FINAL REPORT

STATE: U.S. Virgin Islands

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PROJECT TITLE: Recreational Fisheries Habitat Assessment

STUDY TITLE: **The determination of mangrove habitat for nursery ground of recreational fisheries in St. Croix.**

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Introduction

Fisheries resources in the U.S. Virgin Islands have markedly declined in the last decade. Studies conducted by Olsen and La Place (1978), Olsen et. al.(1983) and Wood and Olsen (1983), have shown that these resources were finite. Certain species were over harvested in the past while others were approaching the limits of their resource potential. The unregulated harvest of Nassau grouper spawning aggregations has resulted in the inability of this species to successfully reproduce and to replenish local fish stocks. Nassau grouper are now fisheries extinct. Declining numbers of red hind, also heavily fished during spawning aggregation time, have alerted fisheries managers to an eminent collapse of this fishery. The result has been the establishment of management plans to protect reef fish resources (CFMC, 1985 and 1993). However, a more recent assessment of the shallow water reef fish in the U.S. Caribbean (Appeldoorn, et. al., 1991) shows further declining trends of inshore fisheries resources. The steady decline of fisheries resources cannot be attributed to overfishing alone. Unregulated development of upland and coastal areas have resulted in increased sedimentation rates and the introduction of pollutants which have degraded the water quality of coastal environs (Saenger and McIvor, 1979).

Mangrove ecosystems develop in low-lying coastal embayments and are uniquely tolerant to high saline conditions. Mangrove ecosystems are extremely productive and support a high diversity of fish, birds and wildlife (Rodgers and Teytaud, 1983; UNESCO, 1983). Mangrove lagoons are important habitat for juveniles of many fish species (Heald and Odum; 1970; Austin, 1971; Austin and Austin, 1971a and 1971b; Cintron-Molero, 1987; Thayer et. al., 1987; Boulon, 1992) and can provide nursery areas for estuarine as well as reef fishes (Odum et. al., 1982; Boulon, 1985 and 1992). Many juveniles use detritus and mangrove-associated invertebrates and fish as a food source (Zieman et. al., 1984: Thayer et. al., 1987). The complex prop-root habitat may also provide protection from predation (Orth et. al., 1984; Sogard and Olla, 1993). In addition to providing important habitat, mangroves filter terrigenous sediment and help maintain the integrity of the lagoon seagrass habitat (Cintron-Molero, 1987), also an important nursery area (Dennis, 1992).

Of particular concern to fisheries mangers are economically important species, such as those targeted by recreational and commercial fishermen. The utilization of mangrove habitats by these economical species and their prey species is important (Robertson and Duke, 1987). The documentation of mangroves as nursery areas for recreationally and commercially valuable species, and their prey species, provides impetus for including mangrove habitats in fisheries management plans.

Mangrove habitat in the U.S. Virgin Islands has been severely impacted by shoreline development for marine-related activities (i.e., marinas and commercial ports). On St. Croix, the largest mangrove estuary system in the U.S. Virgin Islands, consisting of more than 700 acres of wetlands, was destroyed in the 1960's with the development of an industrial complex, consisting of an oil refinery, an alumina plant and a commercial port facility. Impacts by natural disasters (i.e., hurricanes) have been severe in recent years.

Mangrove habitat in the U.S. Virgin Islands is primarily mangrove fringe along lagoons and oceanic bays (Boulon, 1992). On St. Croix, the southern-most of the U.S. Virgin Islands, the fringing mangroves (red mangrove - *Rhizophora mangle*) have a well developed, permanently submerged prop-root system that provides potential nursery habitat. Three prominent mangrove systems remain on St. Croix: Salt River, Altona Lagoon and Great Pond.

This study was designed to determine the areal distribution of red mangrove nursery habitat on St. Croix and characterize it on the basis of environmental condition, to determine quantitatively the species composition and abundance of recreationally important fish species occurring in the mangrove fringe habitat, to identify immediate and long-term threats to the existing habitat, to estimate their potential impact on recreational fisheries and to suggest possible mitigation measures. This report presents the results of studies conducted in Salt River and Altona Lagoon. Great Pond is currently under investigation and will not be covered in this report.

Methods

Site Description

Salt River estuary is a red mangrove-fringed lagoon on the north coast of St. Croix, separated from the open ocean by shallow seagrass beds and a fringing coral reef. Salt River is adjacent to deep ocean waters in that it lies at the head of Salt River Canyon. The shallow (<5 m) estuary is composed of an outer bay (Salt River Bay) and two parallel inner bays (Triton Bay to the east and Sugar Bay to the west) (Figure 1). The majority of the fringing red mangrove habitat is along the shorelines of the inner bays, with only limited growth on the western shore of the outer embayment. The Salt River watershed, the second largest on St. Croix, drains an area of approximately 2,880 acres, predominately into the southern extremity of Sugar Bay (Island Resources Foundation, 1993). Past development activities include extensive dredging and filling on both sides of bay between 1968 and 1975. Salt River Marina is located in the western arm of Sugar Bay and residential homes are found on adjacent upland slopes.

Altona lagoon is an enclosed mangrove lagoon on the northeast coast of St. Croix. Formerly an open estuary, the gradual deposition of calcium carbonate sands of biogenic origin over geologic time have formed a baymouth bar to the north, connecting rocky headlands and separating the lagoon from the Caribbean Sea. The lagoon is connected to the Christiansted Harbor backreef area by a single narrow channel <10 m wide. To provide ingress and egress to Fort Louis Augusta and beaches to the north, the Department of Public Works installed three 1.8 m diameter culverts at the Altona Lagoon channel entrance into Christiansted Harbor and added a paved road. Sand buildup in the three culverts further restricts water exchange in Altona Lagoon. Maximum depth of the lagoon is 3.5 m. Red mangroves cover the entire shoreline of the lagoon.

The lagoon has been impacted by past dredge and fill activities in Christiansted Harbor. Previously open to Christiansted Harbor, the mangrove-lined western border of Altona Lagoon was filled with dredge spoil to create fast land in the early 1960's. Development on adjacent properties includes a moderately traveled dirt road on the northern edge of the lagoon, a hotel (The Buccaneer Hotel) and golf course to the east of the lagoon, and a public boat access facility on the western edge of the lagoon (adjacent to the channel entrance). Recreational fishing is conducted in Altona Lagoon, Altona Lagoon channel and the shoreline where the channel enters Christiansted Harbor. Residential developments are found in the upland watershed, which is comprised of approximately 152 acres (BC&E/ CH2M Hill, 1979).

Mangrove Habitat Distribution

The location and distribution of red mangroves fringing the shorelines of Salt River and Altona Lagoon were determined with the aid of National Oceanic and Atmospheric Administration (NOAA) aerial photos taken in February and September 1989. Site surveys were conducted to ground truth red mangrove presence and establish sampling station locations for fish traps and visual transects. More recent ortho-photos, taken by the Army Corps of Engineers in February 1994, were used to estimate the percent coverage of mangrove shoreline (linear) in recovery from the impacts of Hurricane Hugo (September 17-18, 1989). Available qualitative and quantitative information was obtained on benthic communities in Salt River and water quality from previous studies in Salt River and Altona Lagoon to determine the overall health of each wetland community. Due to the lack of available information on benthic communities in Altona Lagoon, an independent quantitative assessment was required.

Field Sampling

The mangrove prop-root habitat of Salt River and Altona Lagoon was sampled monthly with standardized fish traps and visual transects. For Salt River, data were analyzed for a 25-month period from March 1991 to April 1993, following a five-month pilot study. For Altona Lagoon, data were analyzed for a 23-month period from October 1993 - September 1995, following a four-month pilot study.

The red mangrove shoreline was partitioned into sampling sites based on the extent of mangrove cover, human impact, water turbidity and water depth. In Salt River, the turbid shorelines of Triton Bay and Sugar Bay were sampled with standardized baited fish traps. Each bay was divided into two sites, resulting in four total trap sampling sites (Figure 1). Triton bay East and Sugar Bay East have undeveloped, extensively-covered mangrove shorelines, while Triton Bay West and Sugar Bay West are partially impacted by development and have reduced mangrove cover. In Altona Lagoon, red mangroves completely fringed the shoreline. Two fish trap sampling sites were identified along the south shoreline and one each along the east and north shorelines (Figure 2).

Twelve standardized rectangular fish traps, 92 cm x 57 cm x 19 cm, made from vinyl-coated 1.3 cm wire mesh, were baited with herring and set at 50-m intervals along the mangrove fringe.

Each site was sampled over a twenty-four hour period and all four sites were sampled within a five-day sampling interval. All fish caught in the traps were identified, enumerated, measured (fork length and total length) and returned to the capture site.

A quantitative assessment of fish populations was conducted monthly along 100 m x 3 m visual transects in Salt River and Altona Lagoon. All transects were conducted by swimming with snorkel gear along the edge of the red mangrove prop-root habitat and looking into the prop-root system. Two individuals snorkeled each transect, resulting in two samples per transect per month. All transects were completed on a single day within the five day trap-sampling period. All fish species and number of adults and juveniles of each species were recorded for each transect. In Salt River, an undeveloped shoreline of narrow fringing red mangrove along an outer embayment on the west side of Salt River Bay was sampled monthly with four 100 m x 3 m visual transects. A fifth 100 m x 3 m visual transect was located along another section of narrow fringing red mangroves in an outer section of Triton Bay West (Figure 1). In Altona Lagoon, the two shoreline trap sampling areas closest to the lagoon entrance channel (outer bay and inner bay) were sampled monthly with four 100 m x 3 m visual transects in each shoreline section (Figure 2). As in Salt River, visual transects were conducted by swimming with snorkel gear along the edge of the red mangrove prop-root habitat and looking into the prop-root system.

A quantitative assessment of the benthic community in Altona Lagoon was conducted on 18 November 1993 along three 100-m transects, one each in the two trap sampling areas closest to the lagoon entrance in which fish populations were also assessed (Outer Bay and Inner Bay) and one in the middle of the lagoon (Figure 2). Visual estimations of percent cover of benthic organisms within one-meter square quadrats, placed at 10-m intervals along the transect, were made by two individuals with snorkel gear, resulting in two replicate samples per transect. Research conducted by Dethier, et al. (1993) compared the accuracy and repeatability of visual versus random-point percent cover estimations. They found that visual estimations were more repeatable and gave a more accurate representation of relative coverage of sessile organisms, and could reduce overall sampling error by making increased sample sizes possible.

Analyses

The number of species and individuals caught per trap (Salt River and Altona Lagoon) and per transect (Altona Lagoon) were analyzed by area with a Kruskal-Wallis one-way non-parametric test (Sokal and Rohlf, 1981). Species were ranked in order of total abundance and the six most abundant recreationally important species were examined for seasonal and between-site variation in abundance and size. Data from all sites were pooled by month and monthly variation in overall abundance and number of species was examined with least-squares regression analysis.

Total number of species and individuals per transect (Salt River) were examined by site with a one-way ANOVA after data were square-root transformed to achieve normality and homogeneity of variances. Species were ranked in order of abundance and the six most abundant recreationally important species were analyzed for seasonal and between-site variation in overall abundance and juvenile abundance. Data from all sites were pooled by month and monthly variation in overall abundance and number of species was examined with least-squares regression analysis.

Results

Salt River

As determined from aerial photographs, the Salt River embayment, comprised of Salt River Bay, Triton Bay and Sugar Bay, is approximately 49 hectares in size. Prior to Hurricane Hugo on 17 September 1989, red mangroves occupied 4,168 linear meters of shoreline, varying from several meters to more than 50 m in width (inner reaches of Sugar Bay). Approximately 50% of this coverage was along the shoreline of Sugar Bay, 13% along the shoreline of Salt River Bay and 37% along the shoreline of Triton Bay. Impacts to the mangrove communities in Salt River from Hurricane Hugo were severe, resulting in the loss of old growth forests. A comparison of September 1989 and February 1994 aerial photo indicates that in 4.5 years approximately 18% or 750 linear meters of shoreline contain isolated pockets of live mangroves.

A total of 3,462 individuals were caught in traps in Salt River, representing 40 species and 19 families (Table 1). The family in highest abundance was Gerreidae (36%) (Figure 3), represented by two species; *Eucinostomus jonesi* and *Gerres cinereus*, in almost equal abundance. The second most abundant family was Pomadasyidae (20%), which was represented by seven species. *Haemulon flavolineatum* accounted for 94.6% and *Haemulon sciurus* for 3.6% of all Pomadasyids. Lutjanidae was third most abundant (16%) and was represented by six species. *Lutjanus apodus* (64.8%) and *Ocyurus chrysurus* (29.5%) accounted for the majority of Lutjanids. Chaeotdontidae was fourth in abundance (14%) and was represented by two species. *Chaetodon capistratus* accounted for all but one individual (99.8%) of the chaetodonts. All other families each had a relative abundance of <2%.

Number of species and number of individuals (Table 2, Figures 4 and 5) were significantly higher in areas of previously reduced mangrove cover (Triton Bay West and Sugar Bay West) than in areas of previously extensive mangrove cover. Total number of species was highest in Sugar Bay, with a total of 33 species in both Sugar Bay East and Sugar Bay West. There were 28 species in Triton Bay West and 24 in Triton Bay East. *E. jonesi, G. cinereus, H. flavolineatum, C. capistratus, L. apodus*, and *O. chrysurus* were the six most abundant species, in varying orders of abundance, in all sites except Triton Bay East, where *L. apodus* was ranked eighth (Table 3). *E. jonesi* and *G. cinereus* were the two most abundant species in Triton Bay East and Sugar Bay East, the extensive-mangrove-coverage and undeveloped sites. *H. flavolineatum* was the most abundant species in both sites with reduced mangrove coverage and partially developed shoreline, Triton Bay West and Sugar Bay West. Among lutjanids, *O. chrysurus* was in similar abundance in all four sites, but *L. apodus* was more abundant at the Sugar Bay sites than in the Triton Bay sites. *C. capistratus* was most abundant in Triton Bay West and least abundant in Sugar Bay East.

There was no significant linear relationship between month and overall mean number of species ($R^2 = 0.095$, $F = 2.403$, df = 1,23, $p > 0.1$) or individuals ($R^2 = 0.066$, $F = 1.621$, df = 1,23, $p > 0.1$) caught in traps.

The five species listed in Table 4 were each dominated by juveniles. The size distribution was skewed toward smaller individuals (Figure 6, 7, 8 and 9) and mean size was similar between months for all species.

The mean monthly abundance per trap for *L. apodus, H. flavolineatum, G. cinereus* and *O. chrysurus* is shown in Figure 10. Annual recruitment for any species caught in traps was difficult to determine due to species abundance variability; however, some trends and abundance peaks were observed. *L. apodus* exhibited a peak in July - October 1991 and a more gradual increase in abundance from June to October 1992. *H. flavolineatum* peak abundance occurred in October 1991, February 1992 and again in November 1992. *G. cinereus* exhibited an abundance peak from May - August 1992 and a second peak in January 1993. *O. chrysurus* exhibited peak abundances in October 1992 and November 1993.

A total of 20,606 individuals were observed in transects, representing 48 species and 26 families (Table 5). The family with the highest relative abundance was Lutjanidae (37.9%) (Figure 11), represented by six species. *Lutjanus apodus* accounted for 89.8% and *Lutjanus griseus* 9.4%, of all lutjanids. The second most abundant family was Pomadasyidae (33.8%), represented by eight species. *Haemulon flavolineatum* accounted for 99.1% of all pomadasyids. Gerreidae was third highest in abundance (9.9%) and was represented by two species; *Eucinostomus jonesi* and *Gerres cinereus* (75.4% and 254.6%, respectively). Pomacentridae was fourth in relative abundance (4.9%) and was represented by seven species. *Abudefduf saxatilis* (52.3%) and *Stegastes dorsopunicans* (29.5%) were the most abundant pomacentrids. All other families each had a relative abundance of < 4%.

There were significant differences between sites in both number of species and number of individuals per transect, and only a few species were in high relative abundance in all transects (Figure 12 and 13). Columbus #4 transect was ranked highest and Columbus #1 lowest in both number of species (Table 6) and number of individuals (Table 7). *L. apodus*, *H. flavolineatum* and *E. jonesi* were the only species ranked among the five most abundant species in the four Columbus transects in the outer embayment, but were in low abundance in Dyck's Beach, within Triton Bay (Table 8). *Halichoeres bivittatus* was in high abundance only in Columbus #1 and Dyck's Beach transects. In contrast, *Lutjanus griseus* was in high abundance only in Columbus #4, #3, and #2 transects in the outer embayment. Mangrove prop-root cover increased significantly from Columbus #1 to Columbus #4 transect. Mangrove prop-root cover in Dyck's Beach and Columbus #1 transect was uniformly low with numerous sandy/algal areas. *L. apodus*, *H. flavolineatum* and *L. griseus* prefer the areas of dense prop-root cover, as opposed to *H. bivittatus*, found in the more exposed sand/algal areas.

There was no significant linear relationship between overall number of individuals and month ($R^2 = 0.014$, $F = 2.405$, df = 1,165, $p > 0.1$). Although the relationship between overall number of individuals and month was significant, the relationship was very weak ($R^2 = 0.046$, $F = 7.986$, df = 1.165, $p < 0.01$).

The majority of individuals of all species were juveniles (Table 5). Only 3 of the 48 species were represented by a majority of adults. Among the most abundant species examined within transects, only one, *L. griseus*, was represented by a high percentage of adults (Table 9).

The mean monthly abundance per transect for *L. apodus*, *H. flavolineatum*, *L. griseus* and *G. cinereus* is shown in Figure 14. The variation in abundance values for the most abundant recreationally important species was not as great per transect as per trap. Unlike trap data, a single dominant abundance peak was evident for all four species occurring in September 1992, reflecting a possible recruitment event within Salt River at that time. Although not considered a recreationally important species, *A. chirurgus* did exhibit a distinct annual recruitment pattern, with abundance maxima in February - April of each year.

Dyck's Beach transect was partially within the Triton Bay West trap sampling site. Thus, only qualitative comparisons were possible. There were 28 total species, or species groups, recorded for both the trap samples and the transect, of which 15 (54%) were present in both. Four of the six most abundant species in the trap samples were also among the six most abundant species observed in the transect..

When species richness levels were compared between outer bay and inner bay sites, species richness was greater in the outer bay. This was true among transects as well as between transects and traps.

The benthic community in Salt River was not assessed in this study; however, previous studies conducted by Antillean Engineers (1983) and Sugar Bay Land Development (1986) indicate a diverse marine flora and fauna in shallow waters <2.0 m. Coarse sediments along mangrove fringe shorelines are dominated by *Halimeda opuntia, Halimeda incrassata, Caulerpa sertulatioides, Caulerpa cupressoides* and *Penicillus capitatus*. In areas along Dyck's Beach, *Halimeda opuntia* forms extensive "reefs" along the sloping shoreline. The seagrasses *Thalassia testudinum, Syringodium filiforme* and *Halodule wrightii* were the most abundant marine plants found in the outer embayment waters. Fine bottom sediments and light attenuation in deeper waters greatly reduce benthic community diversity.

Water quality data for sampling stations in Salt River were collected during the study period by the Division of Environmental Protection as part of their island-wide water quality monitoring program. The minimum and maximum ranges for the parameters measured were as follows: water temperature 25.9 - 29.1 C, salinity 35.0 - 38.5 ppt, dissolved oxygen 4.60 - 7.55 ppm, fecal coliform bacteria 0 - 250, and turbidity (ntu) 0.98 - 4.6.

Altona Lagoon

Based on aerial photographs, Altona Lagoon is approximately 37 hectares in size. A continuous band of live red mangroves fringe the 4,910 linear m of shoreline. Due to its more sheltered location, hurricane impacts were not as severe as more exposed locals.

A total of 12,405 individuals were caught in traps in Altona Lagoon, representing 22 species and 14 families (Table 10). The family Gerridae had the highest abundance (93.7%) (Figure 15), represented by three species, *Gerres cinereus, Eucinostomus jonesi and Eucinostomus argenteus.* Of these three species, G. cinereus and E. jonesi represented 65.2% and 33.9%, respectively, of the total Gerridae abundance and 61.1% and 31.8%, respectively, of the total fish abundance caught in traps. The family Lutjanidae was second in family abundance (2.8%), represented by five species. *Lutjanus apodus* represented 95.1% of the Lutjanids. Pomadasyidae was third in family abundance (2.6%), represented by two species. *Haemulon flavolineatum* represented 98.4% of the Pomadasyids. All other families each had a relative abundance of < 0.3%.

The number of species caught per trap and per transect area was not significantly different; however, there was a significant difference in the number of individuals caught per trap per transect area for Area 3 (Table 11). Area 3 was located at the shallow eastern end of Altona Lagoon, where mangrove coverage was the greatest. Area 3 was also adjacent to and downstream from the hotel, golf course and upland residential developments. Mean number of species per trap was greatest in Area 4 and least in Area 3 (Figure 16). Mean number of individuals per trap was greatest in Areas 2 and 4 and least in Areas 1 and 3 (Figure 17). *G. cinereus, E. jonesi, L. apodus, H. flavolineatum and S. barracuda* were the six most abundant species caught in the four trap areas in order of abundance, with the exception of *H. flavolineatum* and *S. barracuda* in Area 3 (Table 12). *G. cinereus* was in nearly equal abundance in Areas 1, 2 and 4, but less abundant in Area 3. *E. jonesi* was least abundant in Area 1, closest to the mouth of Altona Lagoon, and most abundant in Area 2, farthest from the mouth. *L. apodus* most abundant in Area 1 near the lagoon mouth. *H. flavolineatum* was most abundant in Area 4 while *S. barracuda* were found in nearly equal abundance throughout Altona Lagoon.

The mean sizes by site and for all sites combined and minimum and maximum lengths for all sites combined for the five most abundant recreationally targeted species caught in traps are shown in Table 13. All five species represented (*G. cinereus, E. jonesi, L. apodus, H. flavolineatum* and *S. barracuda*) were dominated by juveniles (Table 13). Length-frequency distributions for *G. cinereus, E. jonesi, L. apodus, H. flavolineatum* and *S. barracuda* verify the abundance of smaller individuals in all trap samples (mean length (Figures 18, 19, 20, 21, and 22, respectively).

Mean monthly abundance per trap is shown in Figure 23. Annual recruitment events were not apparent; however, abundance peaks were evident for some species. *G. cinereus* had peak abundances in May - August 1993, March - May 1993, December 1994 - February 1995 and may - June 1995. E. jonesi exhibited major abundance peaks in July - August 1993 and December 1993 - February 1994, with lesser peaks October 1994 and March 1995. Abundance peaks were not evident for *L. apodus* and *H. flavolineatum*

A total of 97,536 individuals, representing 25 species and 13 families, were observed in transects (Table 14). The family with the highest relative abundance was Gerreidae (37.3%), represented by three species, *G. cinereus, E. jonesi* and *E. argenteus* (Figure 24). *G. cinereus and E. jonesi* accounted for 69.4% and 29.7%, respectively, of all gerreids. Second in relative abundance was Engraulidae (25.6%), represented by one species, *Anchoa lyolepis*. The third most abundant family was Clupeidae (14.2%), also represented by one species, *Harengula humeralis*. Both *A. lyolepis* (bullhead fry) and *H. humeralis* (readear sardine) are important baitfish species. Lutjanidae was fourth in total abundance (4.6%), represented by four species. Of these four species, *L. apodus* represented 85.3% of all Lutjanids. All other families had a relative abundance of <2%.

There were no significant differences between the number of species and number of individuals per transect by area (Table 11, Figures 25 and 26). The six most abundant species observed in visual transects were *G. cinereus, A. leyolepis, E. jonesi, H. humeralis, L. apodus flavolineatum* (Table 15). All six species were more abundant in Area 1, furthest from the lagoon mouth.

The six most abundant recreationally targeted species observed in the visual transects were *G. cinereus, E. jonesi, L. apodus, H. flavolineatum, L. griseus* and *S. barracuda* (Table 16). The percent of total abundance represented by juveniles in all transects for all species was >70%, with the exception of *H. flavolineatum* on two transects and *S. barracuda* on four transects. However, total abundance represented by juveniles for these species were still >57%.

Mean monthly abundance for transect data in Altona Lagoon is shown in Figure 27. Both *G. cinereus* and *E. jonesi* exhibited similar trends in abundance with one or more peaks per year. *G. cinereus* had an annual abundance peak from April - May 1994 and February - May 1995. *E. jonesi* had two minor peaks in September - October 1993 and February - April 1995 and two major peaks in April and November 1994. A similar trend in abundance to *G. cinereus* and *E. jonesi*, but at a much lower amplitude, was evident for *L. apodus* and *H. flavolineatum.*

Estimates of percent cover of mangrove prop root fringe benthic community for Altona Lagoon indicate that the outer bay (embayment closest to the lagoon entrance) was comprised of open bottom (49.5%) and the macro algae *Gracilaria sp.* (20.8%), *Halimeda sp.* (10.7%) and *Caulerpa sertularioides* (10.6%) (Table 17). A more diverse benthic community was found in the inner bay (embayment further removed from the lagoon entrance than the outer bay). This area was dominated by the macro algae *Caulerpa prolifera* (43.7%), *Penicillus capitatus* (40.0%), *Thalassia testudinum* (30.0%), *Acanthophora spicifera* (20.4%), *and Microcoleus lyngbyaceous*

(20.0%). The benthic jellyfish *Cassiopea sp.* was extremely abundant in the inner bay area, comprising 40.5% cover of the bottom. Anemones also comprised a significant portion of the benthic community (20.0%). The middle bay, central area of the lagoon >50 m from the mangrove fringe, was less diverse than the other two areas, but had the greatest coverage by marine plants. *Caulerpa prolifera* (75.6%) dominated the benthic community followed by *Cassiopea sp.* (18.9%). Only 9.3% of the middle bay was uncolonized bottom sediments.

Discussion

Salt River and Altona Lagoon are two very different mangrove ecosystems. The continuum of ecosystems within Salt River (mangroves, seagrass beds, coral reef and deep reef environs) provides habitat and a diverse source for larval recruitment, enhanced by good water exchange. Due to its exposed location on the north coast, Salt River's old growth mangroves have been adversely impacted by recent hurricanes. Linear shoreline coverage of the fringing red mangrove community has been reduced by approximately 80%. Decaying less rapidly than portions of the trees above water, the submerged mangrove prop roots continue to provide similar functions as live prop roots; however, these functions may have been altered or reduced. In time, the structural complexity of the food web in Salt River will be altered with a shift towards the detrital food web. No significant upcurrent or upwind seed source exists to accelerate natural mangrove reforestation.

Also located on the northern coast of St. Croix, Altona Lagoon has been spared most of the mangrove devastation from recent hurricanes. This may be due to its more isolated physical location and/or the direction of approach by the tropical weather systems. As a result, reforestation via natural propagation from upwind seed sources has been possible. Larval recruitment into Altona Lagoon is likely less than Salt River, due to the poor exchange of water through the narrow entrance channel and the greater distance the lagoon entrance is from the marine ecosystems inhabited by adult fish.

As would be expected, species diversity was greater for Salt River than Altona Lagoon; however, overall trap and transect fish abundance was greater in Altona Lagoon. Many of the most abundant species were common to both areas. These species are also directly targeted in the recreational fishery on St. Croix. *E. jonesi* are caught with nets and used as bait for larger species, such as *S. barracuda* and lutjanids. Large *G. cinereus* are caught with hook and line or speared in back-reef areas. Lutjanids of recreational importance include *L. apodus*, *O. chrysurus* and *L. griseus*. Juveniles of many other species were found in low abundance in these ecosystems (Tables 1, 3, 10 and 14). The adults of these species are also important components of the local recreational fishery.

The fish community present in Salt River and Altona Lagoon was similar to other mangrove lagoon communities (Baelde, 1990; Van der Velde et al., 1992; Rooker and Dennis, 1991; Thayer et al., 1987; Tzeng and Wang, 1992 and Dennis, 1992). Gerreids, a family of high abundance in both locals, are found in many estuarine systems throughout the world, including mangrove lagoons (Matthes and Kapetsky, 1988; Baelde, 1990; Rooker and Dennis, 1991; Thayer et al., 1987). Species of the families, Lutjanidae, Pomadasyidae, Scaridae and Chaetodontidae, are primarily found on reefs as adults, but are common in mangrove lagoons as juveniles (Baelde, 1990; Van der Velde et al., 1992; Rooker and Dennis, 1991). The abundance of juvenile *C. capistratus* and *A. chirurgus* in Salt River and low abundance in Altona Lagoon may be related to the close proximity of the adjacent coral reef fringing the entrance of Salt River.

The baitfish *A. lyolepis* (bullhead fry) and *H. humeralis* (redear sardine) were in high abundance in visual transects in Altona Lagoon and not observed in Salt River. *A. lyolepis* and *H. humeralis* may have been abundant elsewhere in Salt River and simply not present in the areas sampled. Salt River is also more accessible to fishermen, both from shore and by boat, and more heavily fished, placing more pressure on baitfish resources. Greater baitfish resources in Altona Lagoon support the greater abundance of sphyraenids and carangids in Altona Lagoon than found in Salt River. Gerreids were often observed in Altona Lagoon with healed scars, presumably from encounters with large picivorous fishes.

The abundance of juvenile fishes in trap and visual transects in both Salt River (Tables 5 and 9) and Altona Lagoon (Tables 14 and 16) supports the hypothesis that the fringing red mangrove prop root community serves as important nursery habitat. The mean length of individuals and the juvenile/adult ratio remained relatively constant over time and length-frequency histograms were highly skewed toward smaller fish (Salt River, Figures 6 -9; Altona Lagoon, Figures 18 - 22). The complex habitat afforded by the mangrove prop-root community reduces predation (Orth et al., 1984; Sogard and Olla, 1993; Hixon, 1991) and increases the overall number of small fish (Hixon and Beets, 1992).

Recruitment trends were generally more difficult to determine from trap data than transect data. Trap catch was biased towards smaller individuals due to mesh size. Single or multiple abundance peaks per year were evident for the most abundant species in traps and in transects in Salt River and Altona Lagoon. For Salt River, most notable was a recruitment event observed in transect data as a uniform abundance peak of varying amplitude occurring for *L. apodus, H. flavolineatum, L. griseus* and *G. cinereus* during the September 1992 (Figures 10 and 14). Similar events are noticeable for *G. cinereus* and *E. jonesi* in Altona Lagoon transect data during 1994 and 1995 (Figure 23 and 27). Both trap and transect data show a seasonal component in abundance during 1994.

Immediate and long-term threats to the existing nursery habitat in Salt River and Altona Lagoon include non-point source and point source pollution, coastal development, permitted water-dependent activities, land-based recreational activities and natural disasters. The upland watersheds of Salt River and Altona Lagoon are primarily in the second tier of the Coastal Zone Management system, where development guidelines are less stringent than those in the first tier.

The improper installation of erosion and sedimentation control features, or the lack thereof during construction, continues to allow vast quantities of terrestrial sediments to enter the marine environment during major rainfall events. In Salt River, a proposed flood control project by the U.S. Army Corps of Engineers will channelize flow into the estuary at the southern extremity of Sugar Bay and has the potential to increase the velocity and volume of water discharged into sensitive nursery habitat.

Heavy rainfall events saturate soils and allow septic tank leachate to flow into inshore waters. Typically, public collection systems are also stressed at this time and have the potential to overflow into coastal embayments. High fecal coliform bacteria levels of unknown origin have been recorded periodically for Salt River. A sewer line discharge into Altona Lagoon on at least one occasion has caused fish mortality during the study period and resulted in the cancellation of field studies. The hotel adjacent to Altona Lagoon has an on-site sewage treatment plant which also may contribute to discharges into the eastern portion of the lagoon, when the plant malfunctions.

Coastal development continues to encroach upon nursery habitat. Future plans to upgrade the existing marina in Salt River include increasing dock space to accommodate more vessels. With the increase in vessels can be anticipated an increase in accidental spills of petroleum products, an increase in the amount of toxic anti-fouling bottom paint, an increase in the number of live-aboards and an overall increase in vessel traffic. Recent encroachment by development in Altona Lagoon has included a permitted expansion of the adjacent golf course into the wetlands on the north side of the lagoon. During dredging of the Christiansted schooner channel in 1992, dewatering ponds were constructed on the fast land near the lagoon's western shoreline. The failure of one of the pond dikes resulted in the discharge of dredge spoils into the lagoon near the entrance channel, smothering benthic communities and temporarily increasing water turbidities. Past harbor dredging activities in the 1960's resulted in the creation of fast land, enclosing the lagoon's western shoreline and greatly restricting water flow into and out of Altona Lagoon.

Numerous water-dependent activities adversely impact critical nursery habitat. More and more vessels utilize Salt River as a safe haven during hurricane season. Improper anchoring and the grounding of vessels in the shallow embayment results in damage to seagrass and mangrove communities. The haulout and repair of vessels in improperly zoned areas of the shoreline contribute to mangrove destruction. The use of personal motor craft at high speeds in the embayment generates wave energy that can accelerate shoreline erosion and adversely affect the behavior of juvenile fishes. Commercial fishing methods used in Salt River indiscriminately catch juvenile species. Concentrated fishing pressure at the entrance of Altona Lagoon results in extremely high fishing mortality of juveniles and sub-adults.

Extended camping and cookout activities have resulted in the piece-meal destruction of mangrove habitat. Mangroves have been cleared for campground areas and burned for firewood, particularly in Salt River. At Altona Lagoon, mangroves fringing the entrance channel have been cut to increase available shoreline fishing areas.

Natural disasters, in particular hurricanes, have drastically impacted mangrove habitat. More than 80% of the fringing red mangroves in Salt River were destroyed by Hurricane Hugo in 1989. Although the growth above ground is no longer present, the submerged mangrove prop roots continue to provide important juvenile nursery habitat and a substrate for the attachment of marine flora and fauna. Trees felled by the hurricane have also provided new habitat for fishes in areas where habitat may have been limited previously (Columbus 1, 2, 3 and 4 transects).

Recognizing the significance of Salt River and Altona Lagoon as critical nursery habitat for recreationally (as well as commercially) important fishes, the Government of the Virgin Islands and the private sector have taken initial measures to identify, to protect and to manage these resources. Salt River and Altona Lagoon were identified as important coastal resources and placed on the Coastal Barriers Resources System for the Virgin Islands (USFWS, 1990). In 1992, the Department of Interior and the Government of the Virgin Islands became partners in the development of a joint federal/territorial park called the Salt River National Historical Park and Ecological Preserve.

Under the National Coastal Zone Management Act, the Department of Planning and Natural Resources identified Salt River as an Area of Particular Concern (APC) and an Area for Preservation and Restoration (APR) (Island Resources Foundation, 1993). An APC is defined as an area in the coastal zone that requires special and more detailed planning analyses and the preparation of special plans and implementation mechanisms. An APR is an area designated for preservation or restoration because of conservation, recreation, ecological or aesthetic values. Altona Lagoon was identified as an important nursery habitat within the Christiansted Waterfront APC management plan and recommended for inclusion in a territorial park program.

The Department of Planning and Natural Resources (DPNR) applied for and received wetlands acquisition grants from the U.S. Department of Interior in 1993 and 1994 for the acquisition of wetland habitat in Salt River and subsequent reforestation of these lands back to mangrove habitat. The St. Croix Environmental Association is currently making application to the Fish and Wildlife Foundation for mangrove restoration within Salt River. Public and private efforts will be utilized in both Department of Interior and Fish and Wildlife Foundation grants to make the reforestation projects a unique educational experience for the community.

Upon recommendations from the St. Croix Fisheries Advisory Committee (STX-FAC), a working body established under the Virgin Islands Code to make recommendations to the Commissioners of the Departments of Agriculture and Planning and Natural Resources regarding the preservation and management of fishery resources, regulations were established in 1992 for the harvesting of marine resources from Altona Lagoon and its entrance channel to Christiansted Harbor. Among these regulations included restrictions regarding the use of seine nets, gill nets, traps and motorized vessels. A size limit was also recommended for barracuda within the lagoon. Based on recommendations made by the STX-FAC, the Commissioner of the Department of Planning and Natural Resources designated Salt River as a marine reserve and wildlife sanctuary in 1994. Management regulations within the reserve will be developed following a public review process.

Conclusions

Mangrove ecosystems in the U.S. Virgin Islands have been drastically altered by coastal development in the recent past without due consideration of their ecological significance. The Salt River and Altona Lagoon mangrove ecosystems today are under severe stress due to natural and man-induced perturbations. The most noticeable impact in Salt River has been the loss of >80% of the of the fringing red mangrove community due to hurricane impacts. Although the fringing red mangrove community in Altona Lagoon had been, in most part, spared by recent hurricanes, Altona Lagoon is plagued by sewage discharges into the lagoon which, combined with greatly reduced water exchange, adversely impact the mangrove ecosystem.

The present study demonstrates that the fringing red mangrove ecosystem in Salt River and Altona Lagoon provides important nursery habitat for juveniles of numerous reeffish species, many of which are recreationally important as primary target species or food fishes for primary target species. The fish community in Salt River and Altona Lagoon was similar to other mangrove lagoon communities found elsewhere (Baelde, 1990; Van der Velde et al.; 1992; Rooker and Dennis, 1991; Thayer et al., 1987; Tzeng and Wang, 1992; Dennis, 1992). The overall species diversity was greater for Salt River than Altona Lagoon due to greater adjacent habitat complexity and better recruitment opportunities afforded by good water exchange with nearshore and offshore environs. The most abundant species were common to both areas (*E, jonesi, G, cinereus,. L apodus, L. griseus, O chrysurus* and *S. barracuda*). Members of the Gerreidae (*E. jonesi* and *G. cinereus*), Engraulidae (*A. lyolepis)* and Clupeidae (*H. humeralis)* families were more abundant in Altona Lagoon.

Recommendations

To maintain and to improve the value of the mangroves in Salt River as nursery habitat, it is recommended that a management plan be immediately developed for the marine reserve and wildlife sanctuary, as designated by the Department of Planning and Natural Resources. Critical items in the management plan should include recommendations made by the St. Croix Fisheries Advisory Committee to restrict all commercial fishing within the presently defined boundaries of the Salt River Bay National Historical Park and Ecological Preserve and establish "no-take/release" provisions for recreational anglers. A vessel operation/mooring plan should also be included in the management strategy. Efforts should continue by the public and private sectors (i.e., Government of the Virgin Islands, National Park Service and Nature Conservancy) for the acquisition of wetlands. The reforestation of the red mangrove fringing community on government-owned submerged lands within the estuary should become an immediate priority.

Nursery habitat in Altona Lagoon may be enhanced by improving the exchange of water in the lagoon. This may be accomplished by providing an opening to the Caribbean Sea into Beauregard Bay on the north side of the lagoon and enlarging the entrance from the lagoon into Christiansted Harbor. Both projects would involve permit review by the U.S. Army Corps of Engineers and the Department of Planning and Natural Resources, Division of Coastal Zone Management. Management measures to further restrict net fishing in the entrance channel to the lagoon should be considered. Altona Lagoon should be included in the Division of Environmental Protection's water quality monitoring program to insure the maintenance of good water quality standards for mangrove nursery habitat.

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Table 1. Total abundance of species caught in fish traps, all sites combined, in Salt River, March 1991 - April, 1993. Families listed in decreasing order of abundance.

Family Name Common Name Species Name	Total Abundance
Gerreidae	
Slender mojarra	
Eucinostomus jonesi	673
Yellowfin mojarra	
Gerres cinereus	625
Pomadasyidae	
French grunt	
Haemulon flavolineatum	623
Bluestriped grunt	
Haemulon sciurus	25
Smallmouth grunt	
Haemulon chrysargyreum	4
White grunt	
Haemulon plumieri	4
Tomtate	
Haemulon aurolineatum	2
Caesar grunt	
Haemulon carbonarium	2
Sailors choice	
Haemulon parrai	1
Lutjanidae	
Schoolmaster snapper	
Lutjanus apodus	409
Yellowtail snapper	
Ocyurus chrysurus	173
Gray snapper	
Lutjanus griseus	15
Dog Snapper	
Lutjanus joco	11
Mutton snapper	
Lutjanus analis	5
Mahogany snapper	
Lutjanus mahogoni	1
Chaetodontidae	
Foureye butterfly	
Chaetodon capistratus	481

Table 1. Continued

Family Name / Common Name / Species Name	Total Abundance
Chaetodontidae (cont.)	
Banded butterfly	
Chaetodon striatus	1
Sciaenidae	
Reef croaker	
Odontoscion dentex	70
Spotted drum	
Equetus punctatus	3
High hat	
Equetus acuminatus	2
Sparidae	
Seabream	
Archosargus rhomboidalis	71
Scaridae	
Bucktooth parrotfish	
Sparisoma radians	57
Redtail parrotfish	
Sparisoma chrysopterum	5
Redband parrotfish	
Sparisoma aurofrenatum	3
Emerald parrotfish	
Nicholsina usta	2
Queen parrotfish	
Scarus vetula	1
Tetraodontidae	
Checkered puffer	
Sphoeroides testudineus	59
Bandtail puffer	
Sphoeroides spengleri	1
Holocentridae	
Squirrelfish spp.	48
Pomacentridae	
Damselfish spp.	26
Yellowtail damsel	
Microspathodon chrysurus	10
Beaugregory	
Stegastes leucostictus	2
Labridae	
Clown wrasse	
Halichoeres maculipinna	18

Table 1. Continued.

Family Name Common Name Species Name	Total Abundance
Labridae (cont.)	
Slippery dick	
Halichoeres bivittatus	9
Wrasse spp.	2
Creole wrasse	
Clepticus parrai	1
Clinidae	
Hairy blennie	
Labrisomus nuchipinnis	15
Sphyraenidae	
Barracuda	
Sphyraena barracuda	13
Carangidae	
Horseye jack	
Caranx latus	5
Jack	
Caranx spp.	4
Barjack	
Caranx ruber	1
Centropomidae	
Snook	
Centropomus undecimalis	8
Acanthuridae	
Doctorfish	
Acanthurus chirurgus	7
Muraenidae	
Green moray eel	
Gynothorax funebris	3
Scorpaenidae	
spp.	1
Serranidae	
Grouper spp.	1

Table 2. Kruskal-Wallis comparison of square-root-transformed number of species and number of individuals (Abundance) per trap by area in Salt River. Values listed are non-transformed mean number per trap (+/-SE).

	Area				
	Triton Bay		Sugar Bay		
	East	West	East	West	P*
Species					
	1.14 (0.06)	1.55 (0.08)	1.32 (0.07)	1.65 (0.08)	S
Abundance					
	2.55 (0.24)	3.27 (0.23)	2.90 (0.23)	3.76 (0.32)	S

* P < 0.001; S = Significant Difference

Table 3. Total abundance, mean and standard error (+/-SE), listed by area, of the six most abundant species caught in traps in Salt River. Species listed in decreasing order of abundance. TBE = Triton Bay East, TBW = Triton Bay West, SBE = Sugar Bay East, SBW = Sugar Bay West.

	AREA				
Species	TBE	TBW	SBE	SBW	Total
E. jonesi	188	149	195	135	673
Mean	7.83	8.27	9.75	7.94	
+/-SE	0.5	0.7	0.9	1.0	
G. cinereus	169	136	196	124	625
Mean	7.04	6.18	9.33	6.89	
+/-SE	0.4	0.4	0.6	0.7	
H. flavolineatum	58	254	88	223	623
Mean	5.80	11.04	4.89	10.61	
+/-SE	0.8	0.4	0.5	0.5	
C. capistratus	112	241	19	109	481
Mean	5.89	11.48	2.71	6.41	
+/-SE	0.9	0.7	0.5	0.4	
L. apodus	33	44	181	151	409
Mean	2.35	3.67	7.54	6.86	
+/-SE	0.3	0.7	0.5	0.4	
O. chrysurus	54	60	39	35	188
Mean	3.37	3.16	2.60	3.18	
+/-SE	0.3	0.3	0.4	0.6	
				TOTAL:	2,999

Trap Number: TBE = 300, TBW = 300, SBE = 300, SBW = 276.

Table 4. Mean sizes (total length, mm) (± SE) by site and for all sites combined (Total), and minimum and maximum lengths for all sites combined, for the five most abundant recreationally targeted species caught in traps in Salt River. Species listed in decreasing order of abundance.

	SITE						
	Triton Bay		Sugar Bay				
Species*	East	West	East	West	Total	Min.	Max.
E. jonesi	71.18 (0.77)	71.38 (0.83)	67.96 (0.62)	73.30 (1.04)	70.73 (0.40)	44.0	135.0
H. flavolineatum	78.50 (2.25)	81.84 (1.27)	83.07 (1.81)	76.36 (1.02)	79.72 (0.72)	40.0	140.0
G. cinereus	72.63 (1.84)	79.82 (2.04)	86.57 (1.57)	85.48 (1.73)	81.15 (0.92)	36.0	170.0
L. apodus	84.54 (6.76)	112.58 (7.31)	87.73 (2.06)	107.04 (2.76)	97.72 (1.73)	20.0	210.0
O. chrysurus	90.96 (3.91)	94.97 (4.50)	103.44 (5.77)	87.97 (3.73)	94.25 (2.32)	40.0	194.0

*For each species, a maximum of ten individuals per trap were measured. All other individuals were enumerated.

Table 5. Total abundance of species observed in Salt River visual transects (all transects combined) and percentage of the total that were juveniles for each species. Families listed in decreasing order of abundance.

Family Name / Common Name / Species Name	Total Abundance	Percent Juvenile
Lutjanidae		
Schoolmaster		
Lutjanus apodus	7022	81.5
Gray snapper		
Lutjanus griseus	736	60.0
Dog snapper		
Lutjanus joco	3	0
Lane snapper		
Lutjanus synagris	20	100.0
Yellowtail snapper		
Ocyurus chrysurus	30	100.0
Mahogany snapper		
Lutjanus mahogoni	7	80.0
Pomadasyidae		
French grunt		
Haemulon flavolineatum	6896	88.2
Caesar grunt		
Haemulon carbonarium	2	50.0
Bluestriped grunt		
Haemulon sciurus	48	45.8
Spanish grunt		
Haemulon macrostomum	1	100.0
Sailors choice		
Haemulon parrai	2	0
Striped grunt		
Haemulon striatum	1	0
Porkfish		
Anisotremus virginicus	9	44.0
Gerreidae		
Slender mojarra		
Eucinostomus jonesi	1544	95.2
Yellowfin mojarra		
Gerres cinereus	503	69.8

Table 5. Continued.

Family Name / Common Name / Species Name	Total Abundance	Percent Juvenile
Chaetodontidae		
Foureye butterfly		
Chaetodon capistratus	300	82.4
Banded butterfly		
Chaetodon striatus	1	0
Sphyraenidae		
Barracuda		
Sphyraena barracuda	114	86.8
Sciaenidae		
Spotted drum		
Equetus puncatus	38	93.9
High hat		
Equetus acuminatus	30	53.3
Drum		
Equetus spp.	7	57.1
Reef Croaker		
Odontoscion dentex	3	100.0
Tetraodontidae		
Puffer spp.	6	0
Checkered puffer		
Sphoeroides testudineus	53	42.1
Bandtail puffer		
Sphoeroides spengleri	2	100.0
Mugilidae		
White Mullet		
Mugil curema	38	85.7
Bothidae		
spp.	21	100.0
Pomacanthidae		
French Angel		
Pomacanthus paru	5	100.0
Sparidae		
Seabream		
Archosargus rhomboidalis	4	0
Carangidae		
Horseye jack		
Caranx latus	3	100.0
Clinidae		
Hairy blenny		
Labrisomus nuchipinnis	2	0

Table 5. Continued

Family Name Common Name Species Name	Total Abundance	Percent Juvenile
Holocentridae		
Squirrelfish (spp)	2	100.0
Gobiidae		
Goby (spp)	1	0
Serranidae		
Hamlet		
Hypoplectrus spp.	1	100.0
Centropomidae		
Snook		
Centropomus undecimalis	1	100.0
Scorpaenidae		
Scorpionfish spp.	1	0
Mullidae		
Yellow goatfish		
Mulloidichthys martinicus	1	100.0
Diodontidae		
Porcupinefish		
Diodon hystrix	1	0
Ostraciidae		
Trunkfish		
Lactophrys spp.	1	0
Kyphosidae		
Chub		
Kyphosus spp.	1	0
Ephippidae		
Atlantic spadefish		
Chaetodipterus faber	1	100.0

Table 5. Continued.

Family Name Common Name Species name	Total Abundance	Percent Juvenile
Pomacentridae		
Dusky damsel		
Stegastes dorsopunicans	298	61.3
Beaugregory		
Stegastes luecostictus	81	89.7
Sergeant major		
Abudefduf saxatilis	530	88.7
Yellowtail damsel		
Microspathodon chrysurus	73	85.7
Damsel (spp.)	15	100.0
Pomacentridae (cont.)		
Bicolor damsel		
Stegastes partitus	6	100.0
Coco damsel		
Stegastes variabilis	7	71.4
Acanthuridae		
Doctorfish		
Acanthurus chirurgus	770	94.0
Blue tang		
Acanthurus coeruleus	5	100.0
Scaridae		
Redtail parrotfish		
Sparisoma chrysopterum	69	76.1
Emerald parrotfish		
Nicholsina usta	65	89.7
Redband parrotfish		
Sparisoma aurofrenatum	144	75.6
Striped parrotfish		
Scarus iserti	131	99.2
Bucktooth parrotfish		
Sparisoma radians	263	99.1
Parrotfish (spp)	38	100.0
Stoplight parrotfish		
Sparisoma viride	8	100.0
Yellowtail parrotfish		
Sparisoma rubripinne	5	0
Labridae		
Slippery dick		
Halichoeres bivittatus	604	97.6
Wrasse spp.	30	50.0

Table 6. Effect of transect location on square-root-transformed number of species in Salt River.

a) One-way ANOVA

Source of Variation	SS	df	WS	F
Transect	585.88	4	146.47	14.15*
Error	1532.56	148	10.36	

b) Tukey-Kramer multiple comparisons test of square-root-transformed number of species by transect. Treatments that are not significantly different at the 0.05 level share an underline. Treatments are arranged in increasing number of species.

Columbus 1	Dyck's Beach	Columbus 2	Columbus 3	Columbus 4

*P , 0.001

Table 7. Effect of transect location on square-root-transformed number of individuals in Salt River.

a) One-way ANOVA

Source of Variation	SS	df	MS	F
Transect	1208.15	4	302.04	30.32*
Error	1474.11	148	9.96	

b) Tukey-Kramer multiple comparisons test of square-root-transformed number of individuals by transect. Treatments that are not significantly different at the 0.05 level share an underline. Treatments are arranged in increasing order of abundance.

Columbus 1	Dyck's Beach	Columbus 2	Columbus 3	Columbus 4
______	______	______	______	______

*P < 0.001

Table 8. Six most abundant species observed in visual transects in Salt River, May 1991 - April 1993. Total abundance, mean and standard error (+/-SE) listed for each area. Species listed in order of decreasing abundance.

Species	Columbus 1	2	3	4	Dyck	Total
L. apodus	692	1193	1782	3071	200	6938
Mean	19.2	37.3	52.4	90.3	6.7	
+/-SE	2.6	0.8	5.9	7.1	0.3	
H. flavolineatum	209	1500	1164	2585	1247	6705
Mean	10.5	50.0	36.4	76.0	37.8	
+/-SE	1.0	1.5	1.4	8.3	0.7	
E. jonesi	356	231	333	514	137	1571
Mean	12.3	8.6	9.8	15.1	5.5	
+/-SE	0.7	0.4	1.3	2.1	0.6	
A. chirurgus	52	269	255	193	10	779
Mean	5.8	9.3	11.6	6.4	2.0	
+/-SE	0.7	0.7	0.8	0.4	0.5	
L. griseus	13	299	178	230	10	730
Mean	1.9	14.9	6.6	9.2	1.4	
+/-SE	0.4	0.9	0.6	0.8	0.3	
G. cinereus	100	85	130	175	22	512
Mean	4.2	4.7	4.5	5.3	1.7	
+/-SE	0.3	0.5	0.3	0.3	0.4	
					TOTAL:	17,235

Transect Number: C1 = 35, C2 = 34, C3 = 33, C4 = 34, Dyck = 35.

Table 9. Percent of total abundance represented by juveniles within each visual transect in Salt River for the six most abundant recreationally targeted species and one family. Values are means (±SE). Groups listed in decreasing order of abundance.

Species or Family	Columbus 1	Columbus 2	Transect Columbus 3	Columbus 4	Dyck
L. apodus	88.8 (3.6)	91.2 (1.9)	80.3 (2.5)	76.6 (1.6)	84.2 (6.8)
H. flavolineatum	72.2 (11.0)	76.7 (7.1)	92.7 (2.7)	89.8 (1.6)	89.1 (7.1)
E. jonesi	96.2 (2.9)	93.5 (3.5)	93.2 (2.5)	96.5 (1.7)	98.1 (1.9)
A. chirurgus	89.1 (9.8)	92.3 (3.9)	76.4 (13.2)	90.0 (4.1)	100.0 (1.1)
L. griseus	100.0 (0.4)	56.8 (9.7)	32.5 (9.9)	34.5 (9.6)	33.3 (33.3)
Scaridae	92.9 (4.3)	72.6 (11.0)	82.3 (9.6)	82.1 (8.4)	97.8 (2.2)
G. cinereus	47.9 (13.2)	43.8 (10.4)	58.8 (10.4)	61.6 (7.8)	83.6 (11.1)

Table 10. Total abundance of species caught in fish traps, all sites combined, in Altona Lagoon, October 1993 - September 1995. Families listed in decreasing order of abundance.

Family Name Common Name Species Name	Total Abundance
Gerreidae	
Yellowfin mojarra *Gerres cinereus*	7,577
Slender mojarra *Eucinostomus jonesi*	3,942
Spotfin mojarra *Eucinostomus argenteus*	103
Lutjanidae	
Schoolmaster snapper *Lutjanus apodus*	329
Gray snapper *Lutjanus griseus*	7
Yellowtail snapper *Ocyurus chrysurus*	5
Lane snapper *Lutjanus synagris*	4
Dog snapper *Lutjanus joco*	1
Pomadaysidae	
French grunt *Haemulon flavolineatum*	313
Bluestriped grunt *Haemulon sciurus*	5
Sphyraenidae	
Great barracuda *Sphyraena barracuda*	42
Carangidae	
Yellow jack *Caranx bartholomaei*	27
Horse-eye jack *Caranx latus*	9
Tetraodontidae	
Checkered puffer *Sphoeroides testudineus*	13

Table 10. Continued

Family Name Common Name Species Name	Total Abundance
Clinidae	
Hairy blenny	
Labrisomus nuchipinnis	8
Chaetodontidae	
Foureye butterflyfish	
Chaetodon capistratus	7
Sparidae	
Seabream	
Archosargus rhomboidalis	4
Porgy	
Calamus spp.	1
Muraenidae	
Green moray eel	
Gymnothorax funebris	4
Scaridae	
Bucktooth parrotfish	
Sparisoma radians	2
Monacanthidae	
Filefish	
Cantherhines spp.	1
Bothidae	
Peacock flounder	
Bothus lunatus	1

Table 11. Kruskal-Wallis comparison of square-root-transformed number of species and number of individuals (Abundance) per trap and per transect by area in Altona Lagoon. Values listed are non-transformed mean number per trap (+/-SE).

	Area				
	1	2	3	4	P*
			Trap		
Species					
	1.65 (0.06)	1.58 (0.05)	1.44 (0.05)	1.68 (0.05)	NS
Abundance					
	8.30 (0.44)	10.88 (0.68)	9.85 (0.71)	11.07 (0.78)	S
			Transect		
Species					
	5.07 (0.19)	4.85 (0.19)			NS
Abundance					
	266.90 (22.53)	270.37 (30.19)			NS

* $P < 0.001$; S = Significant, NS = Not Significant

Table 12. Total abundance, mean and standard error (+-SE), listed by area, of the five most abundant species caught in traps in Altona Lagoon. Species listed in decreasing order of abundance.

Species	AREA 1	2	3	4	Total
G. cinereus	1940	2201	1550	1916	7577
Mean	6.24	6.86	6.18	5.56	
+/-SE	0.1	0.2	0.2	0.2	
E. jonesi	530	1282	1004	1126	3942
Mean	1.84	4.48	4.40	4.31	
+/-SE	0.2	0.3	0.3	0.4	
L. apodus	187	68	24	50	329
Mean	0.80	0.32	0.17	0.26	
+/-SE	0.1	0.1	0.2	0.1	
H. flavolineatum	73	59	2	179	313
Mean	0.37	0.30	0.01	0.12	
+/-SE	0.2	0.1	0.1	0.3	
S. barracuda	8	12	10	12	42
Mean	0.04	0.06	0.07	0.07	
+/-SE	0.1	0.1	0.1	0.1	
				TOTAL:	12,203

Trap Number: Area 1 = 338, Area 2 = 337, Area 3 = 264, Area 4 = 302.

Table 13. Mean sizes (total length, mm) (± SE) by site and for all sites combined (Total), and minimum and maximum lengths for all sites combined, for the five most abundant recreationally targeted species caught in traps in Altona Lagoon. Species listed in decreasing order of abundance.

	AREA						
Species*	1	2	3	4	Total	Min.	Max.
G. cinereus	94.35 (1.54)	104.81 (4.18)	109.44 (4.02)	102.52 (4.85)	102.52 (1.86)	10.0	200.0
E. jonesi	79.55 (0.63)	76.51 (0.81)	79.75 (0.71)	82.30 (1.87)	79.43 (0.59)	20.0	198.0
L. apodus	99.78 (2.22)	124.75 (14.94)	96.87 (7.82)	102.94 (7.54)	105.34 (3.64)	31.0	240.0
H. flavolineatum	96.86 (2.94)	71.62 (6.51)	116.50 (6.50)	95.40 (3.81)	91.17 (2.45)	27.0	155.0
S. barracuda	221.88 (42.19)	221.36 (23.39)	219.30 (24.08)	232.45 (18.96)	224.00 (12.72)	120.0	435.0

*For each species, a maximum of ten individuals per trap were measured. All other individuals were enumerated.

Table 14. Total abundance of species observed in Altona Lagoon visual transects (all transects combined) and percentage of the total that were juveniles for each species. Families listed in decreasing order of abundance.

Family Name / Common Name / Species Name	Total Abundance	Percent Juvenile
Gerreidae		
Yellowfin mojarra *Gerres cinereus*	36,397	84.5
Slender mojarra *Eucinostomus jonesi*	15,592	88.8
Spotfin mojarra Eucinostomus argenteus	464	98.1
Engraulidae		
Bullhead fry *Anchoa lyolepis*	24,925	94.2
Clupeidae		
Redear sardine *Harengula humeralis*	13,823	100.0
Lutjanidae		
Schoolmaster *Lutjanus apodus*	3,854	88.0
Gray snapper *Lutjanus griseus*	660	78.8
Mutton snapper *Lutjanus analis*	4	50.0
Snapper sp.	1	0
Pomadasyidae		
French grunt *Haemulon flavolineatum*	1,087	68.1
Bluestriped grunt *Haemulon sciurus*	155	58.7
Tomtate *Haemulon aurolineatum*	17	70.6
Caesar grunt *Haemulon carbonarium*	6	100.0
Sparidae		
Seabream *Archosargus rhomboidalis*	703	90.1
Porgy *Calamus spp.*	2	0

Table 14. Continued

Family Name Common Name Species Name	Total Abundance	Percent Juvenile
Sphyraenidae		
Great barracuda *Sphyraena barracuda*	508	69.5
Scaridae		
Princess parrotfish *Scarus taaeniopterus*	402	99.3
Bucktooth parrotfish *Sparisoma radians*	14	85.7
Parrotfish spp.	10	20.0
Redtail parrotfish *Sparisoma chrysopterum*	4	75.0
Redfin parrotfish *Sparisoma rubripinne*	2	100.0
Redband parrotfish *Sparisoma aurofrenatum*	1	0
Mugilidae		
White mullet *Mugil curema*	14	85.7
Carangidae		
Horse-eye jack *Caranx latus*	2	0
Blue runner *Caranx crysos*	1	0
Caranx spp.	10	100.0
Chaetodontidae		
Foureye butterfly *Chaetodon capistratus*	13	92.3
Labridae		
Clown wrasse *Halichoeres maculipinna*	7	100.0
Wrasse spp.	1	100.0
Tetraodontidae		
Puffer spp.	6	0
Checkered puffer *Sphoeroides testudineus*	7	28.6
Clinidae		
Hairy blenny *Labrisomus nuchipinnis*	5	0

Table 14. Continued.

Family Name Common Name Species Name	Total Abundance	Percent Juvenile
Pomacentridae		
Beaugregory		
Stegastes luecostictus	4	75.0
Damsel (spp.)	1	100.0
Diodontidae		
Porcupinefish		
Diodon hystrix	3	66.7
Ballonfish		
Diodon holocanthus	1	0
Aulostomidae		
Trumpetfish		
Aulostomus maculatus	1	100.0
Elopidae		
Tarpon		
Megalops atlanticus	1	0
Monacanthidae		
Scrawled filefish		
Aluterus scriptus	1	0

Table 15. Six most abundant species observed in visual transects in Altona Lagoon, May 1993 - May 1995. Total abundance, mean and standard error (+/-SE) listed for each area. Species listed in order of decreasing abundance.

Species	Area 1	Area 2	Total
G. cinereus	22,497	13,900	36,397
Mean	138.0	110.3	
+/-SE	0.7	0.6	
A. leyolepis	16,160	8,765	24,925
Mean	99.1	69.6	
+/-SE	1.8	2.8	
E. jonesi	7,951	7,641	15,592
Mean	48.8	60.2	
+/-SE	0.5	0.7	
H. humeralis	8,692	5,103	13,795
Mean	N/A	N/A	
+/- SE	N/A	N/A	
L. apodus	2,585	1,269	3,854
Mean	15.9	10.1	
+/-SE	0.2	0.2	
H. flavolineatum	962	125	
Mean	5.9	1.0	
+/-SE	0.6	0.3	
		TOTAL:	95,650

Transect Number: Area 1 = 225, Area 2 = 122.

Table 16. Percent of total abundance represented by juveniles within each visual transect in Altona Lagoon for the six most abundant recreationally targeted species. Values are means (+/-SE). Species are listed in decreasing order of abundance.

	TRANSECT							
Species	1	2	3	4	5	6	7	8
G. cinereus	84.5 (1.2)	90.0 (1.0)	92.3 (0.9)	91.5 (0.6)	77.4 (1.1)	73.7 (1.0)	84.2 (0.9)	85.1 (0.9)
E. jonesi	84.5 (1.1)	90.1 (1.1)	93.1 (1.2)	94.4 (0.7)	92.8 (1.0)	77.9 (1.1)	90.6 (1.2)	88.9 (0.9)
L. apodus	83.7 (0.3)	83.1 (0.4)	81.9 (0.3)	82.4 (0.4)	80.1 (0.4)	84.1 (0.3)	79.5 (0.3)	91.6 (0.6)
H. flavolineatum	68.1 (0.4)	58.1 (0.6)	86.4 (0.3)	88.6 (0.2)	0.0	100.0 (0.2)	86.2 (0.3)	93.5 (0.6)
L. griseus	73.5 (0.4)	80.2 (0.3)	93.3 (0.3)	70.8 (0.2)	92.5 (0.2)	84.1 (0.5)	77.6 (0.3)	82.4 (0.3)
S. barracuda	63.8 (0.1)	73.6 (0.2)	72.1 (0.2)	69.7 (0.2)	67.4 (0.2)	70.1 (0.2)	69.8 (0.2)	57.1 (0.2)

Table 17. Estimates of percent cover of mangrove prop root fringe benthic community for three areas* in Altona Lagoon, 18 November 1993. Values expressed are means (+/- SE). When SE = 0, n = 1.

SPECIES	AREA Outer Bay	 Inner Bay	 Middle Bay
Acanthophora spicifera		20.4 (6.3)	
Acetabularia sp.	4.9 (1.8)	10.0 (3.0)	1.8 (0.6)
Cassiopea sp.	5.3 (0.8)	40.5 (5.3)	18.9 (5.0)
Caulerpa prolifera	7.1 (6.2)	43.7 (6.1)	75.6 (6.2)
Caulerpa sertularioides	10.6 (3.9)	11.0 (2.6)	5.0 (0.0)
Caulerpa verticillata		8.3 (1.7)	
Dasycladus vermicularus		10.0 (0.0)	
Gelidium sp.		10.0 (0.0)	
Gracilaria sp.	20.8 (13.7)		
Halimeda sp.	10.7 (4.3)	14.2 (5.2)	4.7 (1.2)
Hypnea sp.	5.0 (0.0)	15.0 (7.6)	
Microcoleus lyngbyaceous		20.0 (10.0)	
Penicillus capitatus	3.0 (0.0)	40.0 (0.0)	4.0 (0.4)
Thalassia testudinum	9.3 (3.7)	30.0 (0.0)	
anemone		20.0 (10.0)	
mussel		5.0 (0.0)	
open bottom	49.5 (8.3)	10.0 (0.0)	9.3 (3.0)
prop root	3.7 (1.3)	13.4 (5.2)	
sponge	2.0 (0.0)	4.0 (1.0)	

* Outer Bay: embayment closest to lagoon entrance.
Inner Bay: embayment further removed from lagoon entrance than outer bay.
Middle Bay: central area of lagoon >50 m from the mangrove fringe.

List of Figures

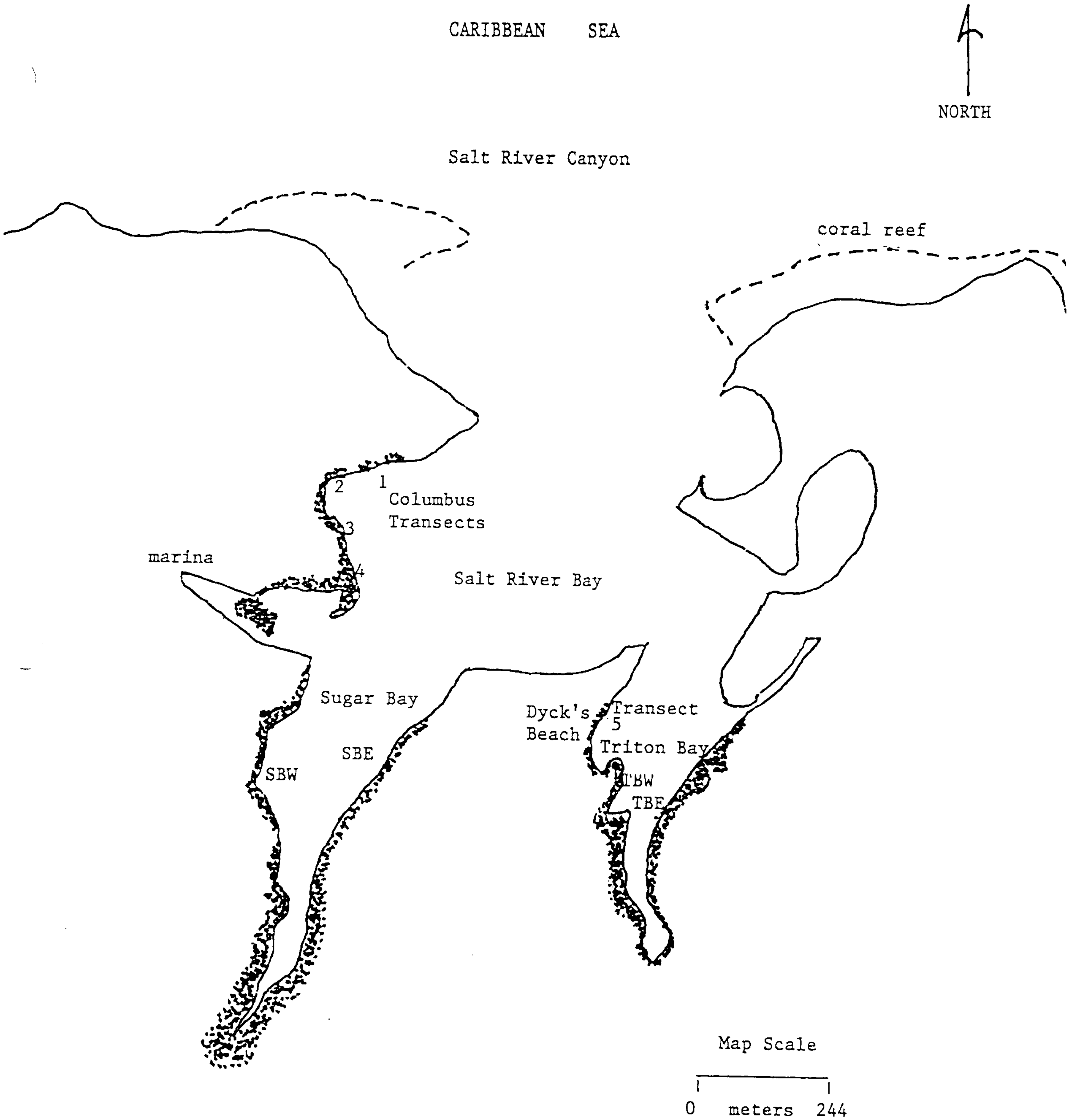


Figure 1. Salt River study site location map. Trap studies conducted in Sugar Bay (SBE = Sugar Bay East, SBW = Sugar Bay West) and Triton Bay (TBE = Triton Bay East, TBW = Triton Bay West). Visual transects conducted at Columbus (1-4) and Dyck's Beach (5).

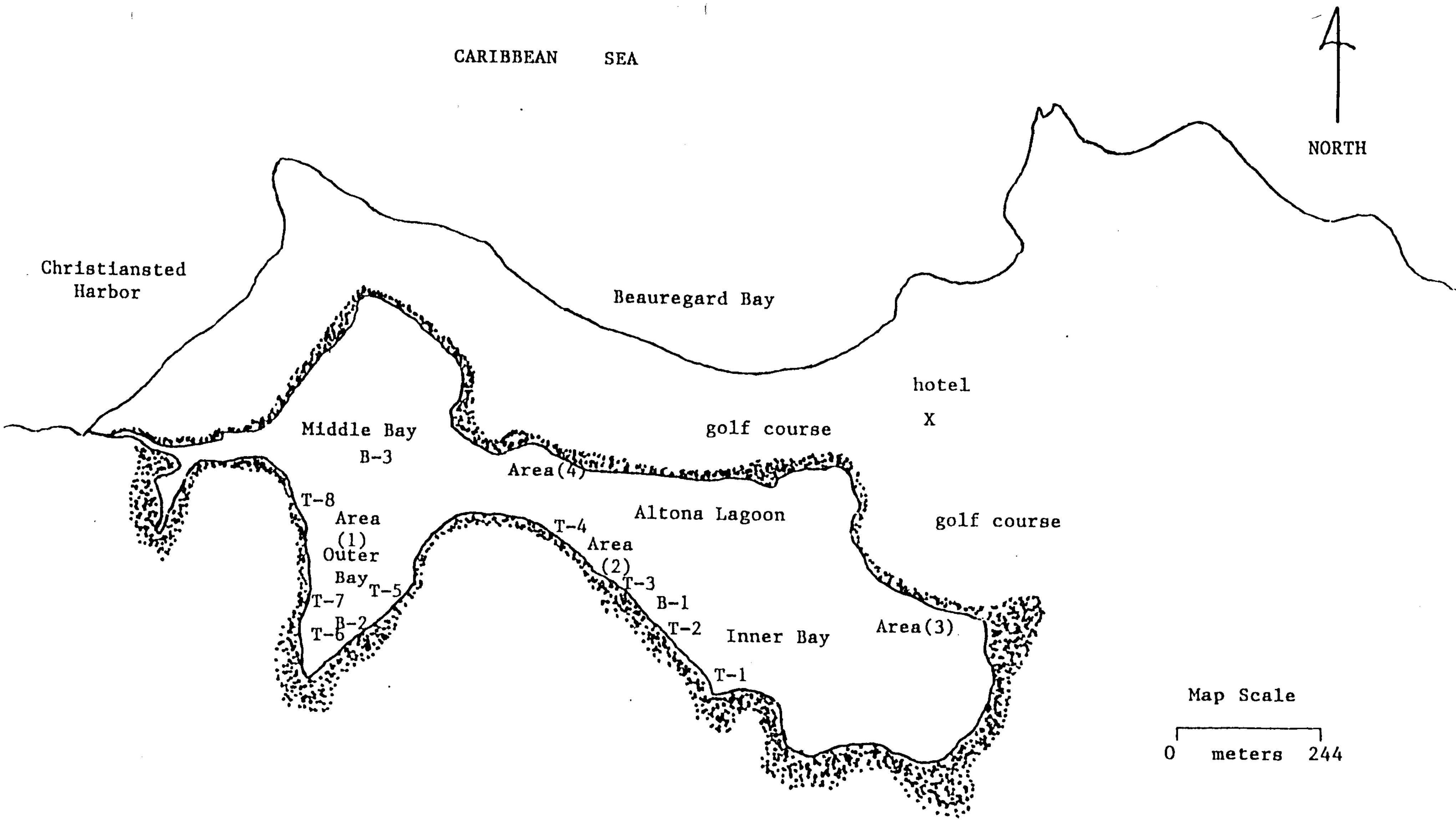
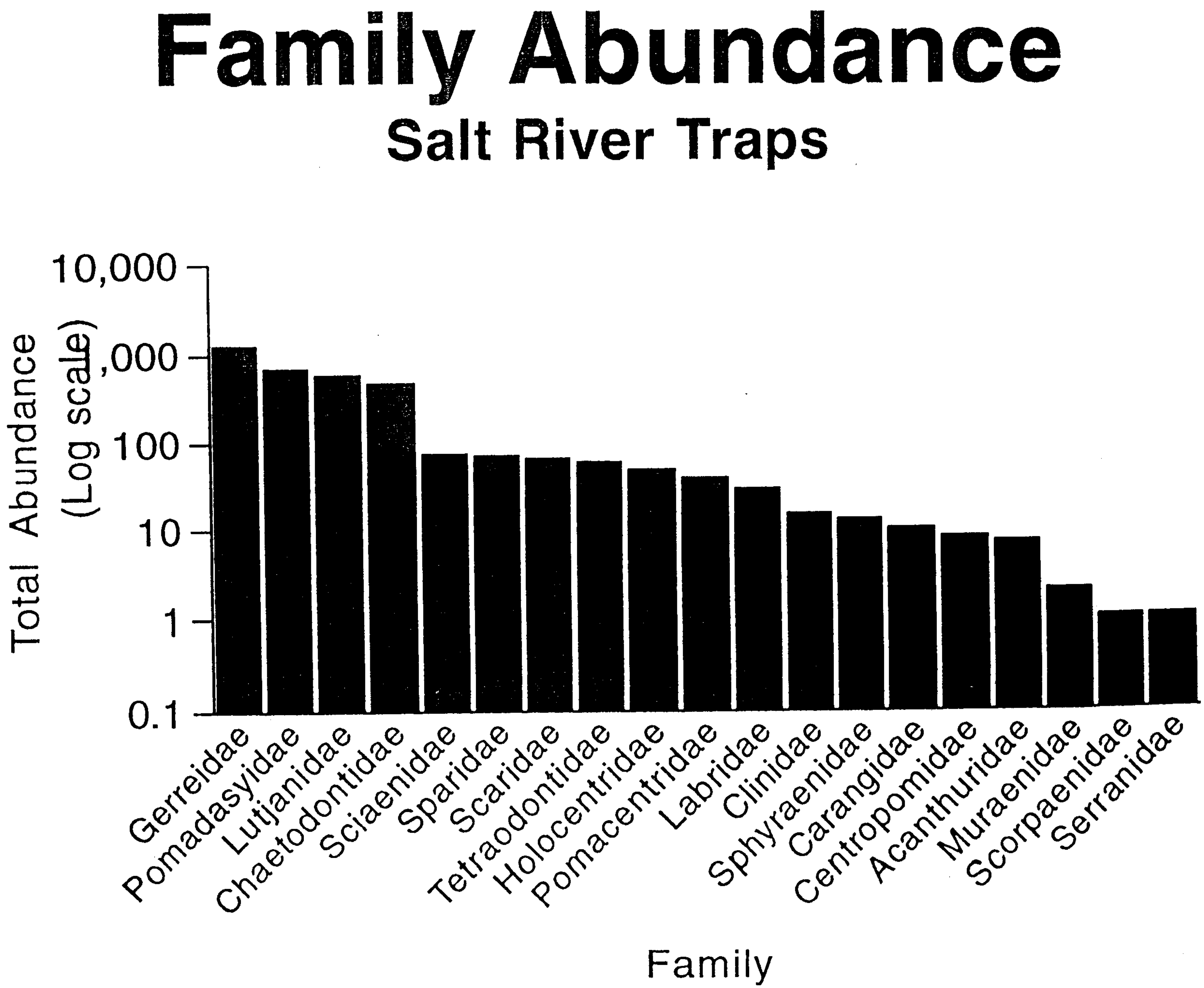


Figure 2. Altona Lagoon study site location map. Trap studies were conducted in Areas (1) - (4). Visual transects were conducted in the Inner Bay (T-1 thru T-4) and in the Outer Bay (T-5 thru T-8). Benthic community studies were conducted in the Inner Bay (B-1), Outer Bay (B-2) and Middle Bay (B-3).



Family Abundance
Salt River Traps
Total Abundance (Log scale)
10,000
1,000
100
10
1
0.1
Gerreidae
Pomadasyidae
Lutjanidae
Chaetodontidae
Sciaenidae
Sparidae
Scaridae
Tetraodontidae
Holocentridae
Pomacentridae
Labridae
Clinidae
Sphyraenidae
Carangidae
Centropomidae
Acanthuridae
Muraenidae
Scorpaenidae
Serranidae
Family

Figure 3.

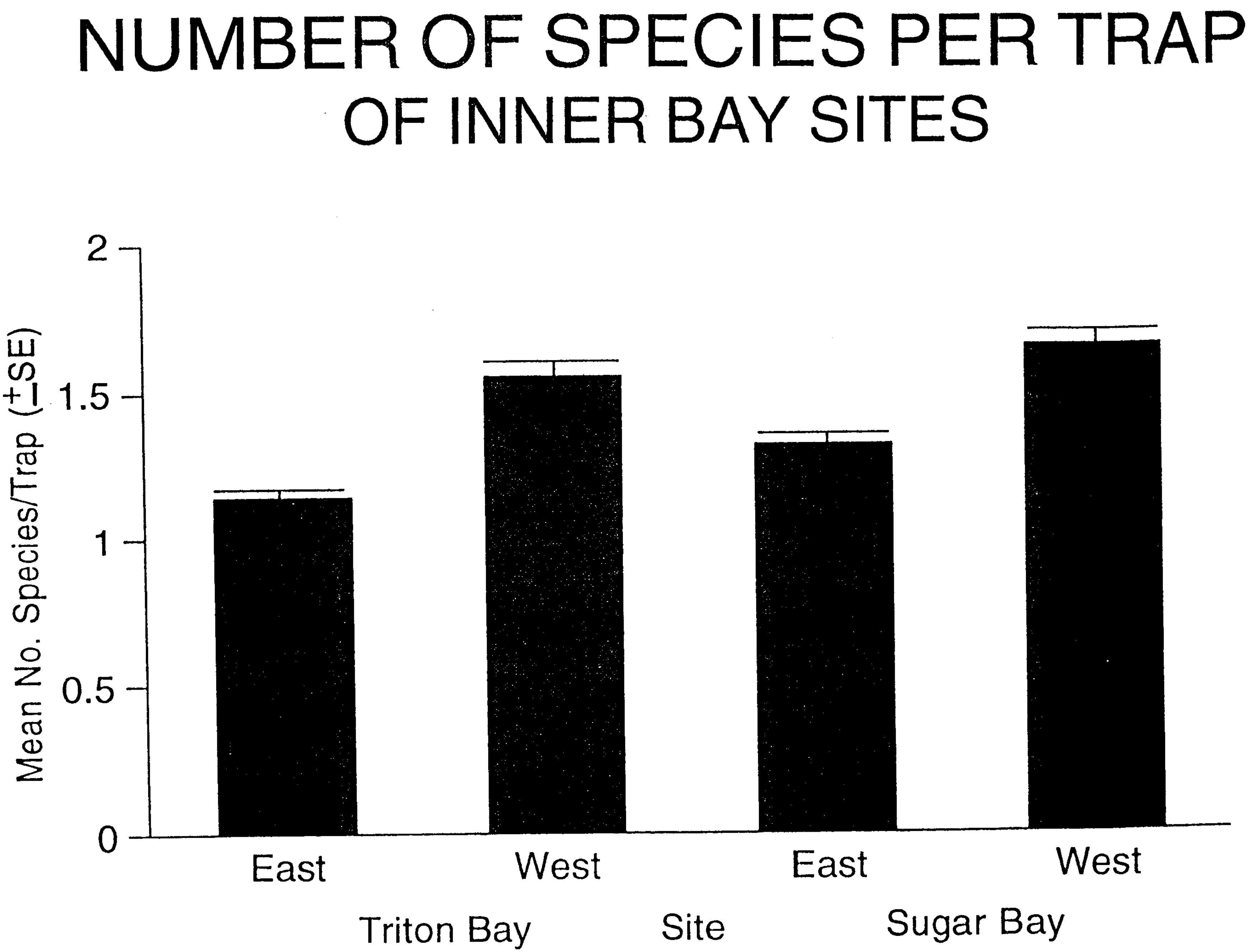

NUMBER OF SPECIES PER TRAP
OF INNER BAY SITES
Mean No. Species/Trap (±SE)
2
1.5
1
0.5
0
East
West
East
West
Triton Bay
Site
Sugar Bay

Figure 4.

NUMBER OF INDIVIDUALS PER TRAP OF INNER BAY SITES

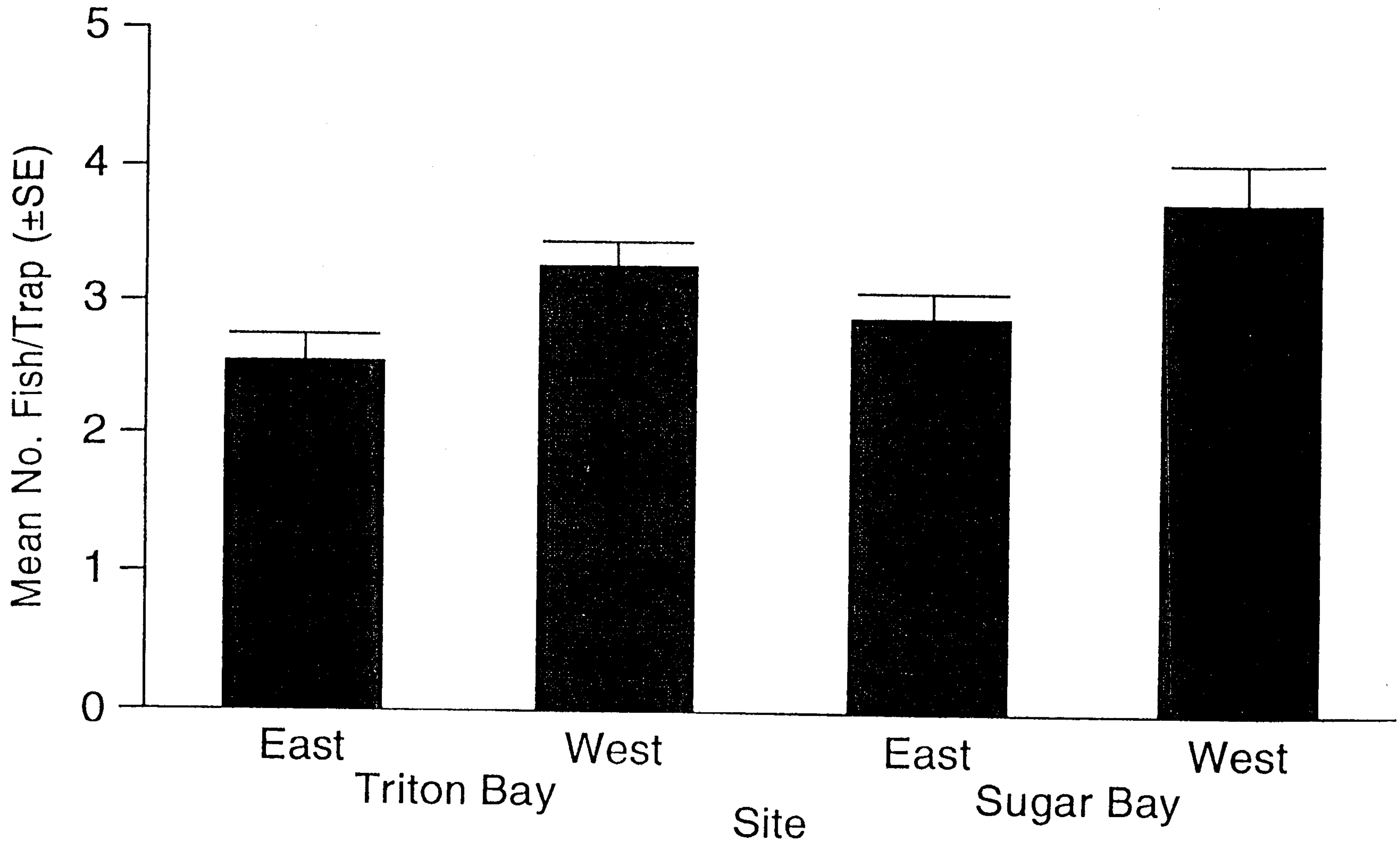


Figure 5.

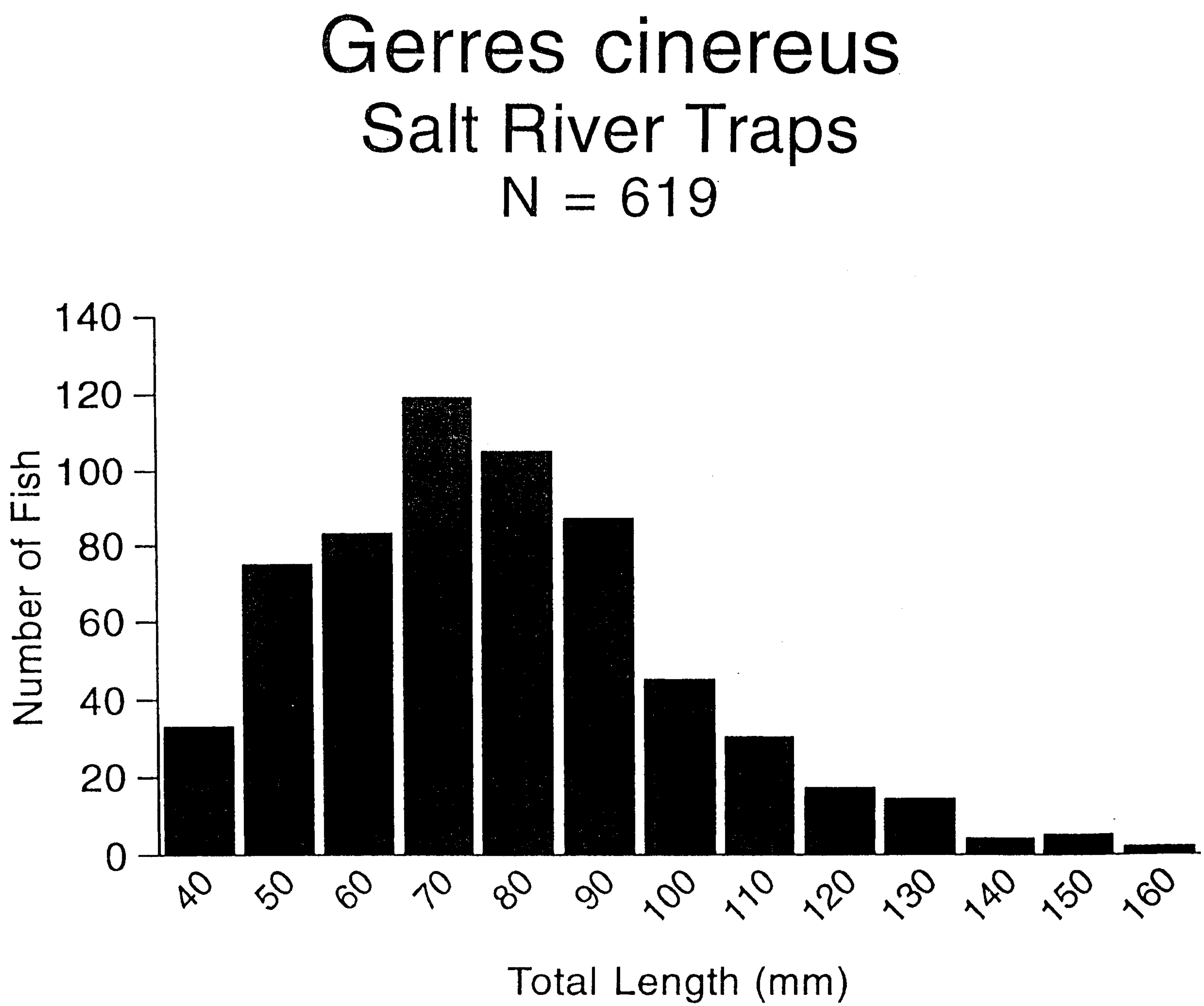

Gerres cinereus
Salt River Traps
N = 619
Number of Fish
0
20
40
60
80
100
120
140
40
50
60
70
80
90
100
110
120
130
140
150
160
Total Length (mm)

Figure 6.

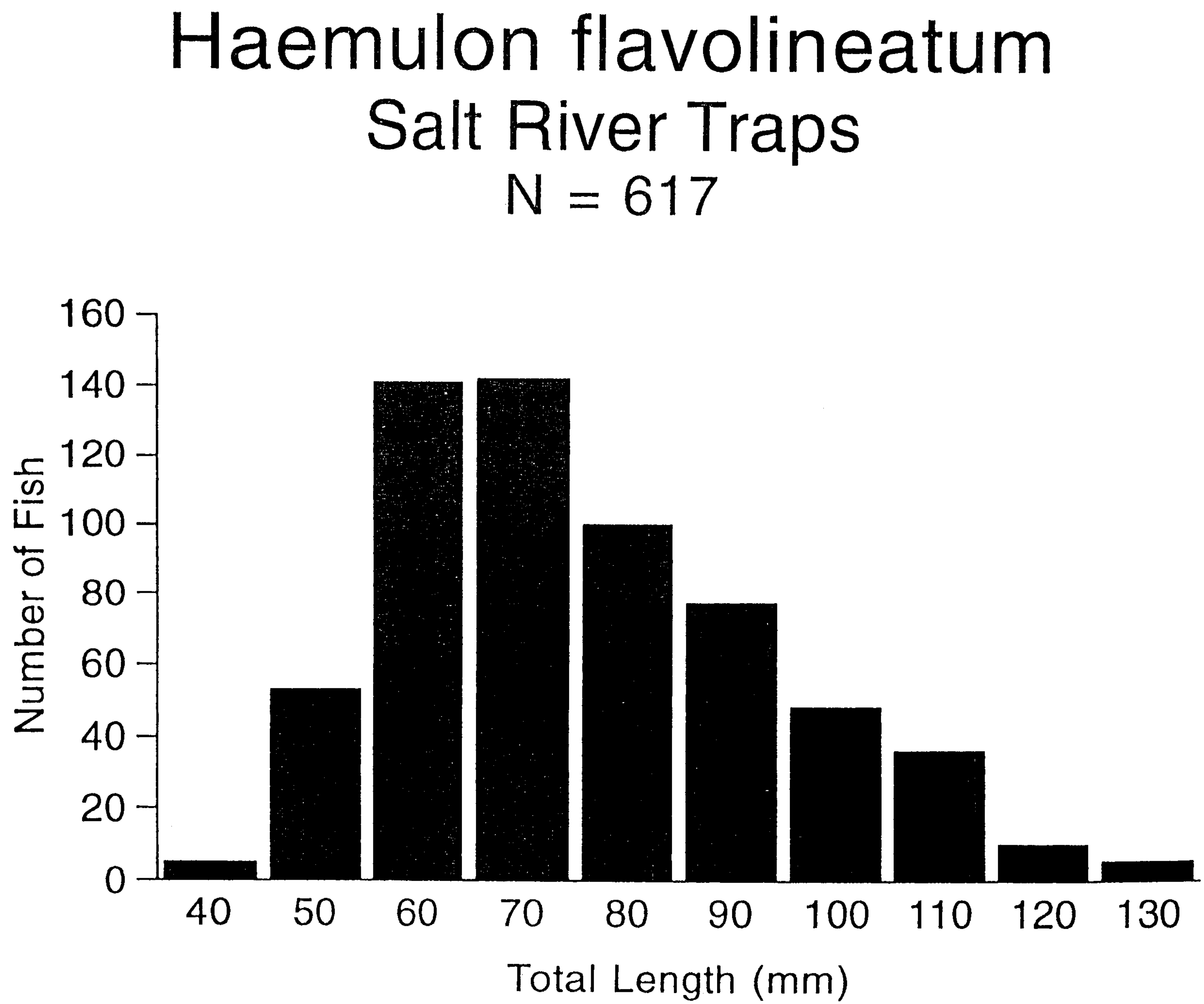
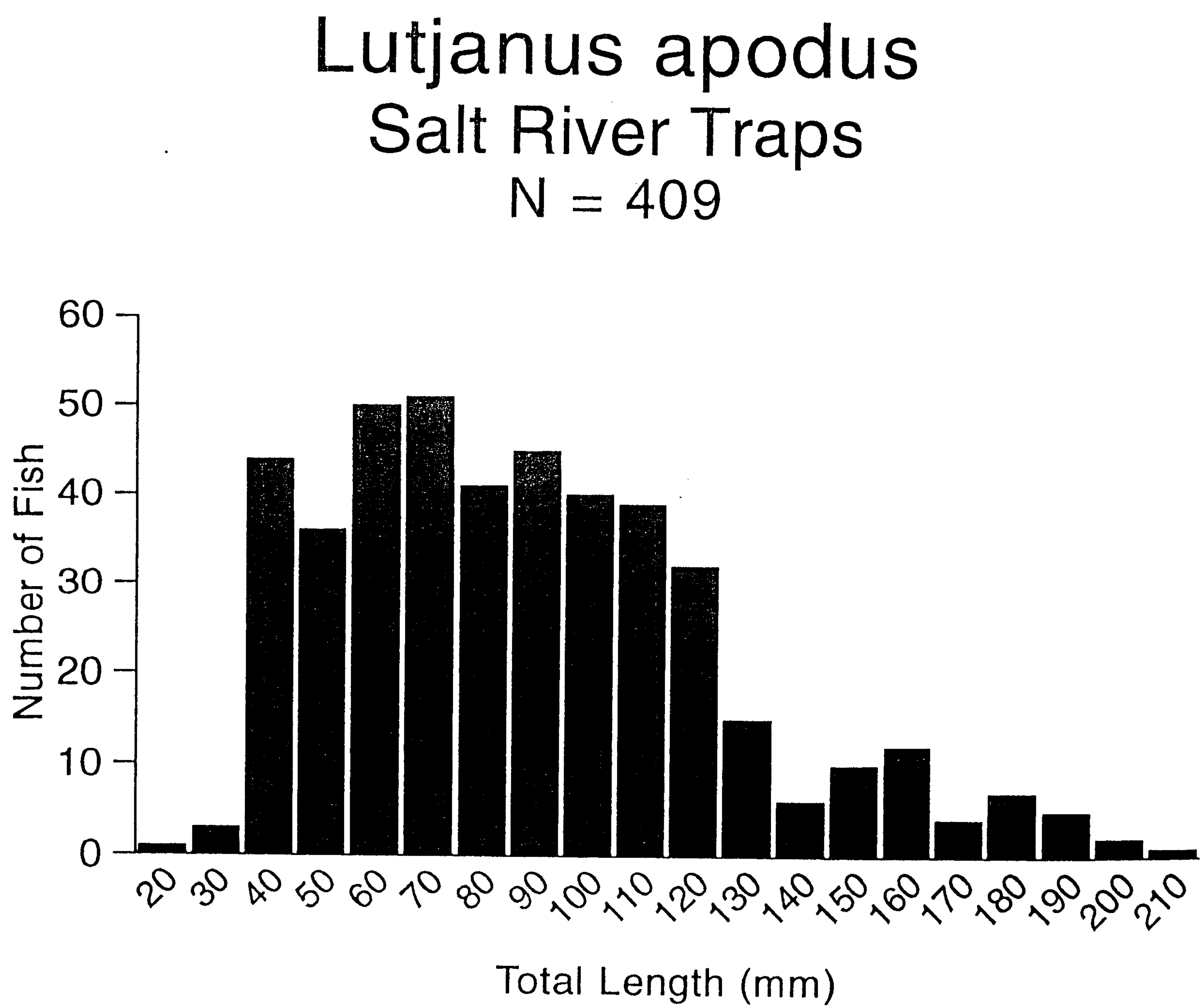
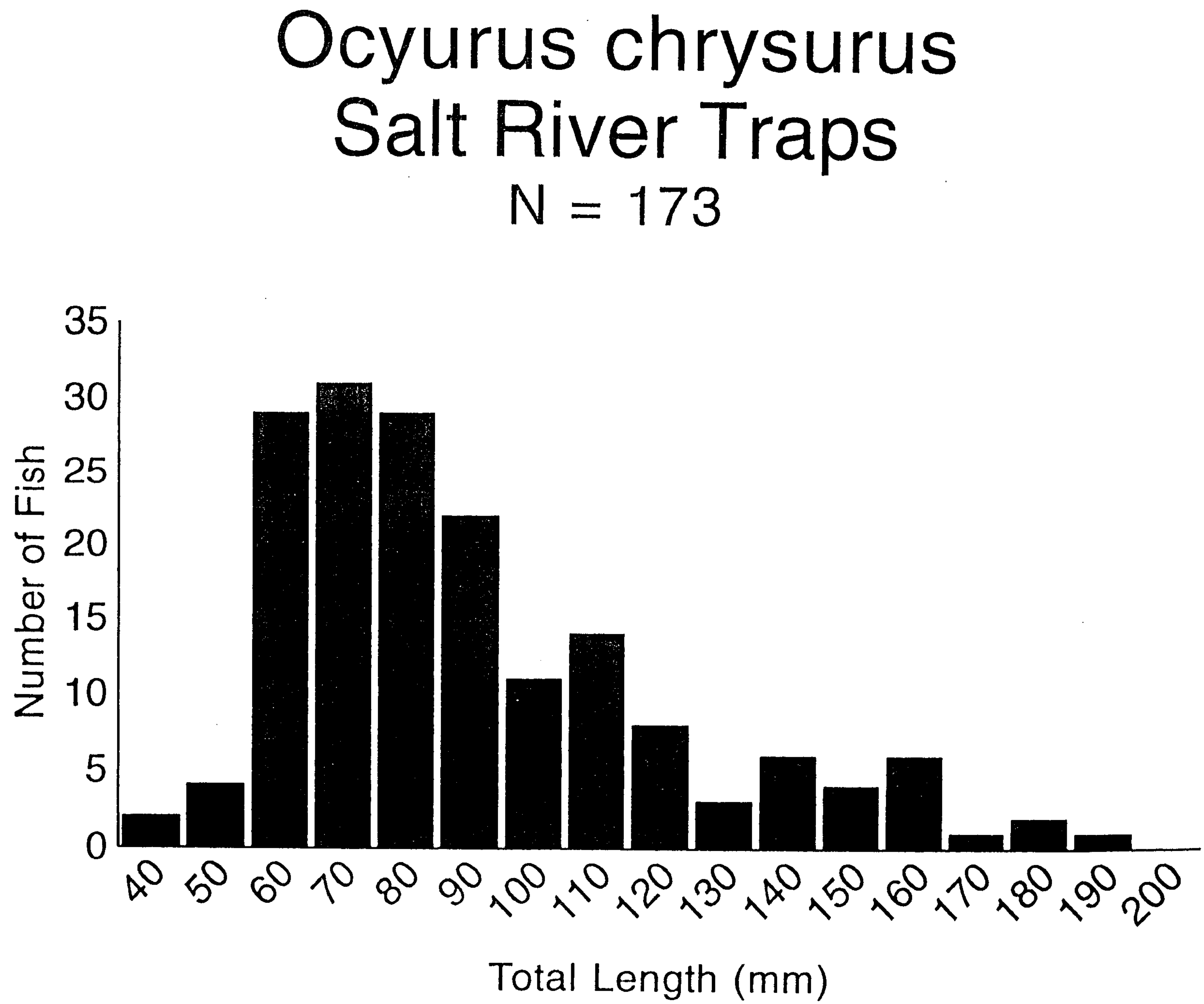

Haemulon flavolineatum
Salt River Traps
N = 617
Number of Fish
160
140
120
100
80
60
40
20
0
40
50
60
70
80
90
100
110
120
130
Total Length (mm)

Figure 7.



Lutjanus apodus
Salt River Traps
N = 409
Number of Fish
0
10
20
30
40
50
60
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
Total Length (mm)

Figure 8.



Ocyurus chrysurus
Salt River Traps
N = 173
Number of Fish
35
30
25
20
15
10
5
0
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Total Length (mm)

Figure 9.

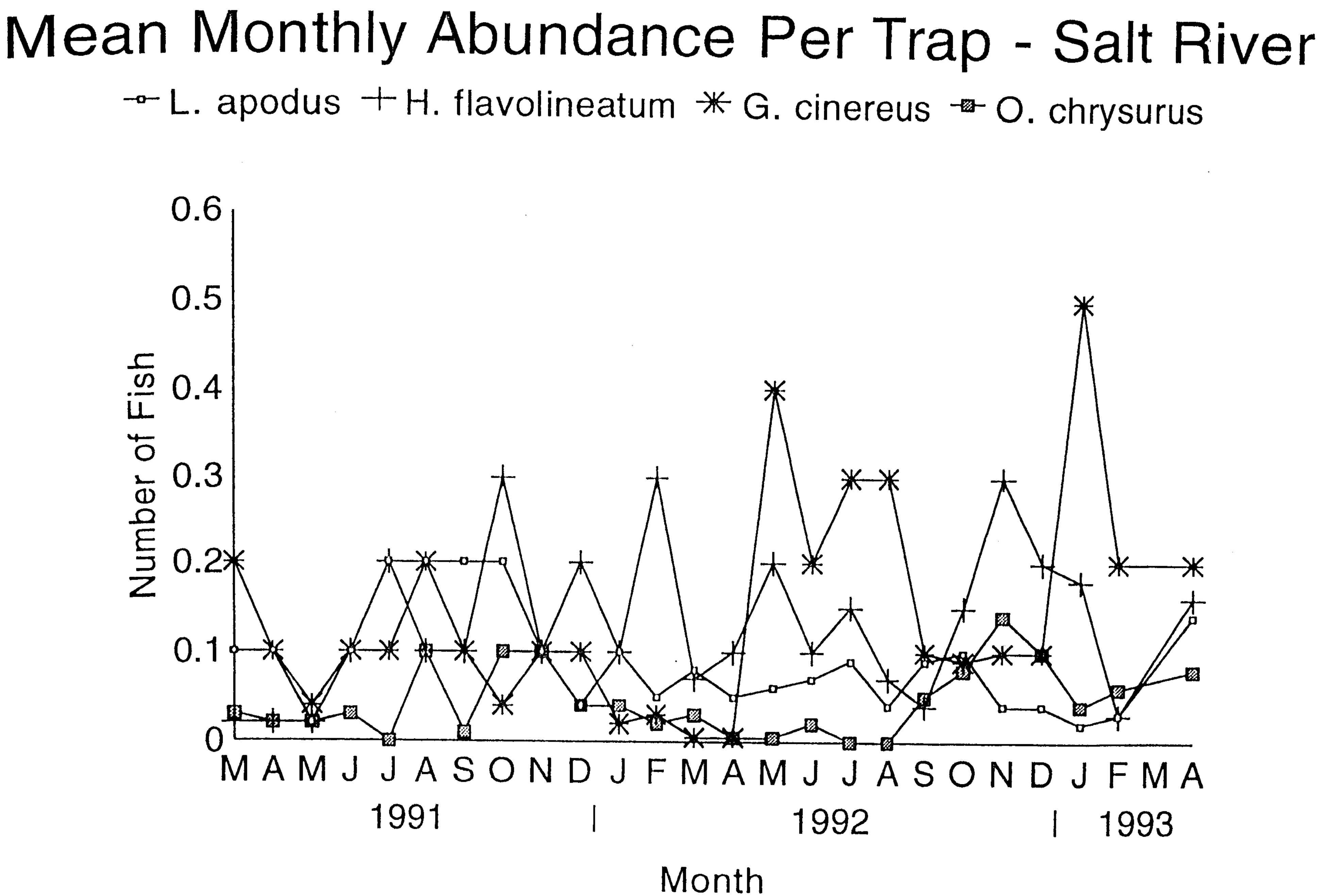

Mean Monthly Abundance Per Trap - Salt River
L. apodus
H. flavolineatum
G. cinereus
O. chrysurus
Number of Fish
0.6
0.5
0.4
0.3
0.2
0.1
0
M A M J J A S O N D J F M A M J J A S O N D J F M A
1991
1992
1993
Month

Figure 10.

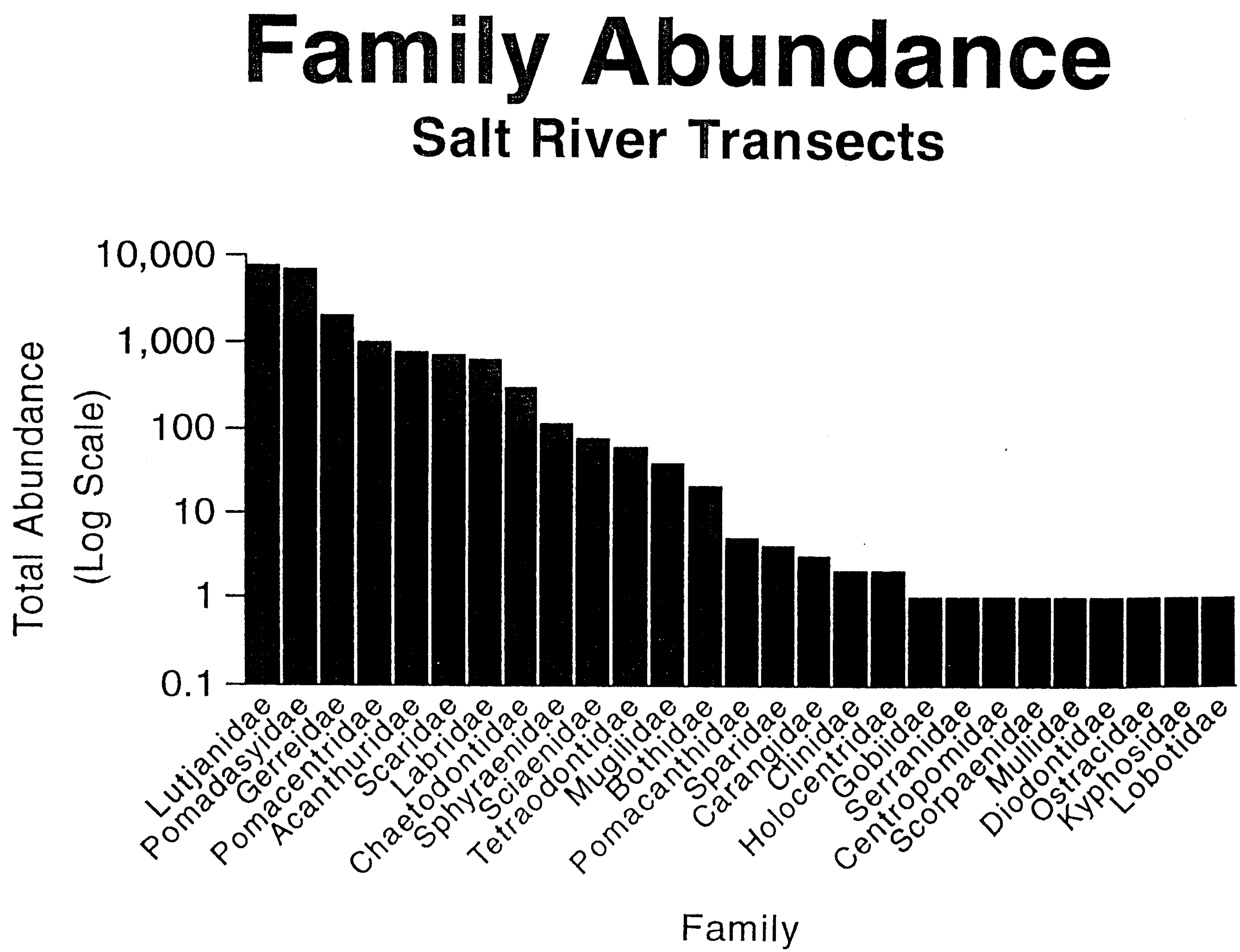

Family Abundance
Salt River Transects
Total Abundance
(Log Scale)
10,000
1,000
100
10
1
0.1
Lutjanidae
Pomadasyidae
Gerreidae
Pomacentridae
Acanthuridae
Scaridae
Labridae
Chaetodontidae
Sphyraenidae
Sciaenidae
Tetraodontidae
Mugilidae
Bothidae
Pomacanthidae
Sparidae
Carangidae
Clinidae
Holocentridae
Gobiidae
Serranidae
Centropomidae
Scorpaenidae
Mullidae
Diodontidae
Ostracidae
Kyphosidae
Lobotidae
Family

Figure 11.

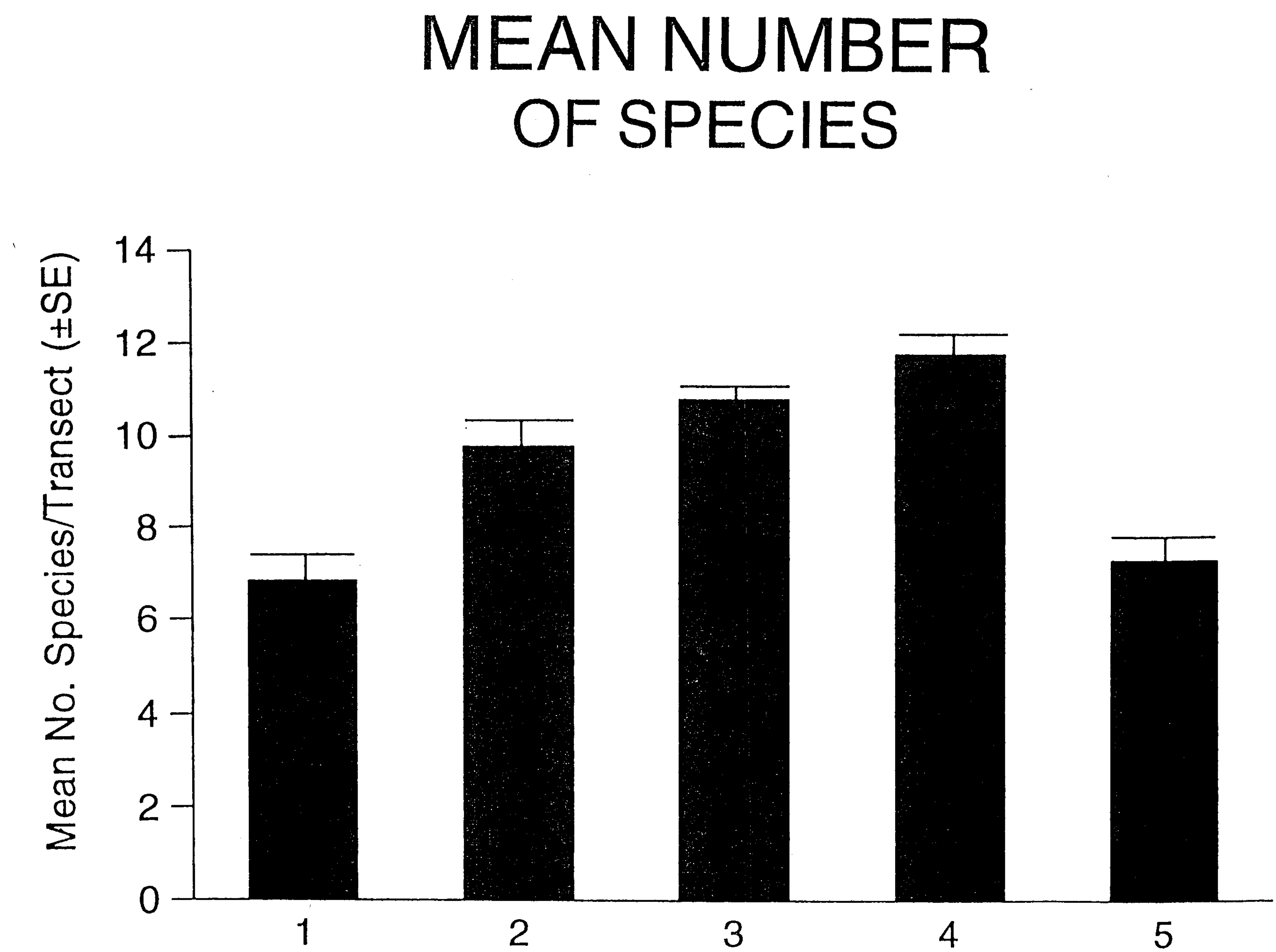

MEAN NUMBER
OF SPECIES
Mean No. Species/Transect (±SE)
14
12
10
8
6
4
2
0
1
2
3
4
5

Figure 12.

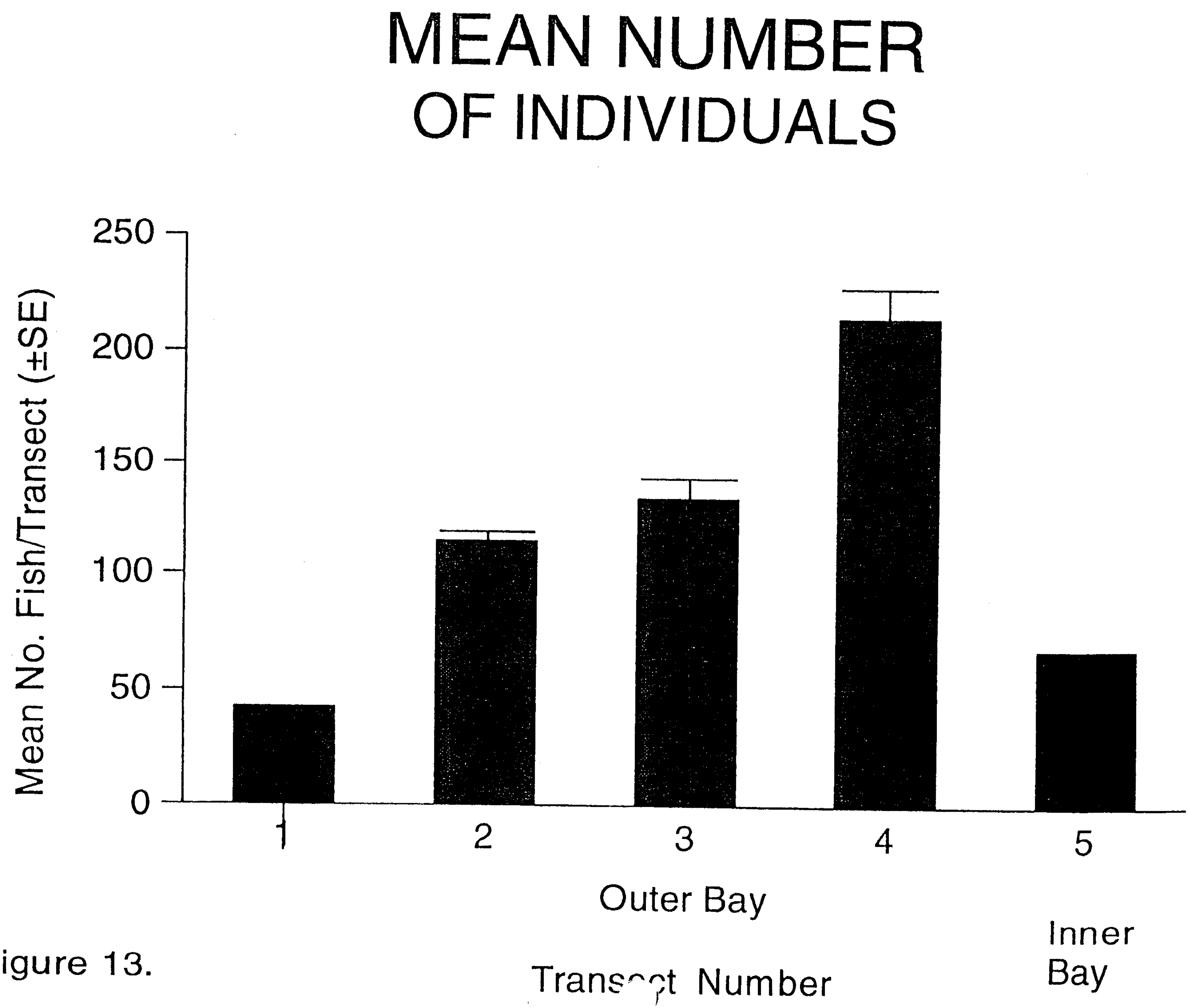

MEAN NUMBER
OF INDIVIDUALS
Mean No. Fish/Transect (±SE)
250
200
150
100
50
0
1
2
3
4
5
Outer Bay
Inner
Bay
Transect Number

Figure 13.

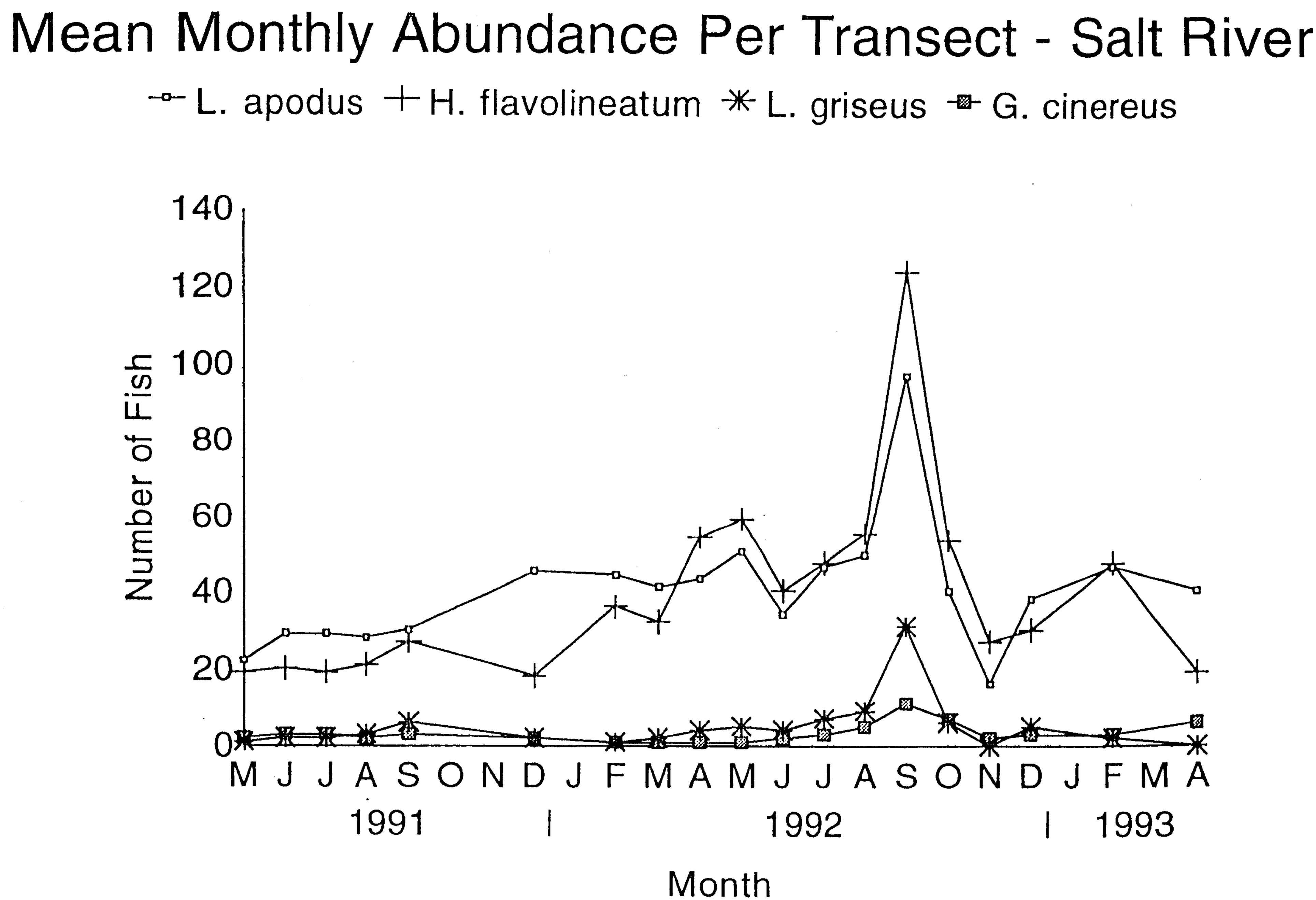

Mean Monthly Abundance Per Transect - Salt River
L. apodus
H. flavolineatum
L. griseus
G. cinereus
Number of Fish
0
20
40
60
80
100
120
140
M J J A S O N D J F M A M J J A S O N D J F M A
1991
1992
1993
Month

Figure 14.

Family Abundance
Altona Lagoon Traps

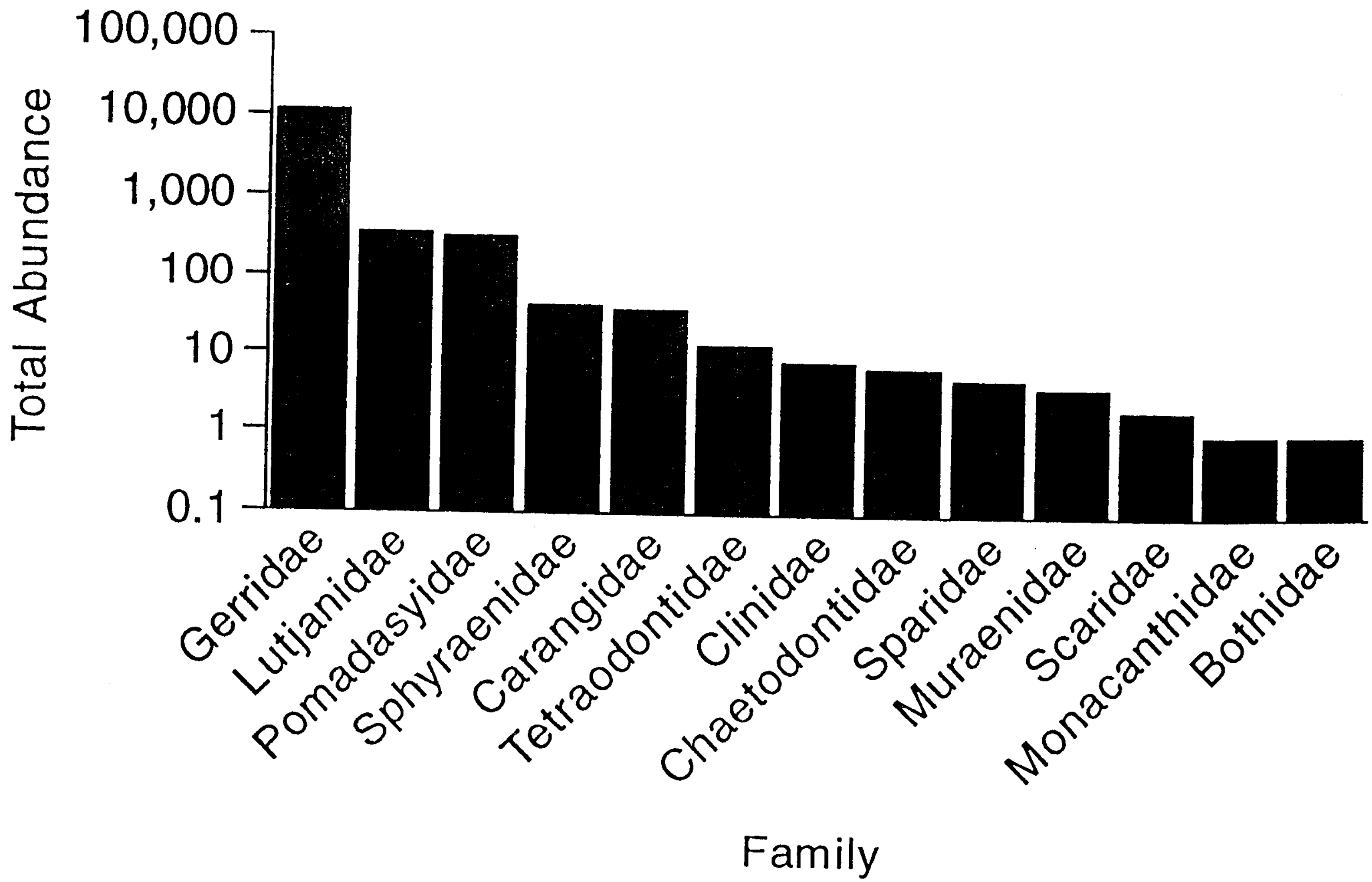


Figure 15.

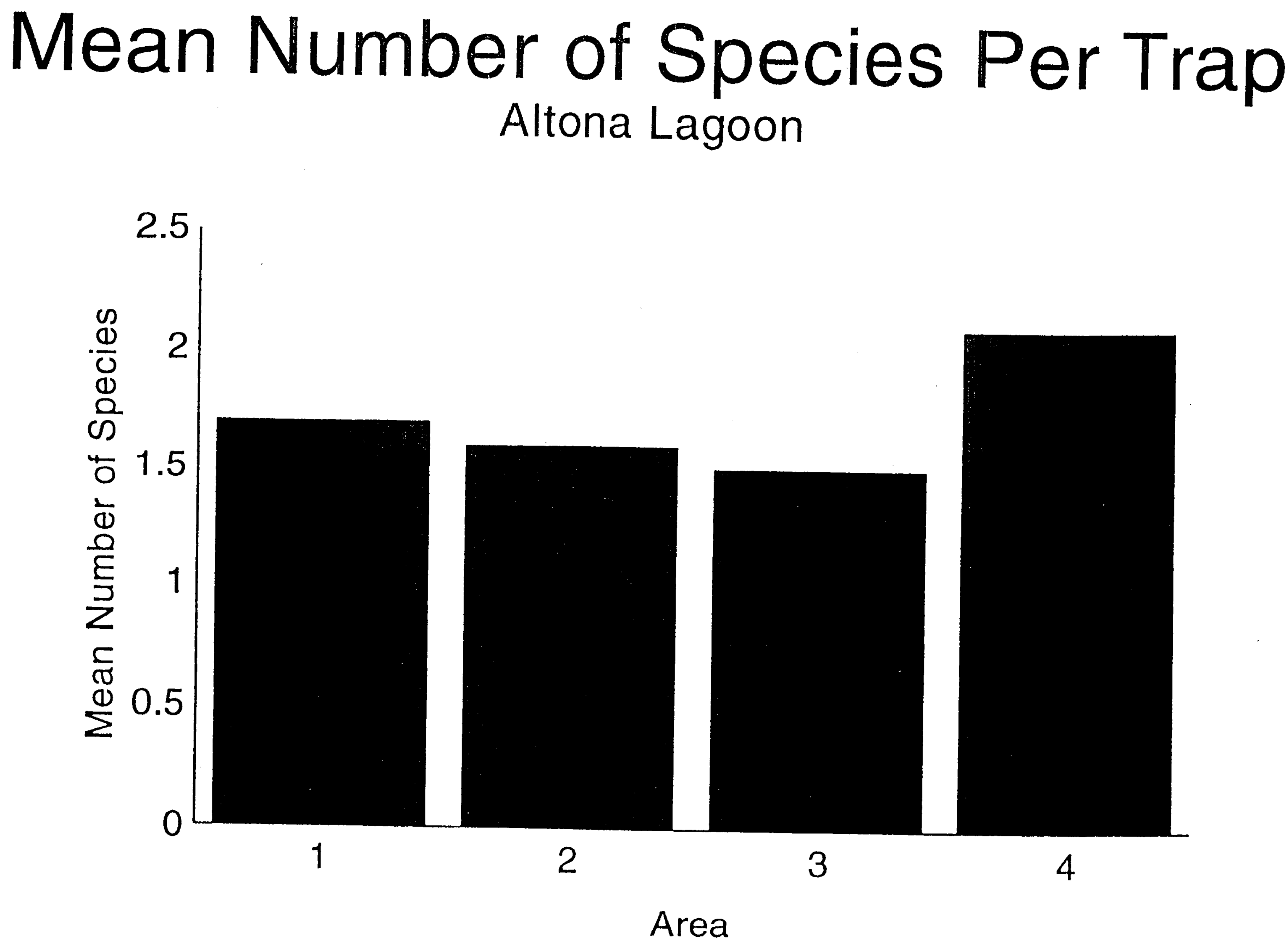

Mean Number of Species Per Trap
Altona Lagoon
Mean Number of Species
2.5
2
1.5
1
0.5
0
1
2
3
4
Area

Figure 16.

Number of Individuals Per Trap

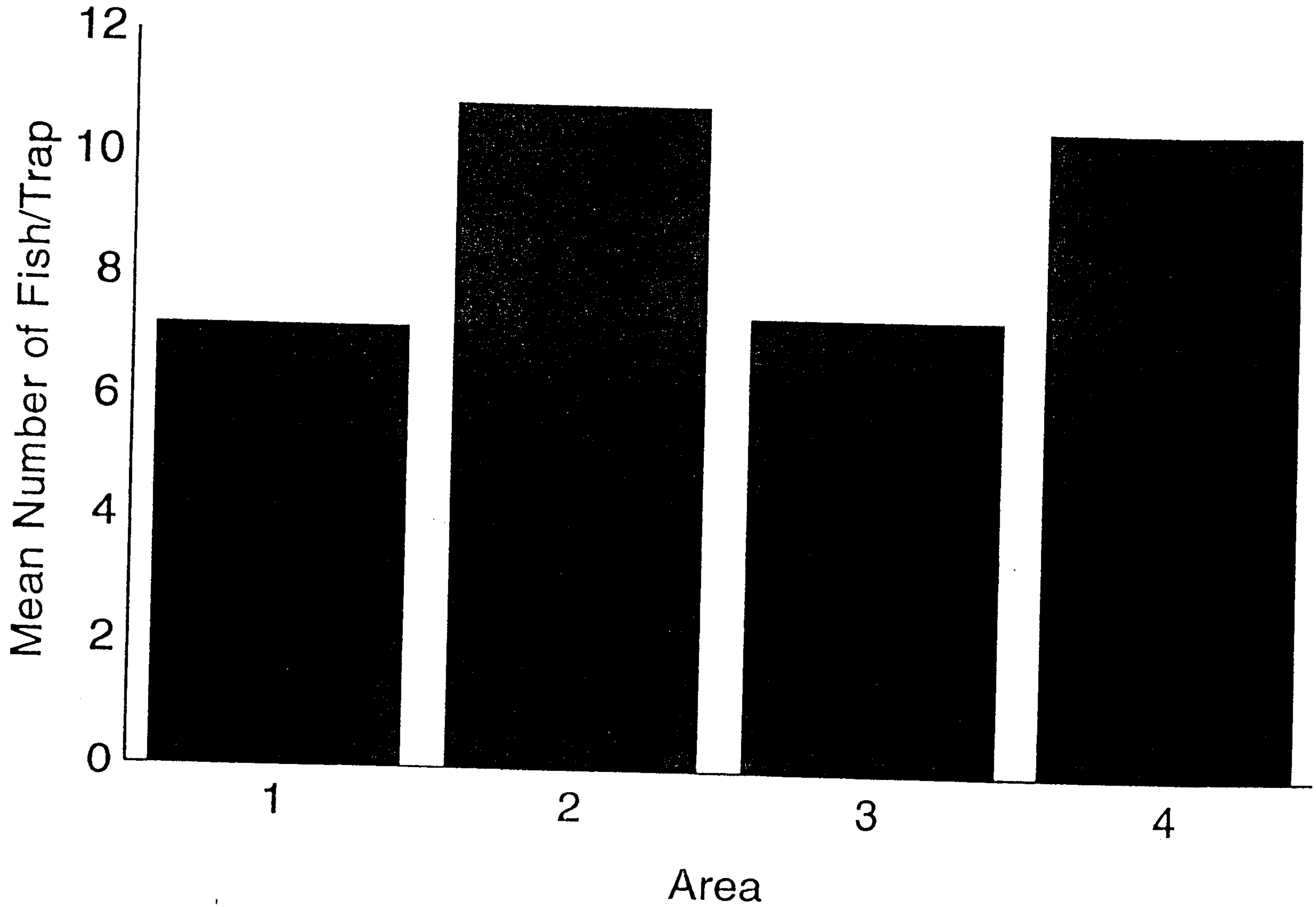


Figure 17.

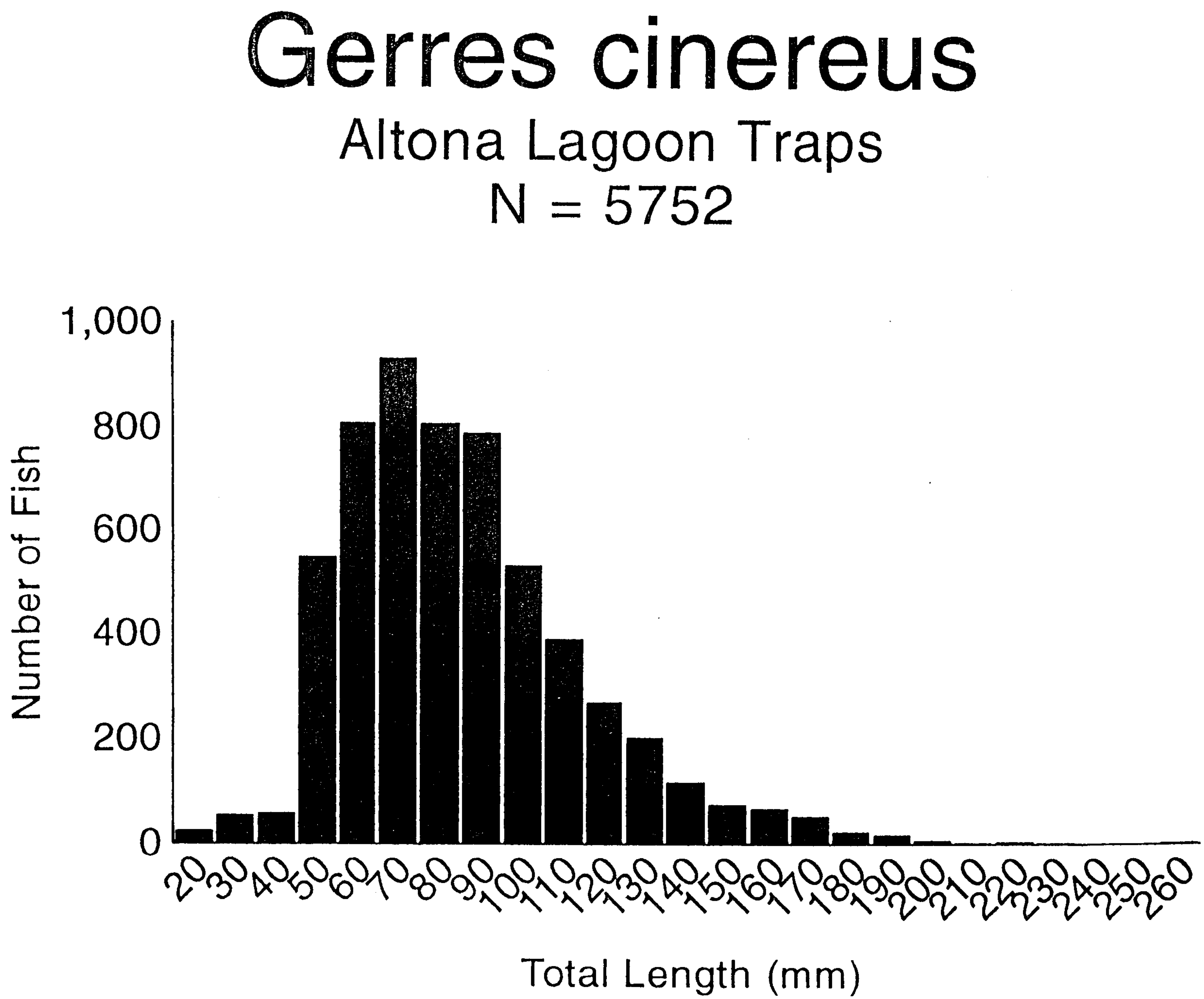

Gerres cinereus
Altona Lagoon Traps
N = 5752
Number of Fish
1,000
800
600
400
200
0
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
Total Length (mm)

Figure 18.

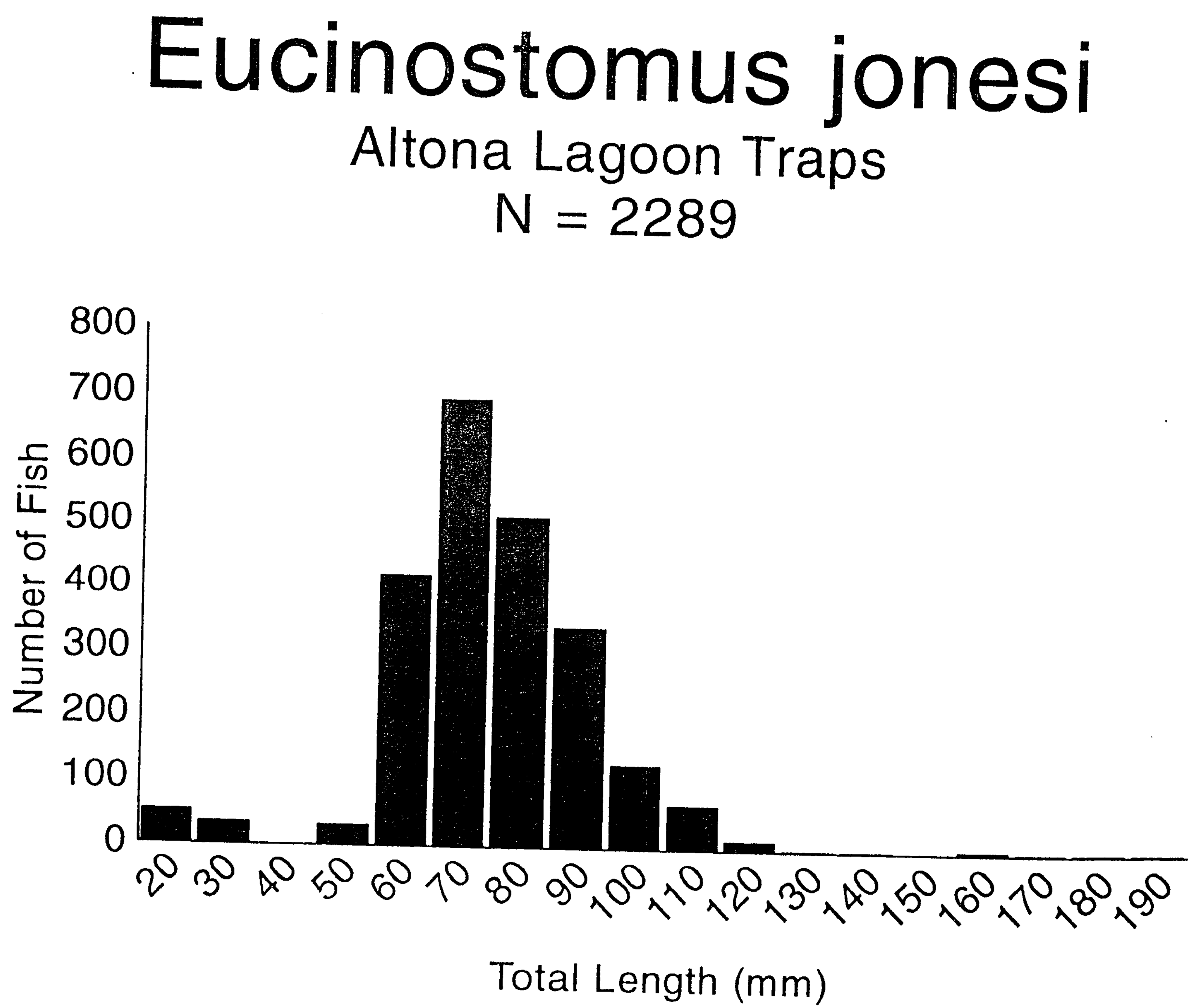

Eucinostomus jonesi
Altona Lagoon Traps
N = 2289
Number of Fish
800
700
600
500
400
300
200
100
0
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Total Length (mm)

Figure 19.

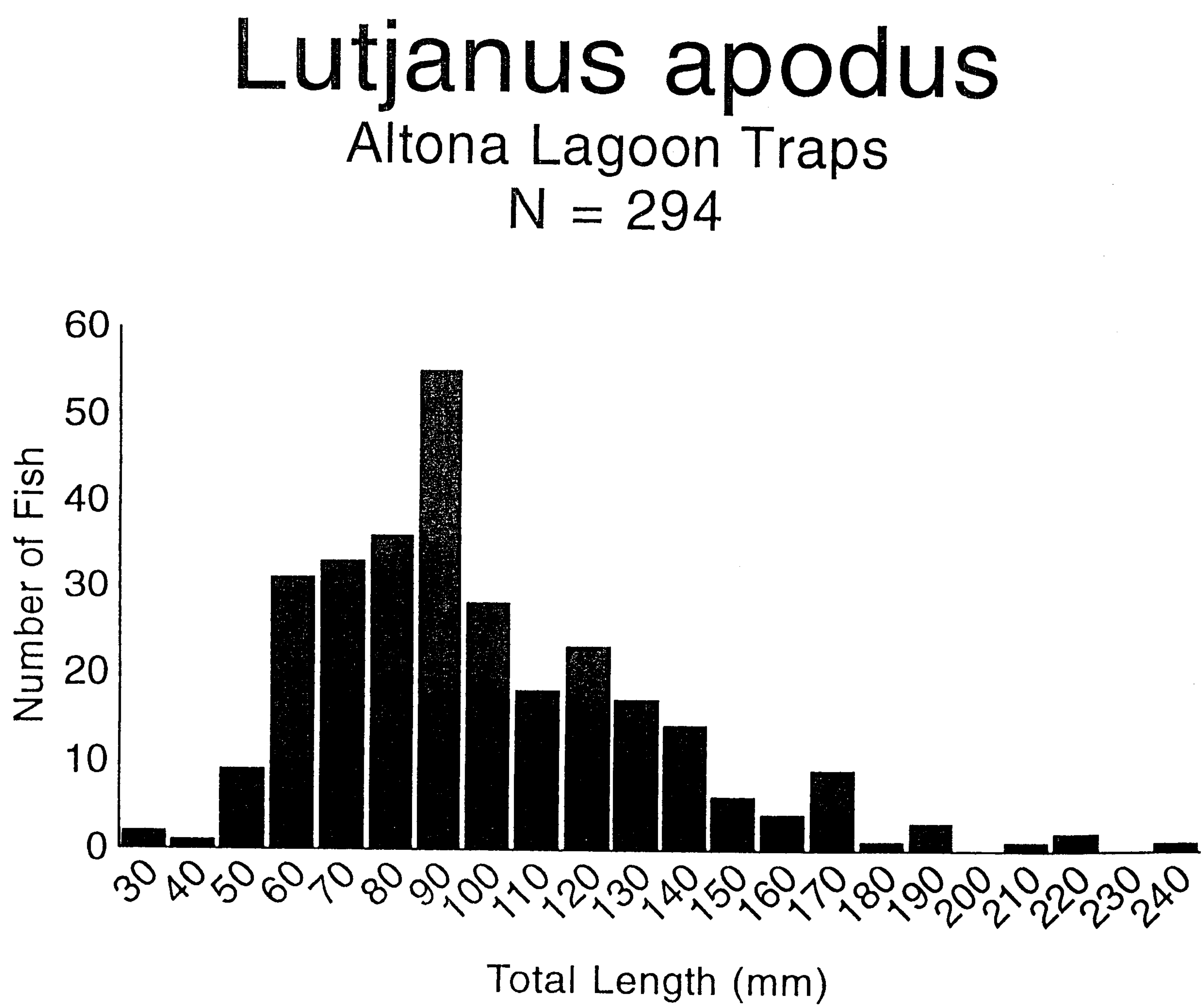

Lutjanus apodus
Altona Lagoon Traps
N = 294
Number of Fish
0
10
20
30
40
50
60
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240
Total Length (mm)

Figure 20.

Haemulon flavolineatum

Altona Lagoon Traps

N = 133

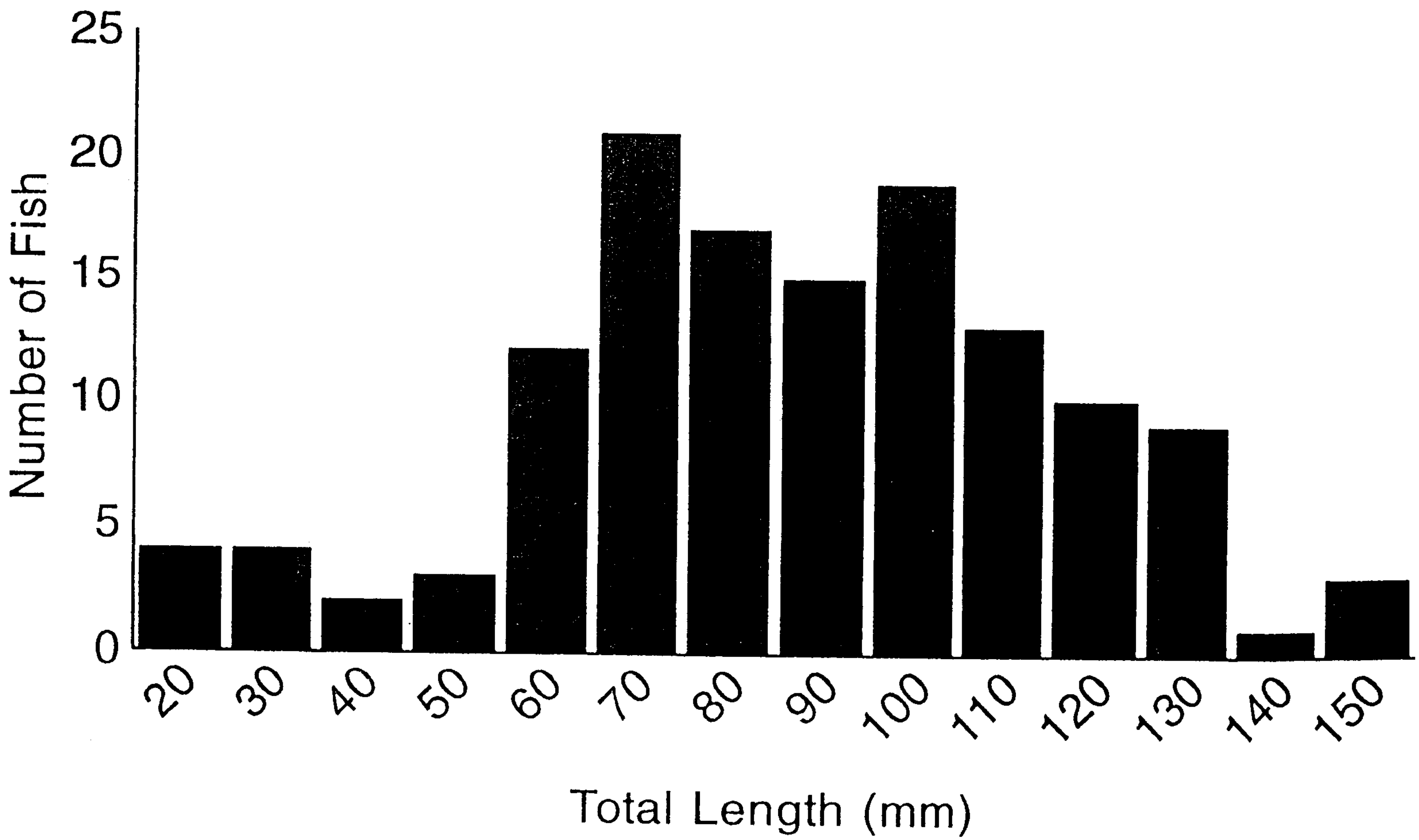


Figure 21.

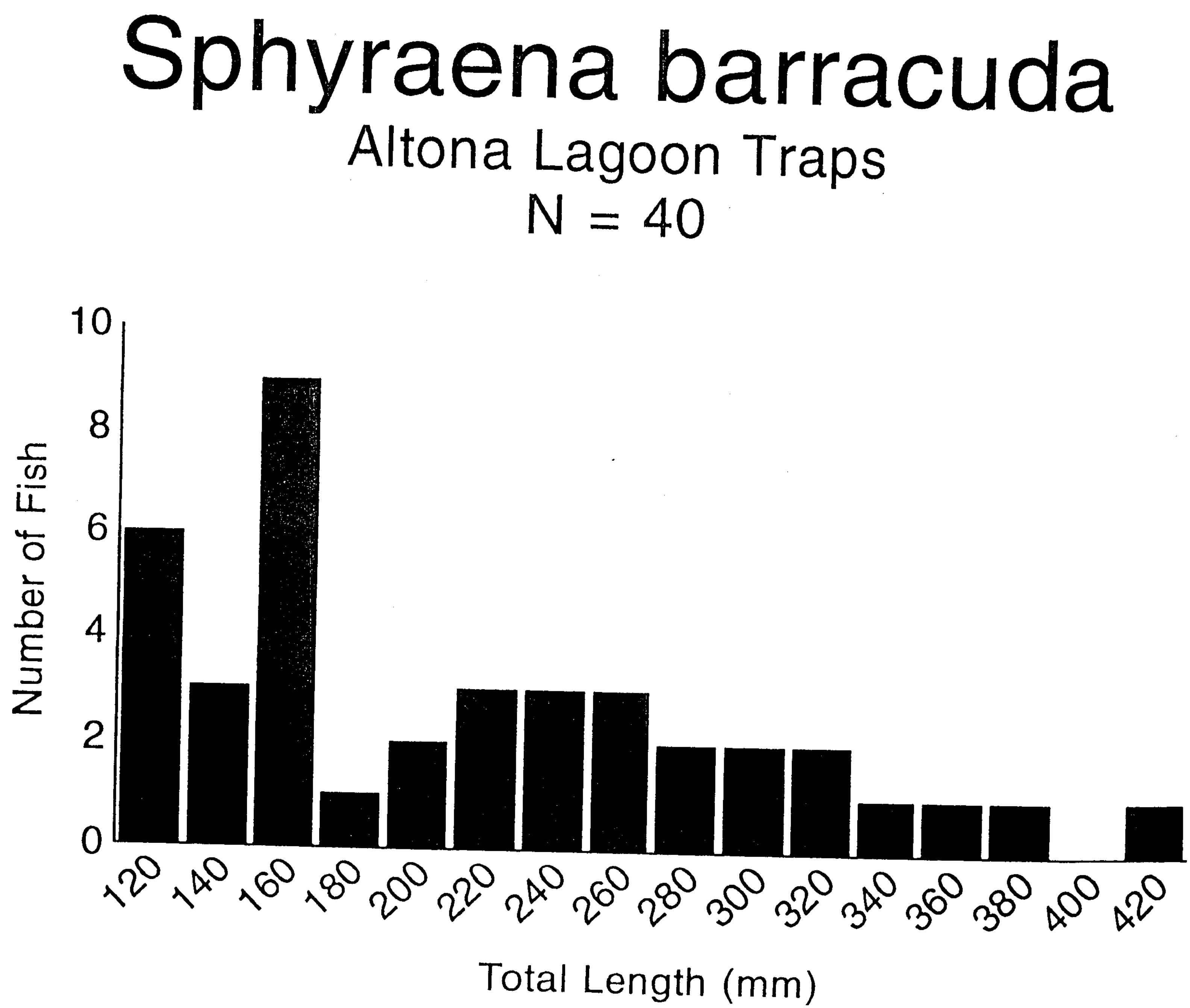

Sphyraena barracuda
Altona Lagoon Traps
N = 40
Number of Fish
0
2
4
6
8
10
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
Total Length (mm)

Figure 22.

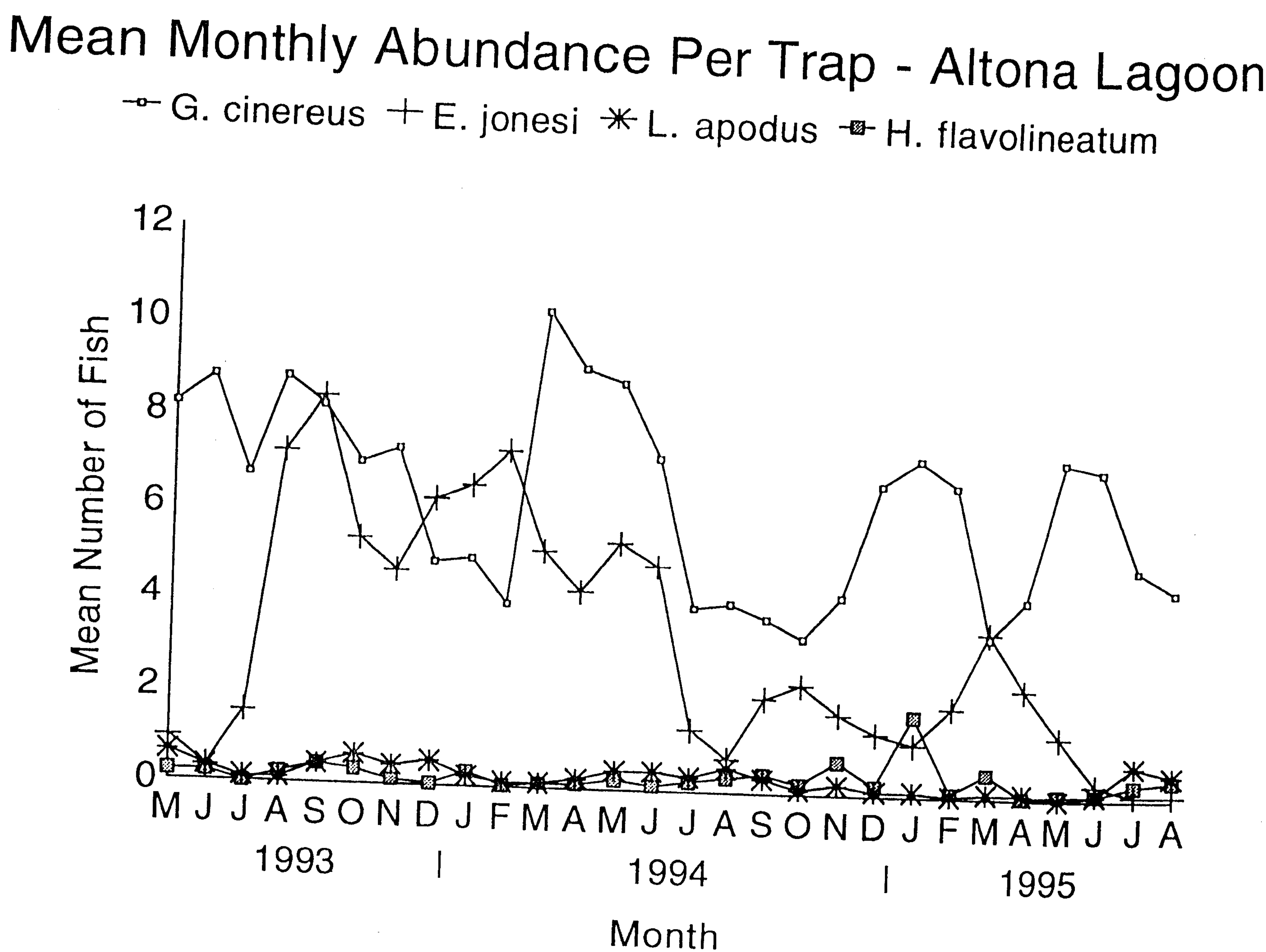

Mean Monthly Abundance Per Trap - Altona Lagoon
G. cinereus
E. jonesi
L. apodus
H. flavolineatum
Mean Number of Fish
0
2
4
6
8
10
12
M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1993
1994
1995
Month

Figure 23.

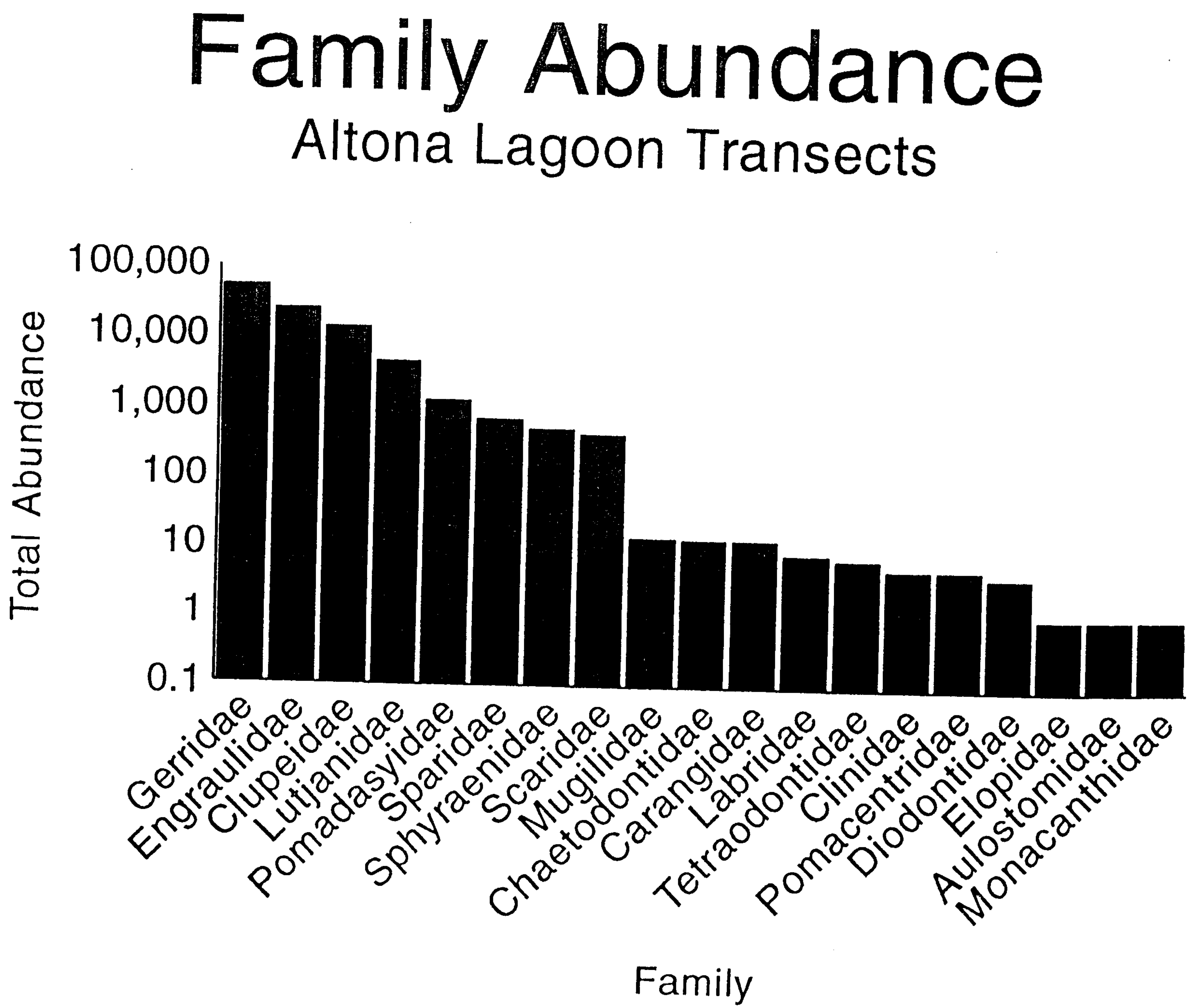

Family Abundance
Altona Lagoon Transects
Total Abundance
100,000
10,000
1,000
100
10
1
0.1
Gerridae
Engraulidae
Clupeidae
Lutjanidae
Pomadasyidae
Sparidae
Sphyraenidae
Scaridae
Mugilidae
Chaetodontidae
Carangidae
Labridae
Tetraodontidae
Clinidae
Pomacentridae
Diodontidae
Elopidae
Aulostomidae
Monacanthidae
Family

Figure 24.

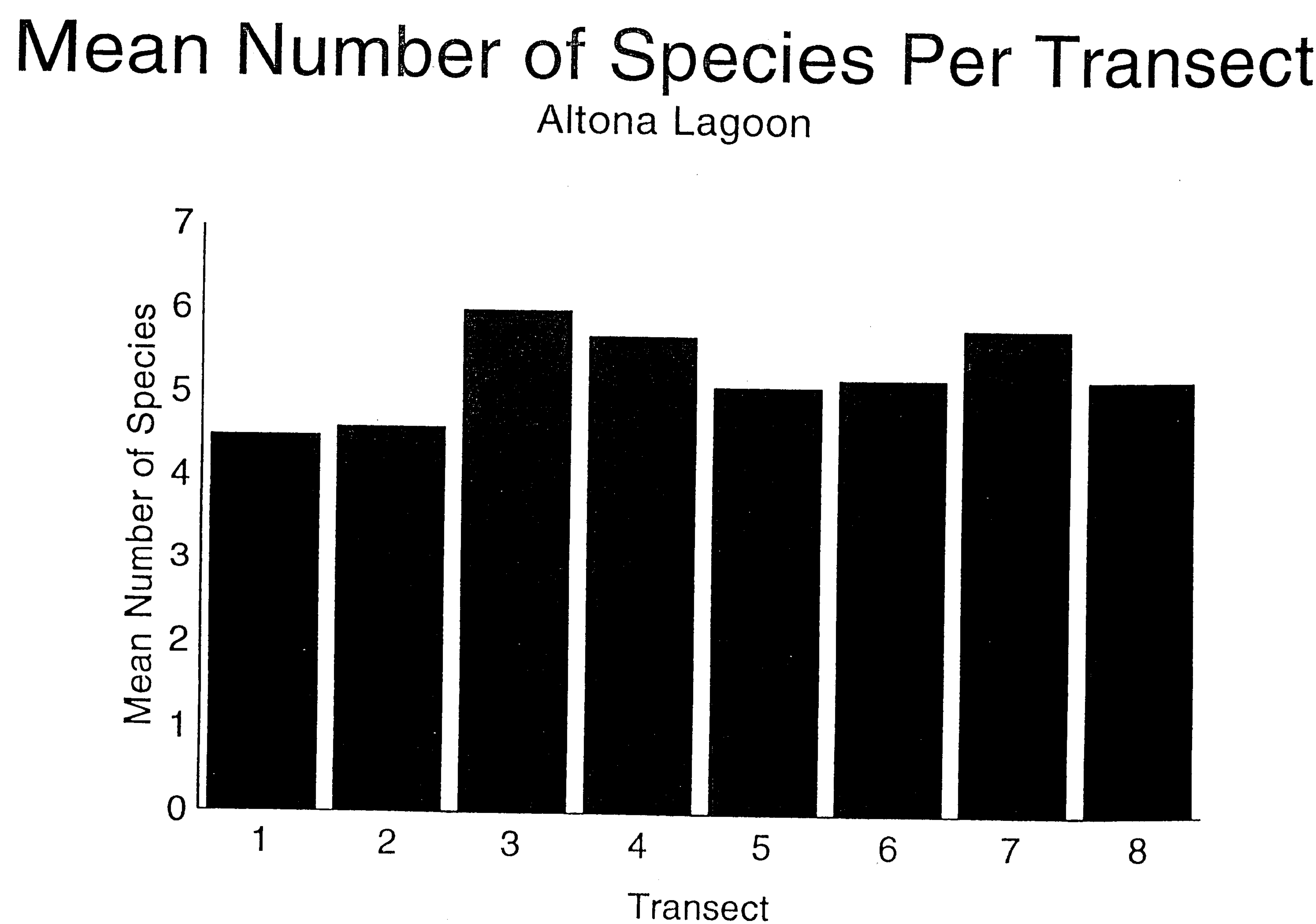

Mean Number of Species Per Transect
Altona Lagoon
Mean Number of Species
0
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
Transect

Figure 25.

Mean Number of Fish Per Transect

Altona Lagoon

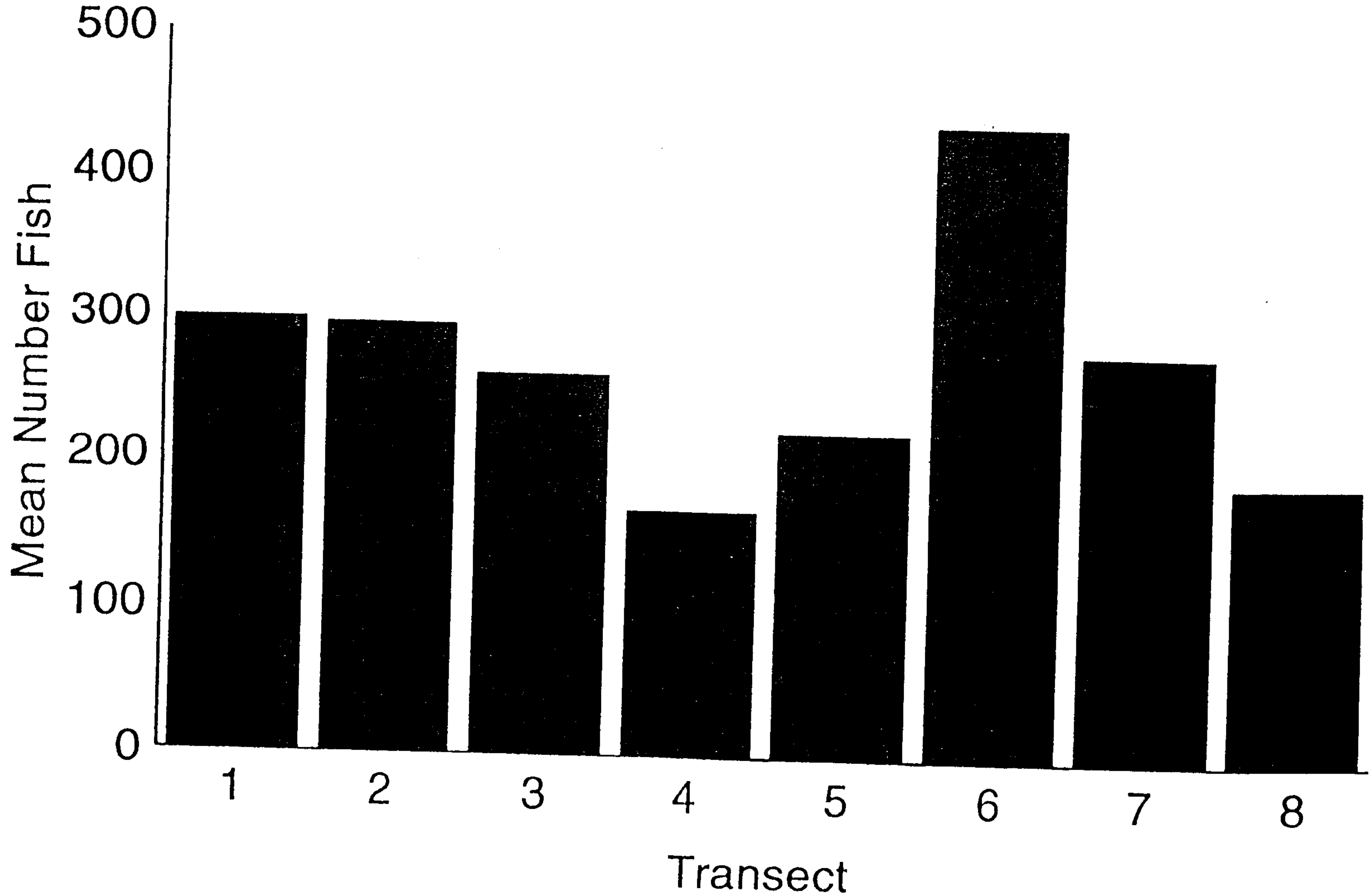


Figure 26.

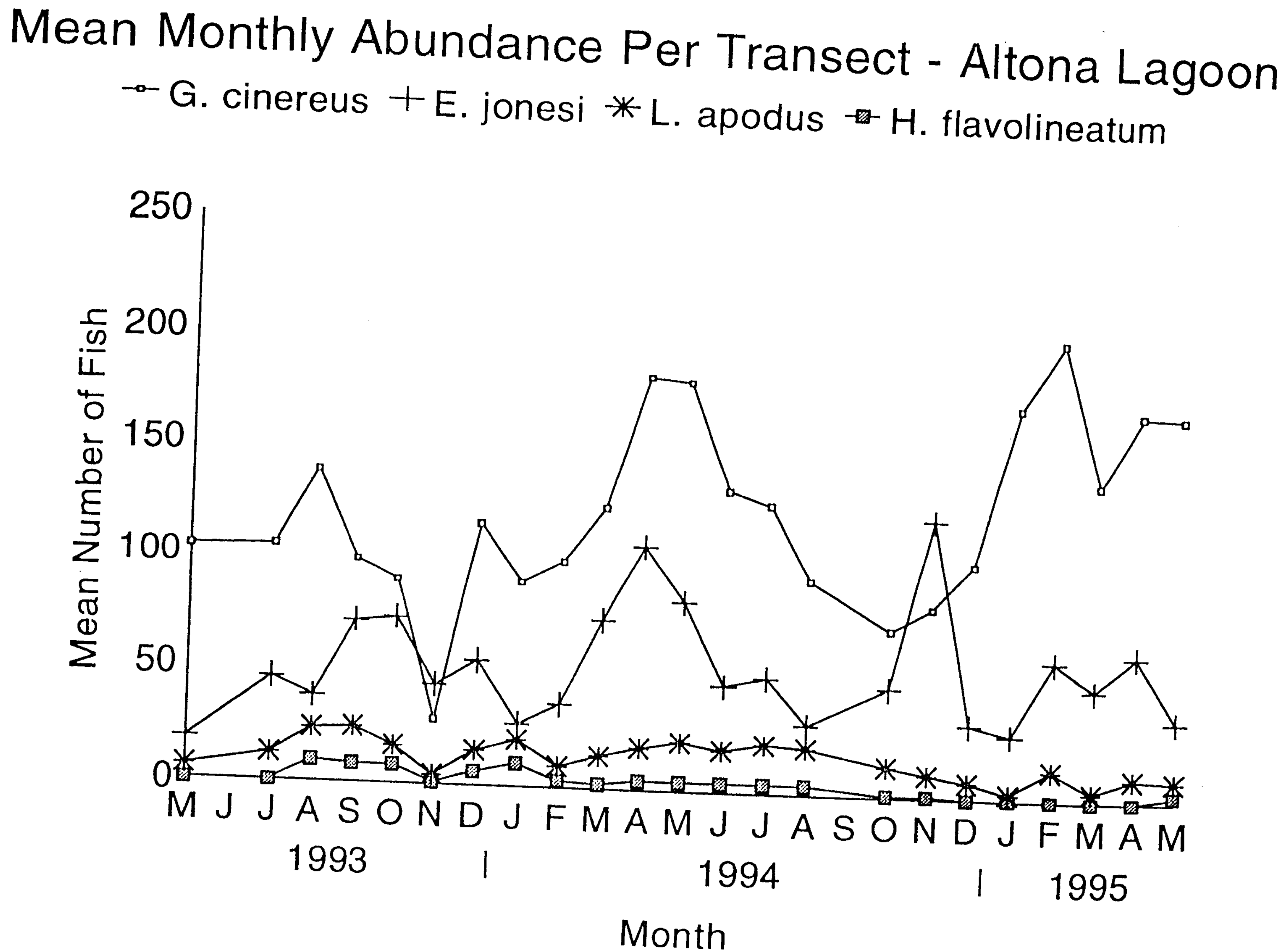

Mean Monthly Abundance Per Transect - Altona Lagoon
G. cinereus
E. jonesi
L. apodus
H. flavolineatum
Mean Number of Fish
0
50
100
150
200
250
M J J A S O N D J F M A M J J A S O N D J F M A M
1993
1994
1995
Month

Figure 27.