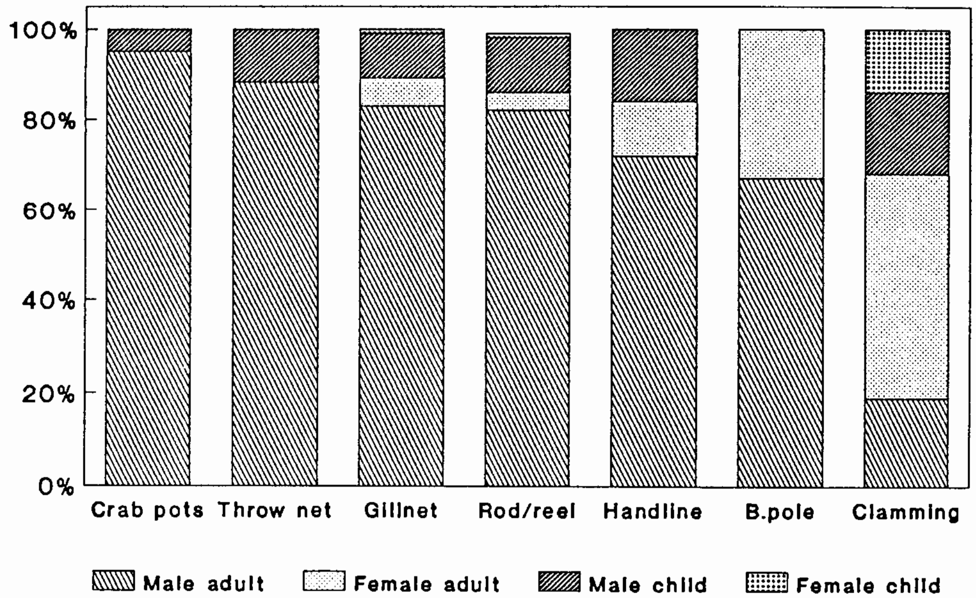

Figure 4. Age and sex composition of fishery participants by fishing method used in the Pala Lagoon in 1991. One hundred percent of the divers and lift net crabbers were adult males.

Past studies have shown high coliform counts in the lagoon and unconfirmed reports of hepatitis from the consumption of lagoon clams have been noted in (Helfrich et al. 1975, Yamasaki et al. 1985). During the present study, clammers were questioned on an informal basis to determine if they suffered any ill effects from eating raw clams. To avoid asking a leading question, individuals were asked what their favorite way of eating the clams was, raw or cooked. If they said cooked, they where then asked why, to determine if it was simply a taste preference or to avoid getting sick.

The eight individuals who harvested pipi had a preference for raw clams and none of them had ever become sick from eating clams. However, of the 20 people interviewed who were harvesting tugane, 15 preferred them cooked, and among them, 8 did so because they had become ill or feared they would become ill from eating the clams raw. All of these individuals cited pollution, especially from piggeries adjacent to the lagoon, as the reason the clams made them sick when eaten raw.

DISCUSSION

Prior to the present study and that by Knudsen (1992), there was little quantitative information on the fishery or fishery resources in Pala Lagoon available. However, comparisons of the results from this study with anecdotal information, historical literature, and with the shoreline fishery on the nearby reef habitat (Ponwith 1991) provide a means to examine changes or trends in the fishery.

Comparison with Historical Information

The only historical information available on the fishery in Pala Lagoon was based the results of a voluntary questionnaire sent out to 150 residents of the lagoon area in 1985 (Yamasaki et al. 1985). Unfortunately, the catch and effort estimates from that study are not directly comparable to those of this study due to the differences in methodology (questionnaire versus creel survey). The results compiled from the 28 responses to the 1985 survey showed that an average of 22 fishing trips per day were made by members of families who lived in villages adjacent to the lagoon. Presently, average of approximately 22 trips per day on weekends and 15 trips per day weekdays are made, but that includes both residents of the area and people from outside the area.

Some changes in species composition of the harvests could be detected by comparing the two studies. Of the species listed by Yamasaki et al. (1985) as having been important in the fishery in 1985, 5 were either missing or were extremely rare in the current catches. Jelly fish (Cassiopeia sp.) were commonly caught in 1985 none was seen or harvested in 1991. To verify this change, two local individuals were questioned regarding this Samoan delicacy. Both agreed that jelly fish had been harvested in great quantities in times past but that they were no longer present in any great abundance.

A major decline in the harvest of the sandworm (Sipunculus rotumanus) also occurred. No catches were sampled which contained the worm in 1991. Harvests of sandworms in Western Samoa have apparently also declined (L. Zann, pers. comm.).

A third species, the mantis shrimp, was extremely rare in the 1991 catch, but was formerly common in the lagoon (Helfrich 1975, Yamasaki 1985). Two other species, rays and silversides were previously present in unknown levels in 1985 catches, but were absent in the 1991 catch. However, rays were occasionally observed in the lagoon during the present study.

According to Yamasaki et al. (1985), the general impression of fishery participants in 1985 was that the fishery in the lagoon was in a state of decline. That is still true today. The consensus among present-day participants is that catch, CPUE and species diversity have declined from their earlier fishing days in the lagoon.

Comparison with Adjacent Coastal Reef

During approximately the same time period that this study was conducted, another similar study was conducted on the coastal coral reefs adjacent to Pala Lagoon (Ponwith 1991). It is therefore of interest to compare the harvests from the lagoon with that of the adjacent coral reefs. The shoreline fishery exploited reef fish and invertebrates from the reef flat and reef front zones of the narrow fringing reef which surrounds the island. The habitat differences between the two study areas were pronounced. The reef habitat was generally comprised of consolidated coral, coral rubble, sand and live coral substrate in very clear water with good flushing rates. On the other hand, lagoon habitat was characterized by organic mud and sandy substrates with a limited area of live coral, eutrophic waters with poor flushing rates and high temperatures.

The two fisheries shared some common features: 1) multiple methods were used to harvest an array of fish and invertebrate species, 2) both fisheries operated 24 hours a day, 7 days a week with fishing activity proportionally highest on weekends, 3) roughly 25% of the catch from both fisheries was sold, and 4) juvenile fishes were common in catches in both areas.

CPUE

There were some distinct differences between the two fisheries, most notably the difference in CPUE (Table 6). For most methods, CPUE in the mangrove lagoon habitat was at least an order of magnitude lower than of the nearby coral reef areas.

A factor which heavily influenced CPUE, which was based on the weight of the catch) was that much of the lagoon catch was comprised of juveniles. As is true of the shoreline fishery in American Samoa, people who harvested fish and invertebrates in Pala Lagoon were totally indiscriminant with respect to the size and species of fish retained. Not one case of a fish being returned to the water as undesirable with respect to size or species wasrecorded during the year-long study period, and only two cases of juvenile mud crabs (Scylla serrata) being thrown back were observed.

Species Diversity and Composition

Species diversity was lower in the lagoon catch than in the reef catch. Accounting as closely as possible for the number of species which were lumped into species groups in both the studies, approximately 55 species of fish were observed in the Pala Lagoon catch compared to roughly 110 species from the reef catch. Likewise, around 10 species of invertebrates were identified in the lagoon catch versus approximately 20 from the reef catch.

Catch composition by family was compared between the two areas. First, the seasonal migrant, atule (Selar crumenophthalmus), which accounted for 46% of the total fish catch from the reef area, was subtracted from the catch to allow the contribution of habitat-resident fish to be compared. The adjusted contributions showed mullet and jack species to be top contributors to both fisheries, accounting for 54% and 39% of the non-atule catch in the lagoon and reef areas, respectively (Table 7). The mullet family was the top contributor in the lagoon while carangids were top contributors on the reef.

Landings of acanthurids (surgeonfish), were notably lower in the lagoon (3% compared to 21%) as would be expected because acanthurids generally inhabit coral reef areas, and live coral is limited to the area near the mouth of the lagoon. The remaining catch was distributed among numerous other families, all of which contributed less than 10% to the total catch in either of the areas.

Table 6. Comparison of CPUE by fishing method for the fisheries in Pala Lagoon and on coral reef habitat between the villages of Lauli'ituai and Nu'uuli.

METHOD	CPUE (lb/gear-hour) PALA LAGOON	REEF AREAS
Throw net	2.0	4.4
Acive gill net	1.1[a]	-
Clamming	0.9	-
Bamboo pole	0.4	0.6
Gill net	0.4[b]	12.0[c]
Rod and reel	0.3	2.6
Handline	0.2	1.4
Crab lift net	0.1	-
Crab pot	0.02	-
Gleaning	-	1.7

[a] lb/person-hour
[b] lb/net hour (i.e. regardless of net length)
[c] primarily passive gill netting but includes some active gill netting

Table 7. Comparison of fish harvests (by family) in Pala Lagoon (this study) and in nearby coastal reef habitat (Ponwith 1991). Reef catches have been adjusted to exclude the catch of atule (Selar crumenthphalmus), a seasonal migrant in the reef area fishery which accounted for 46% of the catch there.

FAMILY	CONTRIBUTION (%) PALA LAGOON	REEF AREA
Mugilidae (mullet)	36	16
Carangidae (jacks)	18	23
Lethrinidae (emporers)	8	1
Kyphosidae (rudderfish)	8	1
Mullidae (goatfish)	6	2
Scombridae (mackeral, tuna)	5	3
Leiognathidae (ponyfish)	3	<1
Acanthuridae (surgeonfish)	3	21
Carcharhinidae (requiem sharks)	2	<1
Teraponidae (terapon perch)	2	<1
Sphyraenidae (barracudas)	2	2
Serranidae (groupers)	1	6
Lutjanidae (snappers)	1	3
Siganidae (rabbitfish)	1	1
Balistidae (triggerfish)	1	<1
Holocentridae (soldierfish)	1	4
Scaridae (parrotfish)	0	3
Pomacentridae (damselfish)	0	1
Other	3	13
TOTAL	100	100

Among the species landed from the lagoon, all but three were also found in the reef catch: mud crabs (Scylla serrata), mud clams (Gafrarium timidum), and mantis shrimp (Lysiosquilla maculata). Each of these species are to some extent reliant on the organic mud and sandy bottom substrate typical of the mangrove lagoon habitat for all or part of their life history (Prasad and Neelakantan 1989, Hyland et al. 1984, Brusca and Brusca 1990).

Yield

Another way to compare the shoreline fishery on reef habitats to the Pala Lagoon fishery is to convert the catch data to a catch per unit area value. For the purposes of comparison, the reef catch of atule was, again, excluded from this exercise to express the values in terms of habitat-resident species. The resulting yield for the reef areas studied is 76,000 lb/mile^2 compared to a yield of 24,000 lb/mile^2 in Pala Lagoon.

Importance and Value of the Fishery

With catch, CPUE, and yield being so much lower in the lagoon than that of the nearby reef area fishery, the question arises as to why people would choose to fish in Pala Lagoon rather than on the nearby reef. Three possible explanations to that question are based on conversations with people who fish in the lagoon. First, people who are residents of the area, especially those who live directly adjacent to the lagoon, fish there because that is their traditional fishing ground. Second, those who are not from the lagoon fish there because of the public access provided by Lion's Park. The third reason is a safety factor; the lagoon is not subject to the high surf and currents common to the reef flat areas, making it a safer place to fish for both the participants and their gear relative to the reef flats along the open ocean.

The value of the 1991 catch from Pala Lagoon was calculated by applying current market prices to the catch:

SPECIES GROUP	CATCH (lb)	PRICE/LB	VALUE
Clams (in shells)	15,513	1.00	$15,513
Fish	14,840	1.80	$26,712
Crab	3,405	7.00	$23,835
Misc.	132	1.80	$ 238
TOTAL	33,890		$66,290

The value of the catch, estimated at $66,000, does not include the less tangible values associated with a predominantly a subsistence/recreational fishery. The value of fishing as a means of providing protein for the family, as a traditional way of life, or as a recreational activity is an essential component when considering the overall importance the lagoon habitat and its fishery.

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