



GOVERNMENT OF THE VIRGIN ISLANDS OF THE UNITED STATES

DEPARTMENT OF PLANNING AND NATURAL RESOURCES

DIVISION OF FISH AND WILDLIFE

6291 ESTATE NAZARETH, 101

ST. THOMAS, VIRGIN ISLANDS 00802-1104

PHONE: (809) 775-6762, FAX (809) 775-3972

TDD (809) 777-8413

Final Report

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Staff: William Tobias, Principal Investigator
Stephen Meyers, Chief of Fisheries
Barbara Kojis, Ph.D. Acting Director
Beulah Dalmida-Smith, Commissioner

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 are 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, alerted fisheries managers to an eminent collapse of this fishery. The result was the establishment of management plans to protect reef fish resources (CFMC, 1985 and 1993). A more recent assessment of the shallow water reef fish in the U.S. Caribbean (Appeldoorn, et. al., 1992) 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, 1974).

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 (UNESCO, 1983). Mangrove lagoons are important habitat for juveniles of many fish species (Heald and Odum, 1970; Austin, 1971a and 1971b; Austin and Austin, 1971; 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 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 managers 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, Krause Lagoon, 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 1,166 hectares, predominately into the southern extremity of Sugar Bay (Island Resources Foundation, 1993). Past development activities include extensive dredging and filling on both sides of the 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 back reef 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 62 hectares (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. At each location all four sites were sampled once a month for a twenty-four hour period for five consecutive days. 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).

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. Chaetodontidae 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, undeveloped sites having extensive-mangrove-coverage. *H. flavolineatum* was the most abundant species at 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.

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 gorsopunicans* (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.

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 locales.

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 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 by area was not significantly different; however, there was a significant difference in the number of individuals caught per trap per transect by area for Area 3 (Table 11), which 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* was 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 for the most abundance species 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 in 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 visual 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*, *H. 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 the mangrove prop root 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 lyngbyaceus* (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, the 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 the cnidarian *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 propagule 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 locales, 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* (redeal 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 piscivorous 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, 1993).

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 and thus sediment 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 stressed at this time and also 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 turbidity. 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 haul-out 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, protect, and manage these resources. In 1992, the Department of the 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 the 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 fringing red mangrove community due to hurricane impacts. Although the fringing red mangrove community in Altona Lagoon has 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 reef fish species, many of which are recreationally important as primary target species or prey species 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*, *I. 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 into the lagoon. This may be accomplished by providing an opening to the Caribbean Sea into Beaugard 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	<i>Eucinostomus jonesi</i>	673
	Yellowfin mojarra	<i>Gerres cinereus</i>	625
Pomadasyidae	French grunt	<i>Haemulon flavolineatum</i>	623
	Bluestriped grunt	<i>Haemulon sciurus</i>	25
	Smallmouth grunt	<i>Haemulon chrysargyreum</i>	4
	White grunt	<i>Haemulon plumieri</i>	4
	Tomtate	<i>Haemulon aurolineatum</i>	2
	Caesar grunt	<i>Haemulon carbonarium</i>	2
	Sailors choice	<i>Haemulon parrai</i>	1
Lutjanidae	Schoolmaster snapper	<i>Lutjanus apodus</i>	409
	Yellowtail snapper	<i>Ocyurus chrysurus</i>	173
	Gray snapper	<i>Lutjanus griseus</i>	15
	Dog Snapper	<i>Lutjanus jocu</i>	11
	Mutton snapper	<i>Lutjanus analis</i>	5
	Mahogany snapper	<i>Lutjanus mahogoni</i>	1
Chaetodontidae	Foureye butterfly	<i>Chaetodon capistratus</i>	481

Table 1. Continued

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

Table 1. Continued.

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

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				P*
	Triton Bay		Sugar Bay		
	East	West	East	West	
<u>Species</u>					
	1.14 (0.06)	1.55 (0.08)	1.32 (0.07)	1.65 (0.08)	S
<u>Abundance</u>					
	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.

Species	AREA				Total
	TBE	TBW	SBE	SBW	
<i>E. jonesi</i>	188	149	195	135	673
Mean	7.83	8.27	9.75	7.94	
+/-SE	0.5	0.7	0.9	1.0	
<i>G. cinereus</i>	169	136	196	124	625
Mean	7.04	6.18	9.33	6.89	
+/-SE	0.4	0.4	0.6	0.7	
<i>H. flavolineatum</i>	58	254	88	223	623
Mean	5.80	11.04	4.89	10.61	
+/-SE	0.8	0.4	0.5	0.5	
<i>C. capistratus</i>	112	241	19	109	481
Mean	5.89	11.48	2.71	6.41	
+/-SE	0.9	0.7	0.5	0.4	
<i>L. apodus</i>	33	44	181	151	409
Mean	2.35	3.67	7.54	6.86	
+/-SE	0.3	0.7	0.5	0.4	
<i>O. chrysurus</i>	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) (\pm 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.

Species*	SITE		Sugar Bay		Total	Min.	Max.
	Triton Bay East	West	East	West			
<i>E. jonesi</i>	71.18 (0.77)	71.38 (0.83)	67.96 (0.62)	73.30 (1.04)	70.73 (0.40)	44.0	135.0
<i>H. flavolineatum</i>	78.50 (2.25)	81.84 (1.27)	83.07 (1.81)	76.36 (1.02)	79.72 (0.72)	40.0	140.0
<i>G. cinereus</i>	72.63 (1.84)	79.82 (2.04)	86.57 (1.57)	85.48 (1.73)	81.15 (0.92)	36.0	170.0
<i>L. apodus</i>	84.54 (6.76)	112.58 (7.31)	87.73 (2.06)	107.04 (2.76)	97.72 (1.73)	20.0	210.0
<i>O. chrysurus</i>	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 <i>Lutjanus apodus</i>	7,022	81.5
Gray snapper	<i>Lutjanus griseus</i>	736	60.0
Dog snapper	<i>Lutjanus jocu</i>	3	0
Lane snapper	<i>Lutjanus synagris</i>	20	100.0
Yellowtail snapper	<i>Ocyurus chrysurus</i>	30	100.0
Mahogany snapper	<i>Lutjanus mahogoni</i>	7	80.0
Pomadasyidae			
	French grunt <i>Haemulon flavolineatum</i>	6,896	88.2
Caesar grunt	<i>Haemulon carbonarium</i>	2	50.0
Bluestriped grunt	<i>Haemulon sciurus</i>	48	45.8
Spanish grunt	<i>Haemulon macrostomum</i>	1	100.0
Sailors choice	<i>Haemulon parrai</i>	2	0
Striped grunt	<i>Haemulon striatum</i>	1	0
Porkfish	<i>Anisotremus virginicus</i>	9	44.0
Gerreidae			
	Slender mojarra <i>Eucinostomus jonesi</i>	1,544	95.2
Yellowfin mojarra	<i>Gerres cinereus</i>	503	69.8

Table 5. Continued.

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

Table 5. Continued.

Family Name	Common Name	Species Name	Total Abundance	Percent Juvenile
Chaetodontidae				
	Foureye butterfly	<i>Chaetodon capistratus</i>	300	82.4
	Banded butterfly	<i>Chaetodon striatus</i>	1	0
Sphyraenidae				
	Barracuda	<i>Sphyraena barracuda</i>	114	86.8
Sciaenidae				
	Spotted drum	<i>Equetus pincatus</i>	38	93.9
	High hat	<i>Equetus acuminatus</i>	30	53.3
	Drum	Equetus spp.	7	57.1
	Reef Croaker	<i>Odontoscion demex</i>	3	100.0
Tetraodontidae				
	Puffer spp.		6	0
	Checkered puffer	<i>Sphoeroides testudineus</i>	53	42.1
	Bandtail puffer	<i>Sphoeroides spengleri</i>	2	100.0
Mugilidae				
	White Mullet	<i>Mugil curema</i>	38	85.7
Bothidae				
	spp.		21	100.0
Pomacanthidae				
	French Angel	<i>Pomacanthus paru</i>	5	100.0
Sparidae				
	Seabream	<i>Archosargus rhomboidalis</i>	4	0
Carangidae				
	Horse-eye jack	<i>Caranx latus</i>	3	100.0
Clinidae				
	Hairy blenny	<i>Labrisomus muchipinnis</i>	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			
		<i>Hypoplectrus</i> spp.	1	100.0
Centropomidae				
	Snook			
		<i>Centropomus undecimalis</i>	1	100.0
Scorpaenidae				
	Scorpionfish spp.		1	0
Mullidae				
	Yellow goatfish			
		<i>Mulloidichthys martinicus</i>	1	100.0
Diodontidae				
	Porcupinefish			
		<i>Diodon hystrix</i>	1	0
Ostraciidae				
	Trunkfish			
		<i>Lactophrys</i> spp.	1	0
Kyphosidae				
	Chub			
		<i>Kyphosus</i> spp.	1	0
Ephippidae				
	Atlantic spadefish			
		<i>Chaetodipterus faber</i>	1	100.0

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
<u> </u>				

*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					Dyck	Total
	1	2	3	4			
<i>L. apodus</i>	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	
<i>H. flavolineatum</i>	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	
<i>E. jonesi</i>	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	
<i>A. chirurgus</i>	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	
<i>L. grisens</i>	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	
<i>G. cinereus</i>	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 (\pm SE). Groups listed in decreasing order of abundance.

Species or Family	Transect				Dyck
	Columbus 1	Columbus 2	Columbus 3	Columbus 4	
<i>L. apodus</i>	88.8 (3.6)	91.2 (1.9)	80.3 (2.5)	76.6 (1.6)	84.2 (6.8)
<i>H. flavolineatum</i>	72.2 (11.0)	76.7 (7.1)	92.7 (2.7)	89.8 (1.6)	89.1 (7.1)
<i>E. jonesi</i>	96.2 (2.9)	93.5 (3.5)	93.2 (2.5)	96.5 (1.7)	98.1 (1.9)
<i>A. chirurgus</i>	89.1 (9.8)	92.3 (3.9)	76.4 (13.2)	90.0 (4.1)	100.0 (1.1)
<i>L. griseus</i>	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)
<i>G. cinereus</i>	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 <i>Gerres cinereus</i>	7,577
	Slender mojarra <i>Eucinostomus jonesi</i>	3,942
	Spotfin mojarra <i>Eucinostomus argenteus</i>	103
Lutjanidae	Schoolmaster snapper <i>Lutjanus apodus</i>	329
	Gray snapper <i>Lutjanus griseus</i>	7
	Yellowtail snapper <i>Ocyurus chrysurus</i>	5
	Lane snapper <i>Lutjanus synagris</i>	4
	Dog snapper <i>Lutjanus jocu</i>	1
Pomadasyidae	French grunt <i>Haemulon flavolineatum</i>	313
	Bluestriped grunt <i>Haemulon sciurus</i>	5
Sphyraenidae	Great barracuda <i>Sphyraena barracuda</i>	42
Carangidae	Yellow jack <i>Caranx bartholomaei</i>	27
	Horse-eye jack <i>Caranx latus</i>	9
Tetraodontidae	Checkered puffer <i>Sphoeroides testudineus</i>	13

Table 10. Continued

Family Name	Common Name	Species Name	Total Abundance
Clinidae	Hairy blenny		
		<i>Labrisomus nuchipinnis</i>	8
Chaetodontidae	Foureye butterflyfish		
		<i>Chaetodon capistratus</i>	7
Sparidae	Seabream		
		<i>Archosargus rhomboidalis</i>	4
	Porgy		
		<i>Calamus spp.</i>	1
Muraenidae	Green moray eel		
		<i>Gymnothorax funebris</i>	4
Scaridae	Bucktooth parrotfish		
		<i>Sparisoma radians</i>	2
Monacanthidae	Filefish		
		<i>Cantherhines spp.</i>	1
Bothidae	Peacock flounder		
		<i>Bothus lunatus</i>	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				P*
	1	2	3	4	
<u>Trap</u>					
<u>Species</u>	1.65 (0.06)	1.58 (0.05)	1.44 (0.05)	1.68 (0.05)	NS
<u>Abundance</u>	8.30 (0.44)	10.88 (0.68)	9.85 (0.71)	11.07 (0.78)	S
<u>Transect</u>					
<u>Species</u>	5.07 (0.19)	4.85 (0.19)			NS
<u>Abundance</u>	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				Total
	1	2	3	4	
<i>G. cinereus</i>	1940	2201	1550	1916	7577
Mean	6.24	6.86	6.18	5.56	
+/-SE	0.1	0.2	0.2	0.2	
<i>E. jonesi</i>	530	1282	1004	1126	3942
Mean	1.84	4.48	4.40	4.31	
+/-SE	0.2	0.3	0.3	0.4	
<i>L. apodus</i>	187	68	24	50	329
Mean	0.80	0.32	0.17	0.26	
+/-SE	0.1	0.1	0.2	0.1	
<i>H. flavolineatum</i>	73	59	2	179	313
Mean	0.37	0.30	0.01	0.12	
+/-SE	0.2	0.1	0.1	0.3	
<i>S. barracuda</i>	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) (\pm 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.

Species*	AREA				Total	Min.	Max.
	1	2	3	4			
<i>G. cinereus</i>	94.35 (1.54)	104.81 (4.18)	109.44 (4.02)	102.52 (4.85)	102.52 (1.86)	10.0	200.0
<i>E. jonesi</i>	79.55 (0.63)	76.51 (0.81)	79.75 (0.71)	82.30 (1.87)	79.43 (0.59)	20.0	198.0
<i>L. apodus</i>	99.78 (2.22)	124.75 (14.94)	96.87 (7.82)	102.94 (7.54)	105.34 (3.64)	31.0	240.0
<i>H. flavolineatum</i>	96.86 (2.94)	71.62 (6.51)	116.50 (6.50)	95.40 (3.81)	91.17 (2.45)	27.0	155.0
<i>S. barracuda</i>	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	<i>Gerres cinereus</i>	36,397	84.5
	Slender mojarra	<i>Eucinostomus jonesi</i>	15,592	88.8
	Spotfin mojarra	<i>Eucinostomus argenteus</i>	464	98.1
Engraulidae	Bullhead fry	<i>Anchoa lyolepis</i>	24,925	94.2
Clupeidae	Redear sardine	<i>Harengula humeralis</i>	13,823	100.0
Lutjanidae	Schoolmaster	<i>Lutjanus apodus</i>	3,854	88.0
	Gray snapper	<i>Lutjanus griseus</i>	660	78.8
	Mutton snapper	<i>Lutjanus analis</i>	4	50.0
	Snapper sp.		1	0
Pomadasyidae	French grunt	<i>Haemulon flavolineatum</i>	1,087	68.1
	Bluestriped grunt	<i>Haemulon sciurus</i>	155	58.7
	Tomtate	<i>Haemulon aurolineatum</i>	17	70.6
	Caesar grunt	<i>Haemulon carbonarium</i>	6	100.0
Sparidae	Seabream	<i>Archosargus rhomboidalis</i>	703	90.1
	Porgy	<i>Calamus spp.</i>	2	0

Table 14. Continued

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

Table 14. Continued.

Family Name	Common Name	Species Name	Total Abundance	Percent Juvenile
Pomacentridae	Beaugregory	<i>Stegastes leucostictus</i>	4	75.0
	Damsel (spp.)		1	100.0
Diodontidae	Porcupinefish	<i>Diodon hystrix</i>	3	66.7
	Ballonfish	<i>Diodon holocanthus</i>	1	0
Aulostomidae	Trumpetfish	<i>Aulostomus maculatus</i>	1	100.0
Elopidae	Tarpon	<i>Megalops atlanticus</i>	1	0
Monacanthidae	Scrawled filefish	<i>Aluterus scriptus</i>	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
<i>G. cinereus</i>	22,497	13,900	36,397
Mean	138.0	110.3	
+/-SE	0.7	0.6	
<i>A. leyolepis</i>	16,160	8,765	24,925
Mean	99.1	69.6	
+/-SE	1.8	2.8	
<i>E. jonesi</i>	7,951	7,641	15,592
Mean	48.8	60.2	
+/-SE	0.5	0.7	
<i>H. humeralis</i>	8,692	5,103	13,795
Mean	N/A	N/A	
+/- SE	N/A	N/A	
<i>L. apodus</i>	2,585	1,269	3,854
Mean	15.9	10.1	
+/-SE	0.2	0.2	
<i>H. flavolineatum</i>	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.

Species	TRANSECT							
	1	2	3	4	5	6	7	8
<i>G. cinereus</i>	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)
<i>E. jonesi</i>	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)
<i>L. apodus</i>	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)
<i>H. flavolineatum</i>	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)
<i>L. griseus</i>	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)
<i>S. barracuda</i>	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 by species of mangrove prop root fringe benthic community for three sites* in Altona Lagoon, St. Croix, 18 November 1993. Values expressed are means (+/-SE). When n = 1, SE = 0.

Species	AREA		
	Outer Bay	Inner Bay	Middle Bay
<i>Acanthophora spicifera</i>		20.4 (6.3)	
<i>Acetabularia sp.</i>	4.9 (1.8)	10.0 (3.0)	1.8 (0.6)
<i>Cassiopea sp.</i>	5.3 (0.8)	40.5 (5.3)	18.9 (5.0)
<i>Caulerpa prolifera</i>	7.1 (6.2)	43.7 (6.1)	75.6 (6.2)
<i>Caulerpa sertularioides</i>	10.6 (3.9)	11.0 (2.6)	5.0 (0.0)
<i>Caulerpa verticillata</i>		8.3 (1.7)	
<i>Dasycladus vermicularis</i>		10.0 (0.0)	
<i>Gelidium sp.</i>		10.0 (0.0)	
<i>Gracilaria sp.</i>	20.8 (13.7)		
<i>Halimeda sp.</i>	10.7 (4.3)	14.2 (5.2)	4.7 (1.2)
<i>Hypnea sp.</i>	5.0 (0.0)	15.0 (7.6)	
<i>Microcoleus lyngbyaceus</i>		20.0 (10.0)	
<i>Penicillus capitatus</i>	3.0 (0.0)	40.0 (0.0)	4.0 (0.4)
<i>Thalassia testudinum</i>	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.

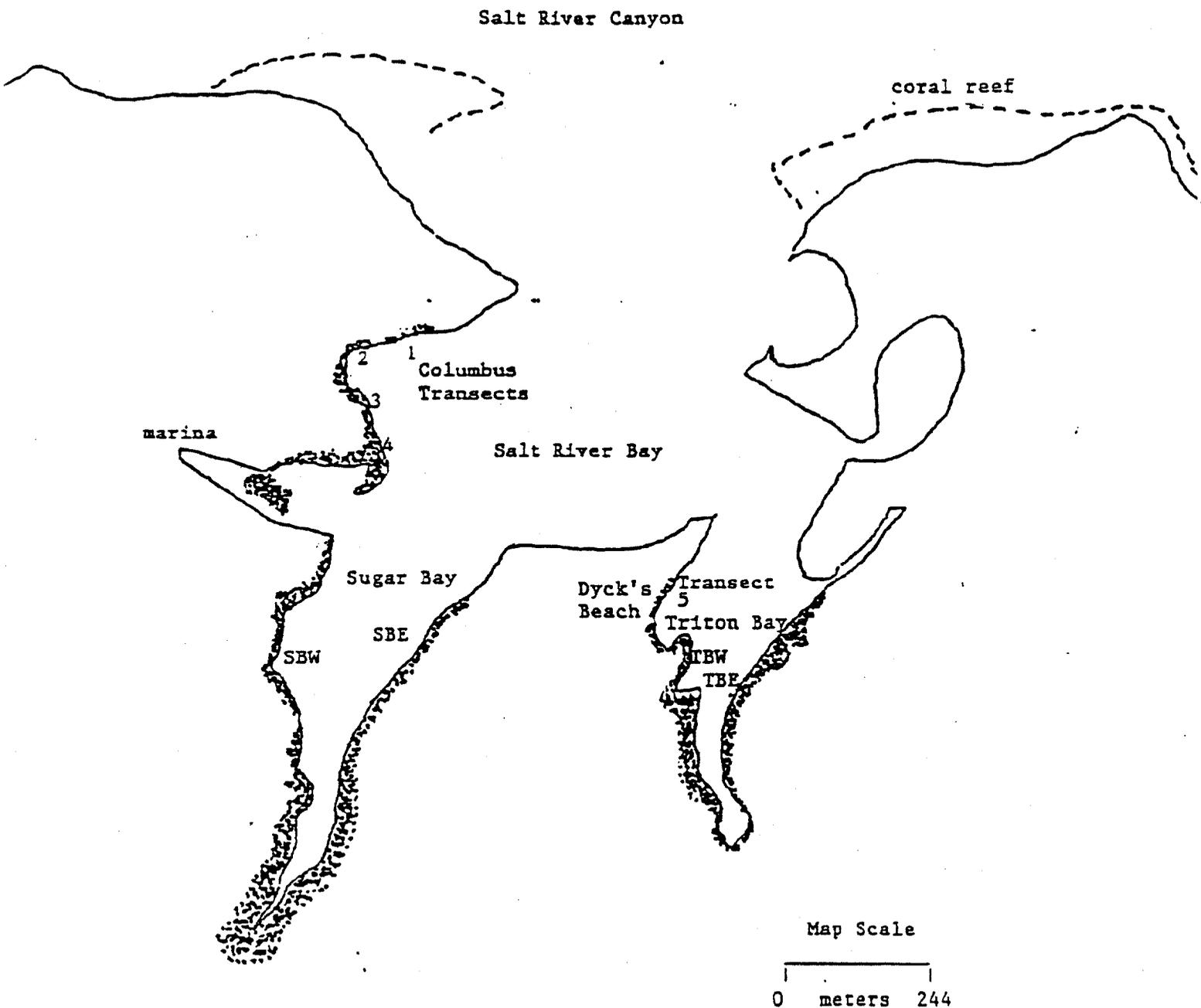


Figure 1. Salt River study site location map. Trap studies conducted in Sugar Bay (SBE = Sugar Bay East, SBW = Sugar Bay West) and Triton Bay (TBE = Triton Bay East, TBW = Triton Bay West). Visual transects conducted at Columbus (1-4) and Dyck's Beach (5).

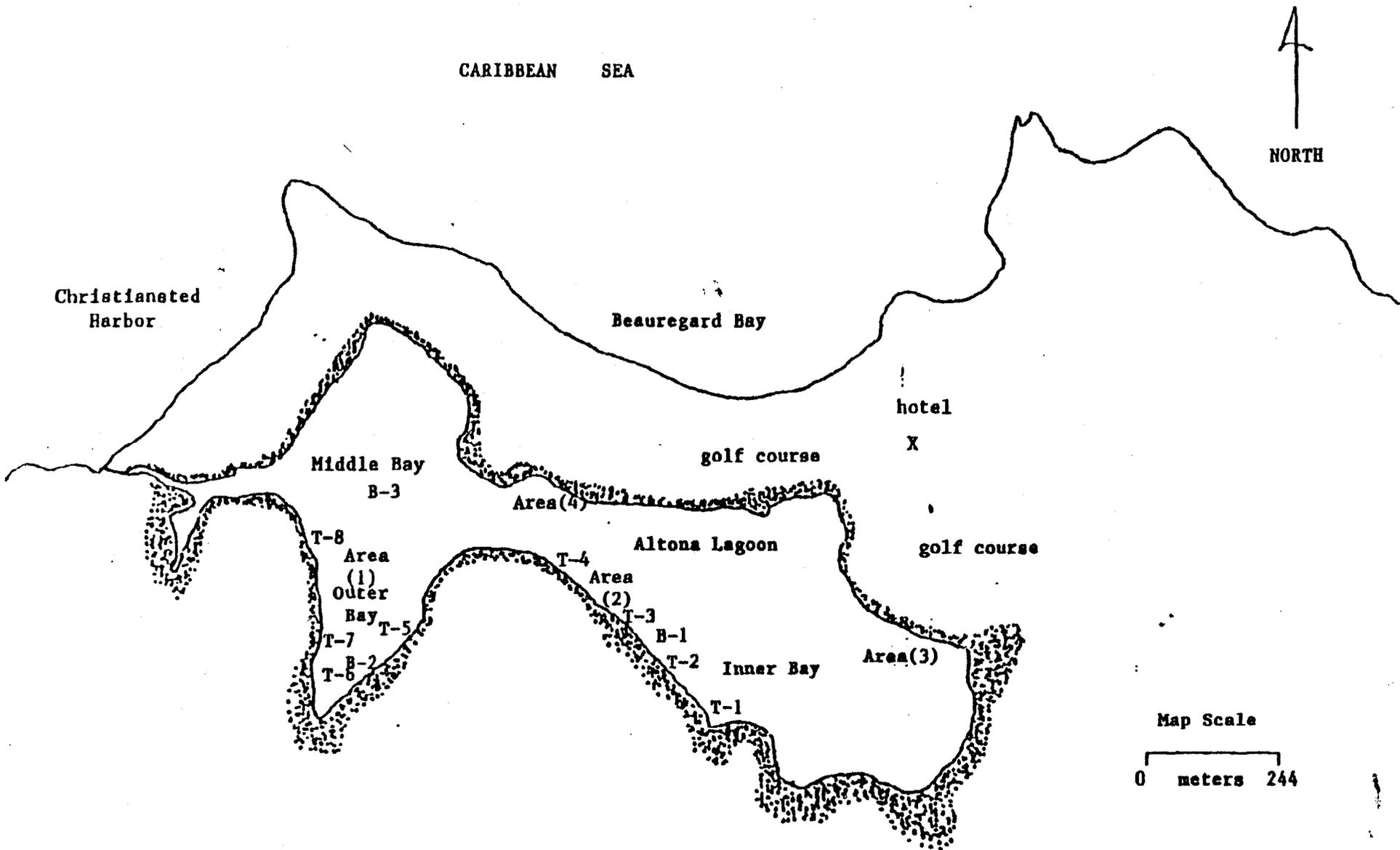


Figure 2. Altona Lagoon study site location map. Trap studies were conducted in Areas (1) - (4). Visual transects were conducted in the Inner Bay (T-1 thru T-4) and in the Outer Bay (T-5 thru T-8). Benthic community studies were conducted in the Inner Bay (B-1), Outer Bay (B-2) and Middle Bay (B-3).

Family Abundance

Salt River Traps

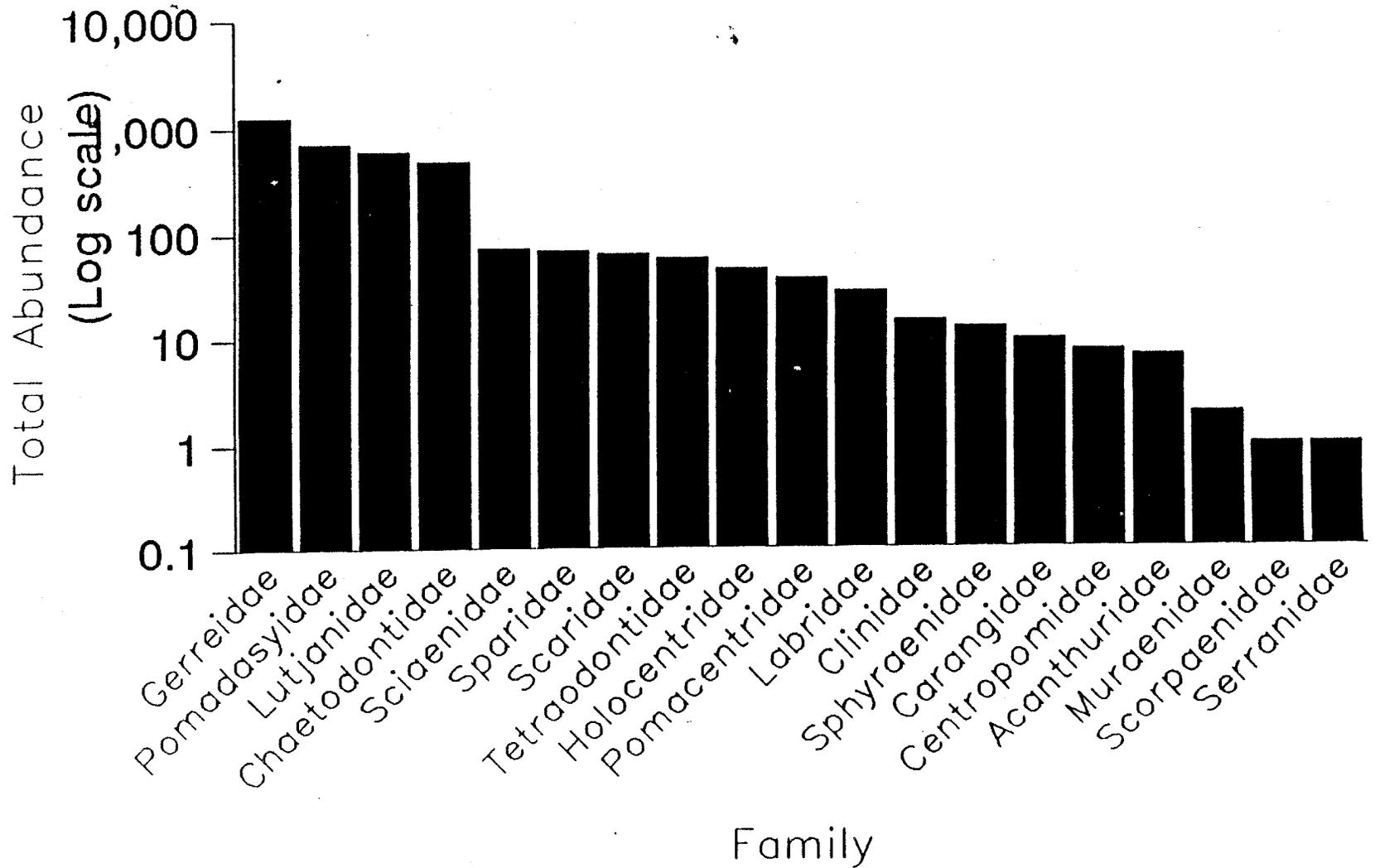


Figure 3.

NUMBER OF SPECIES PER TRAP OF INNER BAY SITES

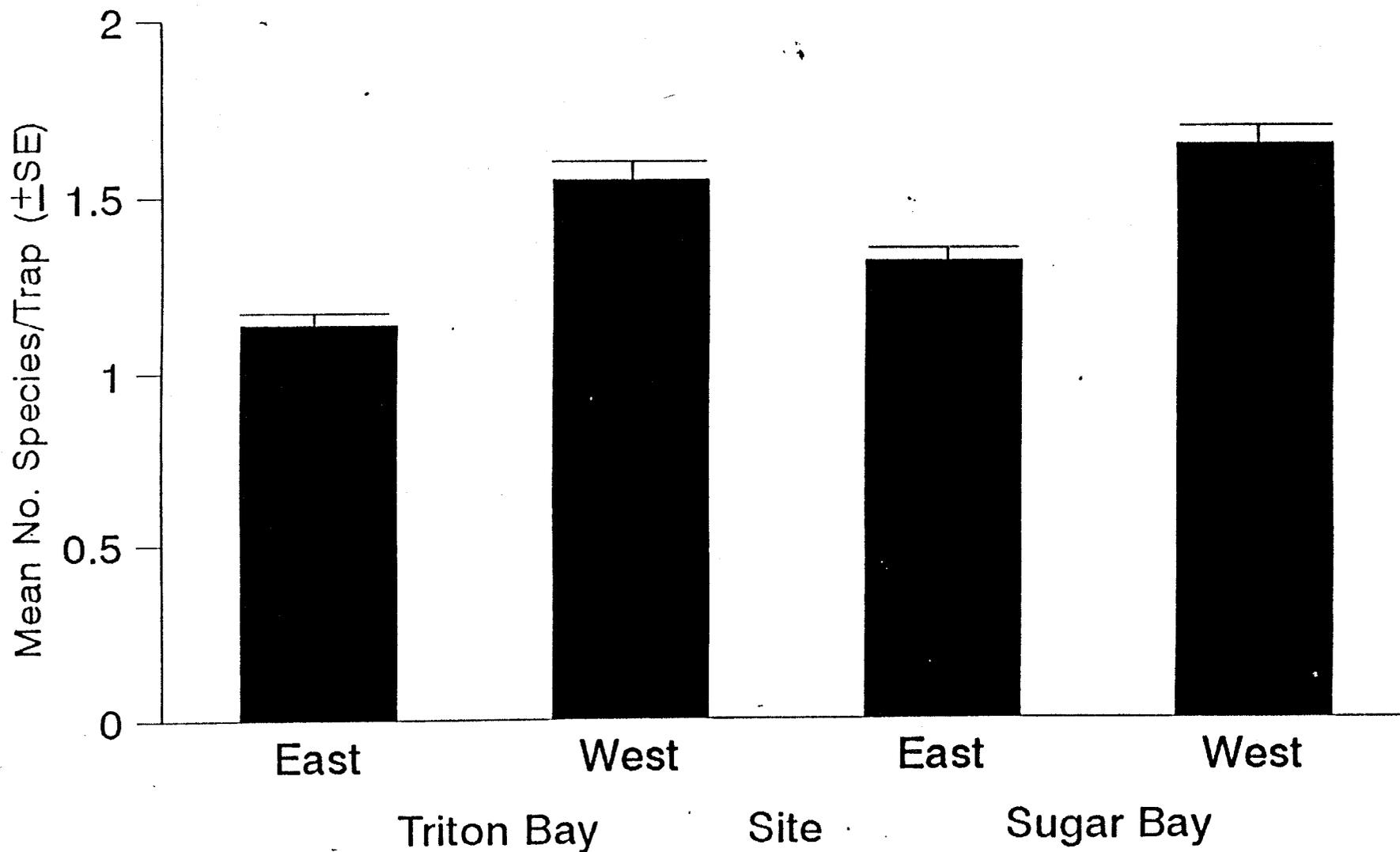


Figure 4.

NUMBER OF INDIVIDUALS PER TRAP OF INNER BAY SITES

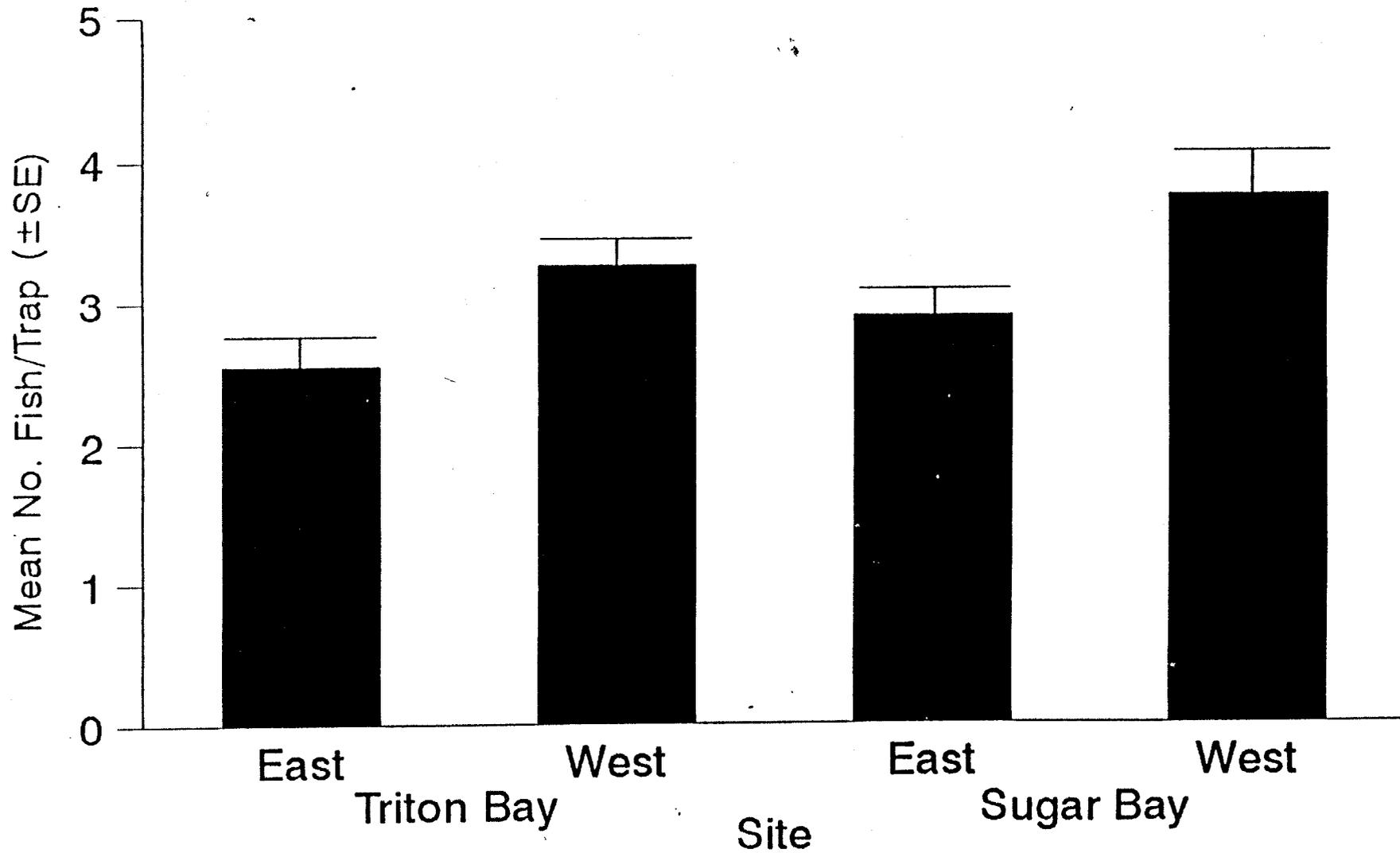


Figure 5.

Gerres cinereus

Salt River Traps

N = 619

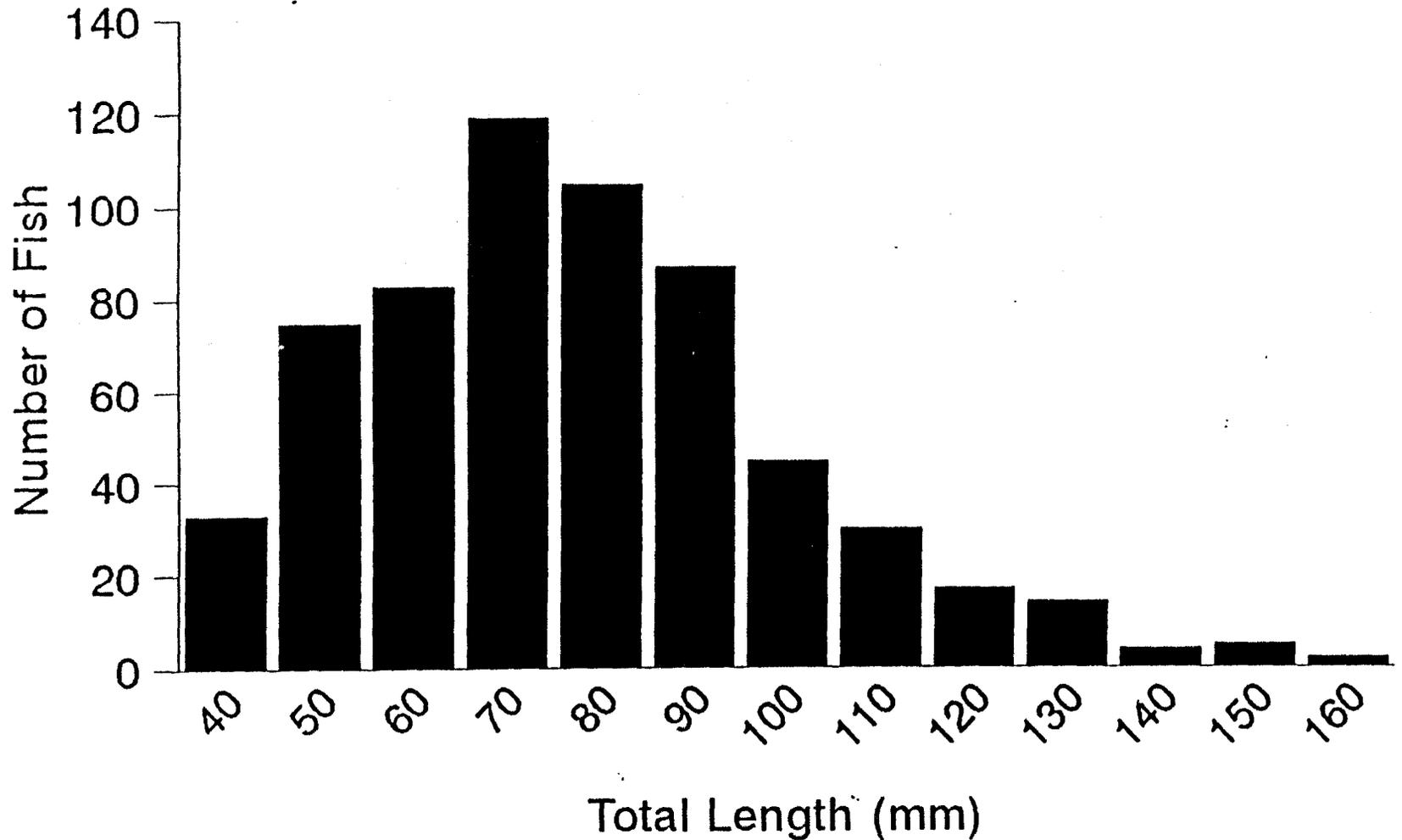


Figure 6

Haemulon flavolineatum

Salt River Traps

N = 617

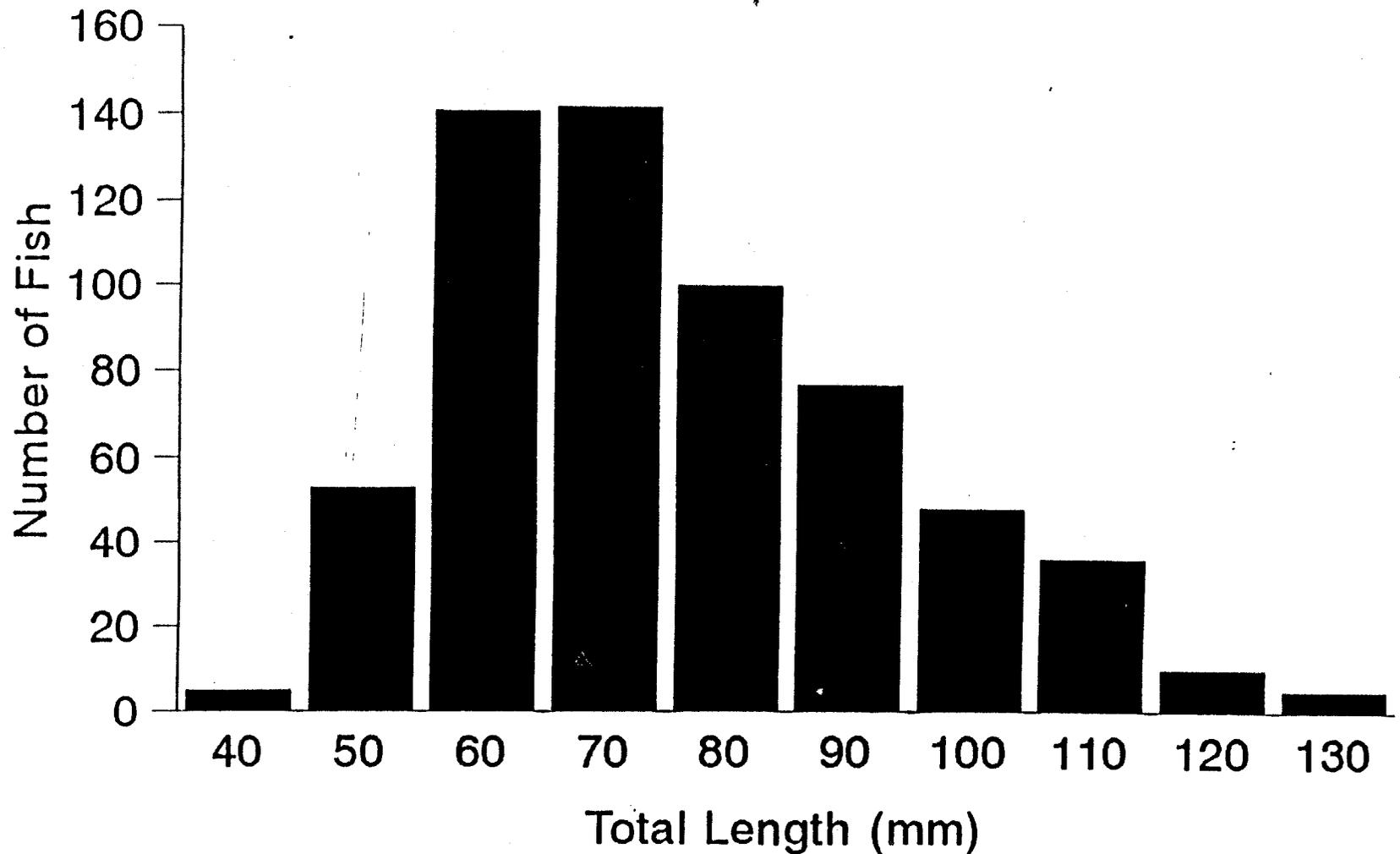


Figure 7.

Lutjanus apodus

Salt River Traps

N = 409

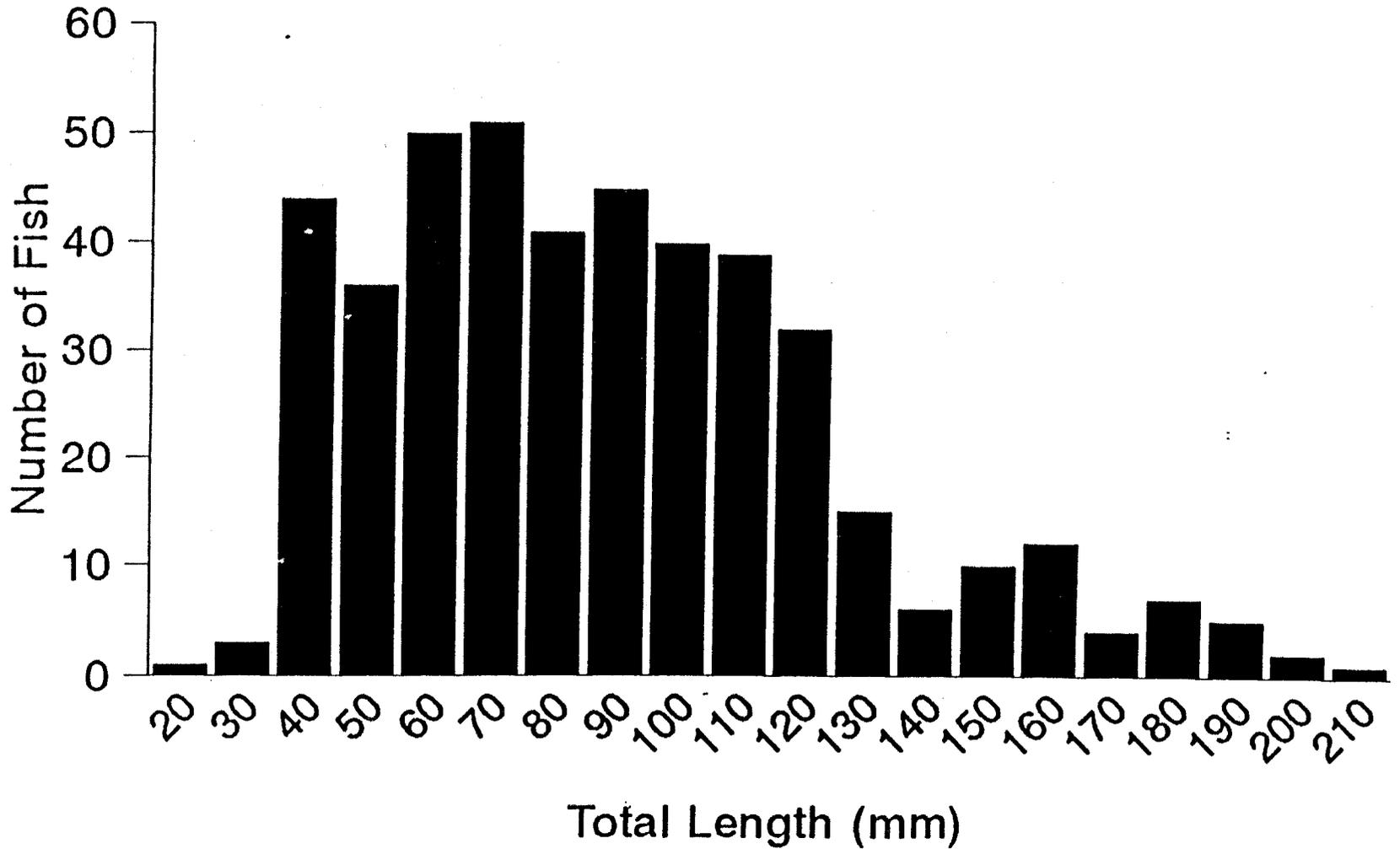


Figure 8.

Ocyurus chrysurus

Salt River Traps

N = 173

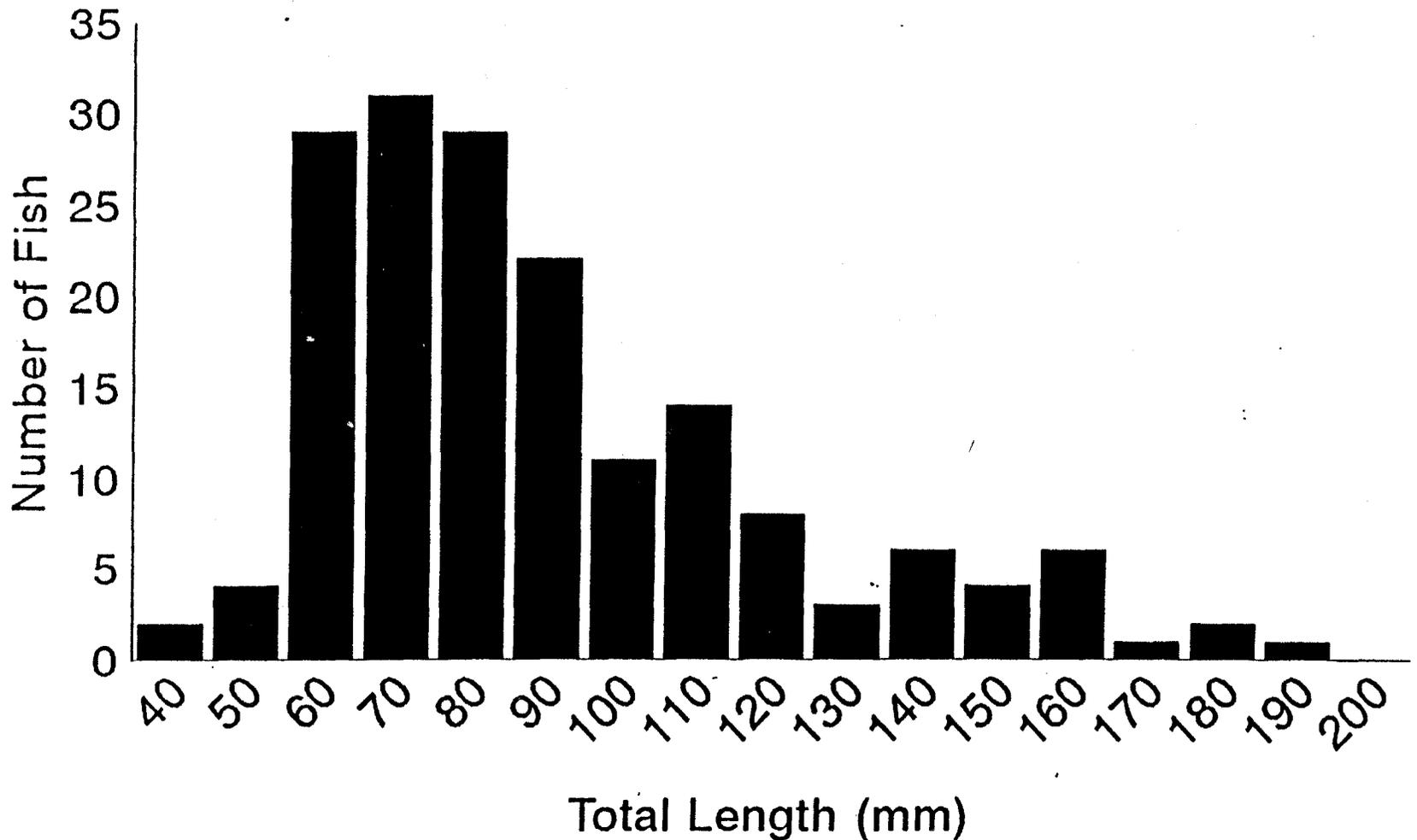


Figure 9.

Mean Monthly Abundance Per Trap - Salt River

○ L. apodus + H. flavolineatum * G. cinereus ■ O. chrysurus

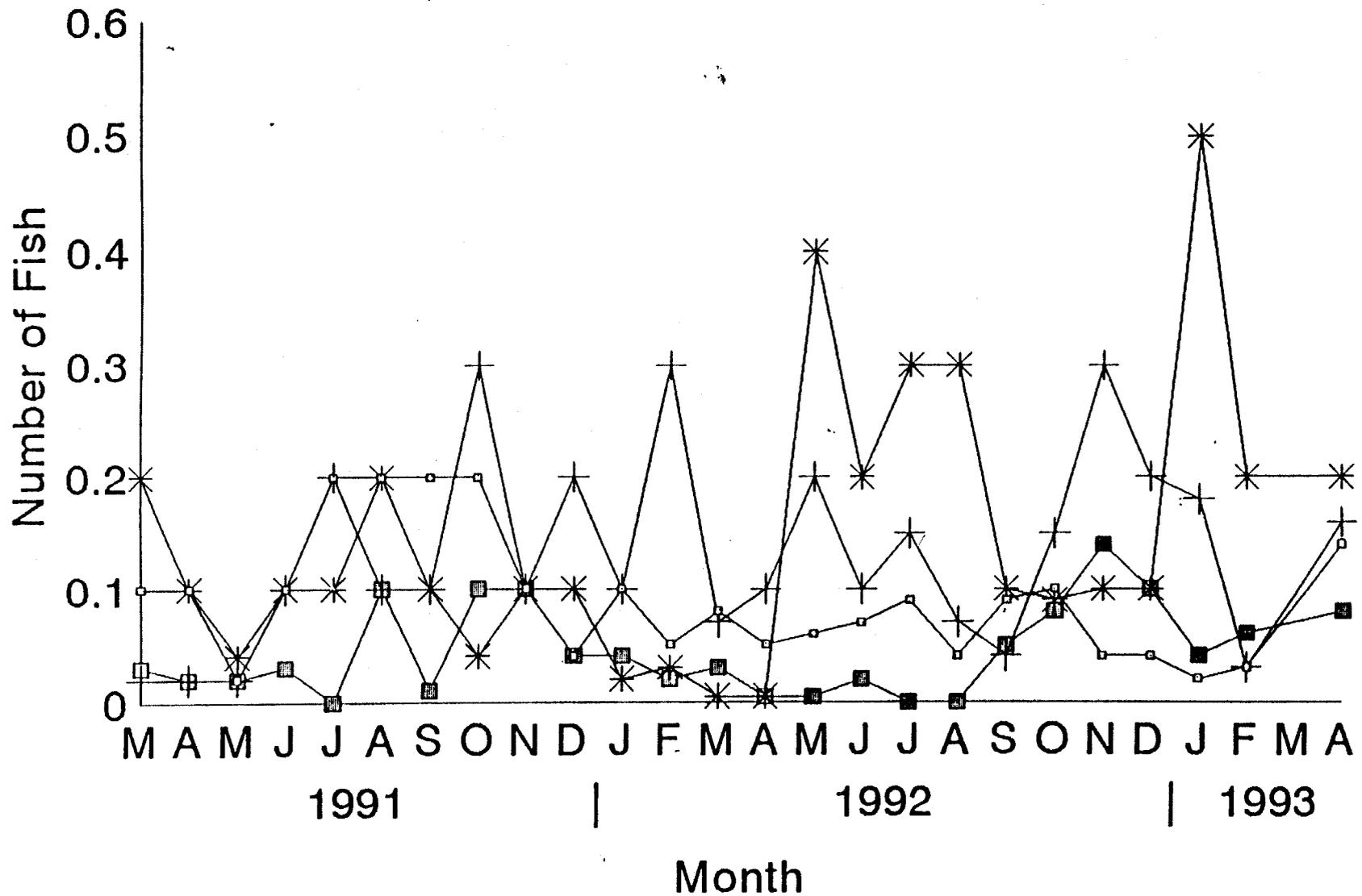


Figure 10.

Family Abundance

Salt River Transects

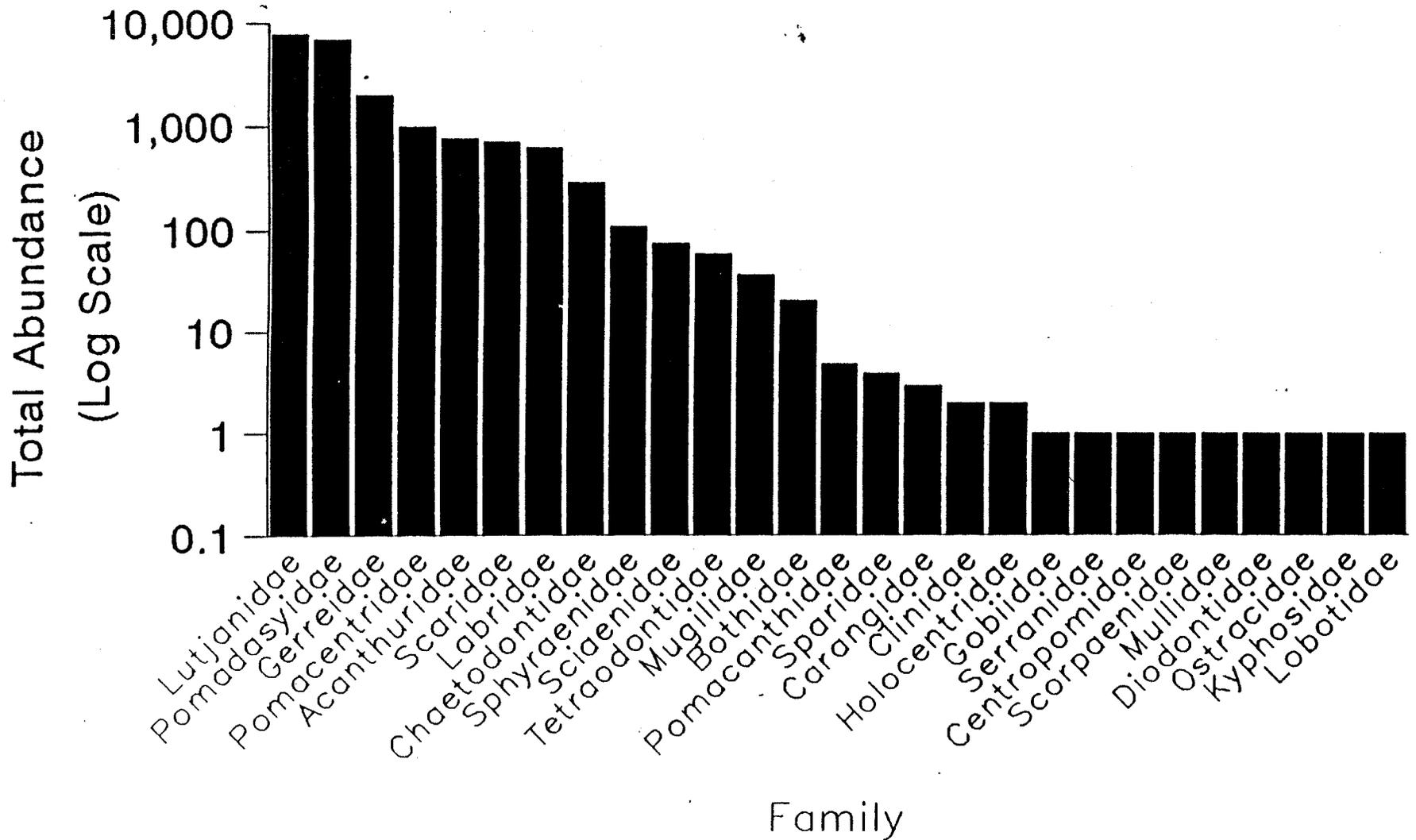


Figure 11.

MEAN NUMBER OF SPECIES

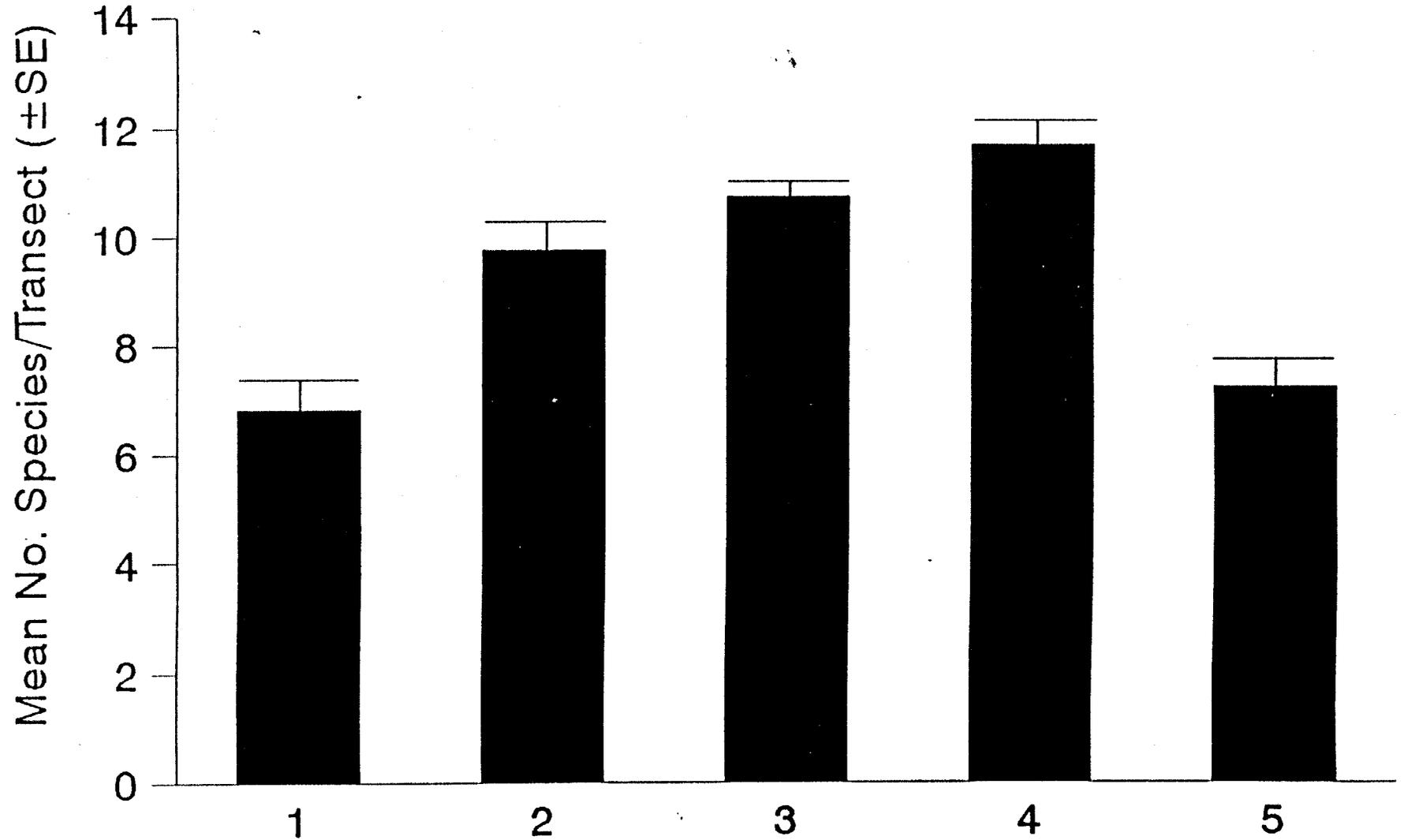


Figure 12.

MEAN NUMBER OF INDIVIDUALS

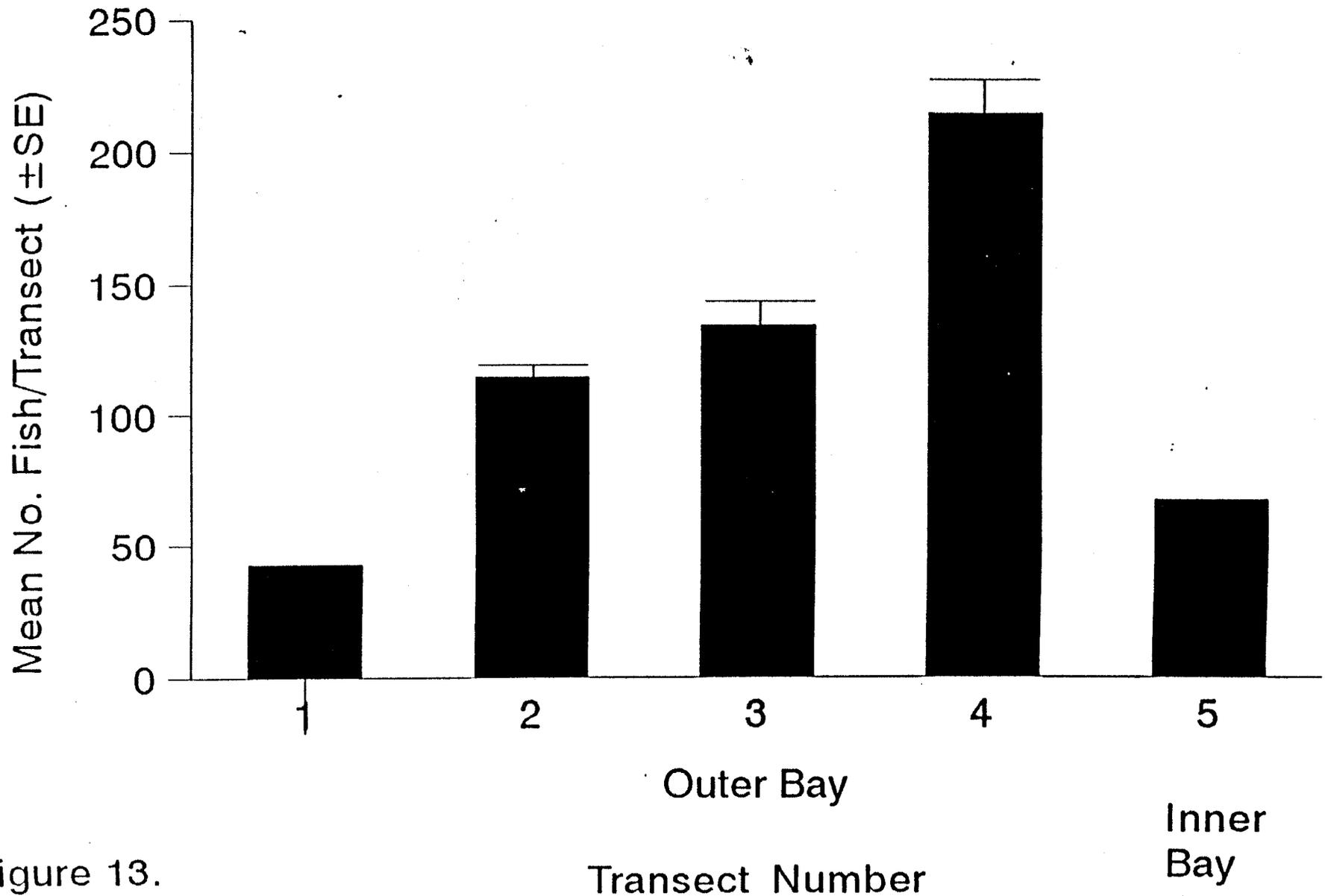


Figure 13.

Mean Monthly Abundance Per Transect - Salt River

□ L. apodus + H. flavolineatum * L. griseus ■ G. cinereus

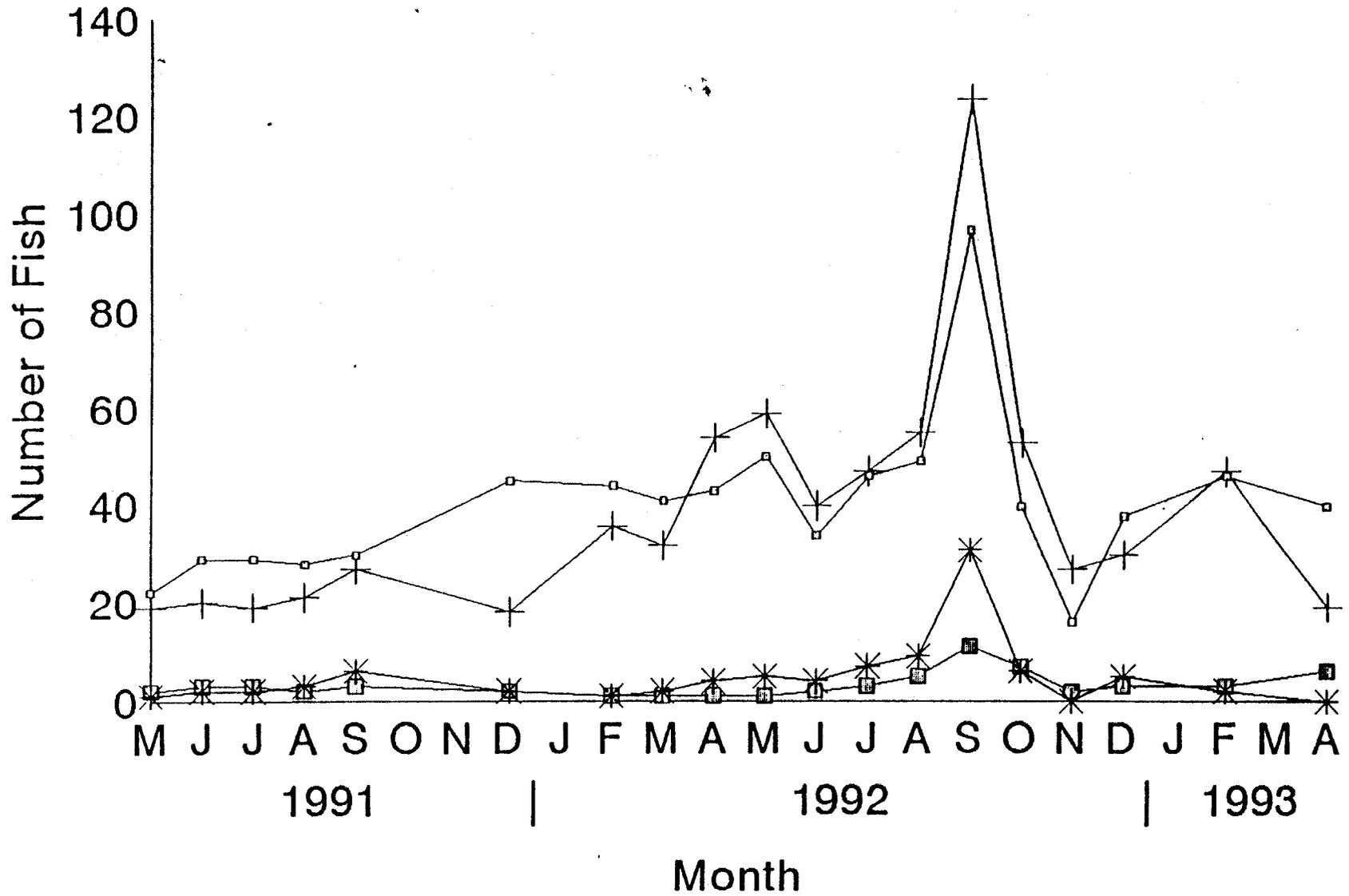


Figure 14.

Family Abundance

Altona Lagoon Traps

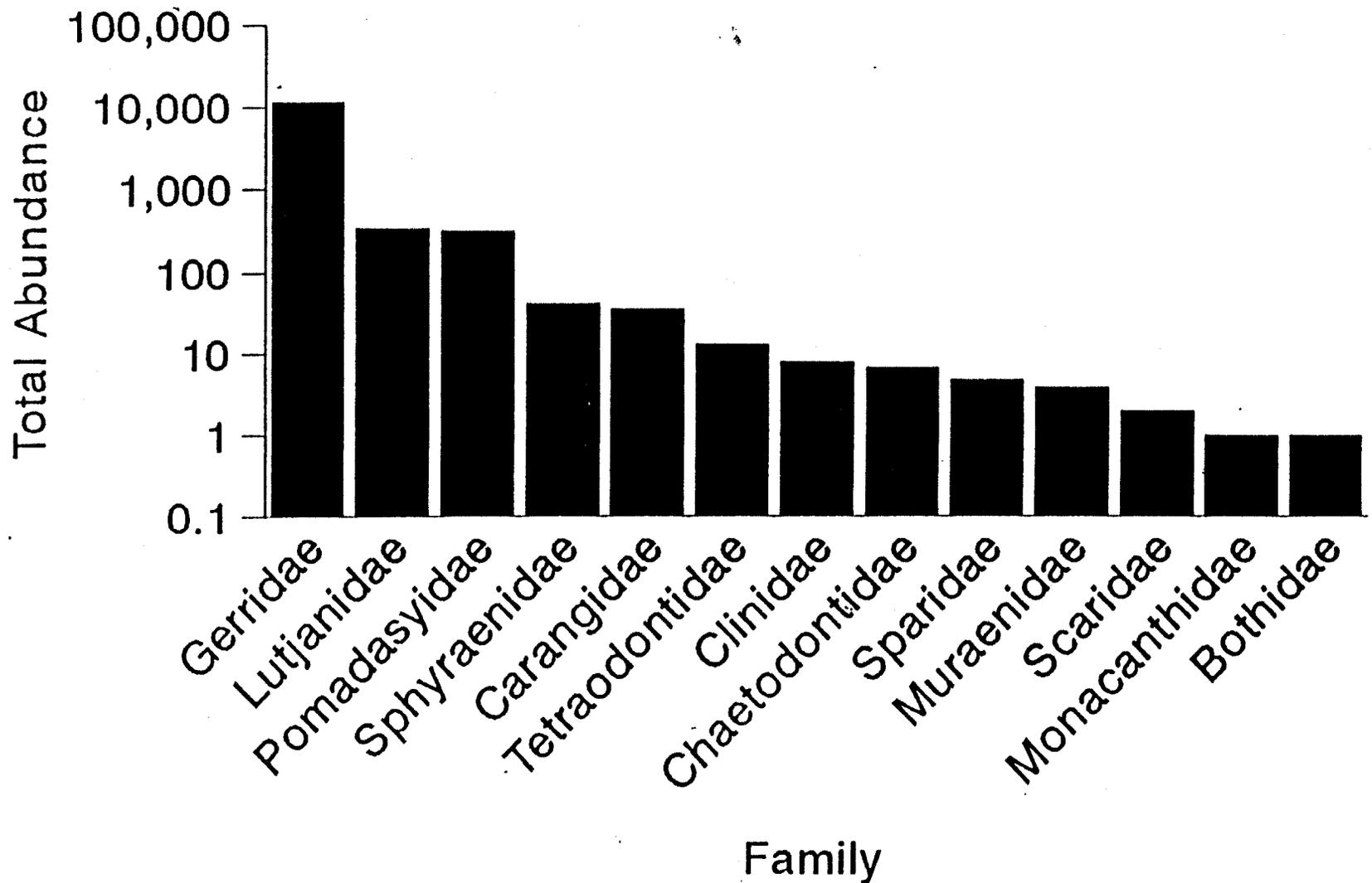


Figure 15.

Mean Number of Species Per Trap

Altona Lagoon

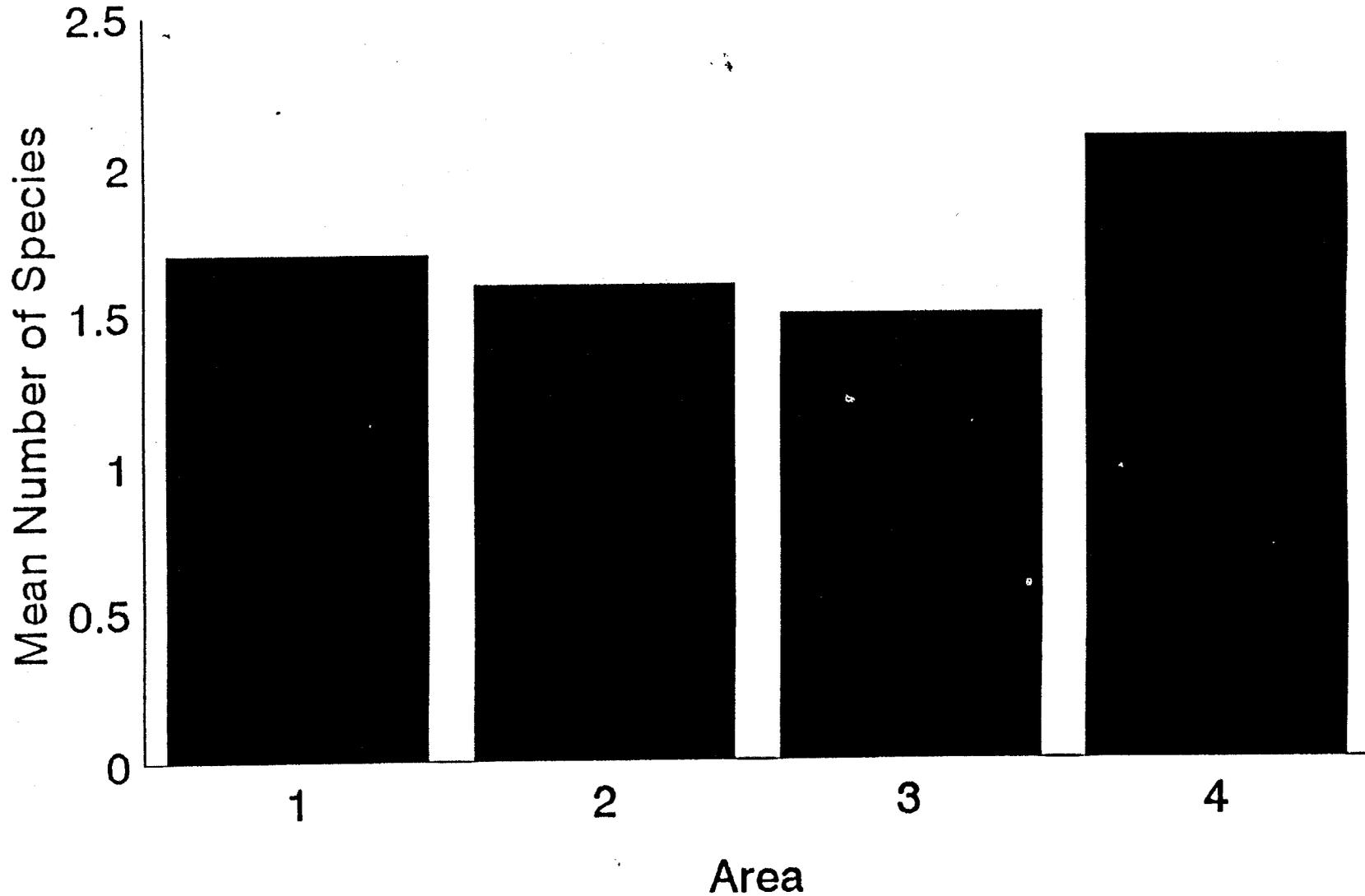


Figure 16.

Number of Individuals Per Trap

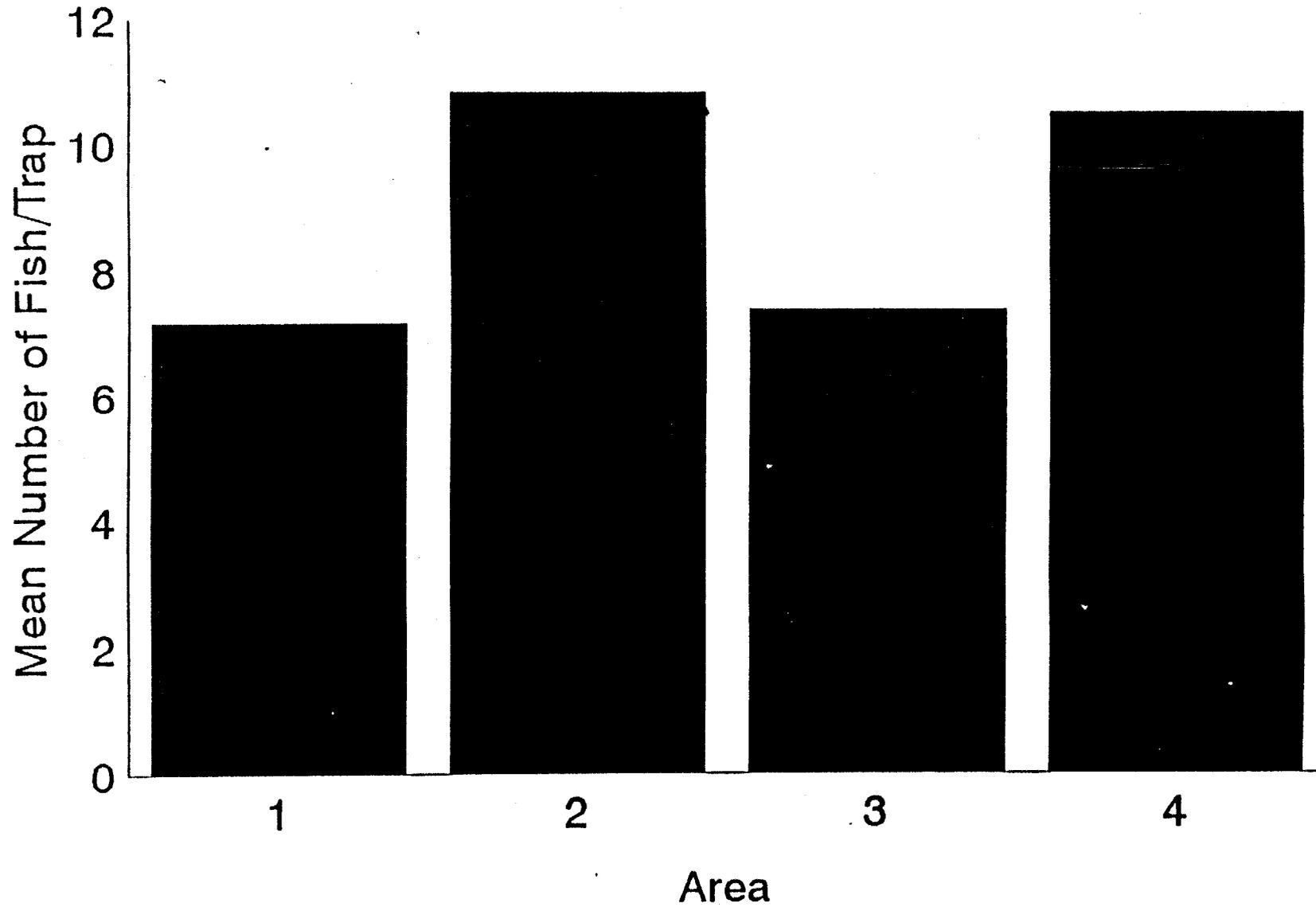


Figure 17.

Gerres cinereus

Altona Lagoon Traps

N = 5752

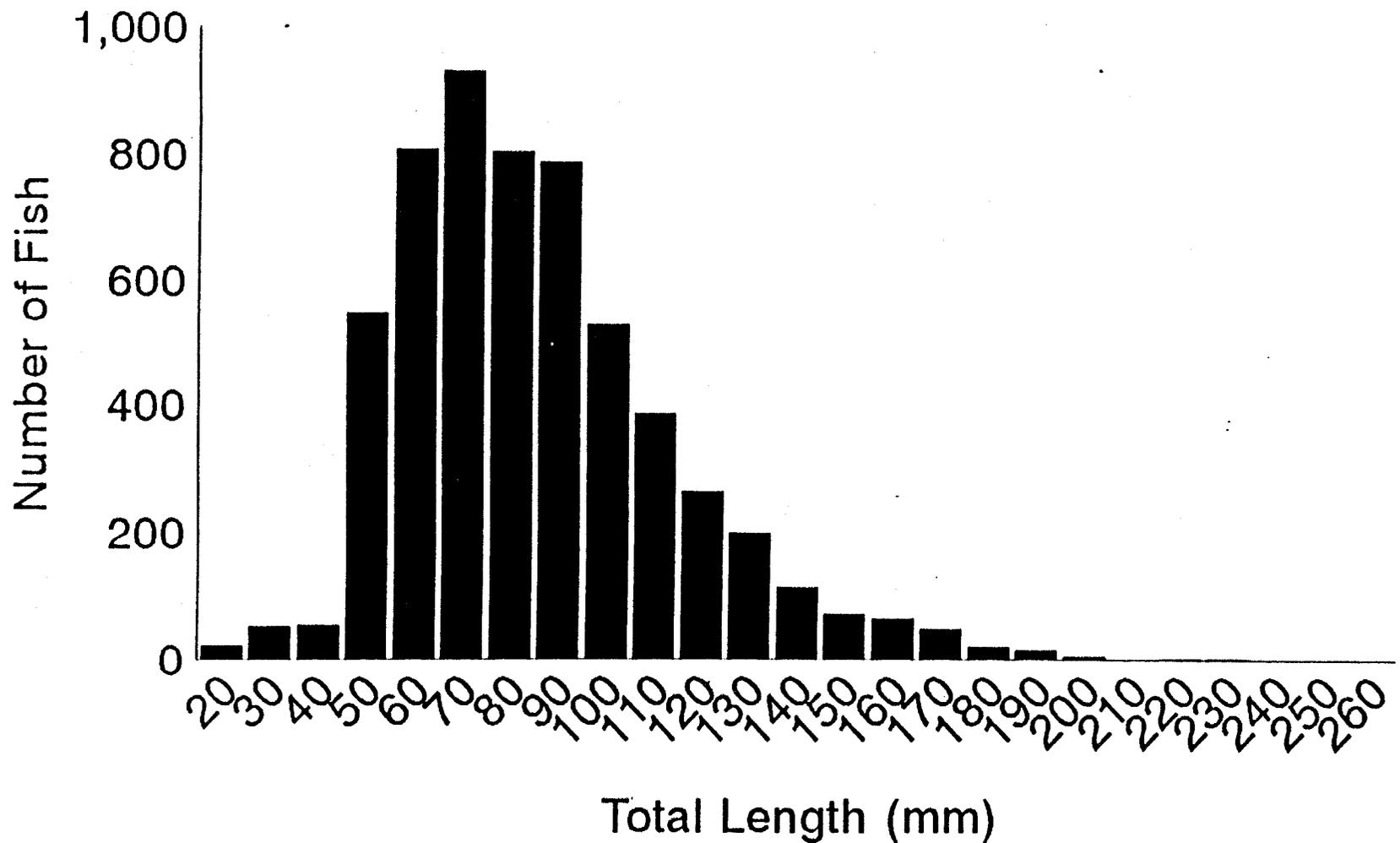


Figure 18.

Eucinostomus jonesi

Altona Lagoon Traps

N = 2289

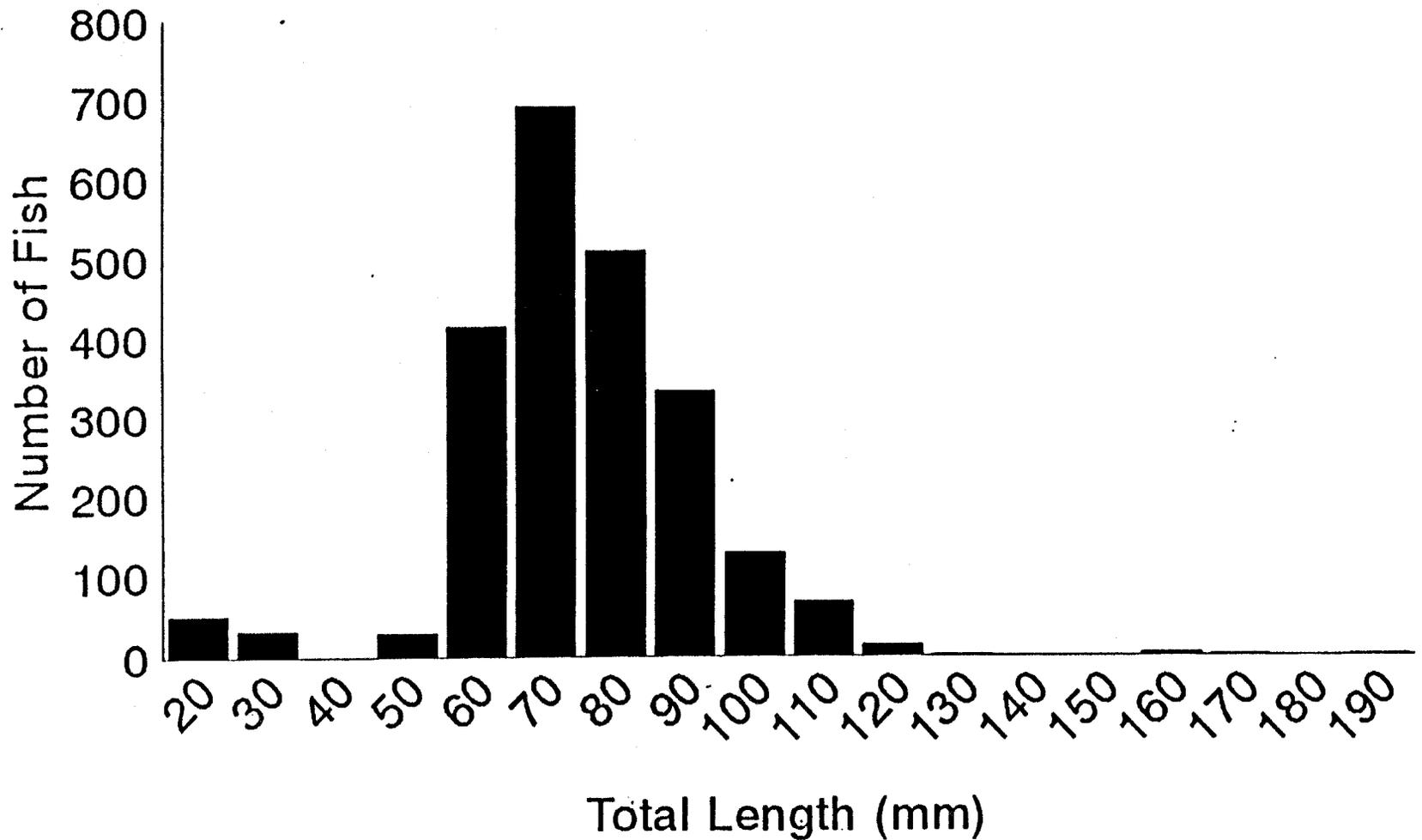


Figure 19.

Lutjanus apodus

Altona Lagoon Traps

N = 294

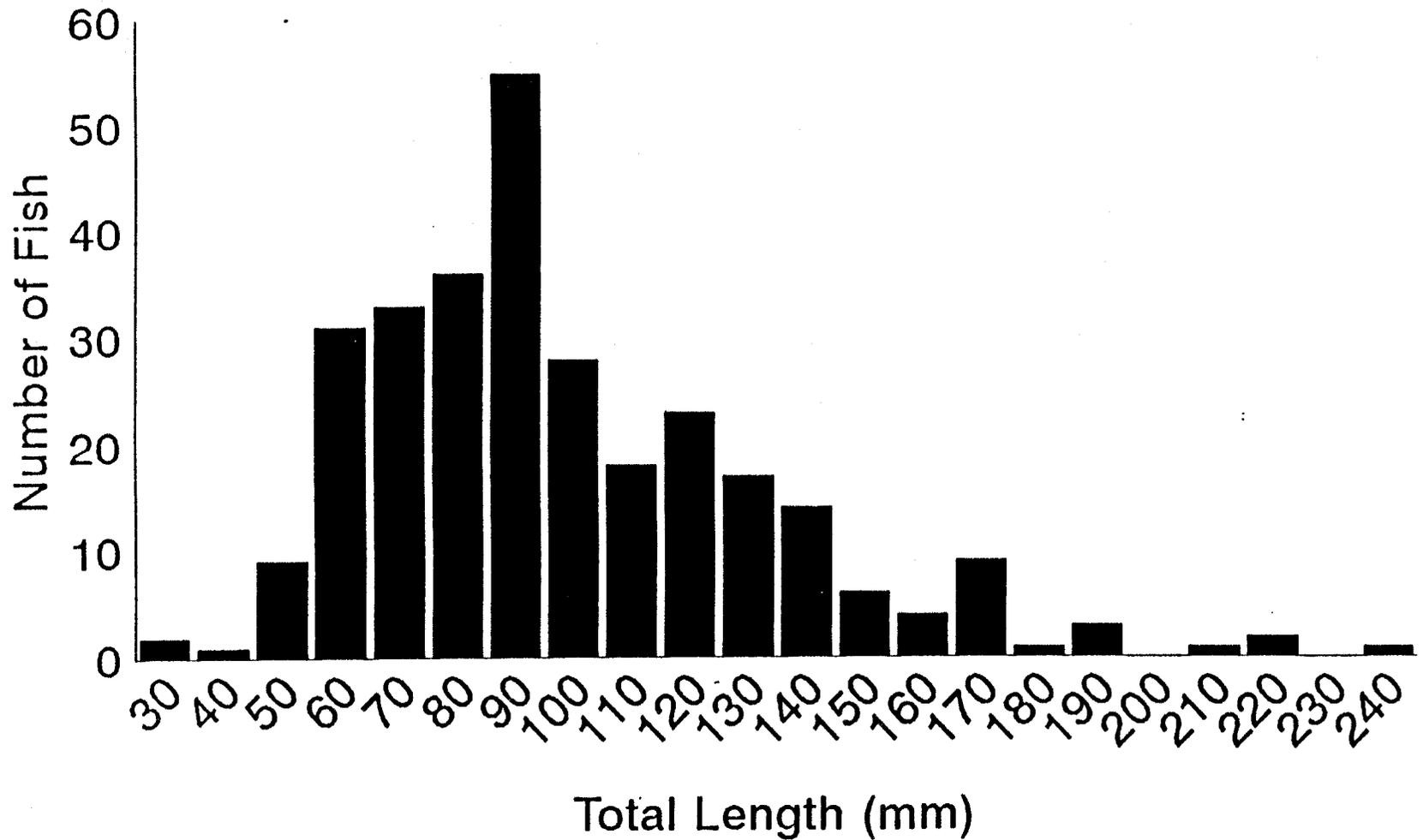


Figure 20.

Haemulon flavolineatum

Altona Lagoon Traps

N = 133

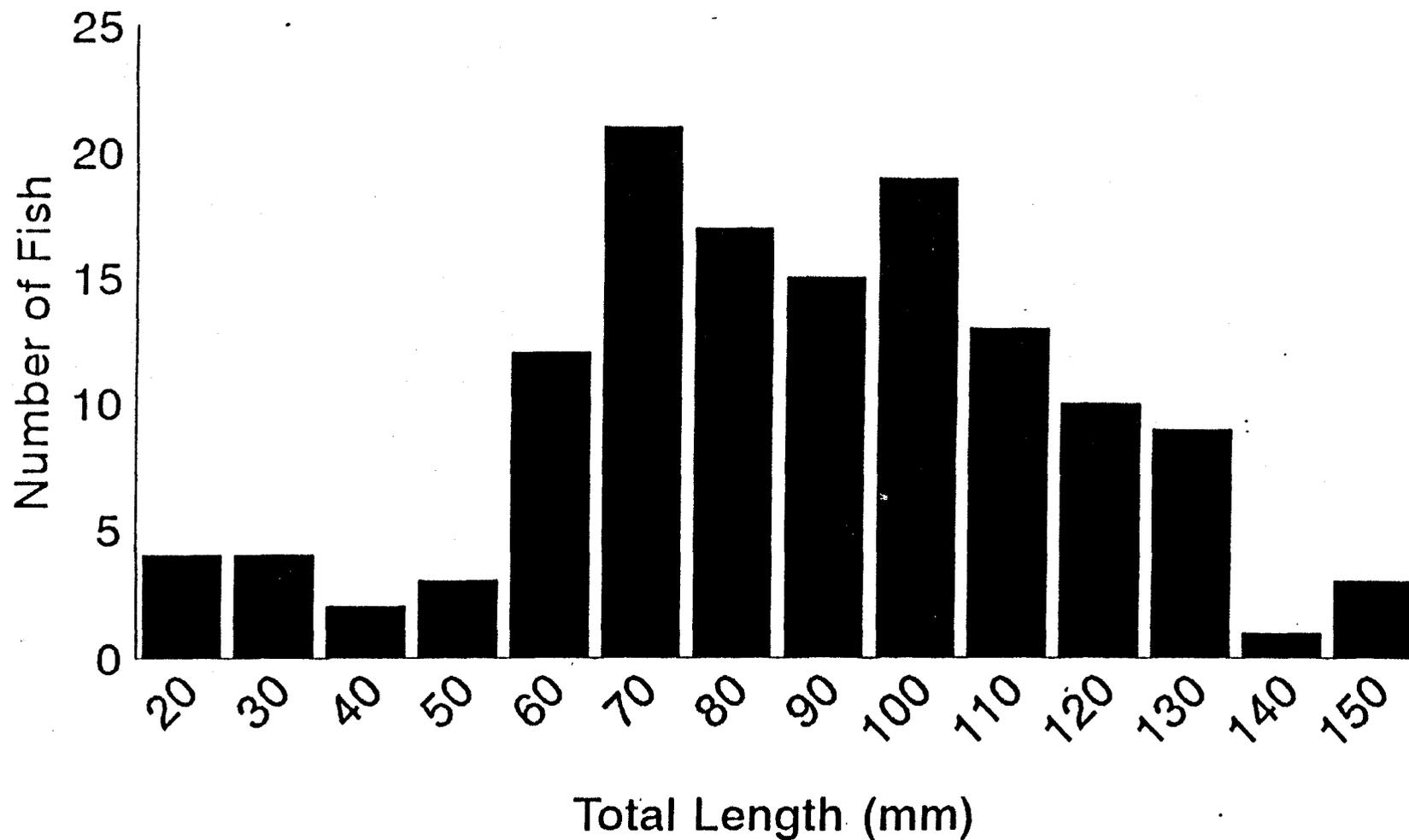


Figure 21.

Sphyraena barracuda

Altona Lagoon Traps

N = 40

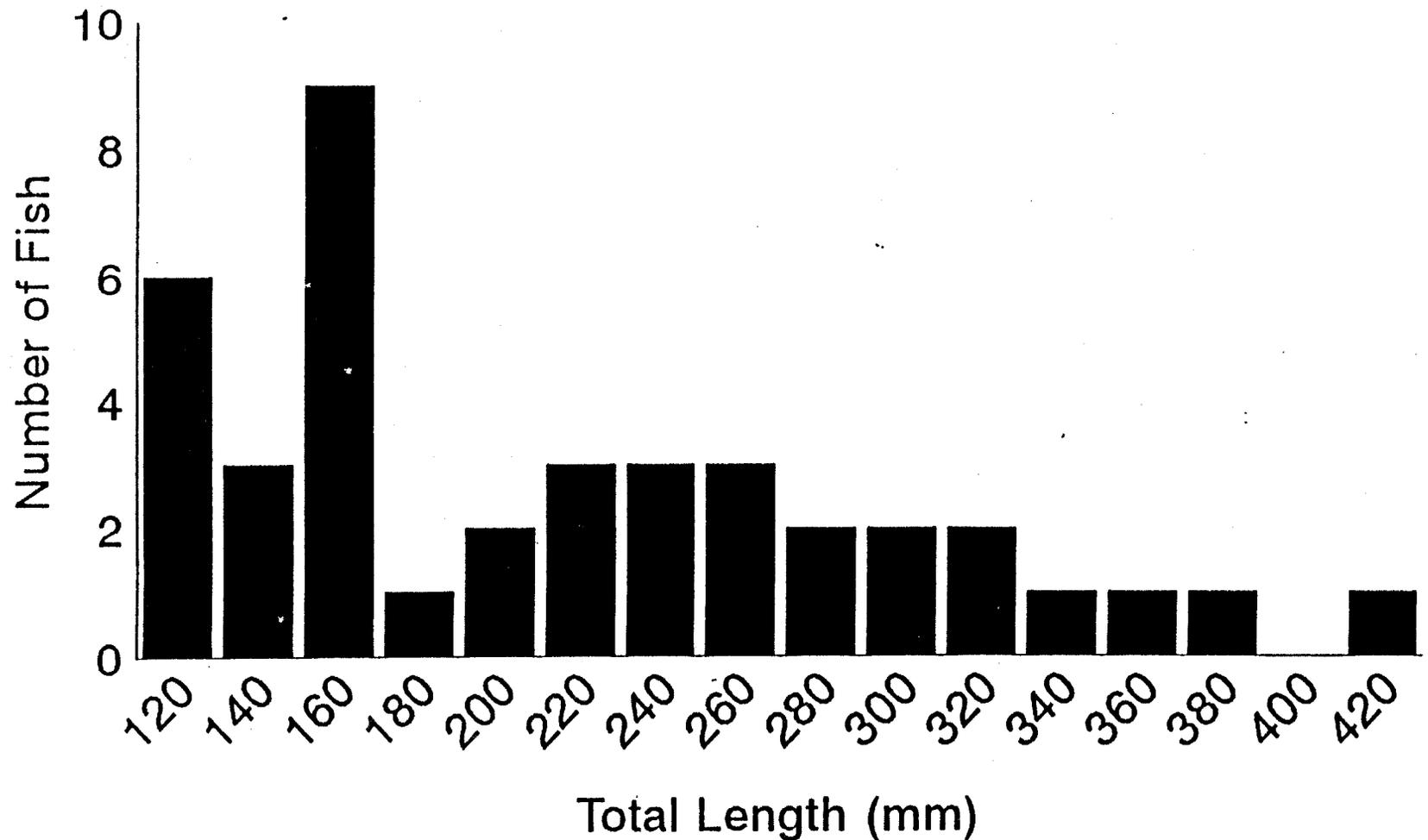


Figure 22.

Mean Monthly Abundance Per Trap - Altona Lagoon

□ G. cinereus + E. jonesi * L. apodus ■ H. flavolineatum

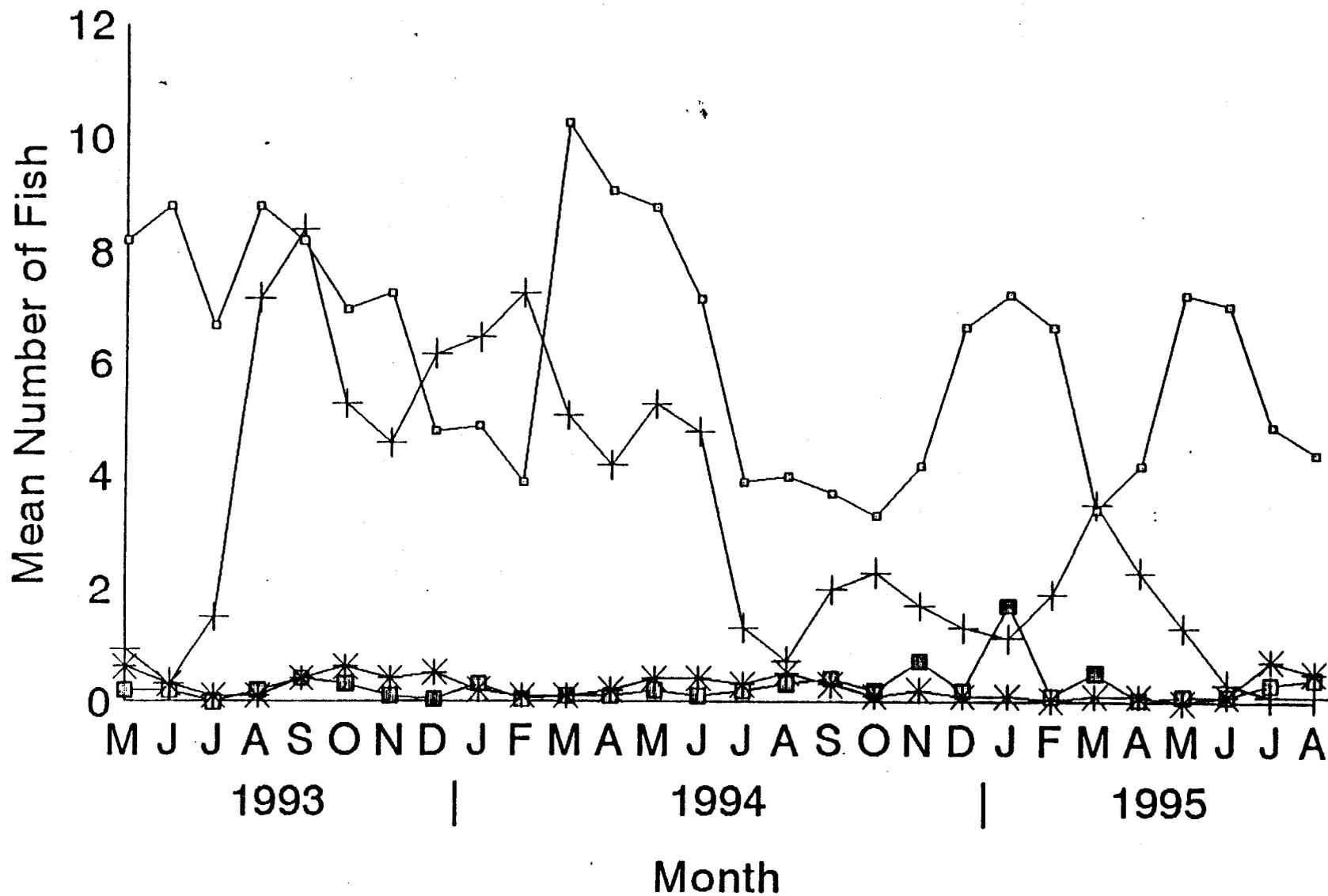


Figure 23.

Family Abundance

Altona Lagoon Transects

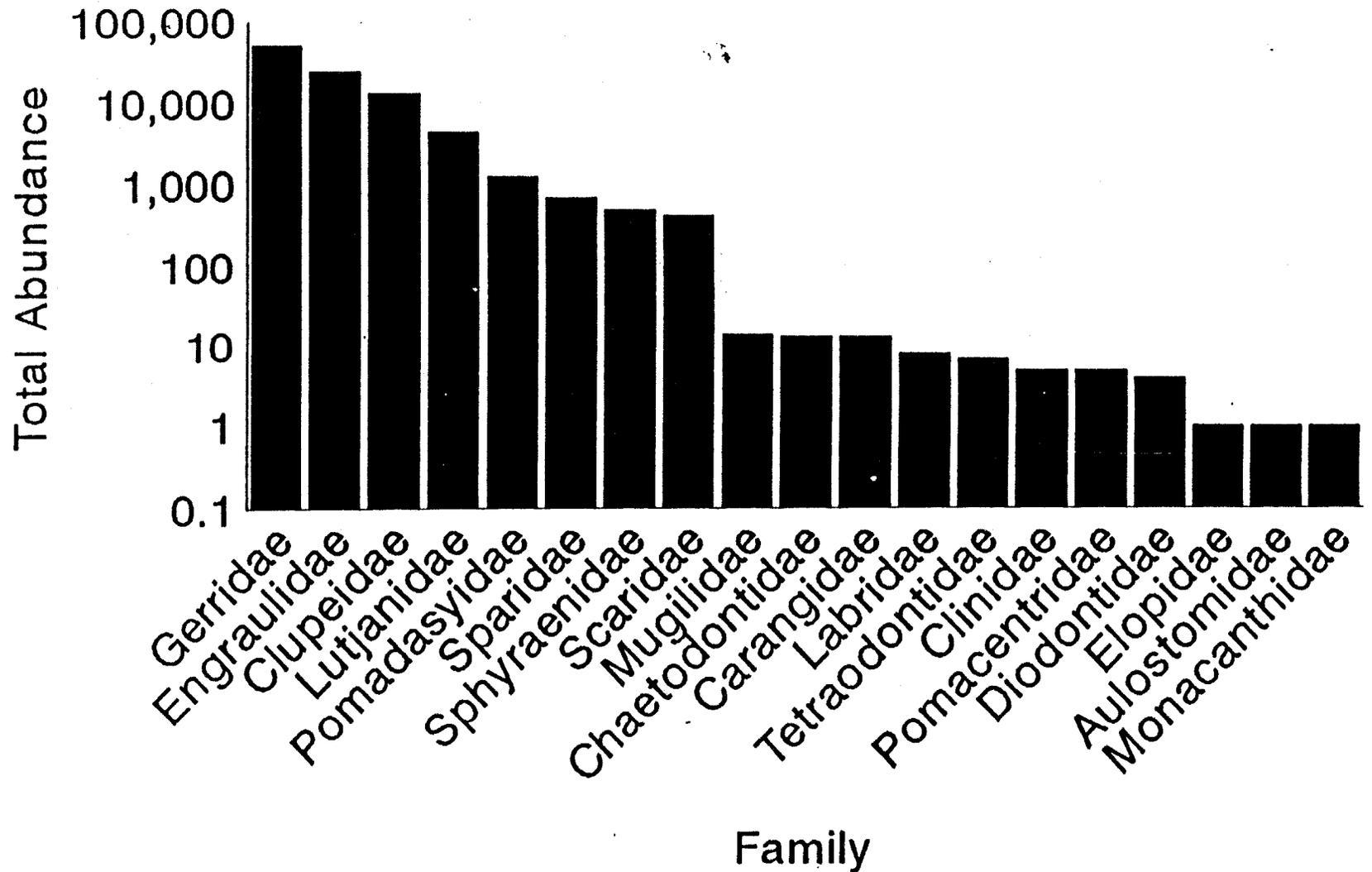


Figure 24.

Mean Number of Species Per Transect

Altona Lagoon

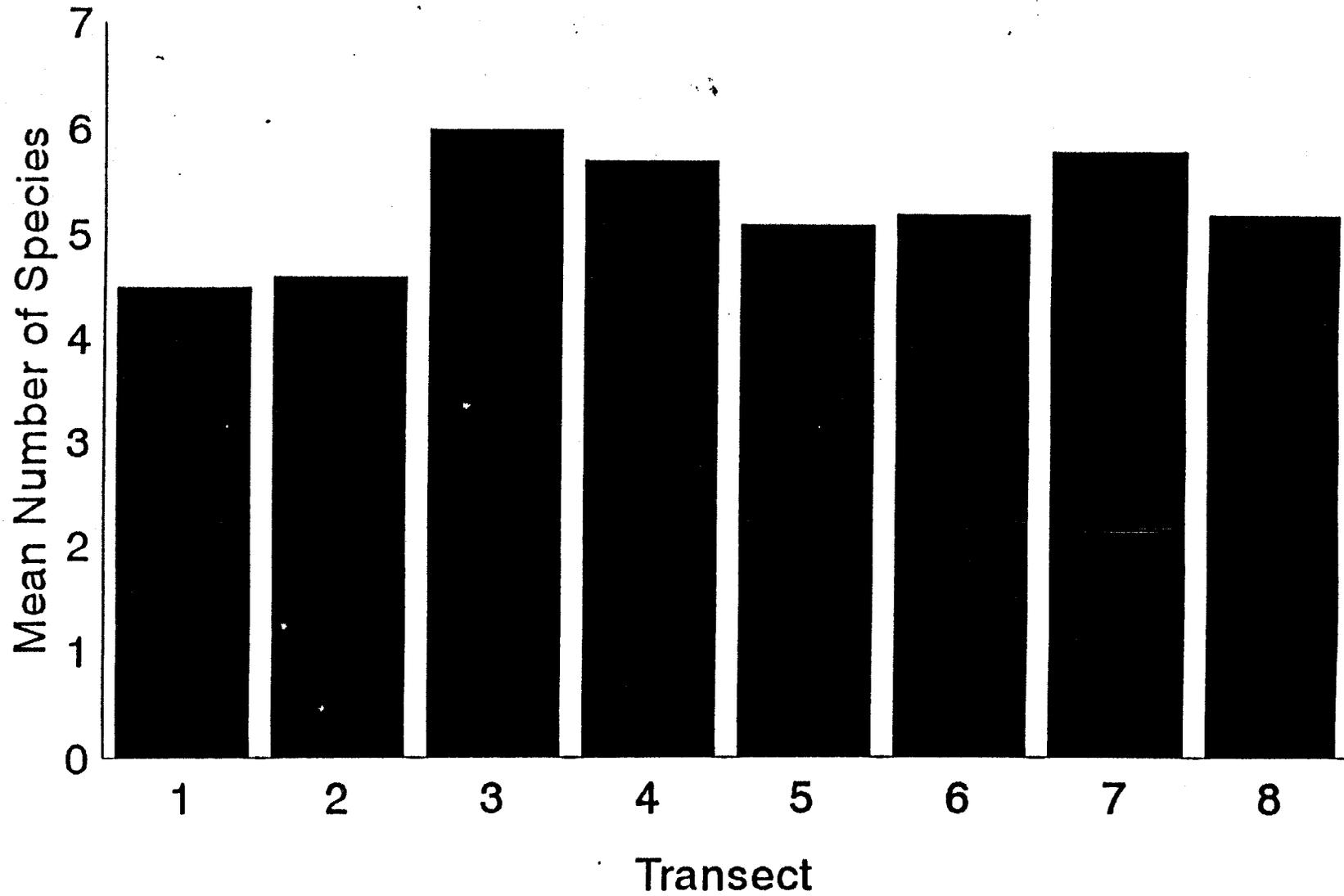


Figure 25.

Mean Number of Fish Per Transect

Altona Lagoon

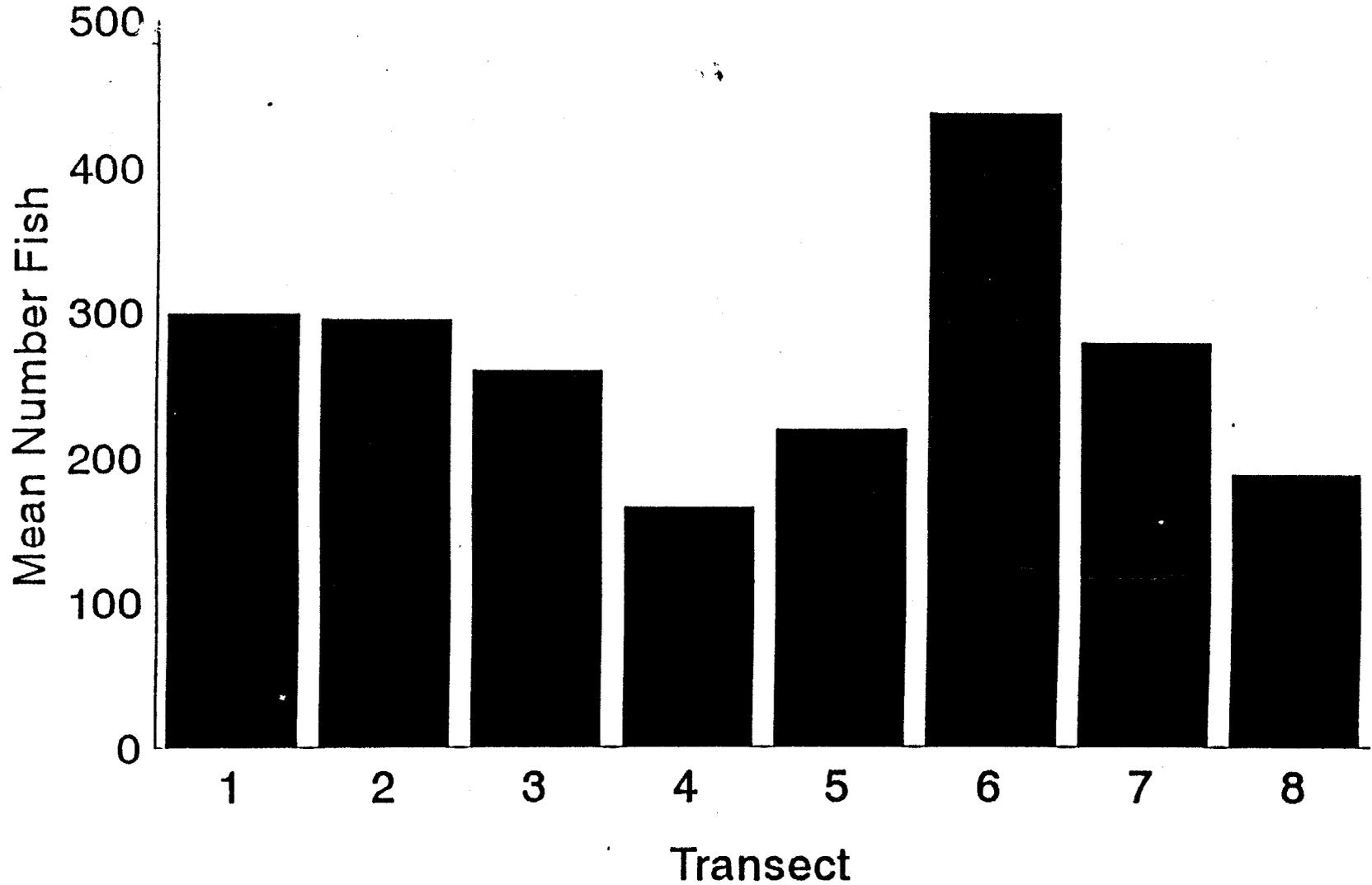


Figure 26.

Mean Monthly Abundance Per Transect - Altona Lagoon

□ G. cinereus + E. jonesi * L. apodus ■ H. flavolineatum

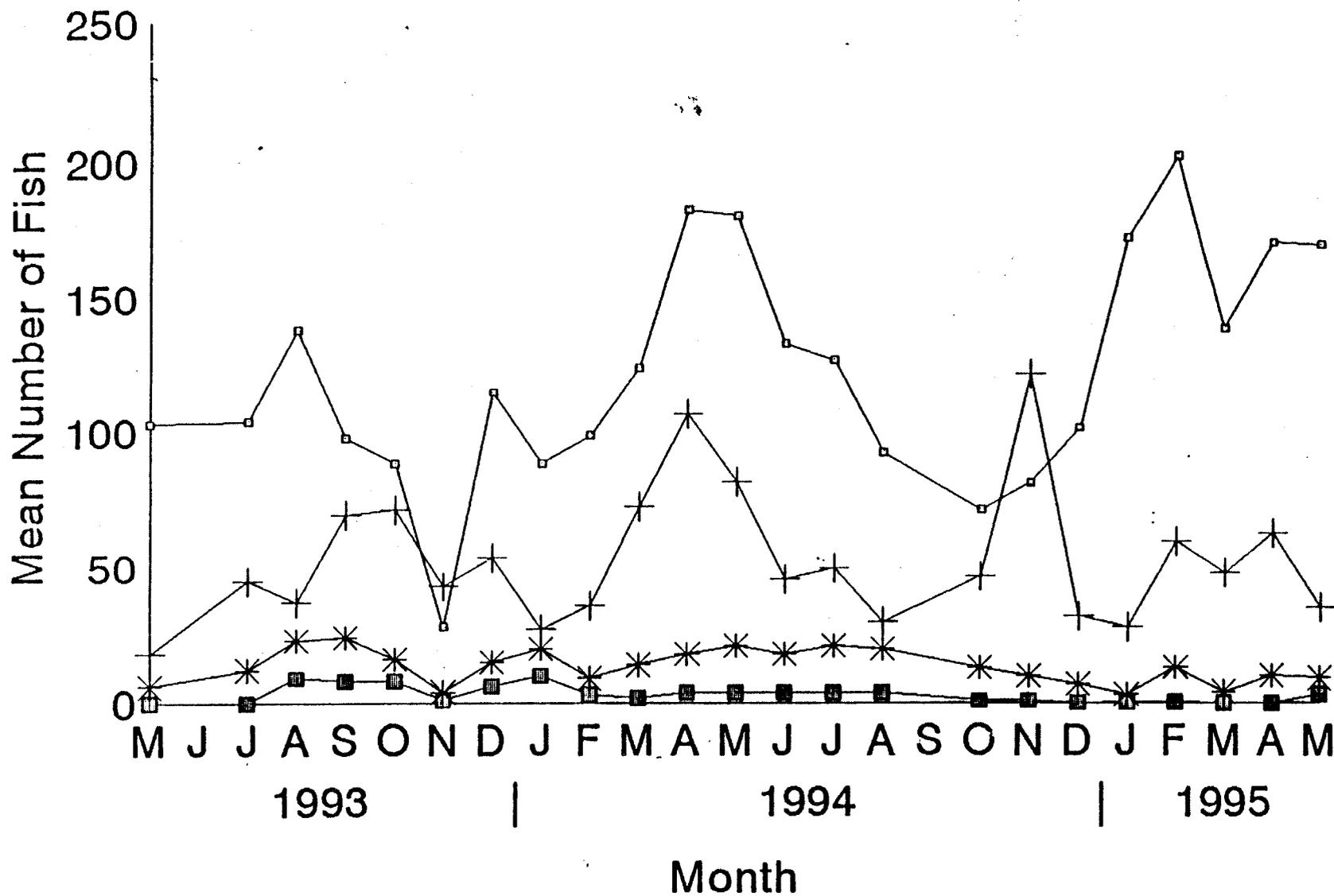


Figure 27.