FPL

Florida Power & Light Company, 6351 S. Ocean Drive, Jensen Beach, FL 34957

March 22, 2000

L-2000-78
10 CFR 50.36b
EPP 4.2.2.2

US Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

RE: St. Lucie Units 1 and 2
Docket Nos. 50-335 and 50-389
Environmental Protection Plan Section 4.2.2.2 (7)
Sea Turtle Entrapment Study

The enclosed report is being submitted pursuant to the requirements of Section 4.2.2.2 (7) of the St. Lucie Units 1 and 2 Environmental Protection Plans. The report provides the results of a study to elucidate the effect of various factors on sea turtle entrapment at the St. Lucie Plant. The study of turtle entrapments at the St. Lucie Plant intake canal was required by condition 7 of the Incidental Take Statement (ITS) of the National Marine Fisheries Service (NMFS) Biological Opinion (BO) dated February 7, 1997. The FPL study proposal was approved by the NMFS and the NRC by NRC letter dated February 22, 1999.

FPL's request for a Section 7 Consultation resulted in a meeting November 10, 1999, with FPL, NRC, NMFS, and Florida Fish and Wildlife Commission (FFWC) personnel. In this meeting, FPL was requested to include a discussion of the alternatives evaluated over the years to reduce sea turtle entrapment in the intake canal when the enclosed study was submitted. This discussion is attached.

Should you have any questions on this information, please contact us.

Very truly yours,

Rajiv S. Kundalkar
Vice President
St. Lucie Plant

RSK/GRM

Enclosure

cc: Regional Administrator, Region II, USNRC
Senior Resident Inspector, USNRC, St. Plant

C001

Green Turtle Lethal Take Discussion

There were a total of four green turtle mortalities at St. Lucie Plant in 1999. The present National Marine Fisheries Service (NMFS) designated lethal take limit for this species at St. Lucie is 3 or 1.5%, whichever is greater. A total of 190 green turtles were removed from the canal during 1999, yielding a green turtle mortality rate of 2.1% for the year. Three of the four mortalities occurred in September of 1999 following the passage of Hurricane Dennis and Hurricane Floyd. Concurrent with these events, there were large influxes of drift algae that accumulated on the primary barrier net, which forced the lowering of the net for several days. It was difficult to ascertain if any of these three mortalities were directly related to conditions encountered in the canal itself.

Exceeding the Lethal Take Limit requires reinitiating of a Section 7 Consultation between NRC and NMFS. FPL's request for a Section 7 Consultation resulted in a meeting November 10, 1999 with FPL, NRC, NMFS, and Florida Fish and Wildlife Commission (FFWC) personnel. This meeting also satisfied the biannual meeting with these agencies required by the plant Environmental Protection Plan, Section 4.2.2.2.10) c). Data presented by FPL during the November 1999 meeting indicates that over the entire period since consultation was initiated, green turtle mortalities were below the 1.5% level. Individual years (1997 and 1999) have exceeded the take limit and reinitiated consultation. In both 1997 and 1999, higher mortalities were associated with hurricanes and jellyfish influxes. It appears that these essentially random and uncontrollable events caused "spikes" in mortality levels that triggered reinitiating of consultation. Thus, while overall the conservation program is effective in achieving the take limit goals, the trigger to reinitiate consultation is perhaps too sensitive.

FPL proposes that individual year limits be set higher, at 6 green turtles or 3%, with a "lifetime" program limit of 1.5%. In support of the above request, FPL would like to reiterate the effectiveness of the sea turtle protection program at the St. Lucie Plant. This program includes the following current activities:

1. The Canal Capture and Release Program - This program has included over 6,500 turtles that have been captured, biological information recorded, tagged, and released back to the environment. The program has provided an invaluable source of population information for Loggerhead and Green Turtle populations, including immature individuals, on the East Coast of Florida. It also serves as a method of capture and rehabilitation of injured or diseased sea turtles that enter the intake canal.

2. The Beach Nesting Survey Program - This program includes a daily survey of sea turtle nests on Hutchinson Island. In 1999, over 7,400 nests were identified to species and counted. This data provides another invaluable tool toward monitoring the long-term trends of Loggerhead, Green, and Leatherback Turtle reproductive populations in the area.

3. The Public Service Turtle Walk Program - This program included 26 Turtle Walks in 1999 and involved approximately 1,100 members of the public. The program is a highly effective tool toward promoting sea turtle protection awareness.

4. Participation in the Sea Turtle Stranding and Salvage Network - In 1999, FPL responded to approximately 30 sea turtle strandings in the local area. This program supports the monitoring of sea turtle disease, injury, and mortality. If necessary, injured or diseased turtles are transported to rehabilitation facilities where they can be treated and released back to the environment.

In addition to the above programs, FPL has initiated many efforts to reduce plant impact on local sea turtle populations. These efforts include studies to reduce turtle entrapment in the canal as well as the development of methods to reduce residence time and mortalities in the canal. These efforts include several deterrent studies, which were conducted during the early to mid-1980's. Deterrent technologies, such as strobe lights, bubble-curtains, electrical fields, and pneumatic guns were tested, but none proved to be effective in the offshore environment.

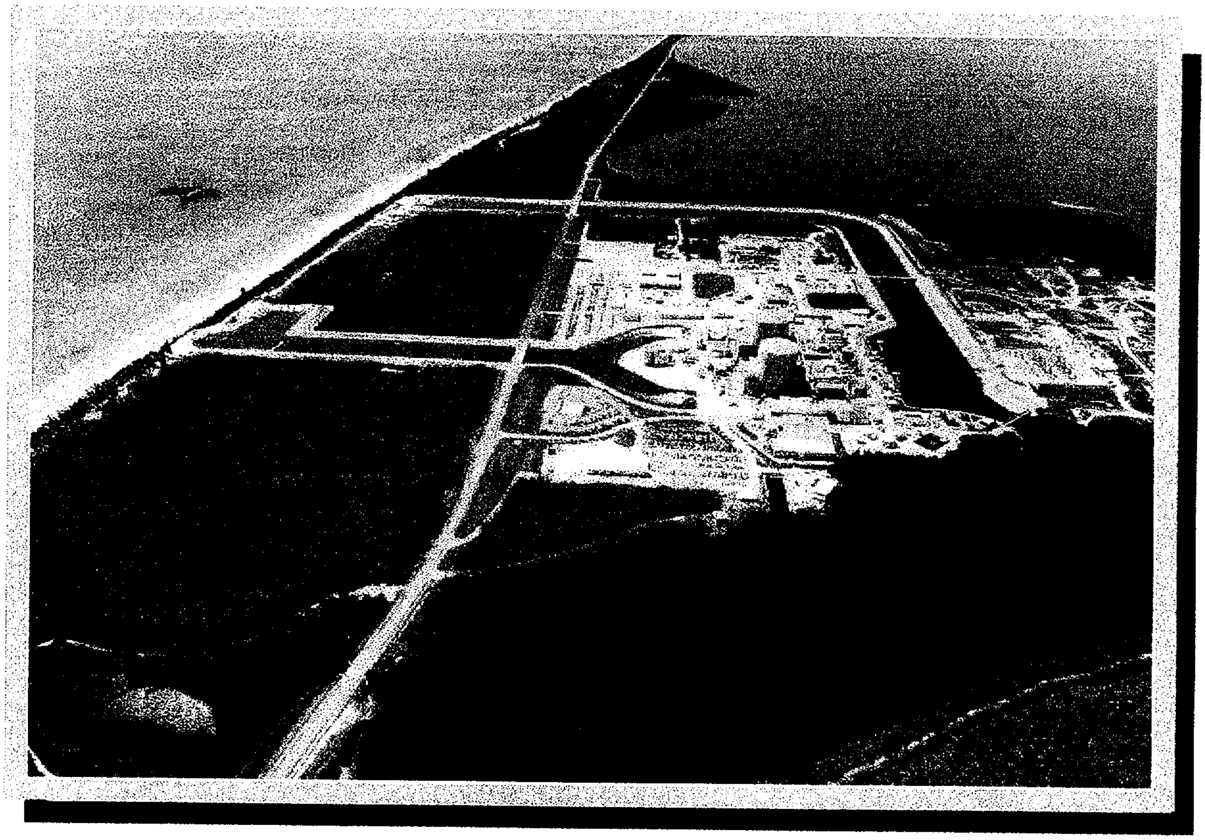
Several physical barrier designs and possible deterrents for the ocean intakes were also considered during the 1980's when the average size of turtle captured in the canal was much larger than the small green turtles that have been captured recently. These alternatives posed potential environmental concerns. These concerns include but are not limited to a net or barrier could become a floating "menace" in the Atlantic Ocean, as well as concerns about animals getting impinged on these devices. Previous analysis of those designs indicated that the capital and maintenance costs for a physical barrier system would be prohibitive and could likely cause a reduction in intake canal flow. In that the grid size of such a barrier would have to be even smaller to prevent entrapment today, such a design would appear to be even less feasible. Other investigations included methods of modifying turtle behavior with lights, air bubble curtains, sound, or electrical current so that the sea turtles would not approach or enter the intake structure. These studies were completed in 1985 and were submitted to the NRC by FPL letter L-85-158 dated April 18, 1985.

The most effective technology developed to date has been the installation of the 5-inch mesh barrier net just downstream of the canal headwall. This barrier net, which was installed in 1996, is an effective method of reducing residency time in the canal and therefore, the probability of injury or death to entrapped turtles.

At NMFS request, FPL commissioned a study in 1999 to investigate factors that might be important in the entrapment of sea turtles at the St. Lucie Plant. This effort is an excellent summary of canal capture information to date, plus it includes an analysis of many physical factors in the environment that could effect sea turtle entrapment. This study indicates that increased entrapment rates of turtles are most likely due to increases in sea turtle populations in the area offshore of the plant and not any change in plant operating characteristics.

Based on the information presented above and continuing efforts to reduce plant impact on local sea turtle populations, FPL believes that the Green Turtle Lethal Take Limit should be increased.

PHYSICAL AND ECOLOGICAL FACTORS INFLUENCING SEA TURTLE ENTRAINMENT LEVELS AT THE ST. LUCIE NUCLEAR PLANT: 1976-1998



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PHYSICAL AND ECOLOGICAL FACTORS INFLUENCING SEA TURTLE ENTRAINMENT AT THE ST. LUCIE NUCLEAR PLANT: 1976-1998

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EXECUTIVE SUMMARY

Florida Power & Light Company operates two nuclear power plants on Hutchinson Island, a barrier island in St. Lucie County, Florida. The adjacent marine environment provides foraging and developmental habitat for juvenile loggerhead and green sea turtles, and the adjacent beaches support high density nesting by adult loggerheads.

The St. Lucie Plant obtains its cooling water through a canal system connected to the Atlantic Ocean by underground pipes. Sea turtles, attracted to the offshore structures housing the intake pipes, are frequently entrained with cooling water. After passing through the large-diameter pipes turtles become entrapped in the intake canal. Since the plant began operating in 1976, an evolving program has been implemented to capture and safely return these turtles to the ocean.

Between 1976 and 1998, a total of 6,086 sea turtle captures were documented at the St. Lucie Plant. Although five species and all post-pelagic life history stages were represented, nearly 99 percent of the captures were comprised of loggerhead and green turtles, most of which (80 percent) were juveniles.

Over the life of the plant, the number of annual captures appeared to be rising, with unprecedented capture rates being documented beginning about 1993. As part of a Section 7 Consultation between the Nuclear Regulatory Commission and the National Marine Fisheries Service, FPL agreed to perform an analysis of sea turtle entrapment data to assess the extent to which changes in capture rates may be related to plant operating characteristics and/or extraneous environmental conditions. This report summarizes the findings of that study.

The offshore intake structures resemble a reef system in many aspects. They offer vertical relief in an area where the seafloor is relatively flat and provide suitable attachment sites for a variety of encrusting organisms and marine algae. They also provide unlimited and uncontested space for refuge. Both loggerhead and green turtles are known to utilize natural reefs for foraging and shelter, and loggerheads have been shown to associate with artificial structures. Additionally, nearby hard bottom and worm reefs support many of the same species known to be preferred food items in the diets of both species. These natural systems probably attract turtles to the vicinity of the structures.

The intake structures were designed so they would not entrain sea turtles and other motile marine life (nekton) into the structures from the surrounding environment. These animals must actively enter the structures before they encounter water velocities sufficiently strong to affect their entrainment. Once within the intake pipes, velocities prevent most turtles from escaping.

Between 1977 and 1998, there were significant increases in the number of juvenile and adult loggerhead and juvenile green turtle captures at the St. Lucie Plant. Captures of adult loggerheads increased gradually and closely corresponded to increases in nesting on Hutchinson Island. Thus, as more adult turtles were present in the nearshore environment, more individuals of this life history stage were entrained with cooling water. A different pattern emerged with juvenile loggerhead and green turtles. Although the number of captures for both species increased significantly over the life of the plant, the changes were not linear. Nearly all of the increases occurred after 1992.

The addition of a second unit at the St. Lucie Plant in 1983, along with a new and larger intake structure, increased the volume of cooling water drawn from the ocean and altered intake velocities. Although the annualized number of captures prior to Unit 2 startup was less than the number after, the addition of a second unit could not account for the dramatic rise in capture rates during the 1990s. Analysis of data following Unit 2 startup indicated that the volume of water entrained each month was not significantly correlated with green turtle entrapment levels, but it did have a weak influence on the number of juvenile loggerhead turtles captured. However, this influence was temporally limited and could not explain the longer-term patterns that were documented. Repairs to the intake structures, completed in 1992, coincided with a substantial increase in the number of juvenile green turtles captured. However, this was probably more coincidental than causal.

Similar to results for plant operating conditions, water temperatures accounted for some of the seasonal variations in capture rates but could not explain long-term changes. Furthermore, seasonal variation in the numbers of juvenile loggerhead and green turtles captured at the plant may be more closely related to migration patterns than to local environmental conditions. There was no correlation between wind velocities (and by extension ocean turbulence) and either short- or long-term sea turtle capture rates. There were no data to discern whether there had been substantive changes in the composition or relative abundance of plants and animals fed upon by loggerhead and green sea turtles in the vicinity of the St. Lucie Plant. Consequently, it was not possible to correlate changes in entrainment rates with changes in biological conditions adjacent to the plant.

A variety of factors affect the entrainment of turtles at the St. Lucie Plant, some related and some unrelated to plant operating conditions. However, none of the factors evaluated during this study provided a convincing explanation for the dramatic increase in captures of juvenile loggerhead and green turtles observed at the plant since the mid 1990s. Increased nesting on Hutchinson Island by both loggerhead and green turtles and recent unprecedented increases in juvenile green turtle captures in other areas of south central Florida suggest that local sea turtle populations may be increasing. This seems to offer the most logical explanation for increased capture rates at the St. Lucie Plant.

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INTRODUCTION

Florida Power and Light Company (FPL) operates two nuclear power plants (St. Lucie Plant Units 1 and 2) on Hutchinson Island, Florida (Figure 1). Both plants draw cooling water from the nearshore waters of the Atlantic Ocean through submerged intake pipes. Water flows through the intake pipes into a canal system. In 1976, when the first of the two power plants began operation, it was discovered that sea turtles were being entrained into the intake canal with the cooling water. Once in the canal, water velocities in the intake pipes prevented turtles from returning to the ocean.

A sea turtle capture and release program was instituted in 1976 to remove entrapped turtles from the intake canal and release them safely back into the ocean. Data collected from 1976 through 1998 suggested that the number of sea turtles being entrained with cooling water had increased in recent years. In accordance with a Section 7 consultation under the U.S. Endangered Species Act of 1973, FPL was required to assess sea turtle capture trends at the St. Lucie Plant and to identify factors potentially responsible for recent increases. Ecological Associates, Inc. was contracted by FPL to perform that analysis.

OVERVIEW OF ST. LUCIE PLANT DESIGN AND OPERATION

Site Description

The St. Lucie Plant is located on a 437-hectare site on Hutchinson Island, a 36-km-long barrier island on Florida's East Coast. The island is bounded by the Atlantic Ocean on the east, the Indian River Lagoon on the west, the Ft. Pierce Inlet on the north and the St. Lucie Inlet on the south. The plant is located approximately midway between the two inlets (Figure 1).

The shoreline in the vicinity of the power plant consists of sandy beach with intertidal worm reefs located just south of the intake (Figure 2). Submerged coquinoid rock formations parallel much of the island off the ocean beaches (Gallagher and Hollinger, 1977), though no substantial reef formations have been reported immediately offshore of the plant. The sea bottom adjacent to the power plant is reported to consist of a mixture of sand and shell fragments (Ebasco Servcies, Inc., 1971; Gallagher, 1977).

The continental shelf margin is located approximately 30 km offshore of Hutchinson Island. The Florida Current flows approximately parallel to the margin, but oceanic water associated with the western edge of the current periodically intrudes inshore during the summer (Worth and Hollinger, 1977; Smith, 1982). Seasonal variations in both the Florida Current and coastal winds are apparently responsible for annually recurring upwelling along Florida's Atlantic coast (Smith, 1982). These upwelling events occur during the summer and result in anomalously low water temperatures. During such events, water temperatures near the power plant may rapidly decrease by as much as 10°C and remain cool for several days to several weeks (ABI, 1977, 1981, 1986, 1990, 1991, 1992; FPL, unpublished data). Ambient water temperatures of the Atlantic Ocean in the vicinity of the power plant range from approximately 14 to 31°C. Water temperatures are typically warmest in September and coolest in January or February.

St. Lucie Plant Description

The St. Lucie Plant consists of two 850 Mwe, nuclear-fueled, electric generating units that draw once-through condenser cooling water from the Atlantic Ocean (Figure 3). Unit 1 went online in May 1976 and Unit 2 went online in June 1983. Three intake structures (one with a 4.9 m diameter opening and two with 3.7 m diameter openings) are located 365 m offshore in approximately 7 m of water. The two smaller intake structures were completed in late-1975 and the larger structure was completed in mid-1983. The configurations of the intake structures are shown in Figures 4 and 5. Each intake structure consists of a large base with a vertical shaft in the center. Numerous columns support a concrete velocity cap approximately two meters above the base of each structure. This configuration was designed to eliminate vertical water entrainment and reduce horizontal intake velocities thereby minimizing incidental entrainment of marine life.

In August 1989, large holes were discovered in the intake structure velocity caps. These holes added a strong vertical component to water entrainment, creating vortices that reached the ocean's surface. In March 1991, a construction project was initiated to repair the damaged caps. A large elevated platform, from which all repairs were conducted, was erected around the three intake structures. The platform remained in place until repairs were completed in February 1992. Repairs resulted in thicker velocity caps and supporting columns with the vertical clearance between the base of the intake structure and the bottom of the velocity cap remaining the same (Figure 6).

Water moves from the vertical shaft of each intake structure to a horizontal intake pipe. Intake pipes pass under the beach and dune system and connect to a 1500 m long intake canal that transports water to the plant. During the history of plant operation several barrier nets have been installed along the intake canal. The locations of these nets are shown in Figure 3. In 1978, a barrier net with a 20.3 cm square mesh was installed across the canal at the Highway A1A bridge. This barrier was intended to keep large debris and sea turtles away from the power plant. Then in January of 1987, an underwater intrusion detection system (UIDS) was installed on the north-south arm of the canal. This security system consists of a 22.9 cm mesh rigid net. And finally, in January 1996, a barrier net with a square mesh of 12.7 cm was installed east of the A1A bridge. This net was intended to better confine turtles to the eastern portion of the intake canal where capture techniques are most effective.

At the power plants, cooling water is drawn from the bottom of the canal into eight separate intake wells (Figures 3 and 7). In the wells, the water first passes through a series of trash racks (vertical bars spaced approximately 7.6 cm apart) and then through a series of traveling screens with a one centimeter mesh. Finally, the water flows through the circulating water pumps and into the plant's condenser system. As the water moves through the plant's condenser system, it gains heat from the condenser and is expelled into the discharge canal.

The discharge canal is 670 m long and leads to two buried discharge pipes at it's eastern terminus (Figure 3). The pipes transport water beneath the beach dune system back into the Atlantic Ocean. One pipe is 3.7 m in diameter, extends approximately 460 m offshore and terminates in a two-port "Y" nozzle. Installation of this discharge pipe was completed in 1975. The other pipe is 4.9 m in diameter and extends 1030 m offshore. Water is discharged into the ocean through a series of 58 ports that rise above the ocean floor along the easternmost 425 m of the pipe. Installation of this structure was completed in 1981.

St. Lucie Plant Intake System Characteristics

From May 1976 through May 1983, St. Lucie Plant Unit 1 drew 32.56 m^3/sec (1150 ft^3/sec) of water through two 3.7-m-diameter intake pipes during normal plant operation. Water velocities at various locations along the intake system are given in the second row of Table 1. When the power plant was shut down for refueling and/or maintenance, the main circulating water pumps were shut down and auxiliary pumps were run. During these periods, velocities due to the auxiliary pumps were approximately three percent of those for periods of normal plant operation (pers. com., N. Whiting). Water velocities along the intake system during periods when only auxiliary pumps were operating are given in the first row of Table 1. Between 1976 and 1983, during periods of normal plant operation, velocities within the 3.7-m intake pipes were between 159 and 178 cm/sec (5.2 – 5.8 ft/sec). Once within the intake canal, water velocities slowed to about 15.2 cm/sec (0.5 ft/sec).

With the addition of Unit 2 and a third (4.9-m-diameter) intake pipe in June 1983, water velocities along the intake system during normal plant operation changed (see the fourth row of Table 1). Velocities within the 4.9-m-diameter intake pipe were greater than those occurring within the 3.7-m-diameter pipes prior to the addition of Unit 2. However, velocities within the 3.7-m-diameter intakes decrease after addition of the larger intake pipe. Between 1983 and 1998, during periods of normal plant operation, velocities within the smaller intake pipes ranged from 127 – 142 cm/sec (4.2 – 4.7 ft/sec) and in the large intake pipe from 180 – 206 cm/sec (5.9 – 6.8 ft/sec). The addition of the second unit doubled current velocities within the intake canal when both units were operational.

The addition of a second power plant also affected velocities along the intake system during maintenance/refueling periods. After June 1983, maintenance and refueling was scheduled such that one plant was always operating while the other was shut down (with only auxiliary pumps running). So, flow velocities during maintenance/refueling periods were considerably higher after June 1983 than before when only auxiliary pumps were running (see the third row of table 1).

ST. LUCIE PLANT SEA TURTLE CAPTURE PROGRAM

Over the years, most of the turtles entrapped in the St. Lucie Plant were removed by means of large mesh tangle nets. Nets varied in length from 30 to 115 m, were 2.7 to 3.7 m in depth and were usually made of 40.6 cm stretch mesh, multi-strand nylon. Large floats were attached to the surface line and during the first several years the bottom line consisted of hollow braided polypropylene line with lead weights inserted every 61 cm. Since 1982, bottom lines were unweighted. Turtles entangled in the nets generally floated at the water's surface until removed.

Nets were fished at various locations throughout the intake canal, though most netting took place east of the A1A bridge (Figure 3). Throughout the study period, the canal capture program underwent continuous refinement to minimize both entrapment time and any harm to entrained turtles. Prior to April 1990, nets were usually deployed on Monday morning and retrieved Friday afternoon. During deployment, the nets were inspected a minimum of twice per day (once in the morning and again in the afternoon) by biologists. In addition, St. Lucie Plant personnel periodically checked the nets throughout the day and night. Biologists were on call 24 hours per day and were notified immediately if a turtle was observed in the net.

Beginning in April 1990, procedures were revised to decrease response time for removal of entangled turtles from nets and to increase surveillance of the canal for the presence of turtles. Under the new procedures, nets were deployed during daylight hours only (Monday through Friday; approximately eight hours per day) and biologists remained on site during deployment. While on site, biologists were able to assess turtle levels in the canal. Records of daily canal observations were compared with capture data to determine capture efficiencies. Beginning in July 1994, netting effort was increased to seven days per week and 10 to 12 hours per day.

In addition to procedural changes, there were physical changes in the canal that increased the efficiency of the capture program. The A1A barrier net, which was installed in 1978, was constructed to restrict turtles to the easternmost section of the intake canal where netting was most effective. For a number of years after it was installed, the integrity of the barrier net was periodically compromised and turtles were able to move west of A1A. Beginning in January 1987, turtles moving west of A1A were further constrained downstream by the UIDS. Prior to the completion of the UIDS, turtles that breached the A1A barrier net were usually not captured until they reached the power plant's intake wells. The intake wells were inspected throughout the day and night by St. Lucie Plant personnel, and biologists were notified immediately if turtles were observed. Turtles were removed from the intake wells by means of mechanical rakes, dip nets or by hand. Following construction of the UIDS, all but the smallest turtles were restricted from the intake wells. After improvements were made in 1990, the A1A barrier net was effective in confining all turtles larger than 32.5 cm carapace length (28.7 cm carapace width) to the eastern end of the canal.

In response to a dramatic increase in intake canal captures in 1995, consultation was initiated with FPL, the Nuclear Regulatory Commission (NRC) and the National Marine Fisheries Service (NMFS) under Section 7 of the Endangered Species Act. As a result of that consultation, FPL has designed and constructed a small mesh barrier net east of the A1A barrier net. Construction of the net was completed in January 1996. This net was designed to restrict all turtles with a carapace width greater than 18 cm to the extreme eastern portion of the intake canal. Because capture techniques were most efficient in this portion of the canal, residency times of entrained turtles were further reduced after the installation of this net.

Throughout the history of the canal capture program, the entire intake canal was periodically inspected to determine the numbers, locations and species of turtles present. The effort devoted to surveillance of the canal was increased in 1990, and then again in 1994, concurrent with revised netting procedures during those years. Also, surface observations were augmented with periodic underwater inspections, particularly in the vicinity of the barrier nets. These efforts insured that all turtles that were entrapped in the canal were accounted for.

In addition to tangle nets, several other methods were used to remove turtles from the intake canal. Captures at the intake wells were previously discussed. Another technique involved the use of long handled dip nets from boats, canal banks and headwall structures[1] to capture small turtles (carapace lengths of 30 cm or less). This method was moderately effective. Additionally, divers with snorkels or SCUBA entered the canal and hand-captured turtles. Because this latter technique proved to be highly effective in the capture of turtles of all sizes, it was used extensively from 1990 through 1998. This method was particularly effective in removing less active turtles and undoubtedly helped to reduce residency times for entrapped turtles. Between 1994 and 1998, 12 to 18 percent of the captures that occurred east of the A1A bridge were attributable to hand captures.

Regardless of capture method, all live turtles removed from the canal were identified to species, measured, weighed, tagged and examined for overall condition. Healthy turtles were released into the ocean the same day of capture. Sick or injured turtles were treated and, if necessary, held for observation prior to release. Dead turtles were identified to species, measured and assigned an identity number. Beginning in 1982, necropsies were conducted on dead turtles found in fresh condition.

From 1976 through 1998, 6,086 sea turtles were captured in the St. Lucie Plant intake canal (Table 2). Captures included 3,578 loggerhead turtles, 2,432 green turtles, 21 leatherback turtles, 21 hawksbill turtles and 34 Kemp's ridley turtles. Because the vast majority of the captures consisted of loggerhead (58.8 percent) and green (40.0 percent) turtles, this report will deal only with these two species.

[1] Bulkhead and pier-like structures located at the east end of the intake canal (Figure 3).

The earliest estimates of residency times for turtles in the intake canal were derived from data collected from October 1980 through January 1981 (ABI, 1983). Eleven loggerhead turtles were captured, tagged, released back into the canal and recaptured (ABI, 1983). Recapture occurred one to nine times before individual turtles were released back into the ocean. There were 32 recapture events. The average elapsed time between successive captures was 10.3 days (range: 0.25 to 38 days). Twenty-three of the recaptures (72 percent) occurred within 11 days.

The increased surveillance for turtles in the intake canal that began in April 1990 allowed individual turtles to be identified as they were observed in the canal. As turtles were captured, the date of initial observation was compared to the date of capture and residency times were determined. Data collected for 416 loggerhead turtles from April 1990 through December 1993 indicated that the average residency time was 2.7 days (range: 1 to 50 days; ABI, 1994). Ninety-three percent of these loggerheads were captured within one week of first sighting. Data for 252 green turtles collected during the same period indicated an average residency time of 3.8 days (range: 1 to 61 days). Eighty-six percent of these green turtles were captured within one week of first sighting.

Results of residency time analyses provided the basis for establishing time intervals to be used for analysis of trends in turtle entrainment at the St. Lucie Plant. In this report long-term trends in turtle entrainment are analyzed using annual data. Seasonal trends in entrainment and relationships between turtle entrainment and various environmental and power plant factors are analyzed using monthly data. The latter interval seemed appropriate based on average residency times (time lags between entrainment and capture) of three to ten days. It is recognized that not all turtles captured during a particular month were necessarily entrapped that month. However, overall seasonal trends should be fairly accurately portrayed using monthly data.

Prior to analyzing trends in loggerhead and green turtle captures at the St. Lucie Plant, an overview of pertinent biological characteristics of these two species is warranted. This will aid in interpreting the results of the St. Lucie Plant sea turtle capture program.

BIOLOGY OF LOGGERHEAD AND GREEN TURTLES

Loggerhead Turtles

The loggerhead turtle, *Caretta caretta*, inhabits temperate, subtropical and tropical waters of the Atlantic, Pacific, and Indian Oceans. Most nesting occurs on warm temperate and subtropical beaches (Dodd, 1988). Approximately 50,000 to 70,000 loggerhead turtle nests are deposited on Southeastern US beaches annually, ranking this loggerhead turtle rookery the second largest in the world (NMFS and USFWS, 1991a). The beaches in southeast Florida are especially prolific nesting areas, with Hutchinson Island being a critically important nesting beach (Meylan et al., 1995). Between 5,000 and 8,000 loggerhead nests have been deposited annually on Hutchinson Island during the last ten years (Quantum Resources, 1999).

Most nests on Hutchinson Island hatch within sixty days (Ernest and Martin, 1993; Ecological Associates, Inc., unpublished data). Hatchlings emerge from nests primarily at night. Upon entering the surf, the hatchling swims offshore in a "frenzy" to arrive at floating weed and debris lines (Carr, 1986; Salmon and Wyneken, 1994). Once there, loggerhead turtles feed on various insects, hydrozoans, gelatinous animals, barnacles and other material associated with floating mats of *Sargassum* (Richardson and McGillivary, 1991; Witherington, 1994). Post-hatchling loggerhead turtles from the Florida coast enter the currents of the North Atlantic Gyre that encircles the Sargasso Sea and move toward the eastern Atlantic. They may use magnetic cues to keep them from getting off course and floating into waters too cold for survival (Lohmann and Lohmann, 1996). Bolten et al. (1998) conducted a study of mitochondrial DNA from 131 pelagic juvenile loggerheads captured off the Azores and Madeira in the eastern Atlantic. One hundred and twenty-one of the turtles had known nesting beach haplotypes, and of those, approximately 71 percent were from south Florida, 19 percent from north Florida to North Carolina, and 11 percent from Mexico. The curved carapace length of the turtles from the Azores was 9-71 cm, and for the Madeira turtles 20 to 55 cm. From the eastern Atlantic, some pelagic turtles may enter the Mediterranean Sea, but many drift back around to the shallow coastal waters of the western Atlantic (Bowen et al., 1993; Laurent et al., 1998).

When loggerhead turtles reach the size of approximately 40-60cm straight carapace length (SCL), they leave the pelagic environment and move into various inshore estuaries or reef-system habitats (Carr et al., 1978; Carr, 1986). Most western Atlantic loggerheads are estimated to arrive in coastal waters after five to twelve years of a pelagic existence (National Research Council, 1990; Bjorndal and Bolten, 1994). The nearshore regions where juvenile and subadult loggerheads live and forage have been termed developmental habitats. They may reside in these developmental habitats either seasonally or year round until they reach sexual maturity (Carr et al., 1978). This is estimated to occur between 22 to 26 years of age (Frazer and Ehrhart, 1985; Klinger and Musick, 1995). Few mature adults are found in developmental habitats along the east coast of Florida except during mating or nesting season (National Research Council, 1990).

In the United States, developmental habitats for loggerhead turtles are found from Texas to Nova Scotia (Carr, 1952; Turtle Expert Working Group, 1998). Aerial surveys conducted in summer months indicated that 54 percent of the post-pelagic loggerheads in US coastal waters were found off the southeast coast; 29 percent were off the northeast coast; 12 percent were in the eastern Gulf of Mexico; and 5 percent were in the western Gulf of Mexico (Turtle Expert Working Group, 1998).

While immature loggerhead turtles are found in south Florida waters year round, their occurrence in northern estuaries and bays is seasonal. Generally, the northern habitats are only occupied during the late spring, summer, and early fall (Lutcavage and

Musick, 1985; Keinath et al., 1987; Morreale et al., 1992; Epperly et al., 1995). Over 90 percent of the loggerhead turtles that migrate seasonally to northern waters are sexually immature (Rankin-Baransky, 1997; Coles, 1999).

Coles (1999) reported that loggerhead turtles in the Chesapeake Bay have been found in areas with water temperatures ranging from 13 to 29°C. Most juvenile sea turtles enter the bay in the late spring as temperatures approach 20°C, and they leave in the fall after temperatures fall below 20°C. Many of the turtles entering the bay have migrated from areas south of Cape Hatteras. When they arrive, water temperatures in the bay are still rather cool, and thus the turtles spend proportionately more time near the surface and in deeper areas where temperatures are warmest (19-21°C). This behavior keeps the turtles away from their benthic food supply and exposes them to hazards such as boat collisions. Already weakened from their recent migration, these turtles are also less likely to avoid or survive incidental capture in pound nets and other types of fishing gear (Byles, 1988). Consequently, most dead, ill and injured marine turtles are found in the Chesapeake Bay during the spring (usually May). Loggerhead stranding numbers decrease as bottom temperatures heat up (Keinath et al., 1987; Epperly et al., 1995; Coles, 1999). Klinger and Musick (1995) estimated the age of most loggerheads foraging in the Chesapeake Bay to be between six and ten years old.

Often in the fall, temperatures in the shallower bays along the Atlantic seaboard will drop rapidly before some turtles have migrated south. When water temperatures fall below 8°C, the turtles become hypothermic and float to the surface where many die. This is termed a cold-stunning event. Cold-stunning events have been documented from Cape Cod to the Mosquito Lagoon in the northern region of the Indian River Lagoon system (Witherington and Ehrhart, 1989a; Morreale et al., 1992). Witherington and Ehrhart (1989a) pointed out that these events often occur in estuaries where the outlet to deeper, warmer waters lies to the north – a path opposite to the one that a turtle would instinctively follow to reach warmer waters. Cold-stunning events have also been reported in the Laguna Madre of Texas (Shaver, 1990).

Turtles survive the cold winters in Florida waters by residing in the warmer regions or currents, or by burying themselves into the muddy substrate of deep channels (Ogren and McVea, 1982). Loggerhead turtles are often found buried in the muddy substrates of the Cape Canaveral Ship Channel during the winter. Most of these individuals are subadults or juveniles.

Surveys conducted by trawling vessels in the vicinity of Cape Canaveral, Florida captured immature loggerhead turtles throughout the year, but the majority were caught during the winter months (Henwood, 1987; Bolten et al., 1994). In the central Indian River Lagoon, Ehrhart et al. (1996, 1999) also captured immature loggerhead turtles in tangle nets throughout the year. However, unlike the Canaveral Ship Channel, no seasonal trends in catch per unit effort (CPUE) were apparent.

Since 1989, netting has been conducted on the sabellariid worm reefs just south of Sebastian Inlet, Florida by Ehrhart et al. (1996, 1999). Surprisingly, few loggerhead turtles have been captured on the reef. Ehrhart et al. (1996) found the paucity of loggerheads over the reefs somewhat perplexing in light of the large number of loggerheads occurring in similar habitat near the St. Lucie Plant. However, Ehrhart et al.'s study site was in water depths of less than 3.5 meters and within 150 meters of shore compared to the St. Lucie Plant intake that is in a water depth of approximately 7 meters and is 365 meters from shore. Additionally, netting on the worm reefs was only performed during the summer months.

Nocturnal SCUBA surveys were conducted from 1986 through 1990 on nearshore hardbottom habitat in Broward County. Turtles encountered by divers were captured by hand. During the period of study, only one loggerhead turtle was captured, compared to 134 juvenile green turtles and 5 juvenile hawksbill turtles (Wershoven and Wershoven, 1990). The loggerhead was captured in the most seaward section of one of the study sites.

Genetic studies performed on immature loggerheads entrapped in the St. Lucie Power Plant intake canal indicate that 70 percent were from South Florida nesting populations, 20 percent from Yucatan nesting populations, and 10 percent were from northern Florida to North Carolina nesting populations (Bass, 1999). The results were similar to a mitochondrial DNA (mtDNA) study of stranded turtles from the northeastern US coast, where 58 percent of the loggerheads originated from south Florida nesting stock, 25 percent were from the north Florida to North Carolina stock, and 17 percent were from Mexico (Rankin-Baransky, 1997). Genetic research has also been done on loggerheads from the Chesapeake Bay, Charleston Harbor, and Kings Bay, Georgia. The genetic origin of these populations seems to be split between north Florida/North Carolina stock and South Florida stock (Sears, 1994; Norrgard, 1995; Sears et al., 1995).

Radioimmunoassay (RIA) analysis of testosterone titer levels on blood serum has allowed researchers to determine the sex of immature sea turtles. The pooled sex ratio of immature loggerhead turtles (40-76 cm SCL) captured at the St. Lucie Plant was 2.1 females for each male (n=218; Wibbels et al., 1991). The sex ratios did not vary by season, or by size class, suggesting that the female bias may be a temporally stable phenomenon, at least within the juvenile stage of the life history. These data are consistent with a previous study done by Wibbels et al. (1984) on immature loggerheads from four locations along the Atlantic Coast of the U. S. in which the ratio of females to males was 1.94:1.0 (female:male). Ehrhart et al. (1999) reported that the juvenile loggerhead population in the Indian River Lagoon also had a female bias (1.6:1.0).

Most of the juvenile loggerhead turtles captured in the Indian River Lagoon and other places along the Atlantic seaboard fall within the size range of 50 to 70 cm straight minimum carapace length (SMCL; Lutcavage and Musick, 1985; Standora et al., 1994; Epperly et al., 1995; Provancha, 1997, 1998; Coles, 1999; Ehrhart et al., 1999). The mean straight carapace length (SCL) for the turtles netted in the central Indian River Lagoon was 62.6 cm (range = 42 – 83 cm; Ehrhart et al., 1999). In the waters around the coast of North Carolina, the mean standard curved carapace length of loggerhead turtles was 66 cm (range = 42 to 105 cm; Epperly et al., 1995). Lutcavage and Musick (1985) reported SCL means of 68.7 cm for the loggerhead turtles occupying the Chesapeake Bay. Mean SCL for stranded, mainly cold stunned, turtles north of Virginia have been reported to range from 48.2 to 54 cm (Morreale et al., 1992; Rankin-Baransky, 1997). These smaller means may result from the greater physiological susceptibility of younger turtles to hypothermia (Witherington and Ehrhart, 1989a; Morreale et al., 1992).

Loggerhead turtles live in the Florida nearshore waters and lagoons until they approach the size of the smallest females nesting on nearby beaches (Ehrhart et al., 1999). It is not known what cues prompt a subadult to leave developmental habitat or at what time of year departure occurs. However, the average size of loggerhead turtles captured in Florida Bay is 80.1 cm SCL (with a range of 48.9 to 98.7 cm). These turtles appear to comprise an intermediate size class that is nearing maturation (Schroeder et al., 1998). Thus, the larger juvenile loggerhead turtles leaving developmental habitats along the eastern U.S. seaboard may reside in Florida Bay for a period before moving on to join the adult population on distant feeding grounds.

While occupying inshore, developmental habitats, juvenile loggerhead turtles primarily feed on decapod crustaceans, mollusks, and fish (Lutcavage and Musick, 1985). They tend to be opportunistic, often exploiting regionally abundant prey items. The preferred food for loggerheads along the mid-Atlantic coast of the United States is reported to be the horseshoe crab, *Limulus polyphemus* (Keinath et al., 1987; Dodd, 1988; Sauls and Thompson, 1988). On the south Texas coast, Plotkin et al. (1993) reported that sea pens (*Virgularia presbytes*; a soft coral) were a major component of the loggerhead diet. Crabs and mollusks were also present in high quantities within loggerhead diet samples from Texas, along with tube worms, sea pansies, whip corals, and sea anemones.

Carr (1952) wrote that loggerhead dietary items consisted of crabs, shellfish (like clams, oysters and conchs), fish, sponges, jellyfish, and sometimes algae. A loggerhead dietary study conducted in the bays around Long Island, New York, concurred with Carr's food list. Burke et al. (1993) found that approximately 90 percent of the juvenile loggerhead turtles they sampled had consumed crabs (spider crabs *Libinia emarginata*, Atlantic rock crab *Cancer irroratus*, and the lady crab *Ovalipes ocellatus*). These loggerheads had also eaten mussels, whelks, and algae (*Sargassum natans*, *Ulva* sp., and *Fucus* sp.). Similar dietary items were reported for turtles stranded off the coast of Virginia by Bellmund et al. (1987) and off of Georgia by Ruckdeschel and Shoop (1988). A comprehensive list of reported food items of the loggerhead turtle is provided by Dodd (1988).

Adult loggerhead turtles nest mainly in the continental United States from North Carolina to the Florida panhandle, with about 90 percent of the nests being deposited on southern Florida beaches (National Research Council, 1990). The average female loggerhead makes reproductive migrations between her foraging grounds and nesting beach every two or three years and deposits about four clutches of eggs during those years that she nests (Richardson and Richardson, 1982; Murphy and Hopkins, 1984).

In the southeastern United States, the first nests begin to appear in late April and the last usually in September. The months of highest loggerhead turtle nesting are in June and July (NMFS and USFWS, 1991a; Meylan et al., 1995; Ernest and Martin, 1999). The mating season begins in early March, prior to the start of nesting season. Mating activity subsides in mid-June, when it is assumed that most males return to their foraging grounds. Stranding reports coincide with the above mentioned seasonal trends. Most of the adult male loggerhead strandings along the Atlantic seaboard occur just prior to and during the beginning of the nesting season (Turtle Expert Working Group, 1998). Far fewer adult loggerhead strandings (especially male) occur outside of the nesting season. Aerial surveys of turtles in coastal waters of Florida are consistent with the stranding data. The fly-over observations have found highest concentrations of adult loggerheads off the coast of primary nesting beaches during spring and summer, with numbers dramatically dropping off in the fall and winter. The numbers of sighted adults are about 15 times higher in the spring and summer than in the fall and winter (Thompson, 1988; National Research Council, 1990). However, some adult loggerhead turtles are found in Florida waters throughout the year.

Surveys conducted by trawling vessels in the vicinity of the Cape Canaveral Ship Channel between 1978 and 1984 resulted in the capture of over 3,000 individuals (Henwood, 1987). Each age class was dominant at different times of year. Adult males were most abundant in April and May. Adult females were most common from May to July, and juvenile and subadults (<83 cm SCL) constituted over 80 percent of the population during the remainder of the year. Adult females did not seem to stay in the area except while nesting. These seasonal patterns were also documented in a later study by Bolten et al. (1994) in Port Canaveral.

Loggerhead turtles that nest on Hutchinson Island are part of a larger, genetically distinct south Florida nesting population (Bowen et al., 1993). The turtles differ genetically from those turtles that nest in north Florida to North Carolina as well as those found in the Mediterranean. This indicates that there is little to no gene flow between rookeries, supporting the predictions of a natal beach homing hypothesis. This hypothesis contends that hatchlings leaving a particular nesting beach will return to that beach to nest as adults. Thus, from a management standpoint, each subpopulation should be treated as unique and vulnerable to extirpation (Turtle Expert Working Group, 1998).

The adult loggerhead foraging grounds for the south Florida nesting population are thought to be in the Bahamas, Cuba, Dominican Republic, eastern seaboard of the United States, Florida Keys, and the Gulf of Mexico (Meylan et al., 1983; Henwood, 1987; Spotila et al., 1997; Rankin-Baransky, 1997). The habitats used as adult foraging grounds are very diverse, ranging from the muddy bayous of the northern Gulf Coast to continental shelves to the clear, shallow waters of the Bahamas (National Research Council, 1990).

In the southeastern United States, adult loggerheads have a mean SCL of 92 cm and a mean body weight of 113 kg. They rarely exceed 122 cm in length (National Research Council, 1990).

The size used to classify individuals as mature adults is somewhat arbitrary, as loggerhead turtles reach maturity at variable sizes. The adult size range is primarily based on the size of females measured on various nesting beaches. Limpus (1991) reported that the average female begins to breed at a size only slightly smaller than the average size of the entire nesting population.

Ernest et al. (1989) used 85 cm SMCL as a breakpoint separating adults from subadults captured at the St. Lucie Plant. Ehrhart et al. (1996) used 83 cm SCL as the cut off point between subadult and adult females based on the range of measurements from 1,207 females nesting on Brevard County beaches; only four percent of nesting turtles in Brevard County were less than 83 cm. Henwood (1987) used the measurement of 83 cm total (or maximum) carapace length (which equates to 81.5 cm SCL) to delineate between subadults and adults in his trawling study at Cape Canaveral.

Adult loggerhead turtles seem to eat the same general prey as juveniles and subadults. However, more dietary research is needed from various adult foraging grounds. Adults are known to eat horseshoe crabs, decapod and cirriped crustaceans, gastropod and pelecypod mollusks, cnidarians, echinoderms, fish, and algae (Lutcavage and Musick, 1985; Dodd, 1988).

Green Turtles

Green turtles are found in tropical seas throughout the world (Hirth, 1997). Off the east coast of the continental United States, green turtles can be found from Texas to Massachusetts, although nesting only occurs on Florida beaches. The number of nests deposited in Florida is relatively small compared to Costa Rica, Aves Island, Ascension Island, and Surinam. However, many juvenile green turtles utilize shallow U.S. coastal waters and bays as developmental habitat (NMFS & USFWS, 1991b).

Similar to the loggerhead turtle, green turtle hatchlings actively swim offshore to oceanic convergence zones after leaving the beach. Pelagic hatchlings from Florida nests are suspected to enter the North Atlantic Gyre system and eventually make their way back to western Atlantic coastal waters (Witham, 1980). During the pelagic phase, green turtles are presumed to be carnivorous, feeding on small animals like ctenophores and tunicates in the plankton (Booth and Peters, 1972; Bustard, 1976; Hirth, 1997). However, further research is needed on this aspect of their biology. Differences in intestinal length proportions between post-hatchlings and adults, suggest a developmental shift from a predominantly carnivorous to a primarily herbivorous diet (Davenport et al., 1989).

When green turtles reach a size of about 20-25 cm SCL, they leave the pelagic habitat and enter benthic feeding grounds (National Research Council, 1990). The juvenile feeding grounds are usually in warm, shallow, protected waters where benthic vegetation is prevalent (Carr et al., 1978). Foraging habitats most commonly consist of sandy bottoms supporting seagrass or algal beds, but small green turtles are also found on coral reefs, sabellariid worm reefs, or rocky substrate where attached algae is present. Some feeding grounds support only a particular size class of green turtles, while other feeding areas support a full range of sizes from juveniles to breeding adults (National Research Council, 1990; Wershoven and Wershoven, 1990; Coyne, 1994; Redfoot et al., 1996; Ehrhart et al., 1996).

Many juvenile green turtles use the southeast coast of Florida year-round as developmental habitat. Both inshore lagoons and nearshore sabellariid reefs are considered prime developmental habitat (Ehrhart et al, 1996). Large reefs constructed by polychaete worms of the Family Sabellariidae have been reported from Brevard through Dade County, Florida (Kirtley, 1966). These worm reefs run roughly parallel to the shore and are the primary basis for an elaborate marine community of encrusting, boring and shelter-seeking animals as well as abundant marine flora (Kirtley and Tanner, 1968).

Green turtles appear in coastal developmental habitats at a much smaller size class than loggerhead turtles (Musick and Limpus, 1997). Zug and Glor (1998) used skeletochronology to age juvenile green turtles that died from a cold stunning event in the Mosquito and Northern Indian River Lagoon. The juveniles ranged in size from 28 to 74 cm SCL, and the age estimates for these individuals were 3 to 14 years old. Zug and Glor estimated that most of the juveniles were recruited to the developmental habitat at about 5 or 6 years of age, and would stay in this or other developmental habitats for 6 to 8 years. The individuals would thus leave between the ages of 10 to 14 years old. Mean growth rate estimates were 3.0-5.2 cm per year.

Sabellariid worm reefs are a prime developmental habitat for green turtles in south Florida. The reefs, which can extend from the intertidal zone out to a depth of ten meters, are found along the Atlantic shoreline from Cape Canaveral to Biscayne Bay, Florida. The reefs generally run parallel to the shoreline, and juvenile green turtles feed on the many species of red and green benthic marine algae present on the reef (Ehrhart et al., 1996).

In 1989, Ehrhart et al. (1996) began conducting netting during the summer over a sabellariid worm reef near Sebastian Inlet, Florida. More juvenile green turtles were caught per unit effort (CPUE) on the reef than at a site in the Indian River Lagoon south of the inlet. These data suggests that there may be a higher number of turtles inhabiting the reef than the lagoon, at least during the summer. Alternatively, capture rates on the reef may be higher, because the foraging area is more concentrated over the reef and therefore capture techniques are more effective. The turtles on the reef were similar in size and weight to those captured in the lagoon. Much of the algae consumed by the turtles grows in both locations. However, the juveniles rarely seem to migrate between the two habitats even though an inlet is nearby (Ehrhart et al., 1996, 1999; D. Bagley, unpublished data).

Inside the central Indian River Lagoon, more juvenile green turtles were captured in the winter than in the summer (Ehrhart et al., 1996, 1999). Ehrhart et al. (1996) hypothesized that seasonal increases in drift algae within the lagoon and migrants from northern climates may be responsible for the increased capture frequency during the cooler months.

North of Florida, green turtles are found in smaller numbers than juvenile loggerhead turtles, but there is evidence that many do migrate seasonally as far north as Cape Cod Bay (Lazell, 1980; Henwood, 1987; Morreale et al., 1992; Epperly et al., 1995; Provancha et al., 1998). Like the loggerhead turtle, their migrations seem to be water temperature dependent, and they are quite susceptible to cold water stunning events (Morreale et al., 1992; Coyne, 1994; Epperly et al., 1995).

In Florida, major cold stunning events have been documented as far south as the northern Indian River Lagoon system (Mendonca and Ehrhart, 1982; Witherington and Ehrhart, 1989a; Schroeder et al., 1990). Over 90 percent of the turtles affected by these events were juvenile green turtles; the remaining 10 percent were loggerhead turtles. The body size and physiology of juvenile green turtles may make them more susceptible to hypothermia than loggerhead turtles. The relatively large number of individuals involved in cold-stunning events demonstrates the importance of the Indian River Lagoon as a developmental habitat for green turtles (Witherington and Ehrhart, 1989a).

In a study conducted in the Mosquito Lagoon, Mendonca (1983) noted that green turtles occupied deeper water, would not eat, and took to wandering long distances when water temperatures were between 11 and 18°C, suggesting that they were looking for warmer waters. In Texas, Coyne (1994) reported that green turtles left the study area or became inactive when water temperatures fell below 16°C. Conversely, green turtles also are known to actively thermoregulate when water temperatures get too warm. Both Coyne (1994) and Mendonca (1983) noticed increased activities in the warmer months of the year. When temperatures rose above 32°C the turtles moved to deeper and cooler water (Mendonca, 1983). During hot summer days, turtles often fed in the early morning and late afternoon, when waters temperatures were coolest, and moved into deeper waters to rest during the midday hours (Bjorndal, 1980; Mendonca, 1983).

Bass and Witzell (in press) compared the mtDNA of 62 juvenile green turtles captured at the St. Lucie Power Plant and reported that approximately 42 percent of the turtles originated from Florida or Mexico nesting populations. About 53 percent came from rookeries in Costa Rica, and 4 percent were from Aves Island (Venezuela) and Surinam. The juvenile green turtles residing in developmental habitats in the nearby Bahamas were also tested and found to be primarily (80 percent) from Costa Rican nesting populations. Individuals representing Aves Island and Surinam (14 percent), United States and Mexico (5 percent), and Ascension Island and Guinea Bissau (1 percent) populations were represented as well (Bass and Witzell, in press). These results indicate that the juvenile green turtles utilizing a particular developmental habitat are not of homogenous origin. As for loggerheads, molecular studies support the hypothesis of natal beach homing in green turtles (Bowen et al., 1992).

The sex ratio of juvenile green turtles captured on sabellariid worm reefs and in the central Indian River Lagoon was studied by Ehrhart et al. (1999). Similar to the loggerhead, the green turtle sex ratio was strongly female biased at 2.9:1.0 (female:male). Redfoot et al. (1996) also measured testosterone levels on small green turtles occupying the Trident submarine basin at Cape Canaveral and found the sex ratio to be highly skewed toward females (10.9:1.0). In the Mosquito Lagoon, the sex ratio of cold stunned green turtles was 1.75:1.0 (Schroeder and Owens, 1994). Only fourteen juvenile green turtles captured in the St. Lucie Plant intake canal have been sexed through blood work. Twelve were females, and two were males, resulting in a 6.0:1.0 ratio (ABI, 1994).

The average size of green turtles netted in the Indian River Lagoon and on the sabellariid worm reef near Sebastian Inlet were 40.7 cm SCL (range = 24 to 72 cm) and 41.1 cm (range = 25 to 67 cm), respectively (Ehrhart et al., 1996). Hand caught green turtles on reefs in Broward County, Florida were similar in size at 43.5 cm mean curved carapace length (CCL; range = 27 to 60 cm; Wershoven and Wershoven, 1990). The mean length of green turtles captured in Florida Bay was recently reported as 46.2 cm SCL (range = 26 to 63 cm; Schroeder et al., 1998). Slightly larger (mean = 52.3 cm SCL; range = 27 to77 cm) turtles were retrieved from the Mosquito Lagoon (northern Indian River Lagoon system) in the cold-stunning event of 1989 (Schroeder et al., 1990). Green turtles netted in the Indian River Lagoon near the Fort Pierce Inlet were of similar size at 53.1cm mean SCL (range = 37 to 75 cm; Bresette et al., 1999). Turtles netted in the Trident Submarine Basin were somewhat smaller averaging about 32.9 cm SCL (range 23 to 48 cm; Redfoot et al., 1996). This was similar to the average size of green turtles (33.8 cm TSCL; range 24 to 68 cm) captured by trawling in the Port Canaveral ship channel (Henwood and Ogren, 1987).

Differences in mean size among study areas may reflect the quantity and quality of food resources available in the habitat. There are some habitats that cannot sustain large individuals because of inadequate food availability (Coyne, 1994; Redfoot et al., 1996). Size class distributions may also be affected by capture methods (Ehrhart et al., 1996). Netting, for example, may undersample very small or large size classes because of mesh size limitations. Net placement at different depths and locations may also influence capture statistics (Ehrhart et al., 1999). Cold stunning may be a very efficient method of sampling turtles. However, as mentioned before, some size groups may be more physiologically susceptible to cooler temperatures than others (Witherington and Ehrhart, 1989a; Morreale et al., 1992).

An extensive list of juvenile and adult green turtle food items from around the globe can be found in Hirth (1997). In many habitats, green turtles are known to exhibit dietary preferences for either algae or seagrass. There are a few places that have populations of turtles that forage primarily on seagrasses within a few kilometers of those that feed primarily on algae (Bjorndal, 1980; Mortimer, 1981a; Coyne, 1994).

Mendonca (1983) found that *Syringodium filiforme* (manatee grass) *and Halodule wrightii* (shoal grass) were the primary food items in the stomachs of juvenile green turtles in the Mosquito Lagoon. These two species of seagrass were also the dominant rooted macrophytes in the lagoon. Although red alga was also abundant, it made up only a small percentage (about 8 percent) of stomach contents. Bjorndal (1980) suggested that switching between a diet high in seagrass to a diet high in algae, or eating both simultaneously, may lead to digestive inefficiency as different fermentative gut microflora are needed to adequately digest each.

The Trident submarine basin at Port Canaveral is about 40km south of the Mosquito Lagoon. Redfoot et al. (1996) studied the diets of juvenile green turtles that inhabited the rock-lined basin. All captured turtles were small (mean = 32.9 SCL), and most of the turtles (58 out of 67) had only algae in their stomachs. Algae and jellyfish were found in 5 of the 67 stomach samples, one sample contained algae and unidentified animal tissue, two samples contained only jellyfish, and one contained only fish. The algae consumed by the turtles were the same species that grew on the rocks in the basin. The researchers suggested that the absence of larger juvenile green turtles (>50cm) was due to limited biomass of the algae growing on the rocks.

In the central portion of the Indian River Lagoon, Ehrhart et al. (1996) found that green turtles were feeding almost exclusively on drift algae instead of nearby seagrasses. The drift algae were comprised of *Gracilaria* spp., *Acanthophora spicifera*, *Bryothamnion seaforthii*, *Hypnea* spp., and *Solieria filiformis*. Ehrhart et al. (1996) also captured turtles on sabellariid worm reefs in the ocean south of Sebastian Inlet. The reefs supported a diverse flora of green, brown, and red algae upon which the turtles foraged. The algae species *Caulerpa prolifera, Ulva lactuca, Bryocladia cuspida, Bryothamnion seaforthii, Gelidium americana, Gigartina acicularis, Hypnea musciformis, Rhodymenia pseudopalmata*, and *Solieria filiformis* were documented on the reef.

In the waters around South Padre Island, Texas, Coyne (1994) studied two populations of juvenile green turtles. The smaller sized turtles (<40 cm SCL) resided near and fed on the algae growing on the large boulders along Brazos Santiago Pass. The larger turtles (>30 cm SCL) were found over the grassbeds of South Bay/Mexiquita Flats. The turtles living near the grassbeds generally fed on *Halodule wrightii*, which was one of the less abundant seagrass species present, indicating that they were selective feeders. Coyne suggested that the algal biomass contained on the boulders in the pass was insufficient to sustain the larger turtles. The study did not determine if the smaller, algae-eating turtles were moving to the grassbeds after leaving the rocky Brazos Santiago Pass.

As noted earlier, green turtles end their pelagic existence and enter shallow coastal waters at an smaller size than loggerhead juveniles. They also leave their developmental habitat at an earlier stage. Unlike loggerhead turtles, green turtles leaving continental US waters are still far from sexual maturity. This is apparent from size range distributions along the coast. The size of most juveniles captured in Florida is between 20 and 65 cm SMCL, while the size of the smallest nesting females on nearby beaches is 83.2 cm SCL (Witherington et al., 1989b).

It has been estimated that juvenile green turtles leave their developmental habitat when they are between 10 and 14 years of age (Zug and Glor, 1998). Estimated age at sexual maturity in Atlantic green turtle populations ranges from 19 to 33 years (Mendonca, 1983; Frazer and Ehrhart, 1985; Frazer and Ladner, 1986; Ehrhardt and Witham, 1992). Thus, there is a period of several years before the juveniles leaving Florida's developmental habitats become part of the adult nesting population. The location and types of habitat supporting subadult green turtles is largely unknown. The Caribbean is one possibility. For example, Ehrhart et al. (1996) had eight remote tag recoveries from green turtles tagged and released in the central Indian River Lagoon. Four of the tags were recovered from Nicaragua, three were from Cuba and one was from Belize. Nicaragua is known to be a prime subadult and adult foraging ground for green turtles that nest in Costa Rica (Mortimer, 1981a). Thus, many of the green turtles that spend their juvenile days on the east coast of Florida may eventually migrate to the Caribbean to spend the subadult phase of their lives.

Adult green turtles occur relatively infrequently in continental United States coastal waters and nest in relatively low numbers along the Florida coast although the numbers appear to be increasing (Dodd, 1981; NMFS and USFWS, 1991b; Meylan et al., 1995). Green turtle nests have been deposited in Florida from Nassau to Okaloosa Counties, but most are deposited in Brevard, Martin, and Palm Beach Counties.

Witherington and Ehrhart (1989b) measured nesting green turtles on Atlantic beaches in central Florida. The mean carapace length was 101.5 cm SCL and ranged from 83 to 117 cm. At Melbourne Beach, Florida, female green turtles generally deposit 3 to 4 clutches of eggs per season with an average internesting interval of about 12.9 days (Johnson, 1994). The mean distance between consecutive nesting sites was 1.8 miles. Females returned to Melbourne Beach after 2 to 6 years; however, a remigration interval of two years seemed to predominate, and no females were found to nest every nesting season.

The location of foraging grounds used by adult green turtles that nest in Florida has not yet been identified (NMFS and USFWS, 1991b; Johnson, 1994). However, satellite transmitters placed on two females that nested on the central east coast of Florida revealed interesting short term trends. After leaving the vicinity of the nesting beach, these females moved south along the Florida coastline and proceeded west along the Florida Keys, possibly to feed and reside in extensive seagrass meadows and coral reefs surrounding the islands (Schroeder et al., 1996).

Because the exact location of foraging grounds used by adult green turtles nesting in Florida has not been firmly established, the primary food item in the adult turtle's diet is also unidentified. Mortimer (1981b) suggested that adult green turtles graze on seagrass throughout most of their range, but in areas where seagrasses are lacking, algae is the primary dietary component. Also, Mortimer (1981a) suggested that turtles migrating from their foraging ground to their nesting habitat may be more opportunistic feeders than when they remain on their foraging grounds. Adult foraging grounds are typically in quiet, sheltered waters containing lush submarine vegetation. The nesting beaches, however, are typically in high energy surf, which may be devoid of food. During their migration from Nicaraguan foraging grounds to Costa Rican nesting beaches, green turtles stay relatively close to shore and feed on *Syringodium* and red algae. However, on their foraging grounds in Nicaragua, the turtle's diet consists primarily (90 percent) of turtle grass (*Thalassia testudinum*), which is the dominant rooted macrophyte.

Stomach contents from three stranded adult green turtles near Fort Lauderdale consisted of the algae *Sargassum natans, Gracilaria cylindrica,* and the hydroid *Bourainvilla carolinensis* (Wershoven and Wershoven, 1990). It is assumed that these turtles were not permanent residents, but rather part of the east coast nesting population.

NEARSHORE ENVIRONMENT AS DEVELOPMENTAL/FORAGING HABITAT

A variety of factors may account for the presence of sea turtles in the vicinity of the St. Lucie Plant. For one, the continental shelf adjacent to the plant is relatively narrow. It decreases in width from about 40 km at the Fort Pierce Inlet, north of the plant, to about 26 km at the St. Lucie Inlet south of the plant (Gallagher and Hollinger, 1977). Aerial surveys have shown that turtle densities are much higher in water depths less than 50 meters (National Research Council, 1990). Thus, a narrow continental shelf would tend to concentrate turtles. Furthermore, Mortimer (1981a) reported that green turtles often stay nearshore when they migrate to nesting areas. Nearshore movements increase the probability of turtles encountering one of the plant's intake structures.

A system of hard bottom substrates and sabellariid worm reefs parallel the shoreline between the Fort Pierce and St. Lucie Inlets. These habitats provide potential foraging and resting areas for turtles moving along the coast. Although the system is not continuous, it does provide intermittent refugia on an otherwise featureless seafloor. Turtles that utilize these natural reefs may be brought into close proximity with the intake structures. The closest sabellariid worm reef is located approximately 450 m southwest of the intake structures.

Documented dietary items of loggerhead turtles were compared to fauna collected during environmental sampling conducted in the vicinity of the St. Lucie power plant by the Florida Department of Natural Resources and Applied Biology, Inc. during the 1970s and early 1980s. Sampling was mostly conducted by trawl or benthic grab.

Crabs are a prevalent item found in most loggerhead dietary studies. Various crabs reportedly consumed by loggerheads have also been collected in the nearshore waters of Hutchinson Island. For example, blue crabs (*Callinectes sapidus*), swimming crabs (*Portunus* spp.), spider crabs (*Libinia* spp.), calico crabs (*Hepatus epheliticus*), speckled crabs (*Arenaeus cribrarius*), purse crabs (*Persephona mediterranea*), box crabs (*Calappa* spp.) and hermit crabs (*Pagurus spp.*) have all been documented as loggerhead turtle food (Mortimer, 1981b; Bellmund et al., 1987; Ruckdeschel and Shoop, 1988; Plotkin et al., 1993; Burke et al., 1993; Godley et al., 1997). Each of these species occurs on the sandy bottoms or sabellariid worm reefs in the vicinity of the power plant (Camp et al., 1977; ABI, 1979). Plotkin et al. (1993) and Ruckdeschel and Shoop (1988) also found barnacles in loggerhead digestive tracts. Several species of barnacles (*Balanus* spp.) have been documented by Camp et al. (1977) and ABI (1981) in the nearshore environment.

Mollusks are a prevalent staple for loggerhead turtles. Mollusks previously documented as food items and found near the St. Lucie Plant include: whelks (*Busycon* spp.; Ruckdeschel and Shoop, 1988; Lyons, 1989; Burke et al., 1993), ceriths (*Cerithium* spp.; Lyons, 1989; Godley et al., 1997), slipper shells (*Crepidula* spp.; ABI, 1981; Lyons, 1989; Burke et al., 1993), tulip shells (*Fasciolaria* spp.; Lyons, 1989; Godley et al., 1997), conchs (*Plueroploca* spp. and *Strombus* spp.; Carr, 1952; Lyons, 1989; Burke et al., 1993; Godley et al., 1997), bonnets (*Phalium* spp.; Lyons, 1989; Godley et al., 1997), and mussels (*Mulinia* spp. and *Mytilus* spp.; ABI, 1981; Lyons, 1989; Burke et al., 1993).

Jellyfish are usually found in low percentages in loggerhead dietary samples, but are probably underrepresented because they are digested so quickly (Plotkin et al., 1993). Jellyfish are often entrained into the St. Lucie Plant intake canal and can become so thick that they clog the plant's cooling system. On occasion the plant has had to reduce power for brief periods because of the massive amounts of jellyfish that were entrained with cooling water (Applied Biology, Inc., unpublished data).

The nearshore environment near the St. Lucie Plant was also evaluated with respect to its suitability as foraging habitat for green turtles. The high-energy environment of the ocean around the St. Lucie Plant precludes the extensive growth of seagrasses. However, both drift and benthic algae are known to occur in the area (Moffler and Van Breedveld, 1979; Bresette et al., 1998).

Gracilaria sp. and *Bryothamnion seaforthii* were the two most abundant food items in immature green turtle dietary samples taken in the summer and fall in the central Indian River Lagoon (Ehrhart et al., 1996). Preliminary observations from a dietary study done on the sabellariid worm reef near the Sebastian Inlet show that immature green turtles feed primarily on algae of the following genera: *Bryothamnion*, *Gracilaria*, *Acanthophora*, *Botryocladia*, and *Solieria* (K. Holloway, pers. com.). All of these genera were included on the list of 119 taxa found in the nearshore area around the St. Lucie Plant (Moffler and Van Breedveld, 1979). Although the sandy-shell hash sediments of the nearshore environment do not support the attachment of larger species of macroscopic algae, a variety of drift algae can often be found near the plant. Additionally, the sabellariid worm reefs along the shoreline support macroscopic algal growth. Moffler and Van Breedveld (1979) estimated that these nearby reefs were the probable source for at least 57 percent of the drift algae species. All of the taxa listed above have been found growing on the sabellariid worm reefs near the St. Lucie Plant.

THE INTAKE STRUCTURES AS TURTLE SHELTER/FORAGING AREAS

In the nearshore environment adjacent to the St. Lucie Plant, where much of the ocean bottom is flat and sandy (Lackey, 1970), the intake and discharge structures provide vertical relief. Both natural and artificial structures attract a variety of marine life, including turtles. For example, divers, NMFS observers, and aerial surveyors have reported that turtles commonly associate with offshore oil platforms in the Gulf of Mexico (National Research Council, 1990). Resting loggerhead turtles are often seen with their heads, or other body parts tucked under rocky ledges offshore (J. Gorham and E. Martin, pers. com.; Wershoven and Wershoven, 1990). Green turtles have also been documented resting under coral heads and rocky outcroppings at night and during the hottest part of the day (Bjorndal, 1980; Mendonca, 1983; Ogden et al., 1983; Wershoven and Wershoven, 1990; Balazs, 1995). The large opening between the velocity caps and the base of the intake structures may very much resemble a reef ledge and appear to offer an ideal resting site to turtles.

Both Mortimer (1981a) and Mendonca (1983) noted that green turtles seem to occupy a home range while residing on their foraging grounds and may return to the same sleeping place on consecutive nights. Coyne (1994) found that juvenile green turtles living in Brazos Santiago Pass spend more time in and exhibit greater site fidelity to rocky/jetty environments relative to other surrounding habitats. Smaller turtles may also use structure as a refuge from predators (Musick and Limpus, 1997).

In a study conducted at the Miami Seaquarium wooden boxes simulating intake structures were placed in a large tank. Loggerhead and green turtles introduced to the tank readily sought out and utilized these boxes during resting periods (ABI, 1980). One apparent reason for seeking out and wedging themselves within the boxes was to maintain a stationary position while resting instead of being moved by the currents. Often, aggressive interactions would occur between turtles at the boxes indicating competition for available space. Turtles were also observed chasing other turtles away from the boxes or hiding inside as an attack avoidance maneuver.

The St. Lucie Plant intake structures closely resemble large reef outcroppings with one notable exception. They provide practically unlimited habitat. When turtles use the structures as shelter they may be rapidly drawn into the intake pipes. Thus, the shelter effectively remains unoccupied and available to other turtles. Competitive interactions are thereby eliminated.

Another plausible reason for the entrainment of sea turtles at the St. Lucie Plant is that the food supply for both loggerhead and green turtles might be greater on the intake structures than on surrounding sandy areas. Bresette et al. (1998) reported that the intake structures are covered by much of the same green, brown and red algae that Ehrhart (1992) found growing on worm-rock reefs in Indian River County. Based on underwater photographs and videos, the growth on the intake structures resembles that of nearby reefs. All of the surface area is covered with epibiota. Epibiota appear to include hydroids, encrusting sponges, large barnacles, bryozoans, algae (primarily on top of the caps), anemones, and some gorgonian coral. Various species of fish were also observed around the structure. Many of these items were previously shown to be components of loggerhead and green turtle diets.

TRENDS IN LOGGERHEAD CAPTURES AT THE ST. LUCIE PLANT

Size Distribution

When the canal capture program was initiated in May 1976, the sizes of captured turtles were estimated. Beginning in July 1976 the straight minimum carapace length[2] (SMCL) and straight carapace width (SCW) of each turtle was measured with calipers. Weights of captured turtles were recorded beginning in November 1976. Measurement of curved standard carapace length (CSCL) and straight standard carapace length (SSCL) began in April 1981 and November 1987, respectively.

In some cases all measurements could not be taken because gear was not available. In other cases, certain measurements could not be accurately determined due to damage to a turtle's carapace.

Because SMCL measurements were available for more turtles than any other measurement and because it is the recommended length measurement (Bjorndal and Bolten, 1989; Bolten, 1999), it was used for all analyses in this report.

Between 1976 and 1998, SMCL measurements were obtained for 3,479 loggerhead turtle captures at the St. Lucie Plant. The mean size of these turtles was 67.0 cm and sizes ranged from 38.6 to 112.0 cm. This is similar to the size range reported for loggerhead turtles in the central and northern regions of the Indian River Lagoon (Ehrhart, 1983; Ehrhart et al., 1999) and in the Canaveral Ship Channel (Henwood, 1987; Bolten et al., 1994)

The size distribution of loggerhead turtles captured at the St. Lucie Plant is presented in Figure 8. There are several important aspects of this distribution. First, most of the individuals captured were less than 70 cm SMCL. Second, there was a paucity of loggerheads between 70 and 85 cm. And third, a secondary accumulation of adults gives the distribution a bimodal appearance. This distribution is similar to that presented by Ehrhart et al. (1999) for the central Indian River Lagoon and Bolten et al. (1994) for the Canaveral Ship Channel.

The Turtle Expert Working Group (1998) referred to loggerhead turtles less than 70 cm as small benthic immature turtles and those between 70 and 91 cm as large benthic immature turtles. Loggerheads ≥ 92 cm were considered adults. Ehrhart et al. (1996), however, used 83 cm SSCL[3] as the minimum size for adult loggerheads captured in the central Indian River Lagoon.

For the purposes of this report, loggerheads with SMCLs less than 70.0 cm are referred to as juveniles, those between 70.0 and 84.9 cm are considered subadults and those ≥ 85.0 cm are designated adults. These criteria follow the general format used by

[2] See Bolten (1999) for definitions of carapace measurements.

[3] 83 cm SSCL is equivalent to approximately 81.7 cm SMCL based on regression analysis of SMCLs and SSCLs obtained from over 2,000 St. Lucie Plant loggerheads.

Ernest et al. (1989) and ABI (1994) to define size classes/life history stages of loggerhead turtles. Based on the reported sizes of nesting loggerheads, no mature animals should be included in the juvenile size class and few immature animals should be included in the adult size class. The subadult size class, however, undoubtedly contains some small mature animals along with the large immature turtles.

Since most of the analyses in this report were segregated by life history stage, it was important to assign as many turtles as possible to one of the three stages. For this reason, turtles lacking SMCLs were placed in one of the stages based on conversion of other available measurements to SMCL. Equations used to make these conversions are presented in Table 3. After conversions, over 98 percent of the loggerhead turtles captured could be assigned to a life history stage.

The size distribution of loggerhead turtles from the St. Lucie Plant suggests that juvenile loggerheads are using the nearshore waters off Hutchinson Island for developmental habitat but begin to leave the area as subadults. Schroeder et al. (1998) hypothesized that Florida Bay may represent another developmental habitat for turtles nearing maturation (75-85 cm). It may very well be that subadult loggerheads from the Florida East Coast move to Florida Bay to complete maturation. Adult turtles then return to the east coast to mate and nest.

Annual changes in the mean sizes of loggerhead turtles captured at the St. Lucie Plant are illustrated in Figure 9. Linear regression analysis[4] (Zar, 1996) of these data indicated a significant ($r^2 = 0.28$, $P < 0.01$, $n = 23$) increase in the mean size of loggerhead turtles between 1976 and 1998. To further investigate this trend, annual size distributions for loggerhead turtles captured at the St. Lucie Plant were plotted (Figures 10-14). Annual size distributions indicate some year to year fluctuations in the proportion of turtles in each size class. In general, the proportion of adults was relatively low between 1976 and 1983, relatively high during 1989 and 1990, and intermediate during other years. This is more clearly illustrated by examining the annual percentage of captures consisting of adults (Figure 15). These data indicate a significant ($r^2 = 0.48$, $P < 0.001$, $n = 23$) increase in the proportion of adults captured between 1976 and 1998. It appears that the increase in mean size of loggerhead captures at the St. Lucie Plant was a result of an increase in the proportion of adults captured. This is substantiated by the fact that there was no significant trend in the mean size of immature (juvenile + subadult) loggerheads (Figure 16).

[4] Regression analysis is a statistical method for evaluating the relationship of two variables. In a linear regression analysis this relationship is described in terms of variation about a straight line. The extent to which the two variables, x and y, are related to one another is described by the equation $y = bx + a$, where b is the slope of the line (amount of change in y when x increases by one unit) and a is the y intercept (value of y corresponding to $x = 0$). The amount of variation about the line is expressed as the coefficient of determination (r^2). It can range from –1 to +1. A negative value indicates that one variable increases as the other decreases, while a positive value indicates that the two variables increase and decrease in unison. Values of r^2 approaching -1 or +1 indicate a strong relationship. The relationship becomes weaker as values approach 0.

Seasonal Distribution of Juveniles

The seasonal distribution of juvenile loggerhead captures at the St. Lucie Plant is presented in Figure 17. Juvenile loggerheads were captured throughout the year, but, overall, tended to be most abundant from January through April. Juvenile loggerheads were also reported to be present throughout the year in the Canaveral Ship Channel (Henwood, 1987; Bolten et al., 1994) and in the central region of the Indian River Lagoon (Ehrhart et al., 1996, 1999). No seasonal trend was observed in the Indian River Lagoon. However, in the Canaveral Ship Channel the largest concentrations of juvenile loggerheads occurred from October through March.

Bolten et al. (1994) suggested that a sharp increase in juveniles in the Channel in January 1993, probably represented a group of juveniles migrating south away from cooler northern temperatures. These researchers also suggested that the appearance of these migrating loggerheads is determined more by water temperature than by absolute time of year so that peaks may occur in almost any month from late fall to early spring. Other authors have also indicated that temperature was an important factor in regulating the movements of loggerhead turtles (Mendonca, 1983; Keinath et al., 1987; Coles, 1999). Likewise, the seasonal distribution of juvenile loggerheads at the St. Lucie Plant may be influenced by influxes of turtles from northern areas as waters cool.

Examination of seasonal distributions for each year from 1977 through 1998 (Figures 18-22) reveals considerable fluctuation from year to year. These annual fluctuations may in part be explained by variations in water temperatures both in northern areas and locally. No long-term change in the seasonal distribution of juvenile loggerheads is indicated.

Long-term Trends in Juvenile Captures

The number of juvenile loggerhead turtles captured each year from 1977[5] through 1998 at the St. Lucie Plant is presented in Figure 23. Linear regression analysis indicated that there was a significant ($r^2 = 0.33$, $P < 0.01$, $n = 22$) increase in the annual number of juvenile loggerhead captures over that period. However, these data include recaptures (turtles that were captured in the canal, released into the ocean then recaptured in the canal). Analysis of recapture data (Figure 24) indicates that there was also a significant ($r^2 = 0.56$, $P < 0.001$, $n = 22$) increase in recaptures during the same period.

To rule out the possibility that the observed increase in juvenile loggerhead captures was simply due to an increase in the number of individuals captured multiple times, data were reanalyzed with recaptures excluded (Figure 25). Analysis of these data indicated that, even when recaptures were excluded, there was still a significant ($r^2 = 0.28$, $P < 0.05$, $n = 22$) increase in juvenile loggerhead captures from 1977 through 1998. However, most of that increase occurred between 1995 and 1998. In fact, when regression analysis was applied to data from 1977 through 1994, no significant trend was

[5] Data for 1976 are excluded because the power plant did not begin operation until May of that year. A total of 20 juvenile loggerheads were captured in 1976.

indicated. Thus, rather than experiencing a gradual increase in captures over the life of the plant, there was an exponential increase after 1994.

Site Fidelity of Juveniles

The fact that some turtles were captured in the intake canal on more than one occasion is an indication that at least some turtles either remained in the vicinity of the power plant or returned to the plant after moving to other areas. The ability of sea turtles to return to a specific site has been referred to as site fixity, site tenacity and site fidelity. These terms usually refer to a female turtle's tendency to return to a specific nesting beach with a high degree of accuracy (Carr, 1975; Bjorndal et al., 1983; Miller, 1997). The term site fidelity will be used here to describe a turtle's tendency to return to the intake structure (as demonstrated by its recapture in the intake canal).

Approximately five percent of the juvenile loggerhead turtles that were captured in the intake canal were documented returning. However, the extent to which turtles may learn to avoid being entrained while remaining in the vicinity of the intake structures is unknown. Thus, this figure may be conservative. Furthermore, the ability to identify a turtle as a recapture was dependent on the turtle's tag remaining intact. Poor retention of tags has been documented in sea turtles by various authors (Balazs, 1982; Henwood, 1986; Gorham et al., 1998). Considering these factors, it is safe to say that at least five percent of the juvenile loggerhead turtles captured in the canal showed site fidelity to the intake structure.

Some juvenile loggerheads returned to the canal only once while others returned repeatedly (23 times in one case). The time interval between a turtle's first and last capture is an indication of how long a turtle shows site fidelity to the area around the power plant. In some cases a turtle may have remained in the vicinity of the plant between captures, while in others it may have traveled to other areas between captures. In either case, the turtle demonstrated site fidelity to the intake structures. The percentage of recaptures that occurred within each of the various time intervals is presented in Figure 26. Based on these data, approximately 76 percent of the juvenile loggerheads that exhibited site fidelity did so for less than one year. Conversely, only 24 percent of the recaptures showed site fidelity for more than a year. When expressed as a percentage of all juvenile loggerheads entrained, this equates to only 1.2 percent of the juvenile loggerheads captured in the canal returning after one year. Though some juvenile loggerheads returned to the canal over periods of more than seven years, only 0.5 percent returned after two years.

Seasonal Distribution of Subadults

The seasonal distribution of subadult loggerhead turtles at the St. Lucie Plant is presented in Figure 27. As with juveniles, subadults were captured throughout the year. In contrast to the seasonal pattern for juveniles, however, subadults were most abundant during June, July and August. The loggerhead nesting season on Hutchinson Island typically extends from mid-April through mid-September with most nesting usually occurring in June and July (ABI, 1987, 1994). Therefore, the higher number of subadult captures between June and August suggests that some adults have been included in the subadult life history stage and/or some subadults follow adults to their nesting/mating areas.

Seasonal distributions of subadult loggerheads at the St. Lucie Plant are presented on an annual basis in Figures 28-32. As with juveniles, there were considerable year-to-year fluctuations in seasonal patterns of abundance. In general though, the percentage of subadults captured in June and July was higher during the last ten years than during the previous twelve years. The increase in the proportion of subadults occurring during these two months coincided with a general increase in the mean size of subadults that began in 1989 (Figure 33). This apparent relationship may be accounted for by one or both of the following: 1) as the mean size of subadults increases it becomes more likely that mature animals are included in this size class, and/or 2) as subadults approach adult size they may be more likely than smaller individuals to join with adults in nesting/mating migrations.

Long-term Trends in Subadult Captures

The number of subadult loggerheads captured each year from 1977 through 1998 at the St. Lucie Plant is presented in Figure 34. The long-term trend was not significant. Because so few subadults were recaptured and because there was no significant long-term trend in recapture rates, the annual capture pattern changed little after recaptures were excluded (Figure 35).

Site Fidelity of Subadults

Nine of the loggerhead turtles that were classified as subadults on initial capture were recaptured in the intake canal. Eight were still within the subadult size class when recaptured, but one had grown to adult size prior to recapture. Intervals between first and last capture ranged from nine days to almost seven and a half years (Figure 36). When expressed as a percentage of all subadult loggerheads entrained, approximately two percent of the subadult loggerheads captured in the intake canal were documented returning. Only five (1.1 percent) returned after one year.

Seasonal Distribution of Adults

Adult loggerhead turtles, like juveniles and subadults, were captured in the St. Lucie Plant intake canal throughout the year (Figure 37). However, the most conspicuous aspect of the seasonal distribution of adult loggerhead captures is that it closely corresponded to the seasonal distribution of nesting on Hutchinson Island. Nesting usually begins in mid-April, increases through May, is highest in June and July, decreases in August, and ends in mid-September (ABI, 1987, 1994). Adult loggerhead captures in the intake canal followed this same pattern.

Of the 649 adult loggerhead capture events in the canal, the sex of the turtle was determined in 637 cases. Determination of sex was based on tail length (Wibbels, 1999). A total of 562 of the adult loggerheads were females and 75 were males. Though both sexes were captured during every month of the year, the seasonal distributions of males and females were different (Figure 38). Females were most abundant from May through August while males were most abundant from February through June. Henwood (1987) found a similar pattern in the Canaveral Ship Channel. He suggested that most breeding occurs in April and May with males leaving the area in June while females remain in the area throughout the nesting season (May – August). This probably explains the seasonal patterns documented for the St. Lucie Plant.

As with the other life history stages of loggerhead turtles, adults exhibited considerable year to year fluctuation in seasonal patterns (Figures 39-43). It should be noted, however, that the number of annual captures from 1977 through 1983 was very low. Larger numbers of adults were captured from 1984 through 1998, and during this period seasonal patterns tended to be more consistent (i.e., most adults were captured during the nesting season). This undoubtedly reflects the fact that over 85 percent of the adult captures were females and probably in the area for the purpose of nesting.

Long-term Trends in Adult Captures

The number of adult loggerhead turtles captured each year at the St. Lucie Plant is presented in Figure 44. As with subadults, few adults were recaptured and no significant increase or decrease in recaptures occurred over the period of study. For those reasons, the annual capture pattern changed little after recaptures were excluded (Figure 45). In contrast to subadults, there was a significant increase in the number of adult loggerheads captured between 1977 and 1998 whether recaptures are included or excluded ($r^2 = 0.60$, $P < 0.001$, $n = 22$).

Since the sexes of most adults were determined, long-term trends were reanalyzed for each sex separately. Because the trends including and excluding recaptures are essentially identical, only trends exclusive of recaptures are presented. The numbers of adult female loggerheads captured each year are presented in Figure 46. Since females comprised over 85 percent of the adult captures, it is not surprising that the trend in female captures was very similar to the trend for all adult captures. As for all adults, female captures significantly ($r^2 = 0.61$, $P < 0.001$, $n = 22$) increased from 1977 through 1998.

The fact that seasonal trends in adult captures coincided with seasonal trends in nesting suggests that many of the females captured at the St. Lucie Plant intake may have migrated to the area for the purpose of nesting. To further investigate this possibility, the long-term trend in female captures was compared to the long-term trend in loggerhead nesting on Hutchinson Island (Figure 47). When analyzed, a significant ($r^2 = 0.54$, $P < 0.001$, $n = 18$) positive relationship between capture rates and nesting was indicated (Figure 48). As nesting has increased on Hutchinson Island, so too have the number of adult females entrained into the St. Lucie Plant intake canal. Female turtles may use reef areas for feeding and/or shelter between nesting episodes and the intake structure may appear to be suitable habitat.

The annual numbers of adult male loggerhead captures are presented in Figure 49. Compared to adult females, the numbers of adult males captured annually were relatively small. However, like females, males exhibited a significant ($r^2 = 0.25$, $P < 0.05$, $n = 22$) increase in numbers from 1977 through 1998.

Site Fidelity of Adults

Seven (six females and one male) of the loggerhead turtles that were classified as adults on initial capture were recaptured in the intake canal. Intervals between first and last capture ranged from three days to over nine years (Figure 50). The male was recaptured 43 days after its initial capture.

When expressed as a percentage of all adult loggerheads entrained, 1.1 percent of the adult loggerheads captured in the intake canal were documented returning. Only four (0.6 percent) returned after one year.

TRENDS IN GREEN TURTLE CAPTURES AT THE ST. LUCIE PLANT

Size Distribution

Between 1976 and 1998, SMCL measurements were obtained for 2,417 green turtle captures at the St. Lucie Plant. The mean size of these turtles was 38.7 cm (range: 20.0 – 108.0 cm). The size distribution of green turtles from the intake canal is presented in Figure 51. Green turtle captures were dominated by juveniles as has been reported on nearshore reefs in Indian River and Broward Counties and in the Indian River and Mosquito Lagoons (Mendonca and Ehrhart, 1982; Wershoven and Wershoven, 1990; Schroeder et al., 1990; Ehrhart et al., 1996, 1999).

Though the mean size of green turtles from the intake canal was similar to that reported by Ehrhart et al. (1996) for green turtles from the central region of the Indian River Lagoon, there was a much higher proportion of very small (< 30 cm) turtles in the intake canal. Only 5.4 percent of the lagoon green turtles, compared to 22.3 percent of those in the intake canal, were less than 30 cm. Though Ehrhart et al. captured a higher proportion (10.0 percent) of these very small turtles at their reef site, the proportion was still less than half of that for the intake canal. These researchers offered two possible explanations for size differences between green turtles captured in the St. Lucie Plant intake canal and those they captured in tangle nets. It was suggested that smaller green turtles could be more susceptible than larger individuals to entrainment by the plant's cooling water system and/or the large mesh of the tangle nets used in their study allowed smaller turtles to escape.

Though differences in capture techniques may contribute to the observed difference in size frequencies, real differences in size structure may exist between green turtles in the nearshore Atlantic and those in the lagoon (Ernest et al., 1988, 1989). This is suggested by the fact that Ehrhart et al. (1996) found a higher proportion of very small green turtles at the reef site versus the lagoon site. This is also suggested by the sizes of green turtles captured in the Canaveral Ship Channel (Henwood and Ogren, 1987) and in the Trident Submarine Basin (Redfoot et al., 1996). The mean sizes of green turtles at these two sites were 33.8 and 32.9 cm, respectively. This is considerably smaller than the mean sizes reported for green turtles in the Indian River Lagoon.

The relatively high proportion of individuals between 20 and 30 cm and the paucity of turtles greater than 50 cm in the St. Lucie Plant intake canal suggests that nearshore coastal waters may be an intermediate developmental habitat for green turtles moving from the pelagic environment to lagoons and estuaries. It has been suggested that the algae available in coastal waters are insufficient to sustain green turtles larger than 50 cm (Coyne, 1994; Redfoot et al., 1996). So, as green turtles in the vicinity of the intake approach this size they may begin to migrate out of coastal waters and into lagoons where algae and seagrasses are more abundant.

Annual changes in mean sizes of green turtles captured at the St. Lucie Plant are shown in Figure 52. Considerable fluctuations in mean sizes exhibited during the early years of the program primarily reflect small sample sizes. After eliminating years in which less than 20 individuals were captured, only two years (1981 and 1988) had means outside of the range of 35 to 41 cm. Consequently, over the period of study, there was no significant increase or decrease in the mean size of green turtles captured in the intake canal. Annual size distributions for green turtles at the St. Lucie Plant are presented in Figures 53-57.

For the purpose of this report, the same size classes/life history stages used for loggerheads were also used for green turtles. Measurements were available for over 99 percent of the green turtle captures, so almost all green turtles could be assigned to a life history stage. Because there were so few green turtles in the subadult and adult life history stages (29 and 28, respectively), subsequent analyses of green turtle captures are limited to juveniles.

Seasonal Distribution of Juveniles

The seasonal distribution of juvenile green turtle captures at the St. Lucie Plant is presented in Figure 58. Though juvenile green turtles were captured during all months of the year, they were most abundant from January through March. Likewise, Ehrhart et al. (1996, 1999) captured more juvenile green turtles in the central Indian River Lagoon in the winter than in the summer. Ehrhart et al. (1996) suggested that increased captures during cooler months may be due to an increase in drift algae in the lagoon and an influx of green turtles from northern climates. No data are available concerning seasonal changes in algae abundance in the vicinity of the intake, so it is unknown whether this factor may affect capture rates. However, it seems likely that higher capture rates during

January through March could be due to seasonal movements of juvenile green turtles from northern areas into the nearshore waters of southeast Florida.

Between 1977 and 1994, the seasonal distribution of juvenile green turtle captures at the St. Lucie Plant exhibited some annual variation, but during most years, captures were greatest during the coolest months (December-March; Figures 59-62). However, beginning in 1995, juvenile green turtle captures tended to be more evenly distributed throughout the year (Figures 62-63). This change in seasonal distribution coincided with an unprecedented increase in juvenile green turtle captures at the St. Lucie Plant.

Prior to 1995, juvenile green turtle captures at the plant were apparently dominated by animals that moved into the area as water temperatures cooled then moved out of the area as water temperatures warmed. These seasonal migrants appeared to make a smaller contribution to annual captures beginning in 1995.

Long-term Trends in Juvenile Captures

The numbers of juvenile green turtles captured annually from 1977 through 1998 at the St. Lucie Plant are presented in Figure 64. Annual captures were relatively low from 1977 through 1992, but increased considerably after 1992. Extraordinarily high numbers of green turtles were captured in 1995 and 1996. Linear regression analysis indicated a significant ($r^2 = 0.43$, $P < 0.001$, $n = 22$) increase in juvenile green turtle captures over the entire period of study. However, analysis of recapture data indicates a similar increase in recaptures during the same period (Figure 65). Likewise, juvenile green turtle recaptures were found to significantly ($r^2 = 0.44$, $P < 0.001$, $n = 22$) increase over the study period.

In order to rule out the possibility that the increase in juvenile green turtle captures was due to an increase in recapture rates, data were reanalyzed after excluding recaptures (Figure 66). Even after recaptures were excluded, juvenile green turtle captures were found to significantly ($r^2 = 0.39$, $P < 0.01$, $n = 22$) increase from 1977 through 1998. However, as with juvenile loggerheads, the increase in captures did not occur gradually over the period of study but rather was limited to the 1990s. A regression analysis indicated no significant trend when applied to data through 1992.

Site Fidelity of Juveniles

Over the period of study, 13.1 percent of the juvenile green turtles that were captured in the intake canal returned. Like juvenile loggerheads, some juvenile green turtles returned on only one occasion while others returned repeatedly (as many as 14 times). Intervals between first and last capture varied from one day to over four years. The percentage of recaptures that occurred within each interval is presented in Figure 67. Based on these data, approximately 67 percent of the juvenile green turtles that exhibited site fidelity, did so for less than one year. Conversely, only 33 percent did so for more than one year. Expressed as a percentage of all juvenile green turtles entrained, this equates to 4.3 percent returning after one year.

Green turtles exhibited a higher incidence of site fidelity than loggerheads. This is consistent with the findings of Mendonca and Ehrhart (1982) in the Mosquito Lagoon. They also found that green turtle recapture rates were higher than those for loggerheads.

Though a higher percentage of juvenile green turtles (4.3 percent) than juvenile loggerheads (1.2 percent) returned to the canal after one year, the longest periods of site fidelity were exhibited by loggerheads. This may be explained by the disproportionately higher percentage of green turtles that were captured, tagged and released during the last five years of the study period. Only 28 percent of the juvenile green turtles captured in the canal had been at large for more than five years at the end of 1998, compared to 63 percent of the juvenile loggerhead turtles.

FACTORS THAT MAY INFLUENCE TURTLE ENTRAINMENT PATTERNS

Power Plant Design and Operating Characteristics

There have been a number of changes to the design of the St. Lucie Plant that may have influenced turtle entrainment. Several changes occurred with the addition of Unit 2 in June 1983. First, another intake structure was installed. This increased the spatial extent of physical structures on the seafloor and may have attracted additional turtles. Second, the addition of another power plant changed flow patterns around the intake structures and within the intake pipes. This may have affected a turtle's likelihood of being entrained when it entered the intake structure. Third, the addition of the second discharge pipe with its 58 ports rising above the ocean surface increased the area of structure just north of the intakes. This may have attracted additional turtles into the general area and eventually resulted in more turtles encountering and entering the intake structures. The second discharge pipe in combination with the second power plant would also be expected to increase the thermal plume in the general area of the intake structures. This might act as an attractant to sea turtles during cooler periods thus increasing the probability of entrainment.

In order to identify changes in entrainment associated with the addition of Unit 2, average annual capture rates for the five-year period prior to construction of the third intake structure (1977-1981) were compared to those for a five-year period after Unit 2 began operating (1984-1988; Table 4). For all loggerhead and green turtle life history stages examined, average capture rates increased after Unit 2 began operation. Juvenile and subadult loggerhead captures increased by 25 and 48 percent, respectively. Average annual captures of juvenile green turtles and adult loggerheads more than tripled. However, when tested with a Mann-Whitney test[6] (Zar, 1996), only the increases for juvenile green turtles and adult loggerheads were statistically significant ($P = 0.05$). Though an increase in entrainment rates was indicated after the addition of the second power plant, this does not necessarily demonstrate that the increase was due to the second

[6] A Mann-Whitney test is a statistical method for determining if two samples have been drawn from the same population. It is used for testing means when the assumptions of the more rigorous t-statistic cannot be met or when sample sizes are relatively small.

plant. For example, the increase in captures of adult loggerheads coincided with a similar increase in loggerhead nesting on Hutchinson Island. So the observed increase in adult loggerhead capture rates may have resulted more from an increase in nesting females in the area than from the addition of the second power plant. Though significantly more juvenile green turtles were captured in the five-year period before, than the five-year period after, Unit 2 went on-line, no significant trend in captures were indicated when all data between 1977 and 1992 were analyzed (see Green Turtles - Long Term Trends in Juvenile Captures and Figure 64). Thus, although the addition of the second unit may have affected capture rates to some extent, it is not clear that this change was responsible for the long-term upward trends in captures of juvenile and adult loggerhead turtles or juvenile green turtles.

Repairs to the velocity caps on the three intake structures also may have affected entrainment rates. The thicker columns and caps may have changed the attractiveness of the structures to turtles and may have affected flow patterns underneath the caps. Since damage to the caps was first observed in August 1989, the period from 1984 through 1988 was used to characterize capture rates for the original three-intake system. Because repairs were completed in February 1992, the period from 1992 through 1996 was used to characterize rates for the modified three-intake system. Average capture rates for each of these five-year periods is presented in Table 5. Though mean capture rates for subadult loggerheads decreased by 21 percent after velocity cap repairs, rates increased for the other groups. Average annual capture rates increased by 31 percent for juvenile loggerheads, 67 percent for adult loggerheads and 851 percent for juvenile green turtles. However, based on a Mann-Whitney test (Zar, 1996) only the change in juvenile green turtle captures was significant ($P = 0.05$).

Whether the increases in juvenile green turtle capture rates were caused by, or simply coincident with, velocity cap repairs is unknown. However, as discussed later, other researchers reported similar increases in the number of juvenile green turtles residing in developmental habitats elsewhere on the east coast of Florida during the 1990s. This would suggest that increases seen at the St. Lucie Plant were part of a larger pattern unrelated to changes in the intake structure.

In addition to changes in power plant design, changes in power plant operations may also affect sea turtle entrainment. In particular, when a power plant is shut down for maintenance or refueling, the circulating-water pumps are also shut down. Though auxiliary pumps are run during these periods, the flow of water through the intake system is considerably reduced. This results in a major reduction in water velocities at the intake structures and within the intake pipes (Table 1). Changes in velocity may affect the probability that a turtle will be entrained into the canal after entering the intake structure. How turtles behave after they enter the structure is unknown, but if they attempt to escape after entering the intake pipe, lower velocities might increase their probability of escape.

Information on maximum swimming speeds of green and loggerhead turtles of the sizes encountered in the canal is fragmentary. However, observations by Ogren et al. (1977) of two adult loggerhead turtles encountering shrimp trawls provides some pertinent information. In both cases the trawls were towed at about 2.5 knots (129 cm/sec). The first loggerhead was observed swimming leisurely in the same direction that the trawl was being towed. As the trawl began to overtake it, the turtle increased its swimming speed until it equaled that of the trawl. The turtle increased its speed further and was able to outdistance and veer away from the trawl. The encounter lasted approximately two to three minutes. So this turtle was able to maintain and exceed a speed of 129 cm/sec for at least two minutes. A second loggerhead, swimming in the same direction as the tow, kept just ahead or even with the net headrope for two to three minutes then slowed its swimming speed. As the headrope passed over the turtle, it increased its swimming speed, swam 2-3 meters to the headrope then rested momentarily and was overtaken by the net. This pattern of swimming was repeated for 8-10 minutes until the turtle was finally swept further back into the net and ceased swimming. This turtle, then, was able to maintain and occasionally exceed a speed 129 cm/sec for at least ten minutes.

J. Mitchel (pers. com.) also made observations of loggerhead turtles encountering trawls. In this case, two-year-old, captive-reared loggerheads were used to test turtle excluder devices in shrimp trawls. Turtles were placed ahead of trawl nets being towed at 2.5-3.0 knots (129-154 cm/sec). Turtles usually kept swimming at those speeds for the first minute then would slow down.

Additional observations of swimming speeds in sea turtles were made on adult females during the nesting season. Using radio telemetry, Tucker et al. (1996) recorded the internesting movements of female loggerhead turtles in Australia. The maximum swimming rate recorded for these turtles was 3.01 km/hr (84 cm/sec). However, these speeds probably do not reflect the maximum speed that these turtles are capable of. Carr et al. (1974) suggested that adult female green turtles in longshore travel maintain a speed of about 1.5 km/hr (42 cm/sec) for several hours at a time and are capable of brief bursts of 4-7 km/hr (111-194 cm/sec).

Based on these swimming speeds, turtles would be expected to easily escape velocities encountered at the velocity caps of all three intakes and in the vertical sections of the 3.7-m intake structures during any operating condition (Table 1). Though turtles should also be able to escape velocities in the vertical section of the 4.9-m intake when one unit is operating, they may not be capable of escaping when two units are running. During the period when there was only one power plant and two intake structures, turtles would not be expected to be entrained when the plant was shut down. However, when the plant was operating turtles would probably have difficulty swimming against the velocities (159-178 cm/sec) within the intake pipes. The addition of the second power plant and third intake structure changed conditions. With only one plant operating, velocities in the 3.7-m pipes are only 66-73 cm/sec. Turtles should be able to easily escape from the pipes at these velocities. Under the same conditions, velocities in the 4.9-m pipe are 93-106 cm/sec. Turtles should be able to escape at these velocities if they begin swimming against the current shortly after they enter the pipe. However, if they drift with the current for several minutes before beginning to swim against it, then they may have difficulty escaping. With both plants running, velocities in the 3.7-m and 4.9-

m pipes increase to 127-142 cm/sec and 180-206 cm/sec, respectively. At these velocities, turtles entering the pipe would be expected to have difficulty escaping and would likely be entrained into the canal.

In order to determine if the operating status of the power plants affected sea turtle entrainment, capture records were examined on a monthly basis. Only the juvenile stages of the two species provided sufficient numbers to allow meaningful interpretation. The monthly operating status of the power plants was based on available information for periods when each of the plants was shut down for refueling and/or maintenance. Only data for major plant outages were available for the entire study period. So some short periods when a plant (and its circulating pumps) may have been shut down or operating at less than capacity, were not taken into account. For the purpose of this comparison it is assumed that the circulating water pumps for each plant continue to run for two days after the plant is shut down and begin pumping two days before the plant goes back on-line. This is the usual operating procedure (N. Whiting, pers. com.). The monthly operating status of the plant is expressed as days per month that the circulating water pumps for each plant were operating.

The operating status of each plant is compared to monthly captures of juvenile loggerhead turtles in Figures 68-75. It is apparent from these figures that there are considerable fluctuations in monthly capture rates even when the operating status of the plants remains constant. These fluctuations probably reflect natural variation in juvenile loggerhead numbers in the vicinity of the intake structures. Such fluctuations make it difficult to interpret the effects of plant operating status on entrainment. However, there are numerous periods in which fluctuations in capture rates appear to correspond to changes in plant status (February - June 1980, January – June 1983, January - April 1987, September – December 1987, June – September 1988, January - April 1989, January - May 1994 and April - July 1996). In some cases there appears to be a one-month delay in the effect (March – July 1979, August – December 1981, September 1990 – January 1991 and October 1991 – January 1992) which may reflect a delay between entrainment and capture. It appears that the operating status of the power plant often affected entrainment of juvenile loggerhead turtles with captures decreasing during periods of plant outages both before and after Unit 2 went on-line.

Juvenile green turtle captures are compared to power plant operating status in Figures 76-83. As with loggerheads, green turtle captures varied considerably from month to month even when there was no change in the operating status of the power plants. Decreases in captures did coincide with plant outages prior to Unit 2 going on-line, however, these results are difficult to interpret because capture rates were often very low even when the plant was operating. During the first nine years after Unit 2 went on-line, there were few indications that outages affected entrainment rates. In particular, the observed peak in captures during January 1984 (during the March 1983 - April 1984 outage of Unit 1) indicates that seasonal fluctuations in juvenile green turtle numbers around the intake structures had more of an effect on entrainment patterns than plant operational status. However, capture rates generally remained low during this nine-year period. Relatively large numbers of juvenile green turtles were not consistently captured until after September 1992. From October 1992 through December 1998, there were eight outages. In three cases fluctuations in capture rates appear to correspond to changes in plant status (September 1995 - January 1996, April - July 1996, April - June 1997). There were another four cases in which outages may have contributed to lower capture rates, but the relationship was not as clear (March - June 1993, January - May 1994, October 1997 - January 1998, and October - December 1998). There was one case in which an outage appeared to have no effect on capture rates (September - December 1994). Observed reductions in capture rates during several outages suggests that entrainment of juvenile green turtles was, at least occasionally, affected by power plant operating status.

In an attempt to quantify results of the qualitative analysis presented above, monthly capture data were segregated into periods when only one unit was on line and periods when both units were on line. Only data collected after Unit 2 went on line (June 1993) were used in the analysis so the number of intake structures remained constant. To segregate seasonal effects, two different periods were evaluated: spring (March, April, and May) and fall (October and November). During the spring period, water temperatures in the vicinity of the plant were typically rising following seasonal lows in January or February (Figure 95). During the fall period, temperatures were generally in decline following seasonal highs in September. Spring and fall also represent the periods when most routine plant outages occurred (Table 6).

During the spring between 1994 and 1998, there were 19 months when only one unit was operating and 26 months when both were operating. A t-test[7] applied to these data indicated that the capture of juvenile loggerheads was significantly higher ($t_{0.05(2)(43)} = 3.30$, $P < 0.002$) during months when two units were operating (mean = 18.7/mo $\pm$ 13.58/mo) than during months when only one unit was on line (mean = 7.7/mo $\pm$ 5.71/mo). Similar results were obtained for juvenile green turtles ($t_{0.05(2)(43)} = 2.08$, $P < 0.05$; mean for 2 units = 23.8/mo $\pm$ 36.75/mo; mean for 1 unit = 5.9/mo $\pm$ 7.91/mo). During the fall, there were 17 months when one unit was on line and 15 months when both were operational. The average number of captures for loggerheads during months when only one unit was operating was 5.9/mo ($\pm$ 4.91/mo). That was only slightly higher than the number of monthly captures when both units were on line (mean = 4.7/mo $\pm$ 2.98/mo). Similarly, the capture of juvenile green turtles during the fall was only slightly higher when two units were on line (mean = 12.3/mo $\pm$ 14.99/mo) than when a single unit was operating (mean = 8.7/mo $\pm$ 13.35/mo). Differences in fall capture rates between the two plant operating modes were not statistically significant for either species. Thus, while the number of units on line may affect capture rates during some seasons, the effect is not universal. Furthermore, plant outages have been a regular occurrence over the life of the plant, and there were no trends in outages to explain the long-term increases in the capture of juvenile loggerhead and green sea turtles.

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[7] A t-test is a statistical method for comparing two sets of samples to infer whether differences exist between the two populations sampled. Sample size and variation of individual values about the mean for each sample are factored into the comparison. A significant t value indicates that the samples were derived from different populations and that the mean values differ because of factors other than random variation.

In a separate analysis of long-term power plant operating trends, the operating status of the plant was determined by calculating the number of days each year that at least one unit was on line (Figure 84). Regression analysis indicated that, over the entire period of study, there was a significant ($r^2 = 0.32$, $P < 0.01$, $n = 22$) increase in the number of days that at least one unit was operating. However, using this criterion, there was no significant trend in the operational status of the plant during the last fifteen years of the study period (1984 – 1998). This was due to the fact that, after Unit 2 went on-line, outages were scheduled so that there was always one unit operating. Thus, the overall trend in operating status was due to the addition of Unit 2 rather than to a gradual increase in plant operating capacity over the period of study.

Because velocities in the intake pipes are proportional to the number of units operating, it was also important to examine periods when both units were on-line. From 1984 through 1998, there was some variation from year to year, but there was no significant long-term trend in the number of days per year that both units were on-line (Figure 85).

Because the operational status of the power plant exhibited no long-term trend between 1984 and 1998, it would not be expected to have been responsible for any increases in turtle entrainment within that period. However, when the entire study period is evaluated it is clear that there was a shift in the operational status of the power plant related to the addition of Unit 2. This shift may have contributed to higher capture rates after Unit 2 went on-line, but if the effect were due strictly to the addition of a second unit, it would be expected to remain constant after 1984. So, for instance, the substantial increases in juvenile loggerhead and green turtle captures that occurred during the 1990s can not be attributed to changes in power plant operating status.

In addition to the duration of outages, the timing of outages could also affect capture rates. Outages would be expected to have a greater effect on annual capture rates if they occurred during months when turtles were more abundant. So a shift in the timing of outages could affect long-term trends in captures. Outage periods for each year are given in Table 6. Throughout the study period, most outages occurred during spring and fall and no long-term shift in timing was indicated. Therefore, the observed increases in loggerhead and green turtle captures can not be attributed to a change in the timing of outages.

More detailed information concerning the operational status of the power plant is available for the period from January 1988 through December 1998. For this eleven-year period actual monthly flow rates are available. These flow rates reflect even short-term outages and periods when circulating water pumps were run at less than capacity. When flow rates were compared to juvenile loggerhead capture rates (Figures 86-87), decreases in capture rates often coincided with decreases in flow rates. The relationship of monthly flow rates to monthly capture rates is shown in Figure 88. Regression analysis indicated a weak but significant ($r^2 = 0.06$, $P < 0.01$, $n = 132$) positive relationship between the two.

When flow rates were compared to monthly juvenile green turtle captures (Figures 89-90), some changes in capture rates seem to coincide with changes in flow rates, but overall there did not appear to be a very strong relationship between the two. This was also indicated when flow rates were plotted against capture rates (Figure 91). Regression analysis indicated no significant relationship between monthly juvenile green turtle captures and monthly flow rates.

These results indicate that flow rates from 1988 through 1998 had a significant but weak effect on juvenile loggerhead entrainment, but no effect on juvenile green turtle entrainment. This may reflect differences in how each species reacts to currents encountered in the intake structures and/or differences in their abilities to escape the velocities encountered.

Regardless of the apparent significant relationship between monthly flow rates and juvenile loggerhead entrainment, flow rates did not appear to be responsible for the considerable increase in juvenile loggerhead captures after 1994. This is indicated by the fact that there was no significant trend in annual flow rates during the period from 1988 to 1998 (Figure 92). When annual juvenile loggerhead captures were compared to annual flow rates during that period (Figure 93), no significant relationship was indicated. Likewise, there was no significant relationship indicated between annual captures of juvenile green turtles and annual flow rates between 1988 and 1998 (Figure 94).

Characteristics of the Nearshore Environment Adjacent to the St. Lucie Plant

Changes in several aspects of the nearshore environment occurring in the vicinity of the St. Lucie Plant during the period that the plant has been operating might affect the numbers of green and loggerhead turtles inhabiting the area. Presumably an increase in the number of turtles near the plant would result in an increase in entrainment rates. For example, changes in the size and structure of nearby worm reefs and coquinoid rock formations might affect the tendency of turtles to utilize these areas. The only data available concerning changes in the dimensions and relief of worm reefs near the St. Lucie Plant were obtained from a study conducted by ABI (1979). Though this study was only conducted between April 1976 and April 1979, the dynamic nature of reef structures was documented. During this study, there was a trend in increasing reef size during the summer with deterioration of the colonies during the winter. Deterioration of the colonies was speculated to be due to increased wave action in fall or natural worm mortality. Major larval settlement resulting in new worm colonies occurred in late fall or early winter. Other rock formations devoid of reef building worms tend to be less dynamic in nature, though some change in relief may occur due to changes in sand levels around the formations.

Changes in the abundance of loggerhead and green turtle food items in the vicinity of the intakes might also affect the abundance of these two species in the area of the intake structures. Changes in the abundance of invertebrates and algae might occur if there were changes in the structure of the nearshore reefs and rock formations or changes in local environmental conditions. However, there were insufficient data available to assess long-term trends.

One factor for which considerable quantitative data were available was water temperature. Mean monthly water temperatures based on daily temperatures recorded at the power plant's circulating water pumps were available for the period from January 1989 through December 1996. Since water temperatures have been shown to affect loggerhead and green turtle movements and behavior (Mendonca, 1983; Keinath et al., 1987; Coyne, 1994; Epperly et al., 1995; Coles, 1999), the potential effect of water temperature on capture rates was investigated.

Monthly juvenile loggerhead captures are compared to mean monthly water temperatures in Figure 95. In general, peaks in captures coincided with cooler water temperatures. When monthly captures were plotted against mean monthly water temperatures, a negative relationship was indicated (Figure 96). This relationship was found to be statistically significant ($r^2 = 0.23$, $P < 0.001$, $n = 96$).

When monthly juvenile green turtle captures were compared to mean monthly water temperatures a similar relationship was indicated (Figures 97 and 98). Likewise this relationship was found to be statistically significant ($r^2 = 0.06$, $P < 0.05$, $n = 96$).

These results are consistent with suggestions by several authors that increases in juvenile loggerhead and green turtles along the east coast of Florida were associated with decreases in water temperatures (Henwood, 1987; Bolten et al., 1994; Ehrhart et al., 1996). It seems likely that water temperatures influenced seasonal trends in juvenile and loggerhead captures at the St. Lucie Plant.

In order to determine if there was a relationship between long-term trends in turtle captures and water temperatures, average annual water temperatures were compared to annual capture rates of juvenile loggerhead and green turtles (Figures 99 and 100). Though there were differences in average water temperatures among years, correlation analysis indicated no significant relationship between average annual water temperature and annual capture rates of either species.

In addition to differences in average annual water temperatures, there were also differences in the seasonal patterns of water temperature among years. For example, the timing and intensity of cool water intrusions (evidenced by temperature decreases during summer months) varied from year to year. However, no patterns could be detected that would explain long-term trends in turtle captures.

The possibility remains that water temperature may have affected long-term trends in turtle entrainment, but additional data may be necessary to detect the relationship. Increases in turtle numbers along the east coast of Florida during the winter have been partially attributed to seasonal migrants from northern climates. Therefore, water temperature patterns in these northern areas may be just as important as local temperatures in influencing trends in turtle abundance in the vicinity of the St. Lucie

Plant. Investigation of temperature patterns in these northern areas was beyond the scope of the present study.

Another characteristic of the nearshore environment that was investigated related to meteorological conditions (i.e., storms/high winds). The wave action that is often associated with high winds might affect a turtle's tendency to enter the intake structures. For example, turtles might seek refuge in the structures from the turbulence created by increased wave action. Conversely, turtles may leave the area around the intake and move to offshore areas to escape the turbulence.

High wind conditions associated with storms often increase wave activity near shore. This is particularly true if the wind is directed towards the coastline. Since no quantitative data on wave conditions near the St. Lucie Plant were available, wind conditions were used as a gauge of wave activity. Data on wind velocity and direction at the St. Lucie Plant were available for the period from January 1995 through December 1998. Wind data were collected hourly at a height of 10 meters just north of the plant's discharge canal. For the purpose of this analysis, winds with bearings of 0-140° and velocities greater than or equal to 10 mph (16.1 km/hr) were considered to be wave generating. In order to compare wind/wave conditions to monthly capture rates, the percentage of wind readings meeting the above criteria was calculated for each month. Occasionally instruments malfunctioned and readings could not be recorded for a period of time. If more than 24 readings (the equivalent of one day's readings) were missing during a month, then that month was excluded from analysis.

Monthly juvenile loggerhead captures are compared to wind conditions in Figure 101. No consistent relationship between captures and wind conditions were apparent. When capture rates were plotted against wind conditions, there did not appear to be a correlation between the two (Figure 102). Likewise, correlation analysis indicated no significant relationship between wind conditions and juvenile loggerhead captures. As with loggerheads, juvenile green turtle captures did not appear to be influenced by wind conditions (Figures 103 and 104). Again, correlation analysis indicated no significant relationship between wind conditions and juvenile green turtle captures. Based on the lack of any relationship between monthly wind conditions and turtle capture rates, it is unlikely that storms influenced long-term trends in loggerhead or green turtle entrainment at the St. Lucie Plant.

Population Trends

One possible explanation for the observed long-term increases in captures of loggerheads and green turtles at the St. Lucie Plant is that the populations of these two species have increased during the study period. Unfortunately, due to their wide and unpredictable distribution among various developmental and foraging habitats, sea turtle populations are particularly difficult to census (Meylan, 1982).

In fact, the Turtle Expert Working Group (1998) stated that results of studies conducted at the St. Lucie Plant provided one of the very few unbiased indices of abundance for benthic immature and adult loggerheads. The only other in-water studies that provide long-term trends in the abundance of loggerhead turtles along the east coast of Florida were conducted in the Indian River Lagoon system.

Ehrhart et al. (1999) analyzed trends in loggerhead population density in the central region of the Indian River Lagoon. They analyzed June and July CPUE (catch per unit effort) data for the years 1983-85, 1988-90, 1993-95 and 1998. The results indicated that loggerhead population density had not changed over the 15-year span of the study.

Provancha et al. (1998) evaluated the relative abundance of loggerhead turtles in the Mosquito Lagoon. Data that they collected in 1994-1996 were compared to data collected in 1977-1979 by Mendonca and Ehrhart (1982). Provancha et al. found that loggerhead CPUE declined from 0.16 to 0.06 between the two periods. Additional studies were conducted during 1997 and 1998 (Provancha, 1997, 1998). Loggerhead CPUEs for these two years (0.09 and 0.12) remained below the 0.16 CPUE for 1977-1979.

Differences among trends in the central Indian River Lagoon (no trend), the Mosquito Lagoon (negative trend), and the St. Lucie Plant (positive trend) may be due to differences in local environmental conditions. Conditions may be quite different between the lagoonal habitats and the coastal habitat near the St. Lucie Plant. Local availability of food items may also affect turtle abundance. Provancha et al. (1998) found the decline in loggerhead numbers coincided with a decline in horseshoe crabs in the Mosquito Lagoon.

Because of the limited number of studies that provide information on population trends for immature sea turtles, indices of population size and stability often rely on estimates of nesting females (see Meylan, 1982; NMFS and USFWS, 1991a). The Turtle Expert Working Group (1998) found that nesting data collected on index nesting beaches represented the best dataset available to index the population size of loggerhead sea turtles. This group also found that annual nesting from Hutchinson Island predicted annual nesting on all Florida index beaches well and may accurately reflect nesting trends for the total South Florida Subpopulation.

The National Research Council (1990) found a possible rising trend in numbers of loggerhead nests on Hutchinson Island from 1973 through 1989. They concluded that there was no decline or a possible increase in the loggerhead assemblage nesting south of Cape Canaveral. The Turtle Expert Working Group (1998) found a significant increase on Hutchinson Island during the period 1971-1994 as well as a significant increase for a composite of eight Florida beaches from 1983 through 1994. Witherington and Koeppel (in press) analyzed loggerhead nesting for the thirty index beach sites throughout Florida and concluded that loggerhead nesting appeared to be stable or increasing between 1989 and 1998.

When loggerhead nesting data for Hutchinson Island were analyzed for the period from 1981 through 1998, a significant increase in nesting was indicated ($r^2 = 0.75$, $P < 0.001$, $n = 18$; Figure 105). It has already been shown that there was a significant positive correlation between adult female loggerhead captures in the St. Lucie Plant intake canal and nesting on Hutchinson Island. However, based on estimates of time spent in the pelagic stage, increases in nesting would not be expected to begin affecting juvenile loggerhead captures for five to twelve years. Consequently, it is difficult to directly correlate changes in juvenile captures with changes in the adult population.

If trends in loggerhead nesting on Hutchinson Island do accurately reflect nesting trends for the total South Florida Subpopulation, then nesting for that subpopulation apparently increased from 1981 through 1998. Based on results of genetic analysis by Bass (1999), the majority (70 percent) of juvenile loggerhead captures from the St. Lucie Plant originated from the south Florida nesting population. So it would be reasonable to conclude that the increase in juvenile loggerhead captures at the plant reflects the increase in this population.

Like loggerheads, in-water studies of green turtles along the Atlantic coast of Florida are limited. The only studies that provide information on long-term trends in abundance were conducted in the Indian River Lagoon system and on worm reefs just south of the Sebastian Inlet.

Ehrhart et al. (1999) analyzed trends in green turtle population density in the central region of the Indian River Lagoon. They analyzed June and July CPUE data for the years 1983-85, 1988-90, 1993-95 and 1998 and found that the 1998 CPUE was significantly greater than CPUE for the other three time periods. These results supported speculation by Ehrhart et al. (1996) that the extraordinary increase in green turtle CPUE that occurred in the winter and spring of 1995-96 may have been an indication of a stepwise increase in the relative population density of the lagoonal green turtle population. Ehrhart et al. (1996) also found that green turtle CPUE during the periods 1988-90 and 1993-95 were significantly greater than the CPUE during 1983-1985.

Ehrhart et al. (1999) also studied green turtles on worm reefs just south of the Sebastian Inlet from 1989 through 1998. Though statistical differences in CPUE were found between years, the fluctuations did not follow any discernible pattern. The researchers suggested that differences among years might reflect changes in surf conditions and water clarity, which affect netting success, or fluctuations in the availability of algae utilized by green turtles as food.

Provancha et al. (1998) evaluated the relative abundance of green turtles in the Mosquito Lagoon. Data that they collected in 1994-1996 were compared to data collected in 1977-1979 by Mendonca and Ehrhart (1982). Provancha et al. found that green turtle CPUE increased from 0.21 to 0.36 between the two periods. Additional studies were conducted during 1997 and 1998 (Provancha, 1997, 1998). Green turtle CPUEs for these two years (0.28 and 0.32) remained above the 0.21 CPUE for 1977-1979.

Recent evidence that a large portion (53 percent) of the juvenile green turtles from the St. Lucie Plant originate from Costa Rican nesting populations (Bass and Witzell, in press) complicates the use of nesting data as an index of overall population status. Trends in the abundance of juvenile green turtles near the plant may be affected by trends in nesting in Costa Rica as well as Florida (42 percent of the juveniles are from the Florida/Mexico nesting population).

Bjorndal et al. (1999) analyzed nesting data for Tortuguero, Costa Rica, during the period from 1971 through 1996. The green turtle population that nests at Tortuguero is the largest in the Atlantic by at least an order of magnitude. Evaluation of the trend in nesting indicated a relatively consistent increase from 1971 to the mid-1980s, constant or decreasing nesting during the late 1980s, and then continuation of an upward trend in the 1990s. Overall, for the entire period, the trend was upward.

Dodd (1981) reviewed available records of green turtle nesting in Florida from 1959 through 1981 and speculated that the nesting population of green turtles in Florida was increasing. Dodd did point out, though, that better surveillance undoubtedly accounted for some of the increase in reported nests.

The National Research Council (1990) reported that the numbers of green turtle nests increased on Hutchinson Island over the period 1971-1989. Considerable nesting was reported to occur on Melbourne Beach, Florida, but nesting surveys had not been conducted for a long enough period to confirm a trend. Wide year to year fluctuations in numbers of nesting green turtles made statistical analysis of trends for this species particularly difficult.

NMFS and USFWS (1991b) reported that the number of green turtle nests in Florida appeared to be increasing. However, it was uncertain whether the upward trend was due to an increase in the number of nests or a result of more thorough monitoring of nesting beaches.

Meylan et al. (1995) reviewed green turtle nesting data throughout Florida from 1979 through 1992 and found an overall upward trend in nesting. These researchers, like others, cautioned that increased survey effort was partially responsible for the observed increase in numbers of nests.

Witherington and Koeppel (in press) evaluated green turtle nesting from 1989 through 1998 on thirty beach sites that are part of the Florida Index Nesting Beach program. They concluded that, over the ten-year period of study, green turtle nesting in Florida appears to be stable or increasing.

Changes in the annual numbers of green turtle nests on Hutchinson Island from 1981 through 1998 are shown in Figure 106. The drastic year-to-year fluctuations in nests numbers observed on Hutchinson Island have been documented at other green turtle nesting beaches and make analysis of trends difficult. However, regression analysis indicated a significant increase in nesting during this period ($r^2 = 0.28$, $P < 0.05$, $n = 18$).

There appears to be evidence that the green turtle nesting populations in Costa Rica and Florida increased between the 1970s and the 1990s. It seems reasonable to conclude that such an increase would result in an increase in juvenile green turtles in the vicinity of the St. Lucie Plant.

CONCLUSIONS

Immature loggerhead and green turtles apparently use the nearshore ocean environment in the vicinity of the St. Lucie Plant as developmental/foraging habitat. This appears to be related to the water depth in the area, the presence of hard bottom substrates and worm reefs, and the occurrence of preferred food items. Based on recapture data it appears that some turtles reside in the area throughout the year, while others transmigrate seasonally. The area is apparently also used as internesting habitat by large numbers of female loggerhead turtles that nest on Hutchinson Island every year.

Turtles migrating along the coast and/or utilizing hardbottom substrates and worm reefs in the vicinity of the plant would be brought into close proximity with the plant's intake structures. Turtles may enter the intake structures to rest or avoid attack from predators and/or competition from other turtles. Green and loggerhead turtles may also be attracted to the intakes for the purpose of foraging, since the structures resemble reefs, important foraging habitat for both species.

The majority of the loggerhead and green turtles entrained into the St. Lucie Plant intake canal between 1977 and 1998 were juveniles. However, loggerhead captures included a higher proportion of subadults and adults than green turtle captures. This probably reflects the fact that the loggerhead nesting population is considerably larger than the green turtle nesting population in the Hutchinson Island area.

There were significant increases in the numbers of juvenile and adult loggerhead captures and juvenile green turtle captures at the St. Lucie Plant from 1977 through 1998. The increase in adult loggerhead captures was more or less continuous and was significantly correlated with increases in nesting on Hutchinson Island. The upward trends in juvenile loggerhead and green turtle captures were primarily due to increases that occurred in the 1990s.

On average, more turtles were captured each year after Unit 2 was placed on line than before, suggesting that the addition of a second unit affected capture rates to some extent. However, this change could not account for the dramatic increases in capture rates of juvenile loggerhead and green turtles that only occurred after Unit 2 had been operating for ten years.

Changes in the physical appearance of the intake structure velocity caps following their repair coincided with substantial increases in juvenile green turtle captures at the plant. However, the extent to which the two are causally related is unclear.

Power plant outages over the life of the plant, at times, appeared to affect short-term trends in juvenile loggerhead and green turtle captures. However, plant outages could not explain the substantial increases in captures of either species that occurred during the 1990s. Flow rates from 1988 through 1998 appeared to have a weak but significant affect on short-term juvenile loggerhead entrainment rates. Again, however, flow rates were not responsible for the long-term increases in juvenile loggerhead captures occurring during this period. Flow rates had no affect on either short- or long-term captures of juvenile green turtles.

Changes in the nearshore environment near the St. Lucie Plant might be expected to affect long-term trends in turtle entrainment. Unfortunately, data relating to the relative size and relief of nearby worm reefs and hard bottom or to changes in the abundance of food items in the area were lacking. One environmental factor that was shown to be significantly correlated with monthly captures of juvenile green and loggerhead turtles was water temperature. However, no relationship between local water temperatures and long-term trends in capture rates could be demonstrated. The frequency of high, wave-producing winds also did not appear to affect entrainment of turtles. Seasonal increases in the number of juvenile loggerhead and green turtles in the vicinity of the plant may be more closely related to the migration patterns of turtles from more northern areas than to local conditions.

There is evidence (mainly from nesting beach surveys) that the adult populations of both green and loggerhead turtles that provide juveniles to the Hutchinson Island area increased during the study period. It would logically follow that the juvenile component of those populations also increased. The number of juvenile green turtles captured at the St. Lucie Plant increased dramatically in the 1990s. A similar increase was documented in the central Indian River Lagoon in an area well beyond the influence of the St. Lucie Plant. Unfortunately, there are relatively few other study sites for which long-term quantitative data are available for juvenile loggerheads. However, the strong correlation between adult loggerhead captures at the St. Lucie Plant and nesting on Hutchinson Island elucidates the relationship between canal capture rates and the relative numbers of individuals in the nearshore environment.

Even though changes in physical plant design and operating characteristics have occurred over the life of the plant, these changes do not appear to be responsible for the long-term increases in the numbers of juvenile and adult loggerhead and juvenile green turtles captured at the St. Lucie Plant. The most logical explanation for these increases is that there are more individuals of these life history stages present in the vicinity of the plant.

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Table 1. Calculated flow velocities along the intake system. Values for two power plants operating with three intakes are from Bellmund, 1982 (see Table 3). All other values were based on these values and the assumption that changes in velocities are proportional to changes in flow rates and the assumption that the 4.9-m pipe conveys 60 percent of the total flow (see p. 36, Bellmund et al., 1982).

Time Period	Number of power plants operating	Number of Intakes	Velocity Cap Flow Velocity (cm/sec)		Vertical Section Flow Velocity (cm/sec)		Pipe Flow Velocity (cm/sec)		Canal Flow Velocity (cm/sec)
			3.7-m	4.9-m	3.7-m	4.9-m	3.7-m	4.9-m	
May76-May83	None[1]	Two	0.4-0.5		1.3-1.5		4.8-5.3		0.46
May76-May83	One[2]	Two	14.0-15.8		44.9-50.2		159-178		15.24
Jun83-Dec98	One[3]	Three	5.8-6.5	14.4-15.7	18.5-20.7	97-106	66-73	93-106	15.70
Jun83-Dec98	Two[4]	Three	11.2-12.6	27.9-30.5	35.9-40.2	188-206	127-142	180-206	30.48

[1] Only auxiliary pumps for one unit operating
[2] Main pumps for one unit operating
[3] Main pumps for one unit and auxiliary pumps for the other unit operating
[4] Main pumps for both units operating

Table 2. Annual numbers of turtle captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

Year	Loggerhead	Green Turtle	Leatherback	Hawksbill	Kemp's Ridley	Total
1976	33	0	0	0	0	33
1977	80	5	1	0	0	86
1978	138	6	3	1	0	148
1979	172	3	0	0	0	175
1980	116	10	0	0	0	126
1981	62	32	2	0	1	97
1982	101	8	1	0	0	110
1983	119	23	0	0	0	142
1984	148	69	0	1	2	220
1985	157	14	0	1	0	172
1986	195	22	1	1	1	220
1987	175	35	0	2	6	218
1988	134	42	0	0	5	181
1989	111	17	1	2	2	133
1990	112	20	0	0	0	132
1991	107	12	0	1	1	121
1992	123	61	1	2	0	187
1993	147	179	5	2	4	337
1994	164	193	2	0	2	361
1995	254	673	1	0	5	933
1996	349	549	0	5	3	906
1997	188	191	2	1	0	382
1998	393	268	1	2	2	666
Total	3578	2432	21	21	34	6086
Annual Mean[1]	162.6	110.5	1.0	1.0	1.5	275.1

[1] Data from 1976 are excluded since the power plant did not begin operation until May of that year.

Table 3. Equations used to convert straight standard carapace length (SSCL) and curved standard carapace length (CSCL) to straight minimum carapace length (SMCL) for loggerhead turtles.

Conversion	Equation	R^2	P	SE	N
SSCL to SMCL	$y = 0.9923x - 0.6948$	0.9986	<0.001	0.57	2061
CSCL to SMCL	$y = 0.9363x - 1.7437$	0.9925	<0.001	1.28	2901

Table 4. Average annual numbers of sea turtle captures for a five-year period before construction of the third intake (1977-1981) and for a five-year period after Unit II began operation (1984-1988), St. Lucie Plant intake canal, Hutchinson Island, Florida.

Species	Life History Stage	Mean Annual Capture Rate	
		1977-1981	**1984-1988**
Loggerhead Turtle	Juvenile	84.8	105.8
Loggerhead Turtle	Subadult	17.4	25.8
Loggerhead Turtle	Adult	7.8	29.0
Green Turtle	Juvenile	10.2	34.2

Table 5. Average annual numbers of sea turtle captures for a five-year period before velocity caps were damaged (1984-1988) and a five-year period after velocity caps were repaired (1992-1996), St. Lucie Plant intake canal, Hutchinson Island, Florida.

Species	Life History Stage	Mean Annual Capture Rate	
		1984-1988	1992-1996
Loggerhead Turtle	Juvenile	105.8	138.4
Loggerhead Turtle	Subadult	25.8	20.4
Loggerhead Turtle	Adult	29.0	48.4
Green Turtle	Juvenile	34.2	325.2

Table 6. Maintenance/refueling outage periods for each of the St. Lucie Plant units. Unit I outages are designated by vertical shading and Unit II outages are designated by black areas. Outages were assigned to months in which circulating water pumps operated for less than 25 days. The asterisks indicate the month (June 1983) in which Unit II went on-line.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1977												
1978												
1979												
1980												
1981												
1982												
1983						******						
1984												
1985												
1986												
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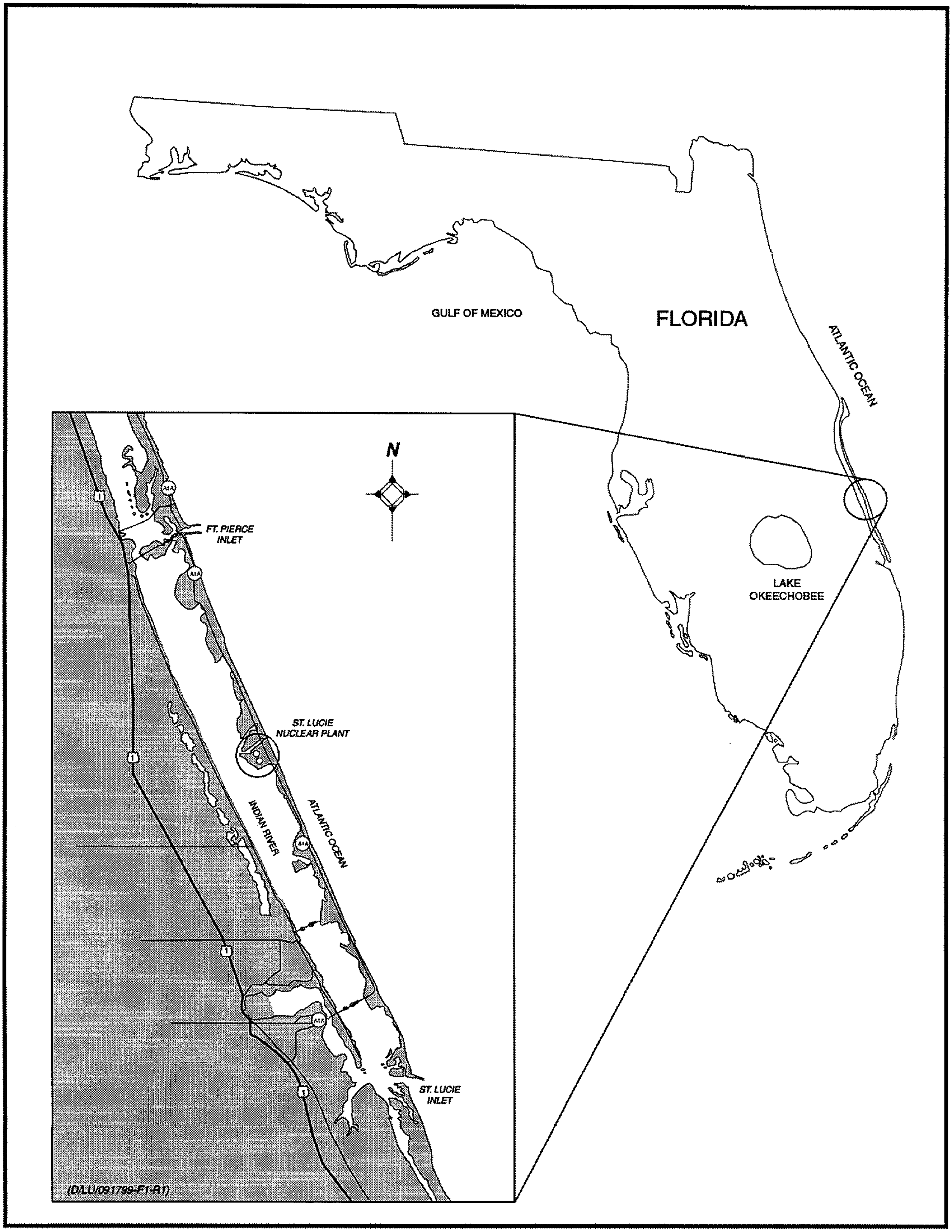

Figure 1. Location of St. Lucie Plant, Hutchinson Island, Florida.

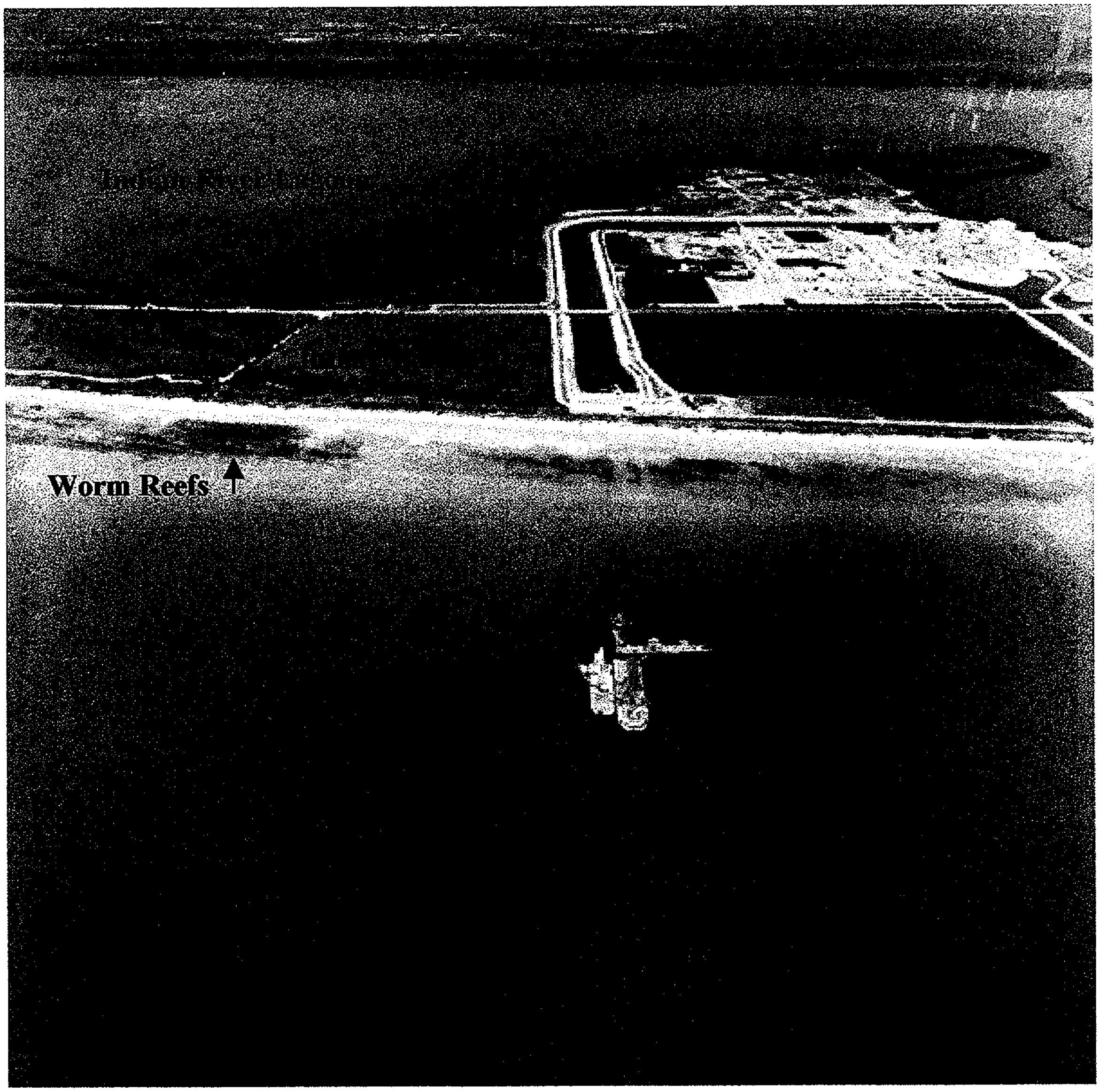

Figure 2. Aerial view of the St. Lucie Plant, Hutchinson Island, Florida. The above-water structures and barges in the vicinity of the intake structures were only present during velocity cap repairs during 1991 and 1992.

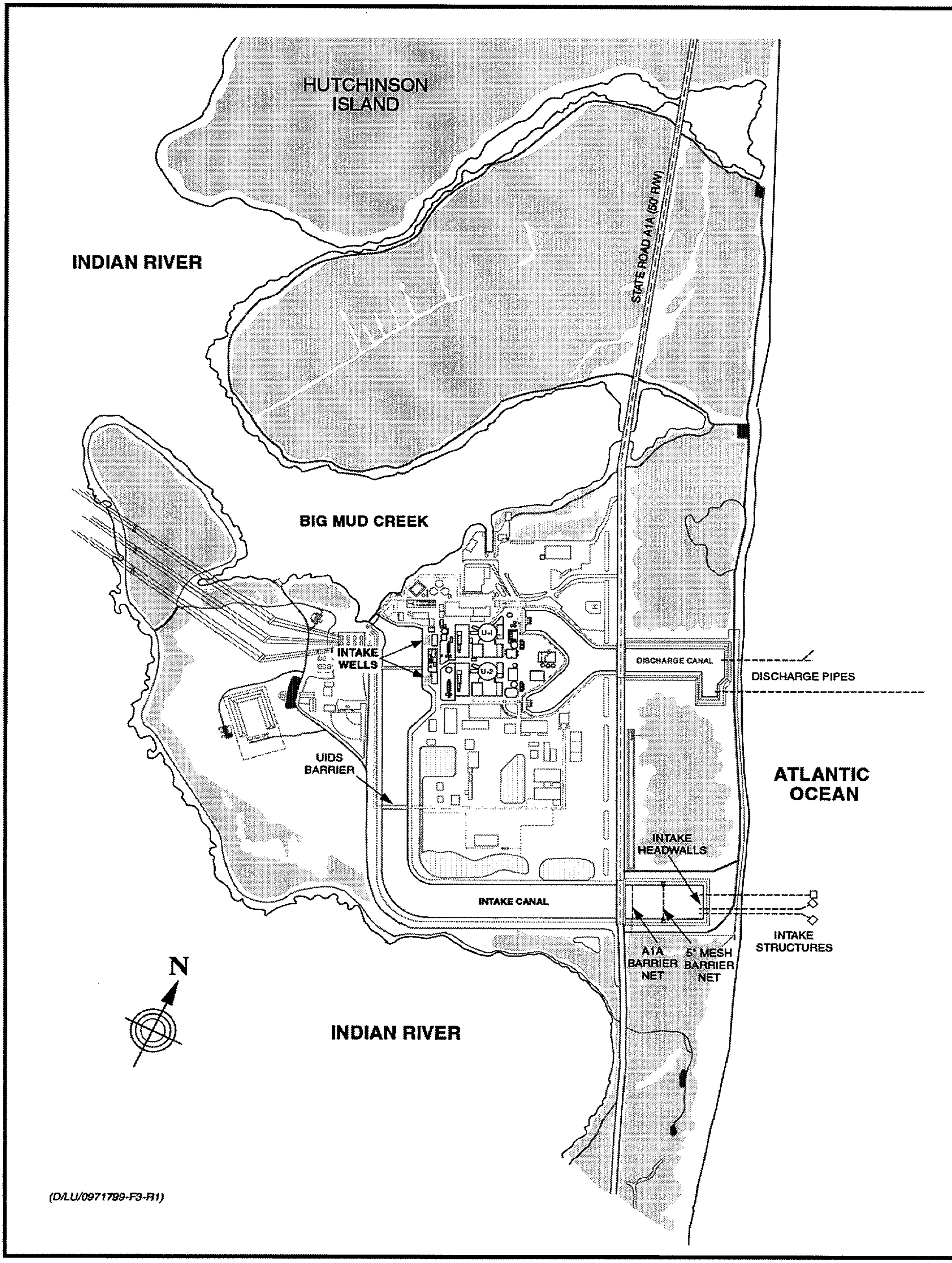

Figure 3. St. Lucie Plant cooling water intake and discharge system.

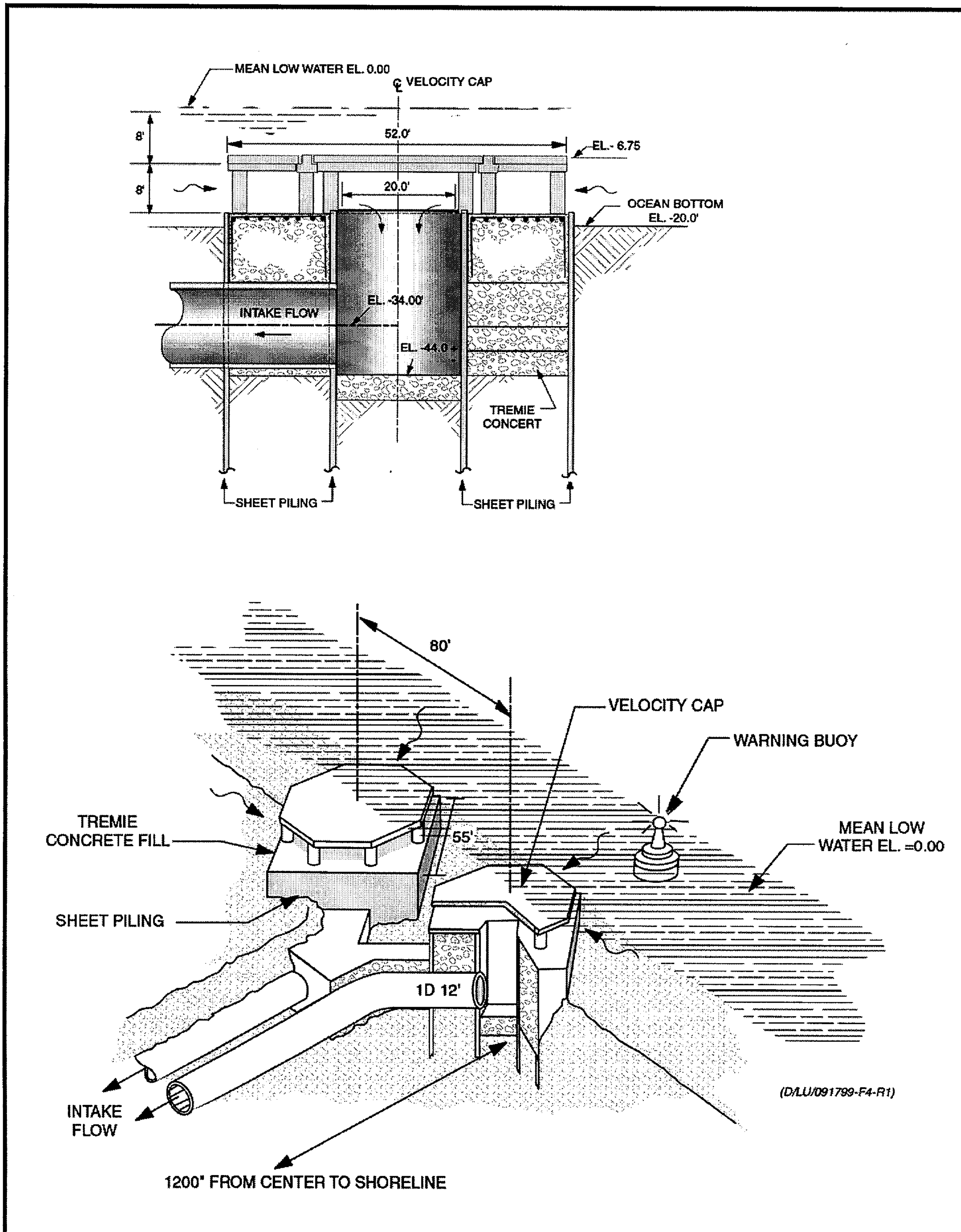

Figure 4. Configuration of the two 3.7-meter-diameter intake structures, St. Lucie Plant, Hutchinson Island, Florida.

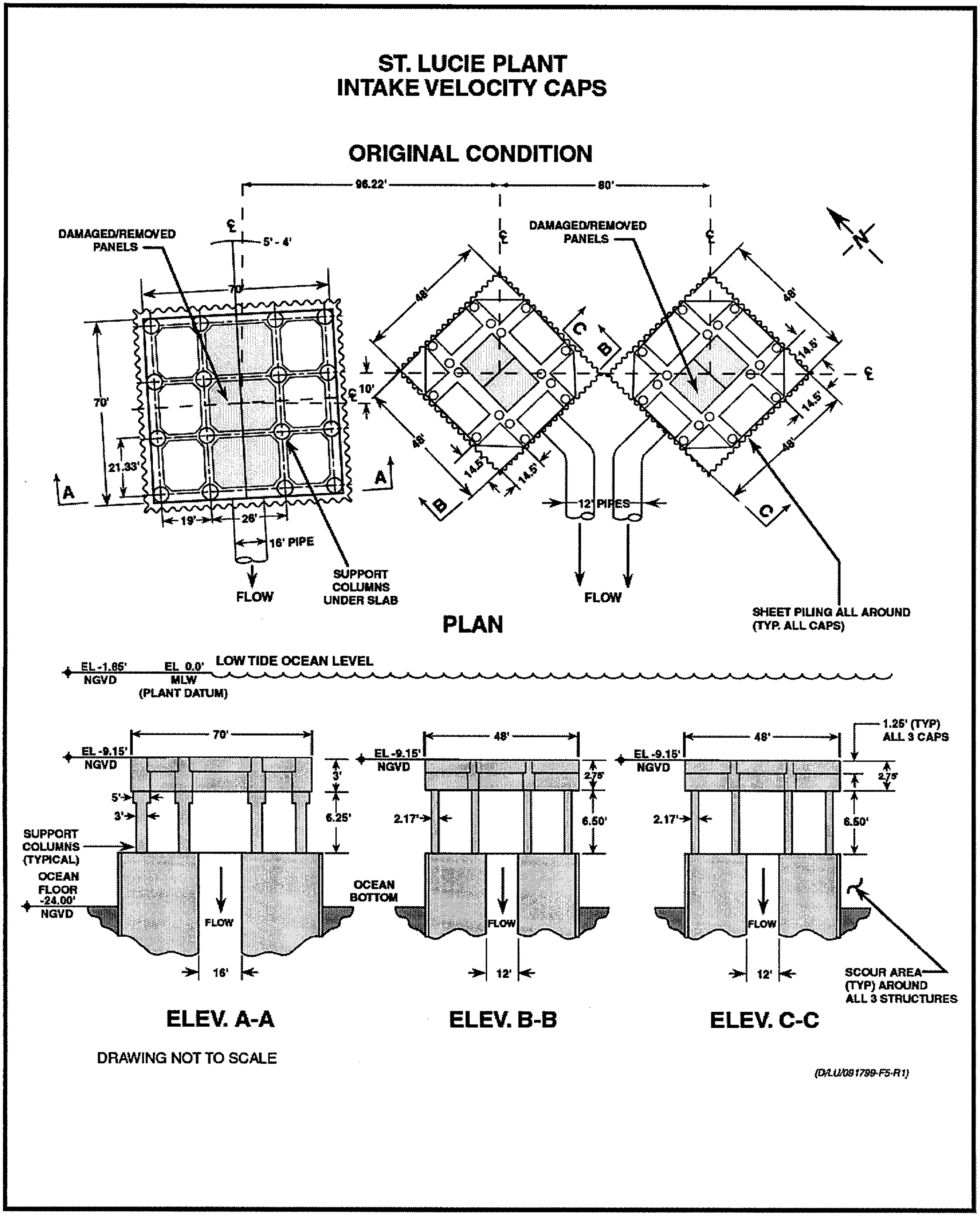

Figure 5. Diagram of the three intake structures located 1200 feet (365 m) offshore of the shoreline at the St. Lucie Plant, Hutchinson Island, Florida. Dimensions represent conditions prior to velocity cap repairs completed in February 1992.

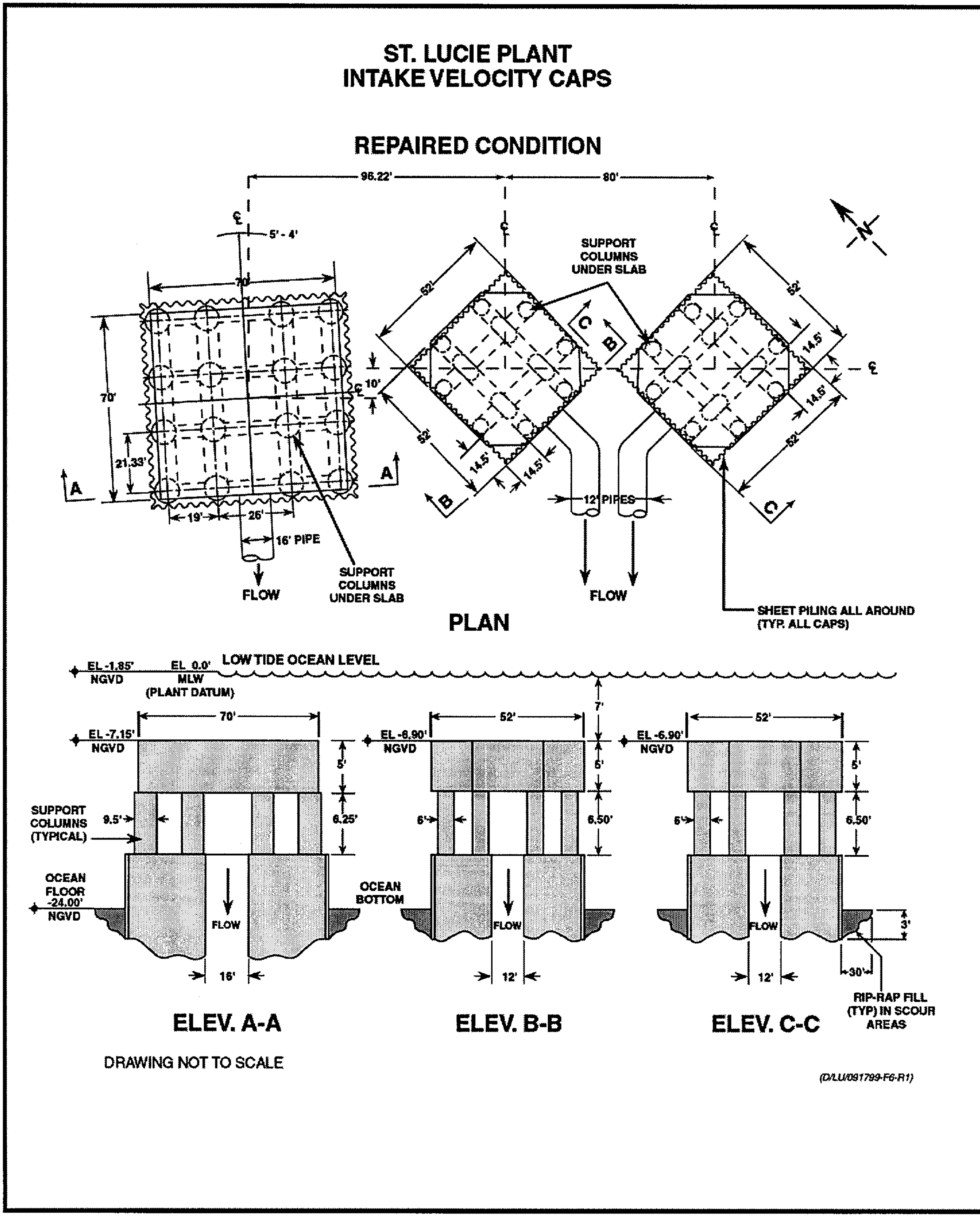

Figure 6. Diagram of the three intake structures located 1200 feet (365 m) offshore of the shoreline at the St. Lucie Plant, Hutchinson Island, Florida. Dimensions represent conditions after velocity cap repairs completed in February 1992.

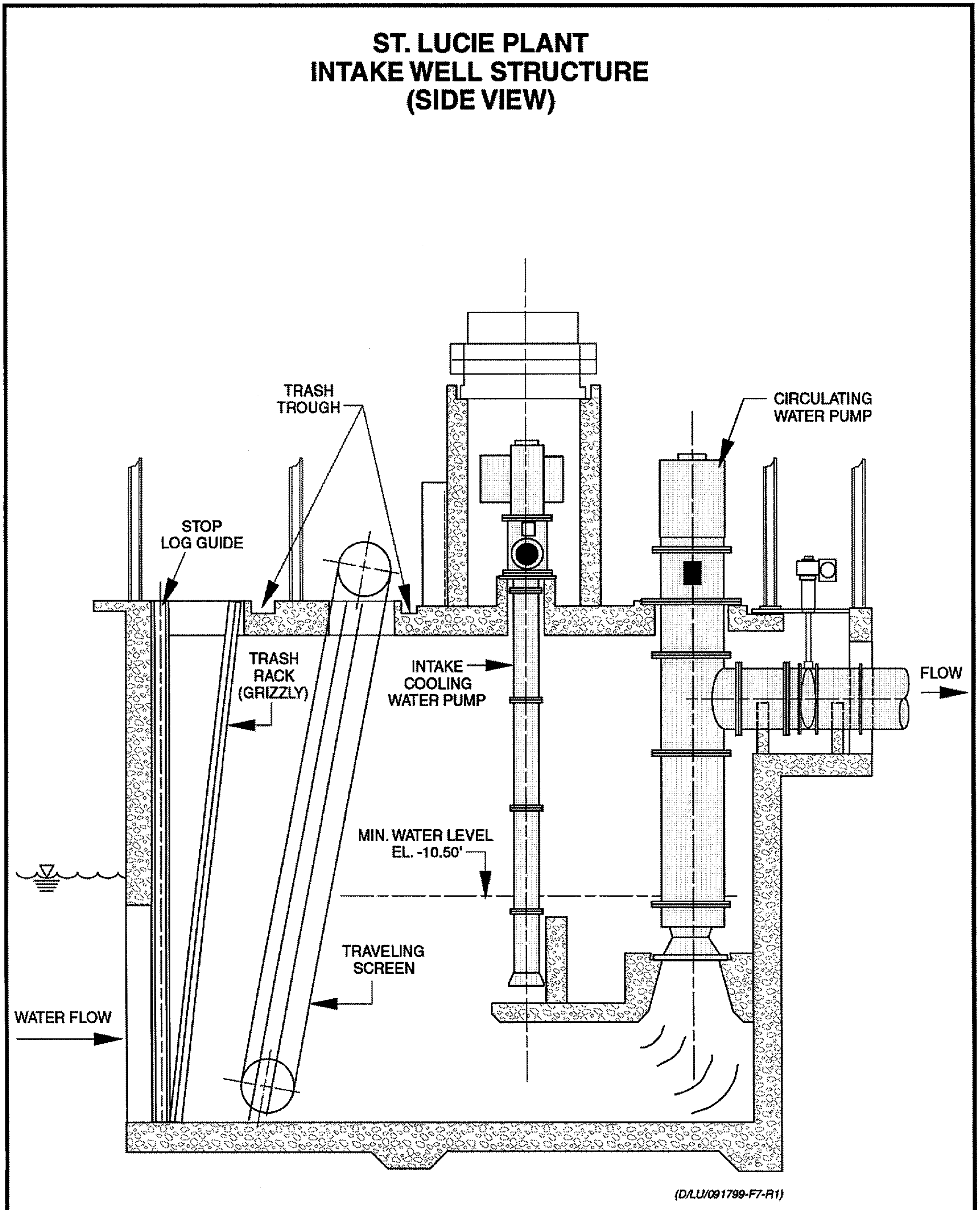

Figure 7. Diagram of an intake well at the St. Lucie Plant, Hutchinson Island, Florida.

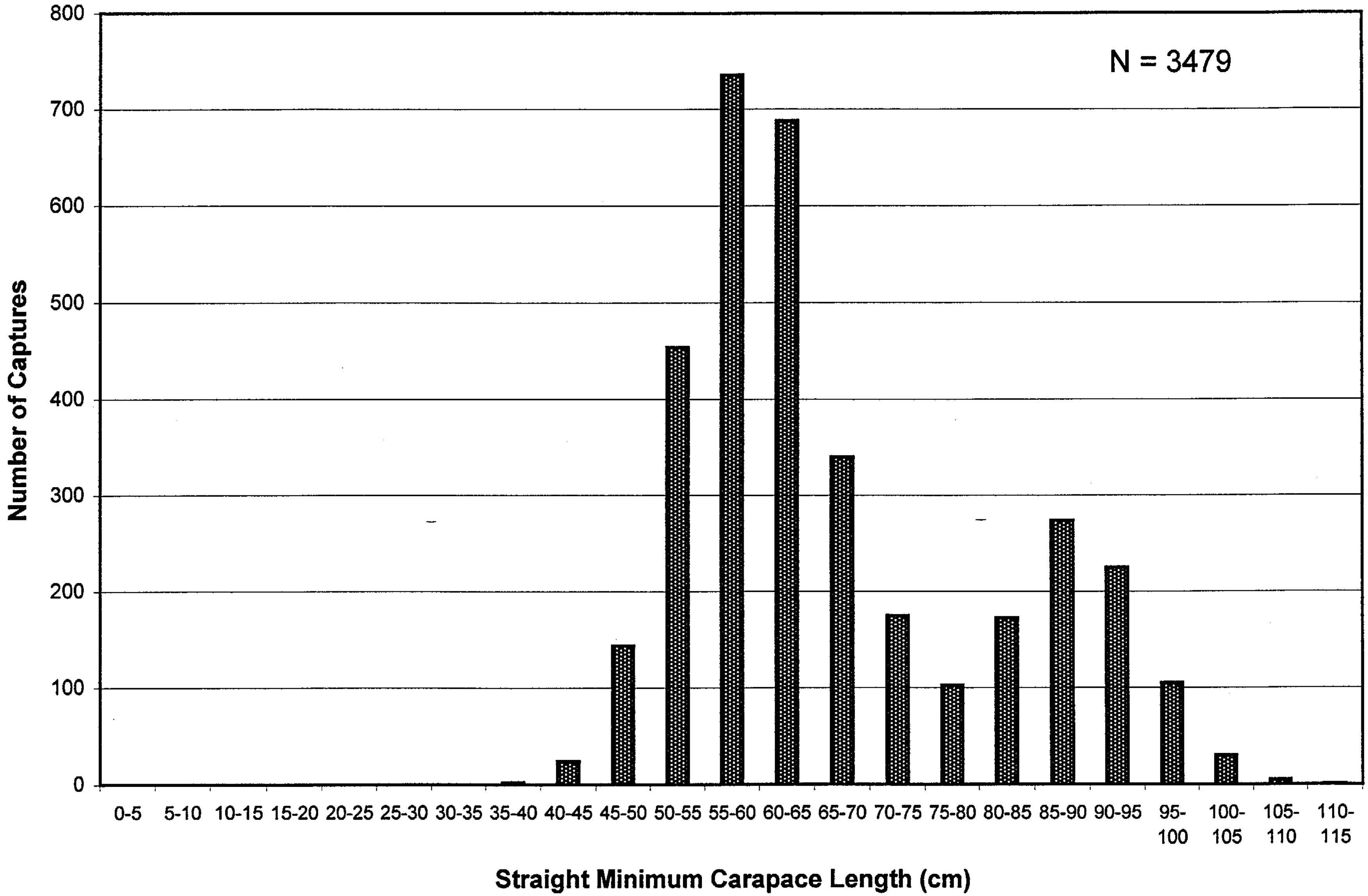

Figure 8. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

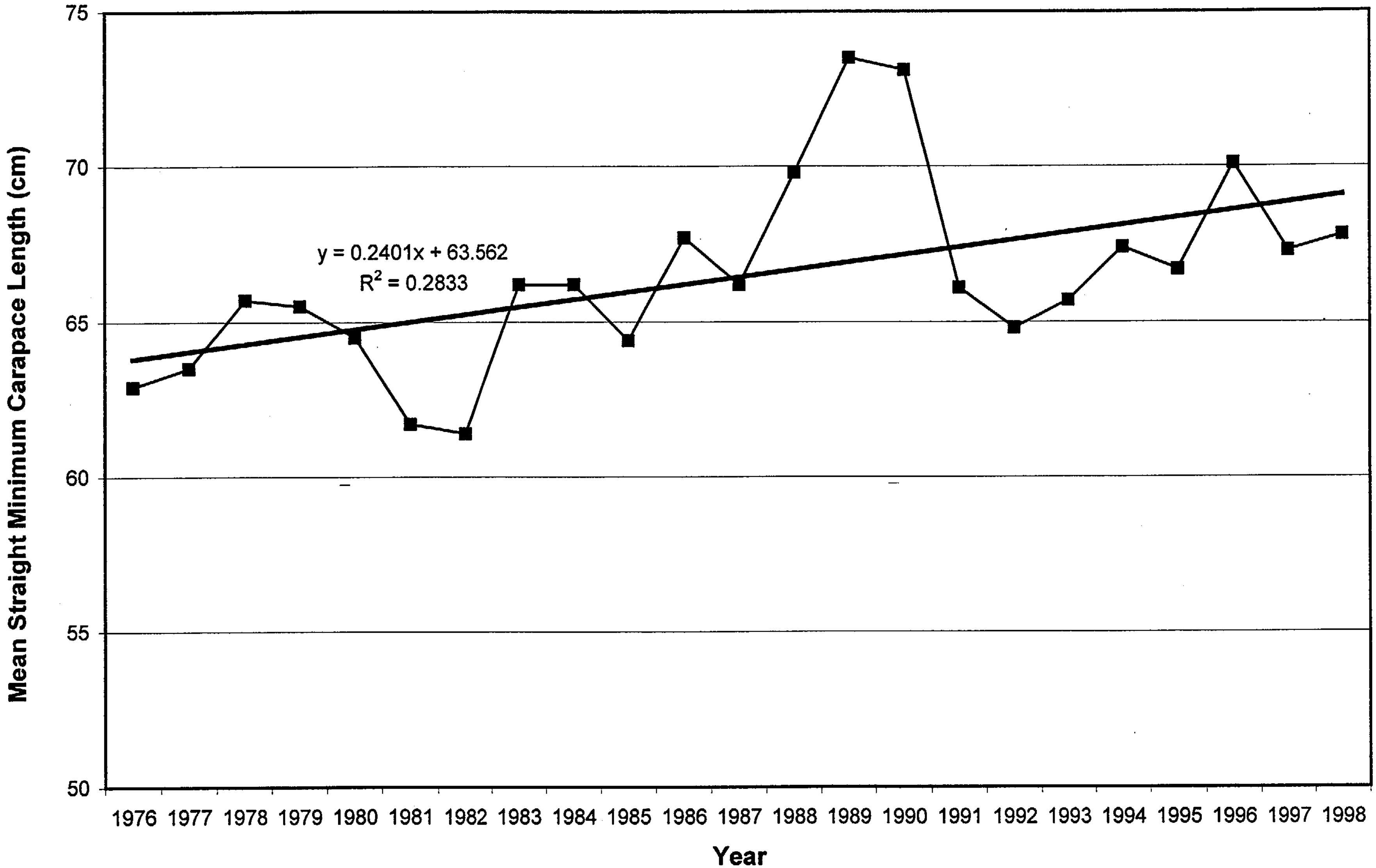

Figure 9. Mean size (straight minimum carapace length) of all loggerhead turtles captured each year in the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

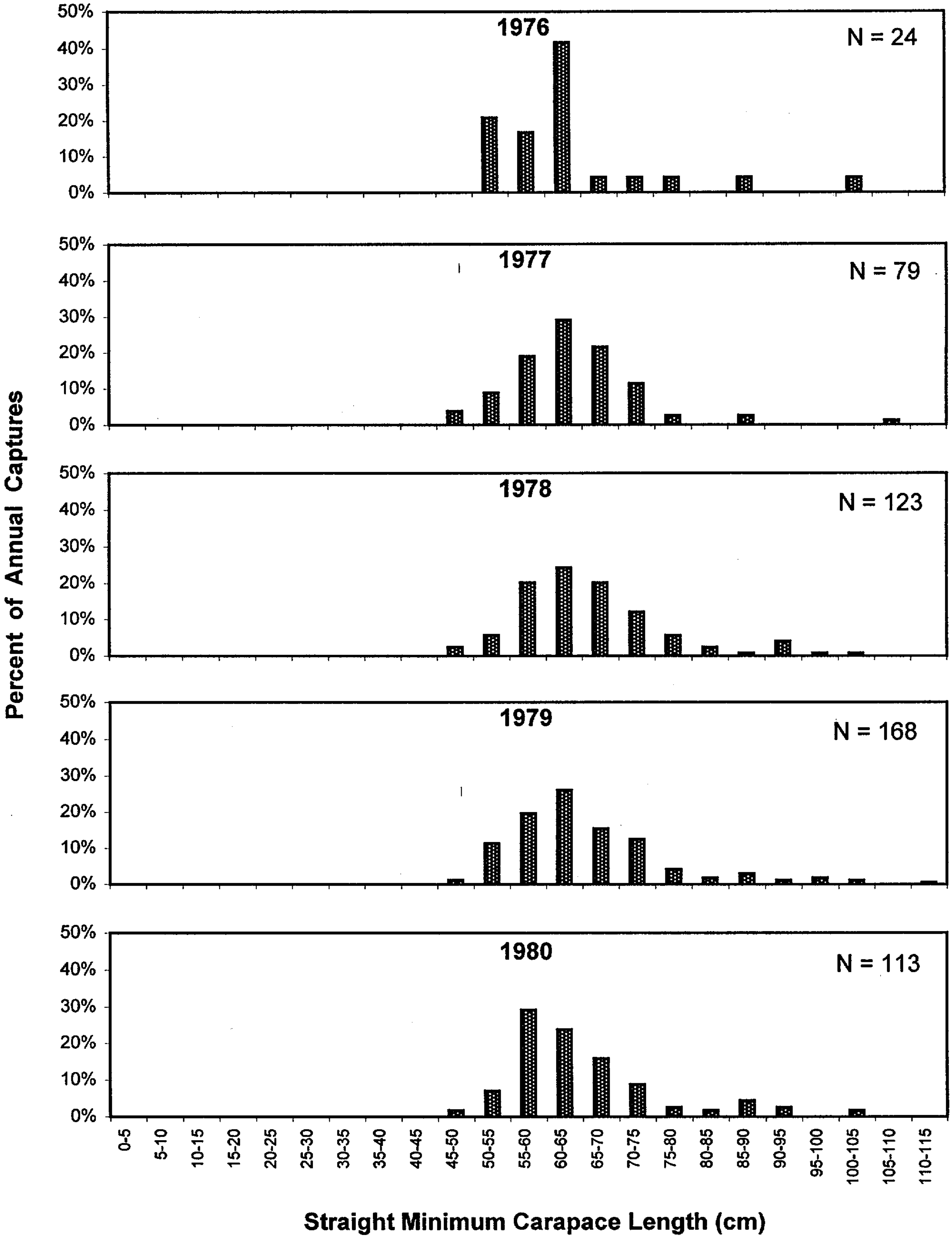

Figure 10. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1980.

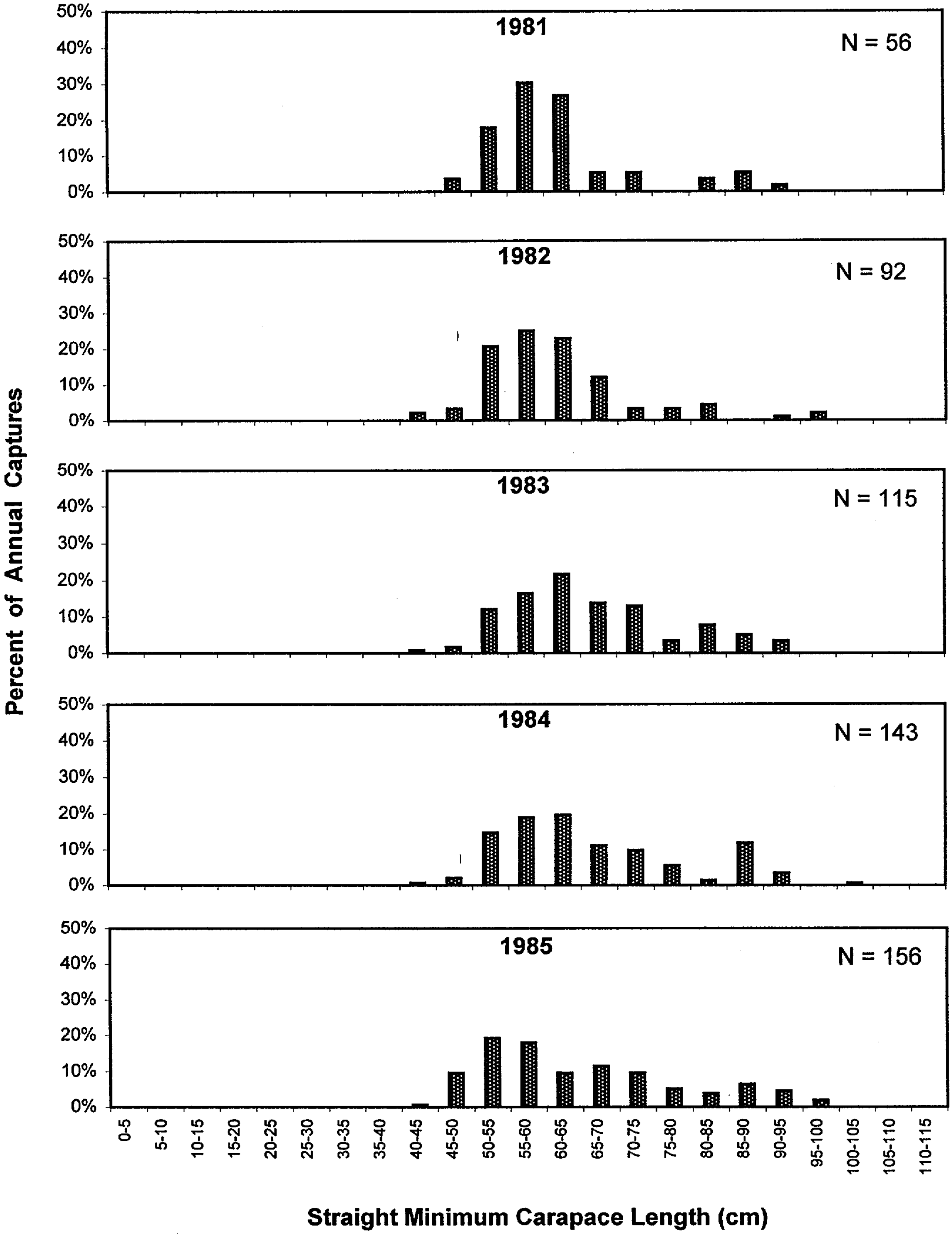

Figure 11. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1981-1985.

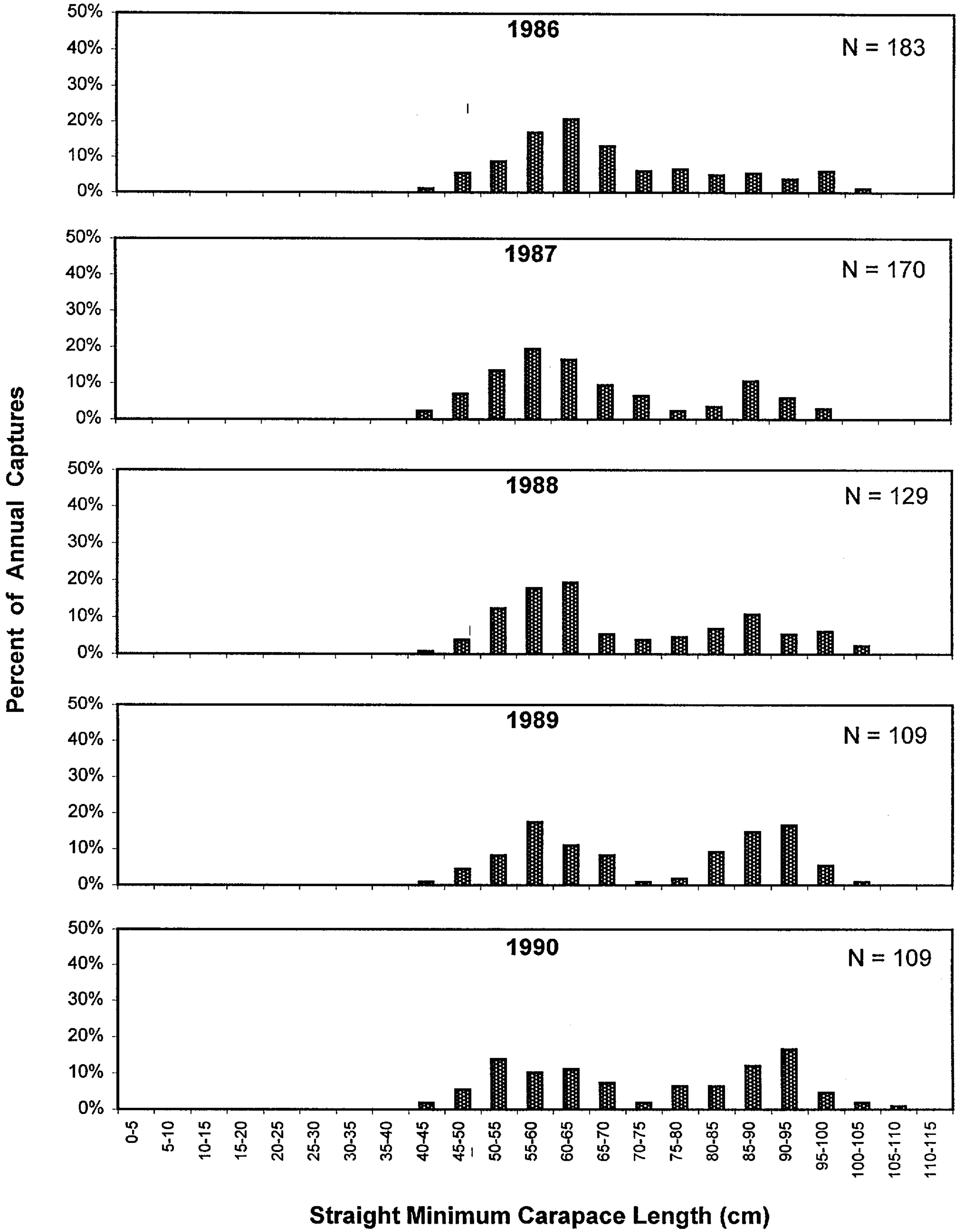

Figure 12. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1986-1990.

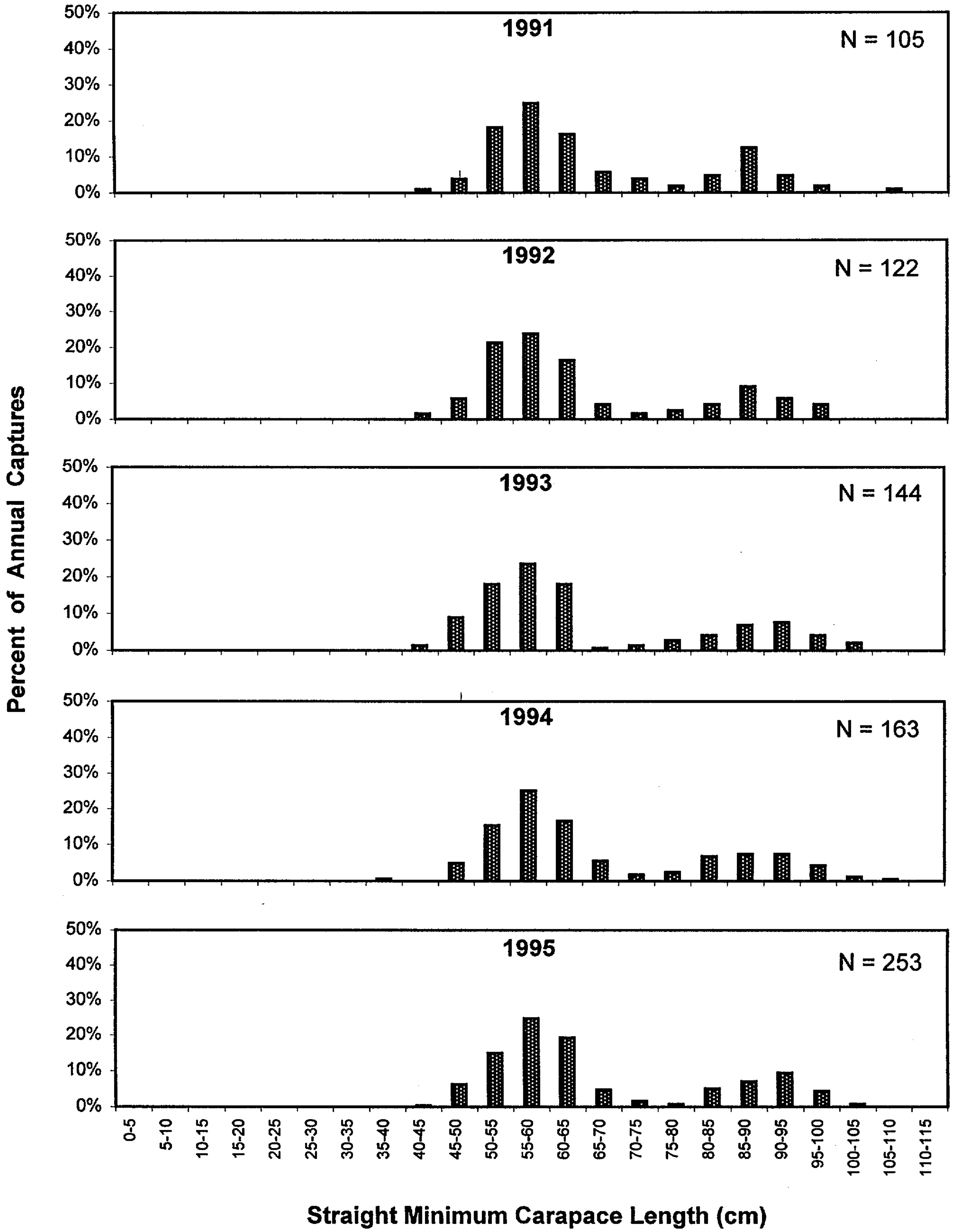

Figure 13. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1991-1995.

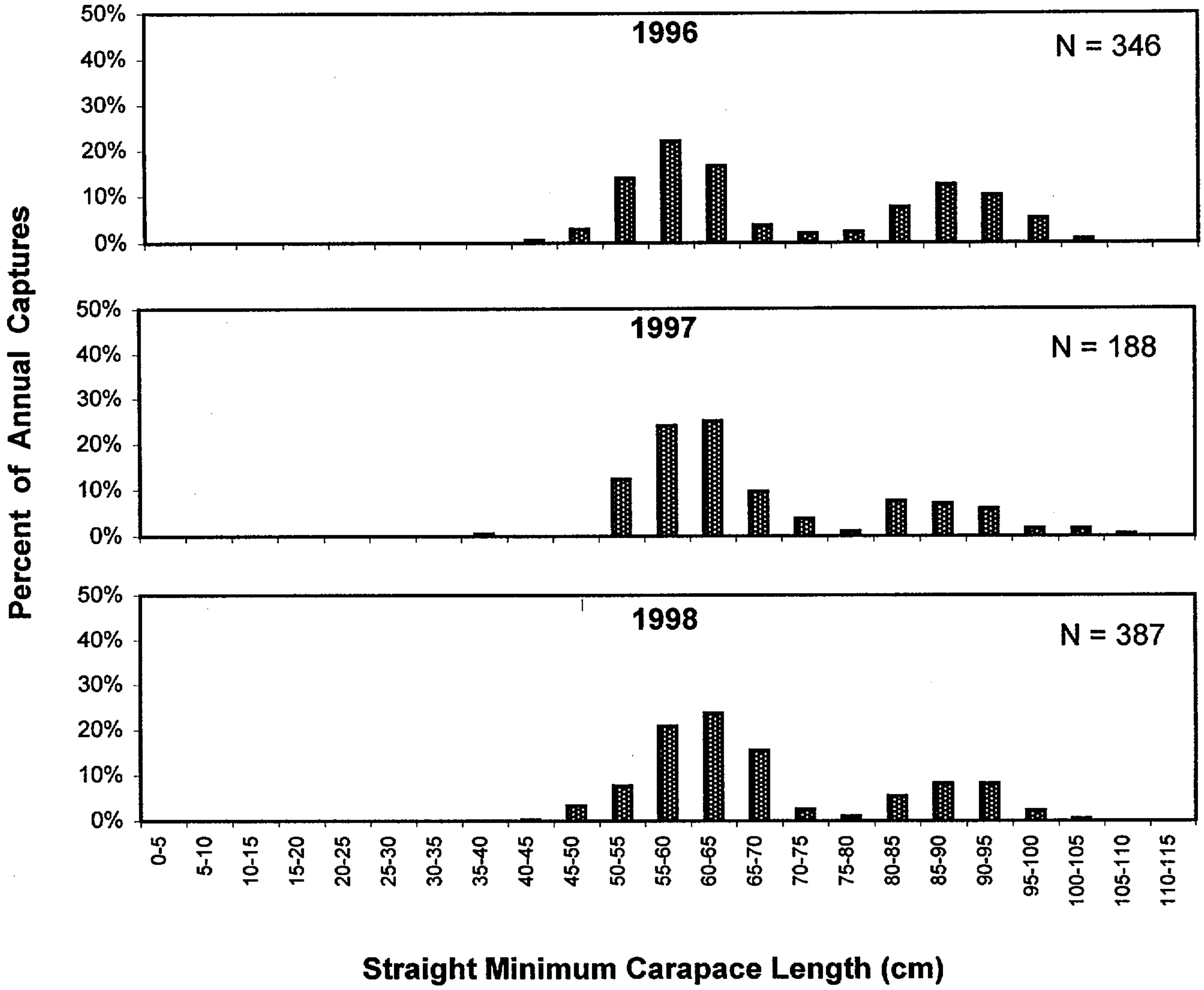

Figure 14. Distribution of straight minimum carapace length measurements for loggerhead turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1996-1998.

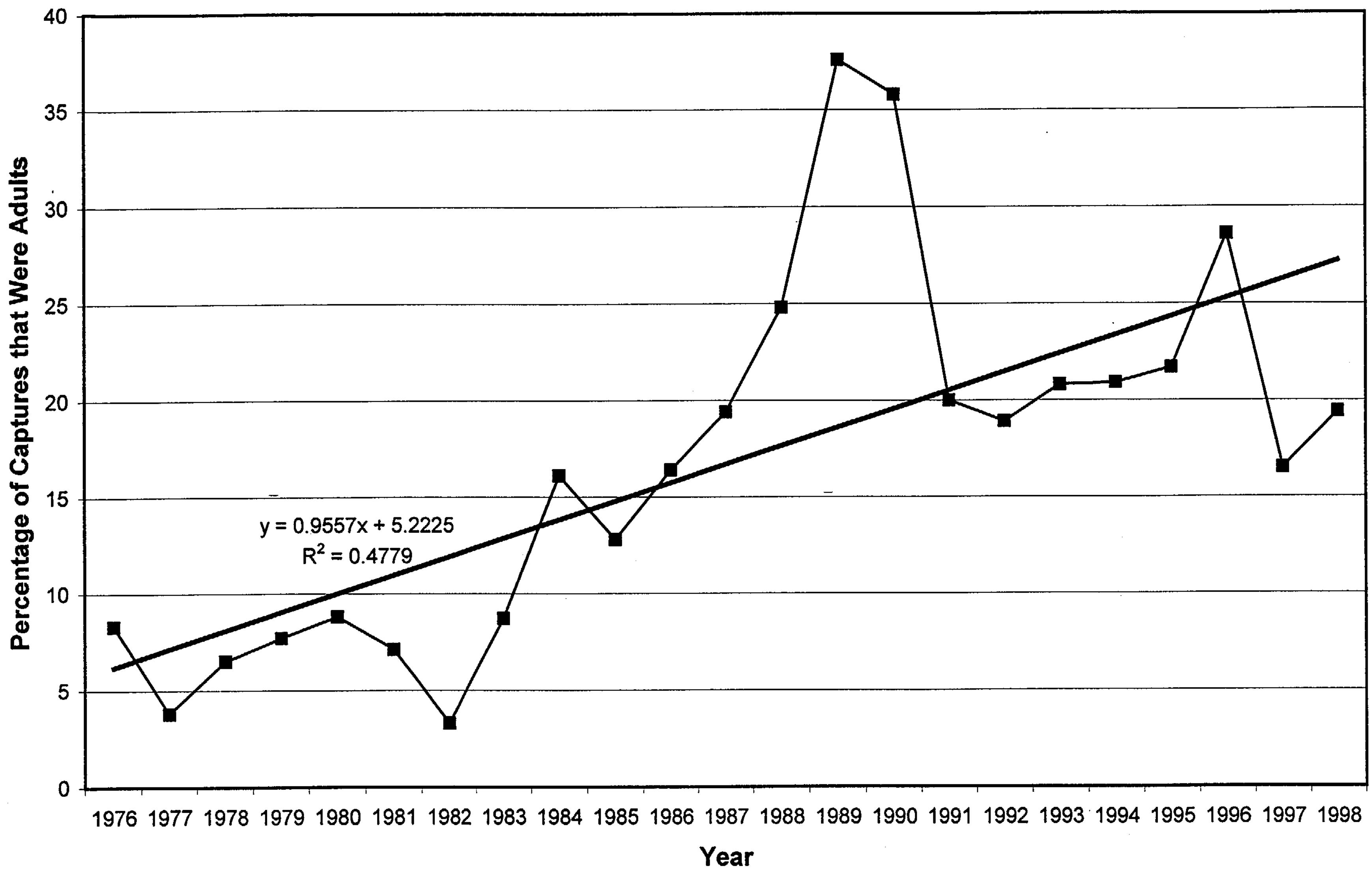

Figure 15. Percentage of annual loggerhead captures that were adults, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

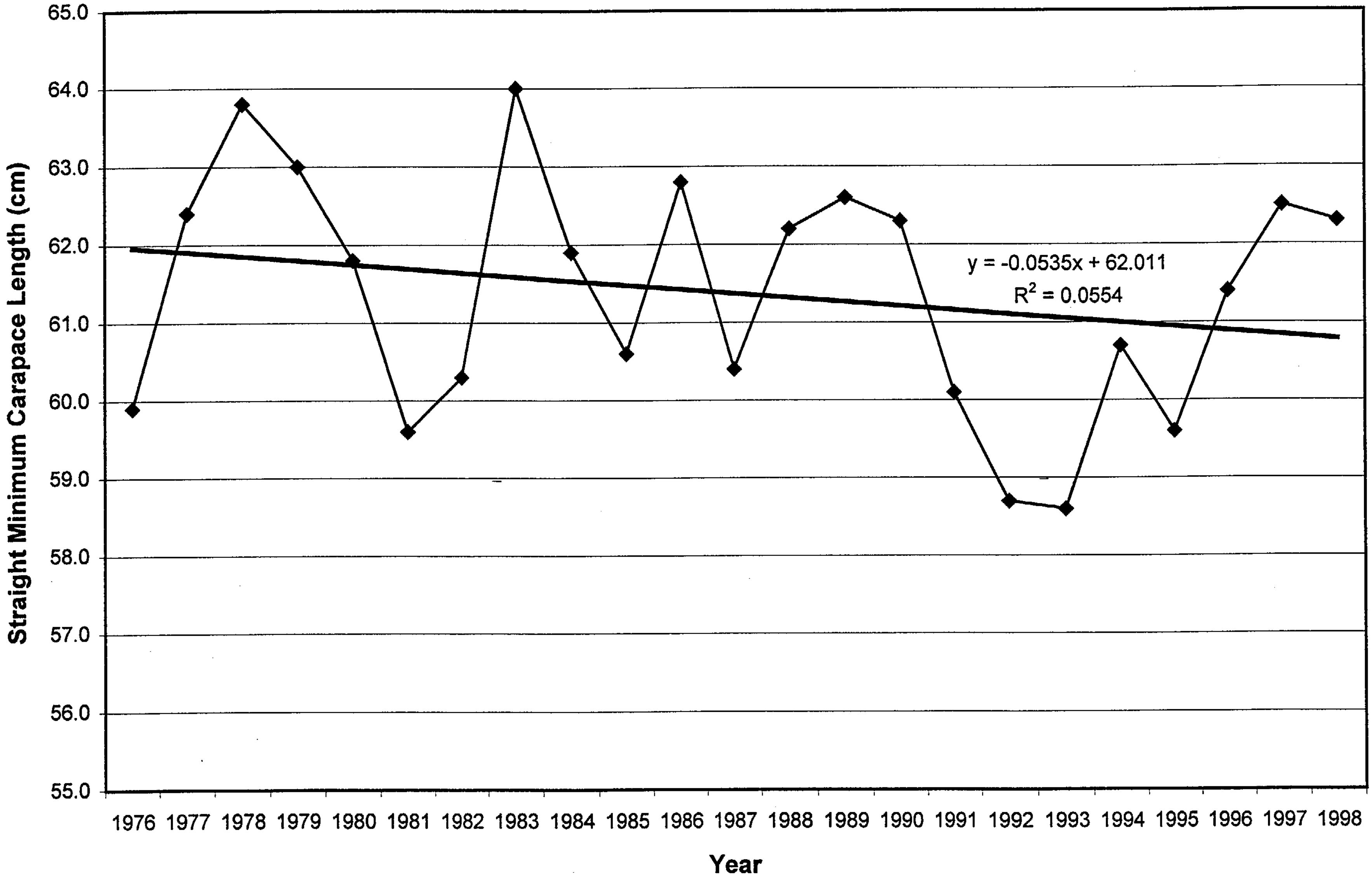

Figure 16. Mean size (straight minimum carapace length) of immature loggerhead turtles captured each year in the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

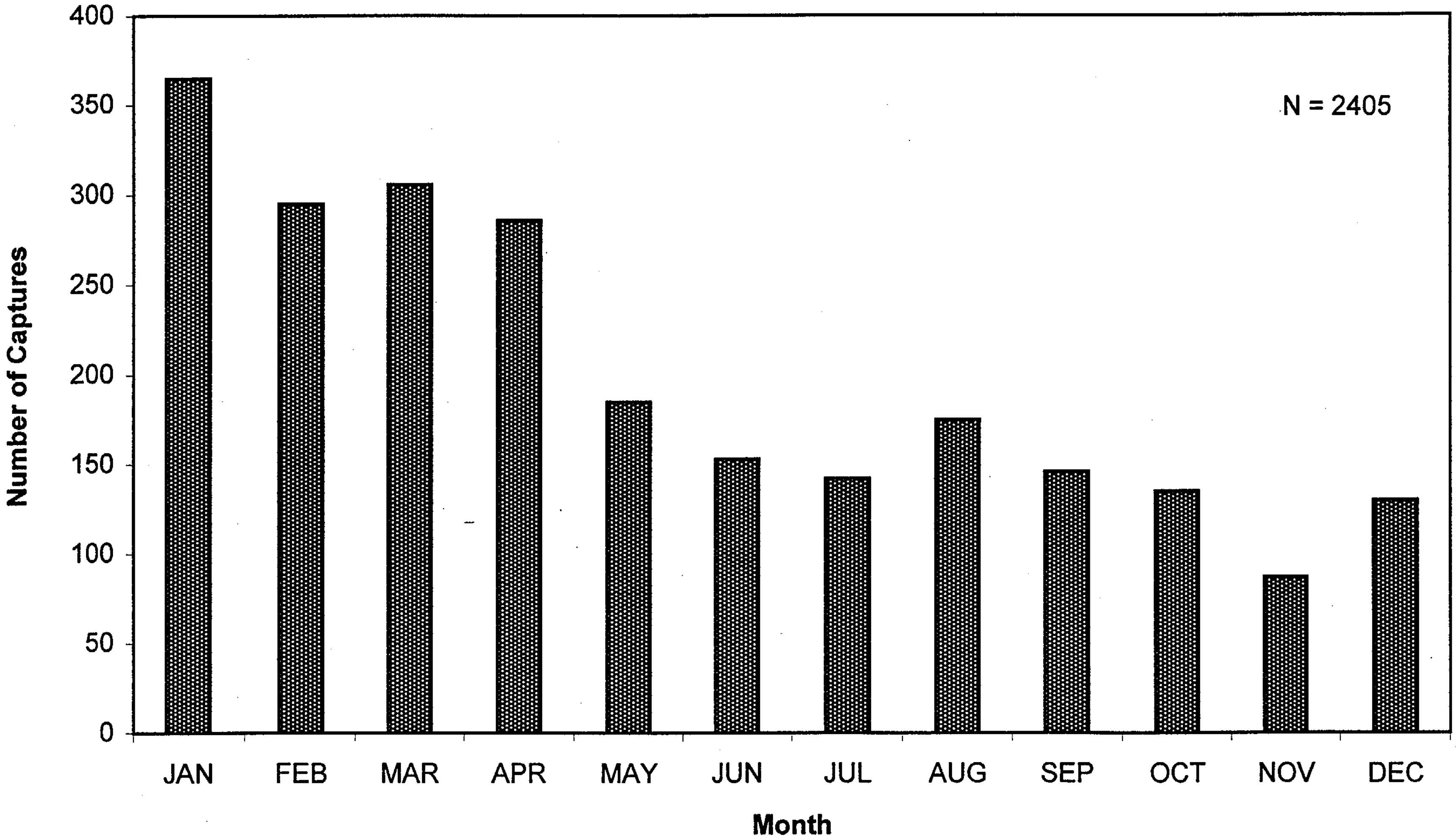

Figure 17. Number of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

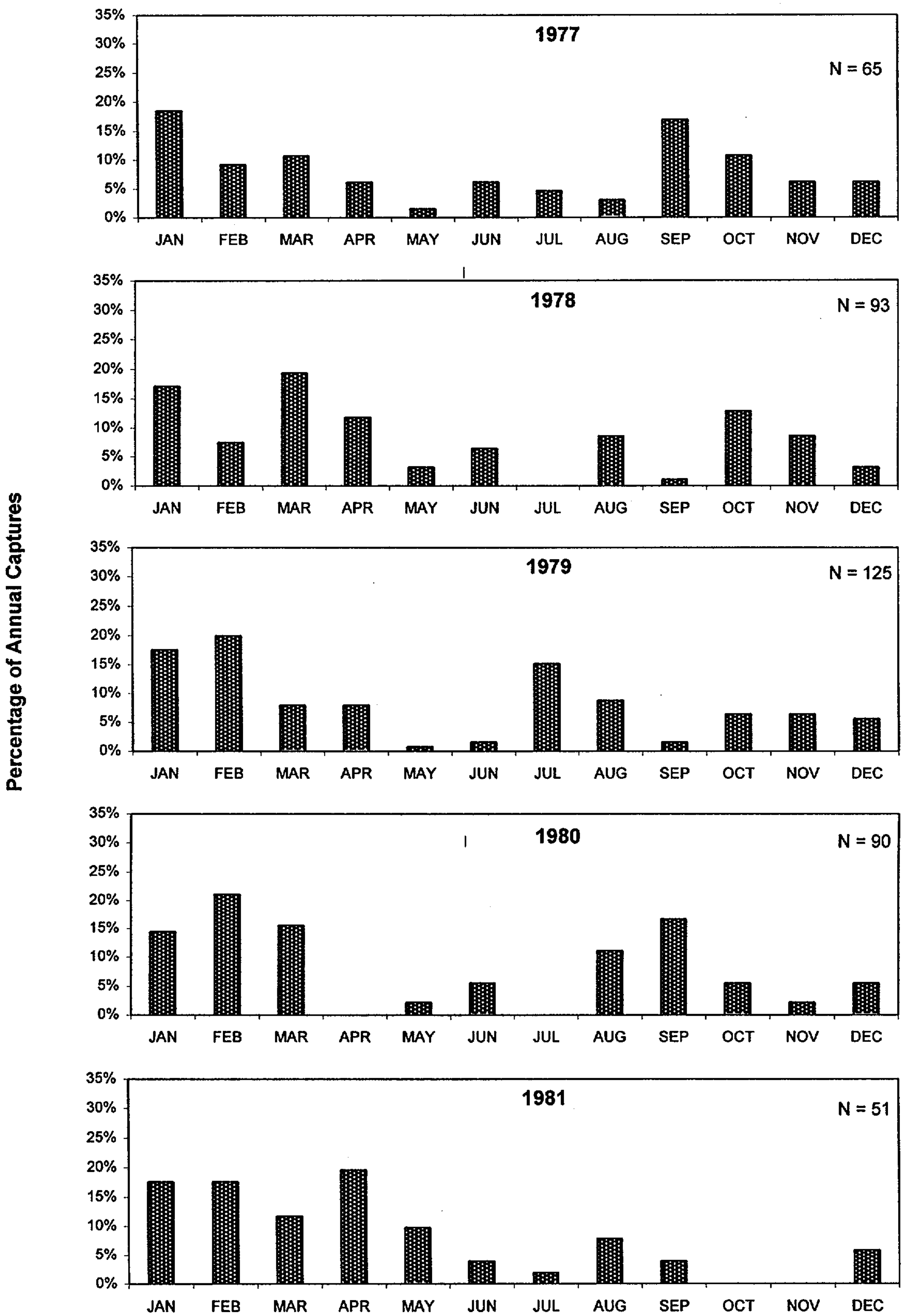

Figure 18. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

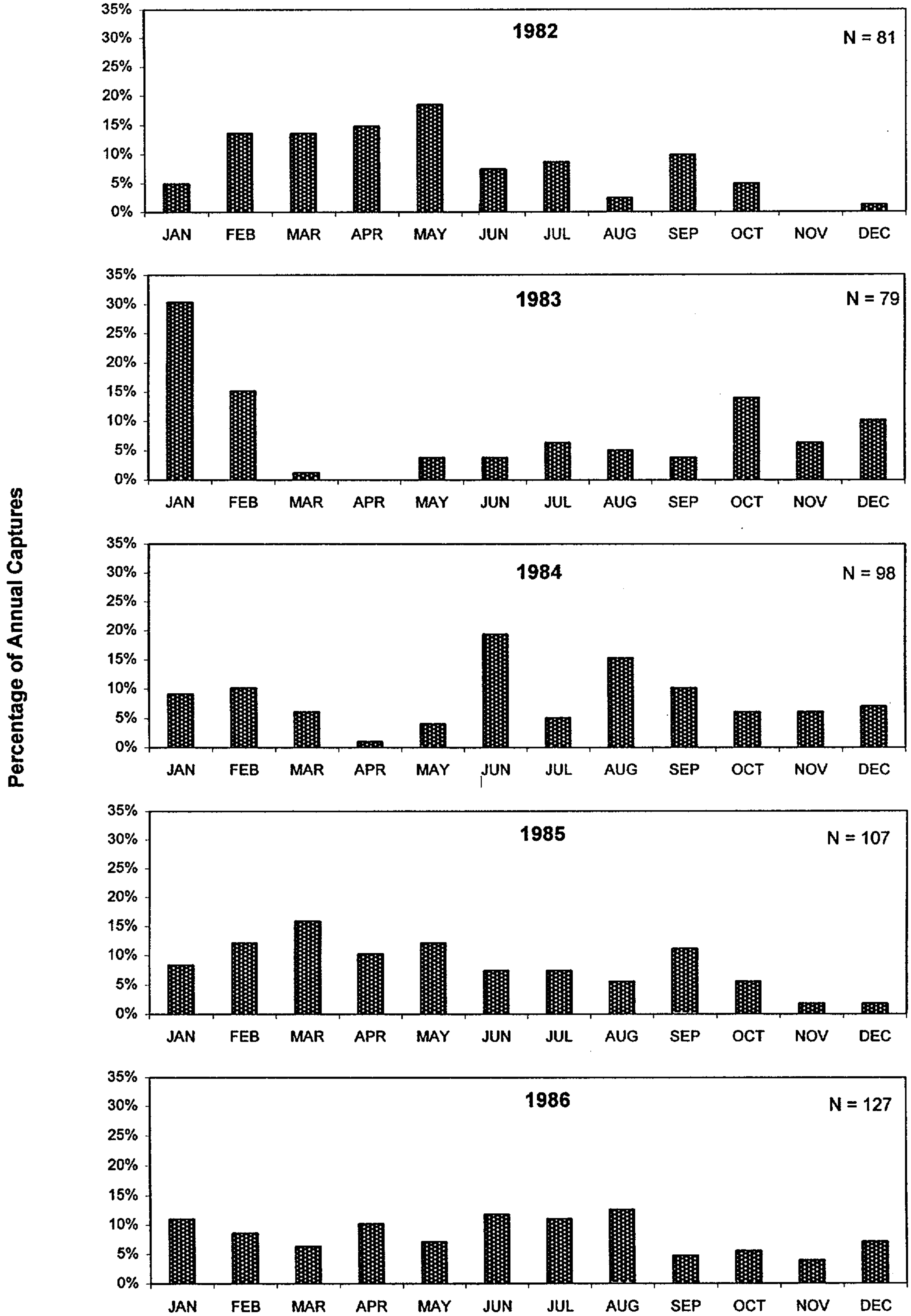

Figure 19. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

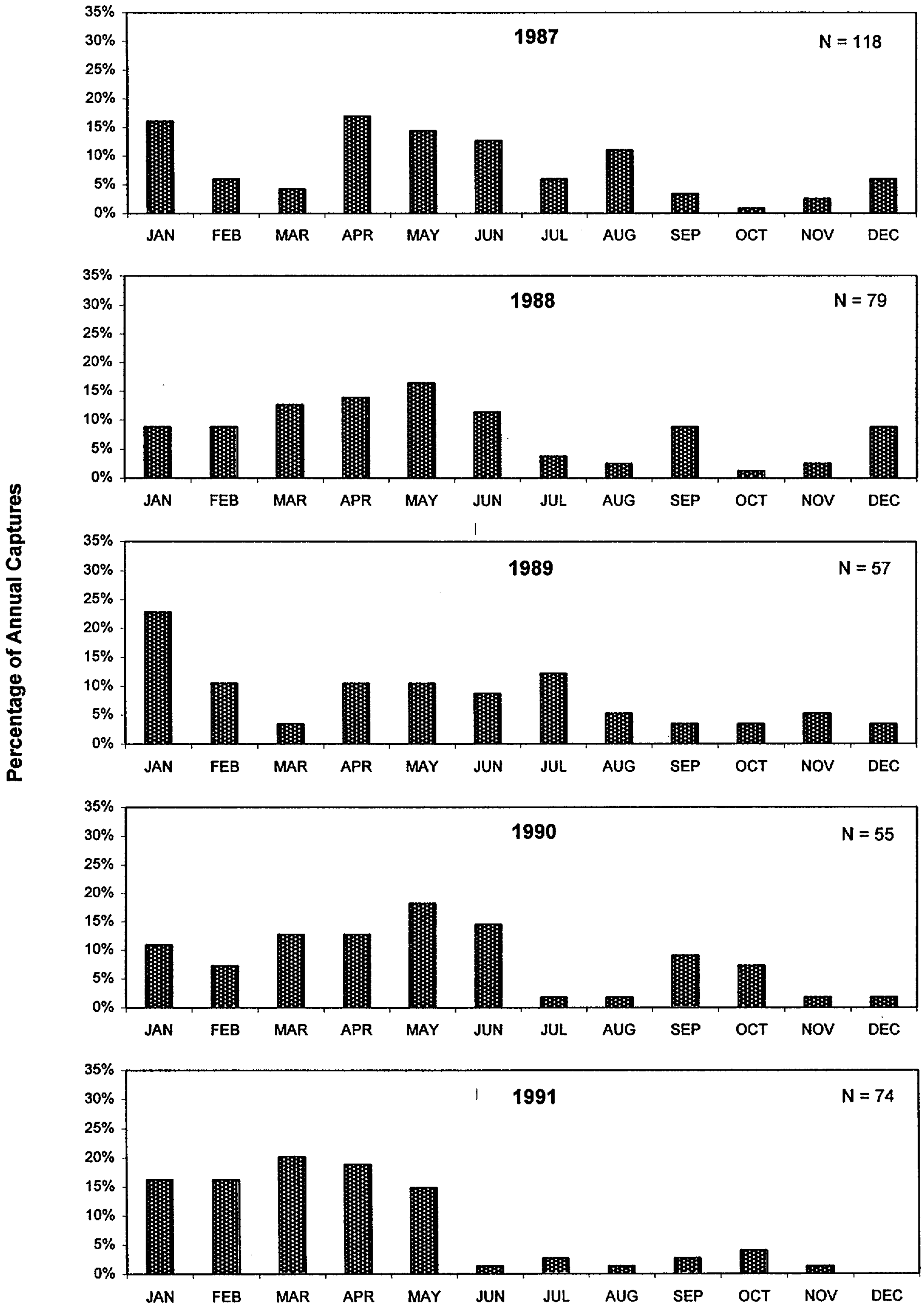

Figure 20. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

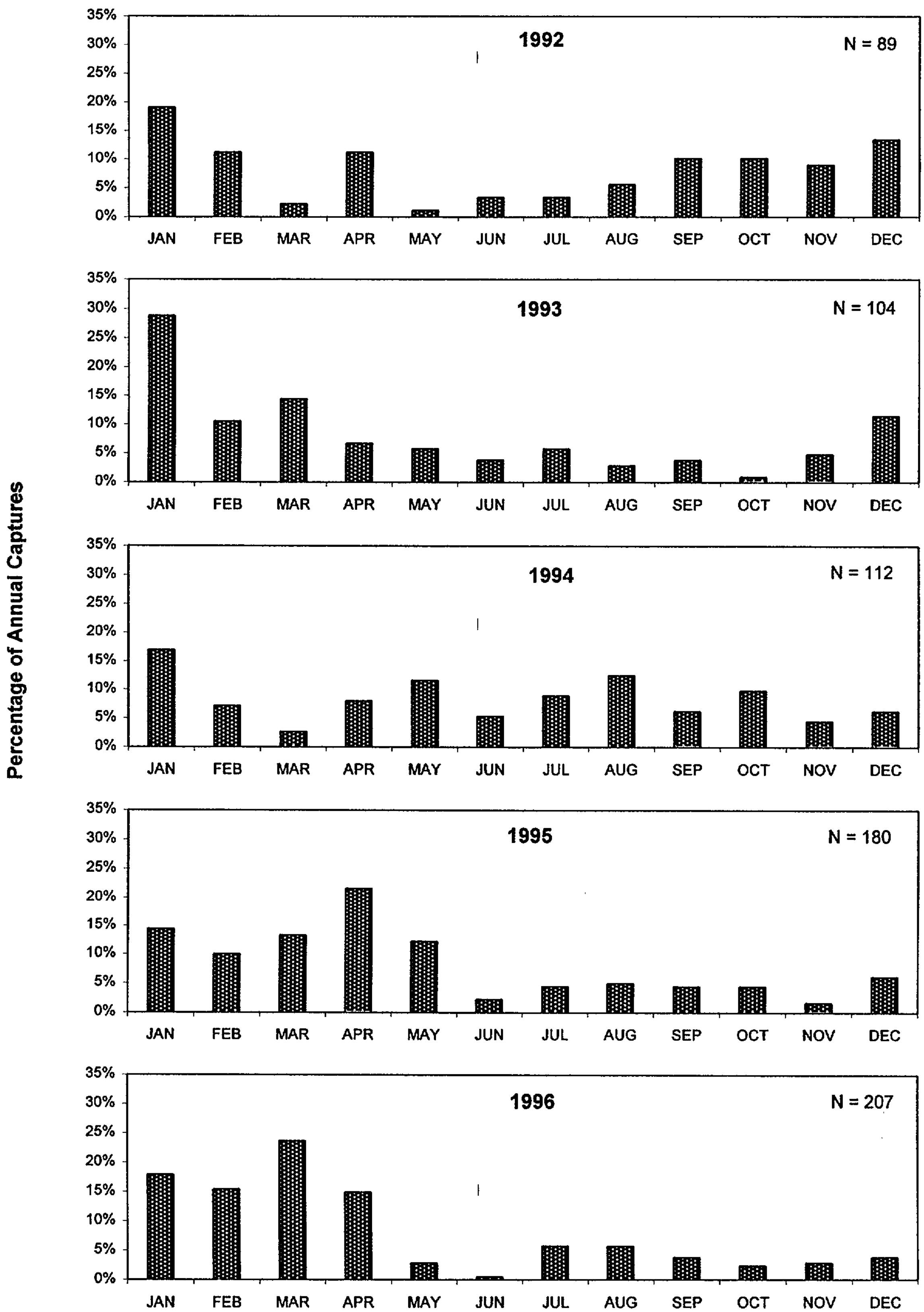

Figure 21. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

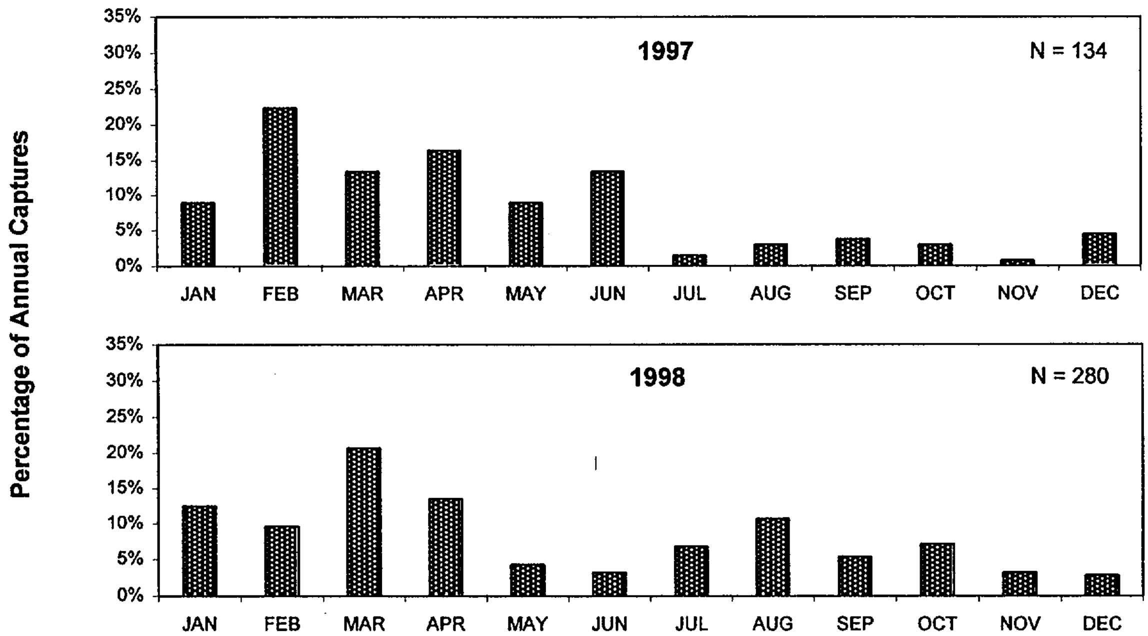

Figure 22. Percentage of juvenile loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

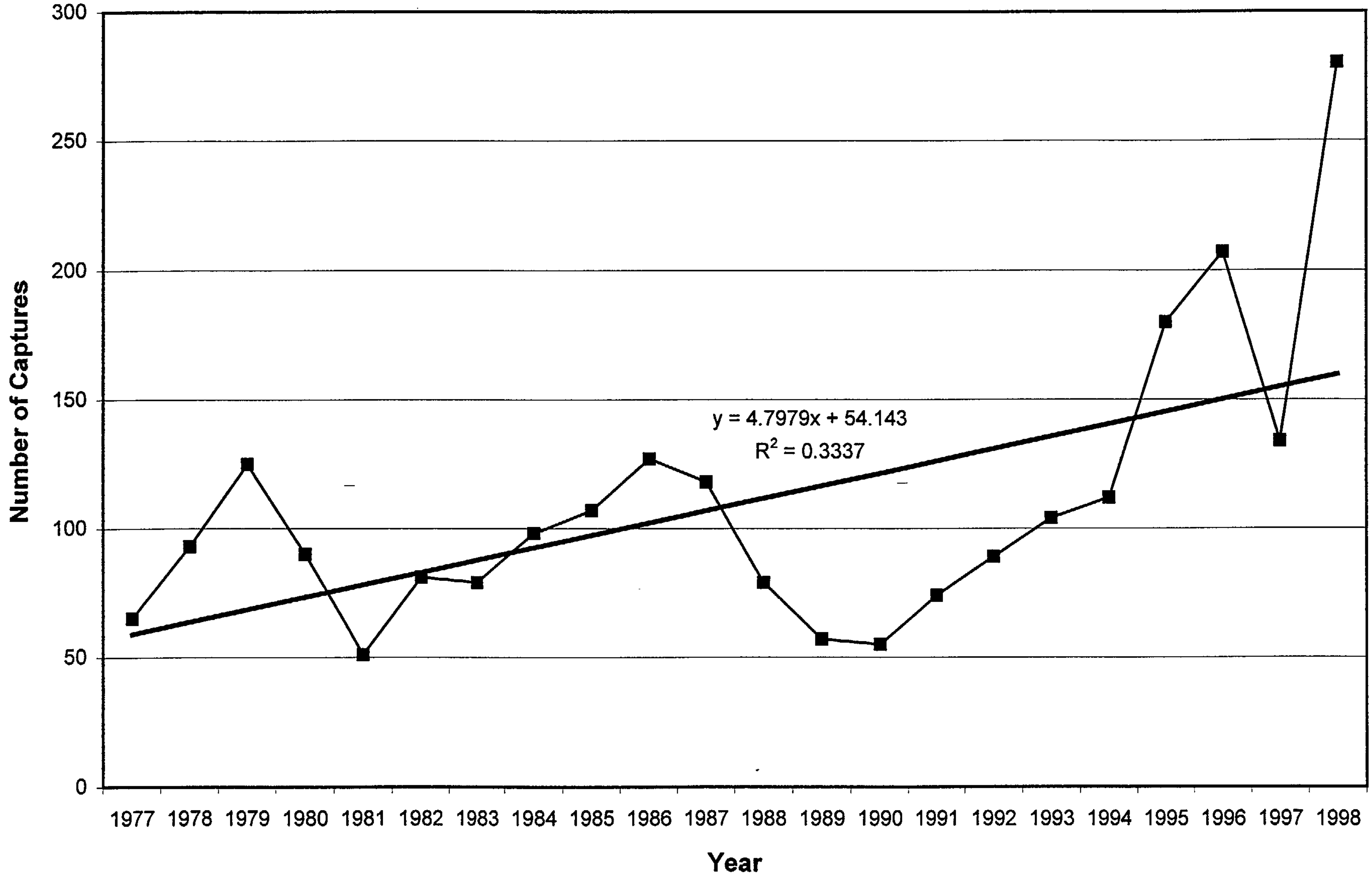

Figure 23. Annual number of juvenile loggerhead captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

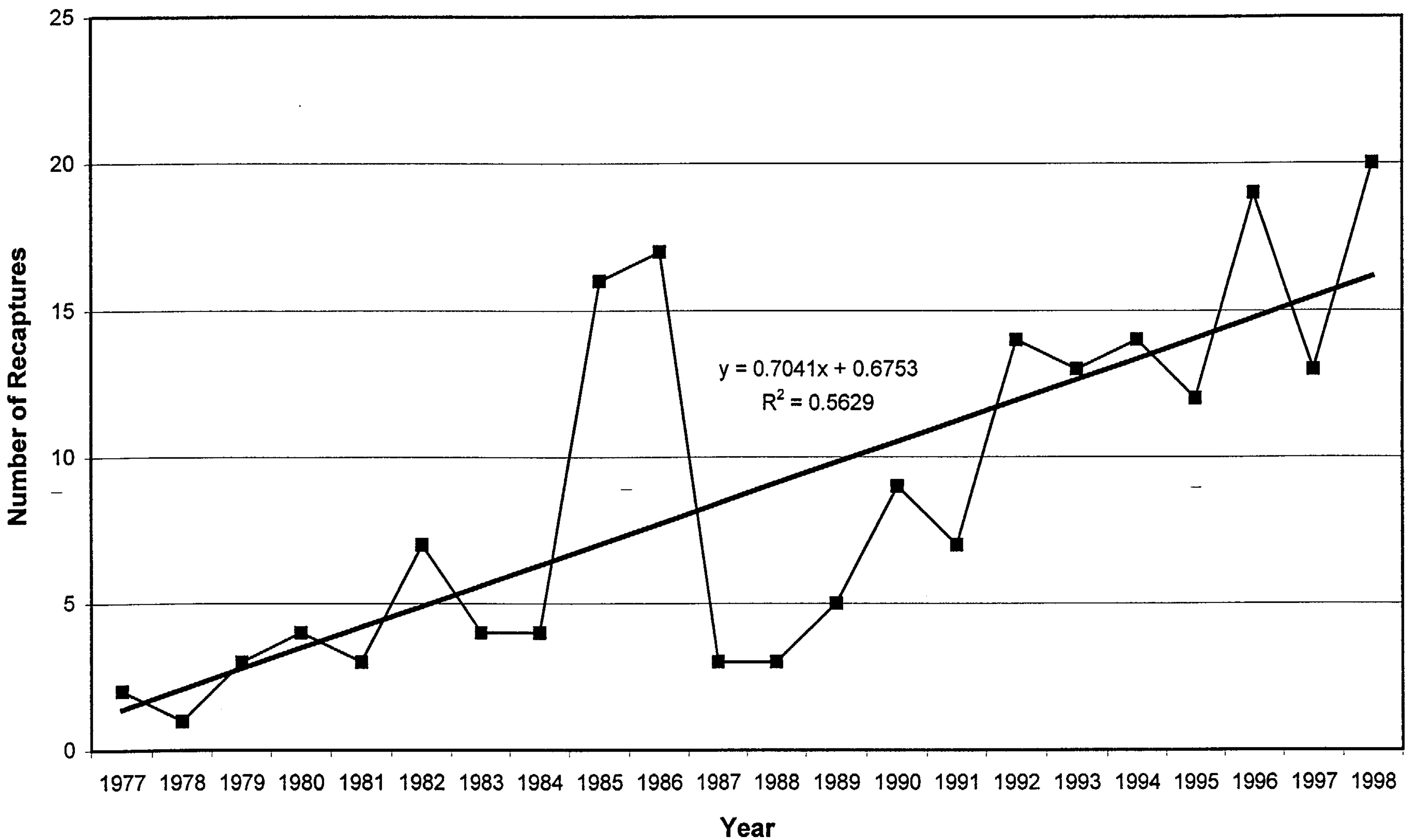

Figure 24. Annual number of juvenile loggerhead recaptures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

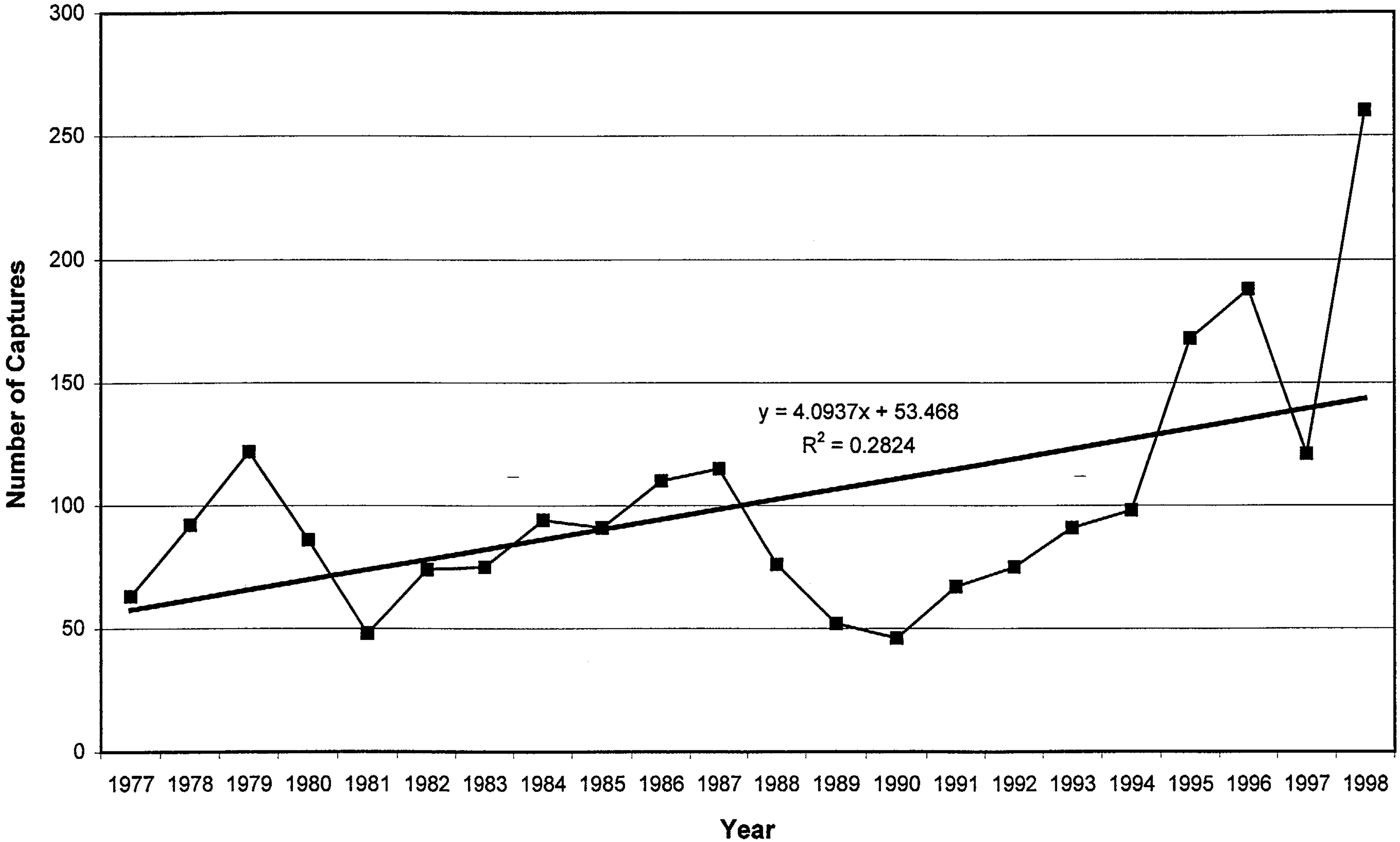

Figure 25. Annual number of juvenile loggerhead captures excluding recaptures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

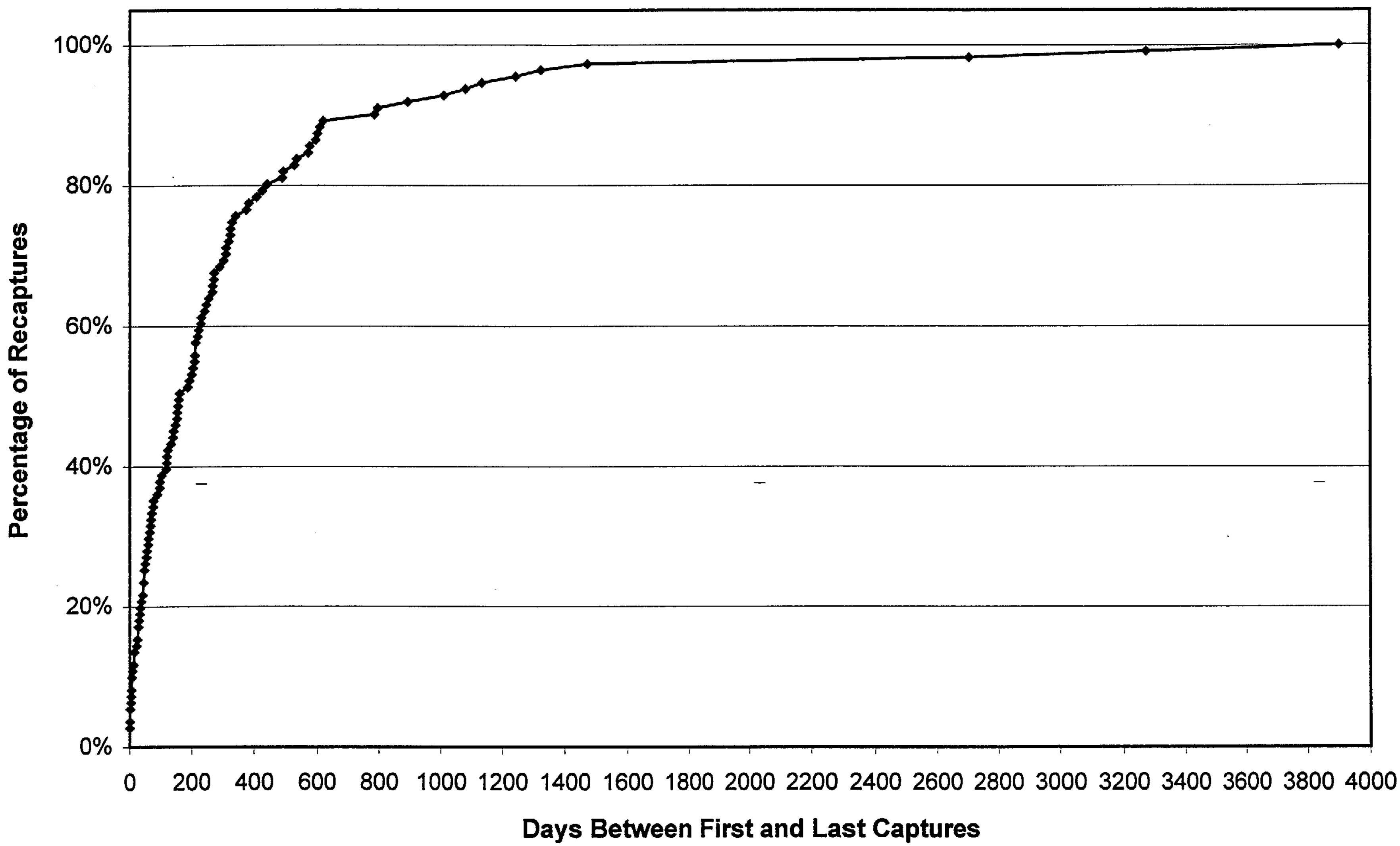

Figure 26. The percentage of juvenile loggerhead recaptures that occurred within each time interval between first and last capture, St. Lucie Plant intake canal, Hutchinson Island, Florida.

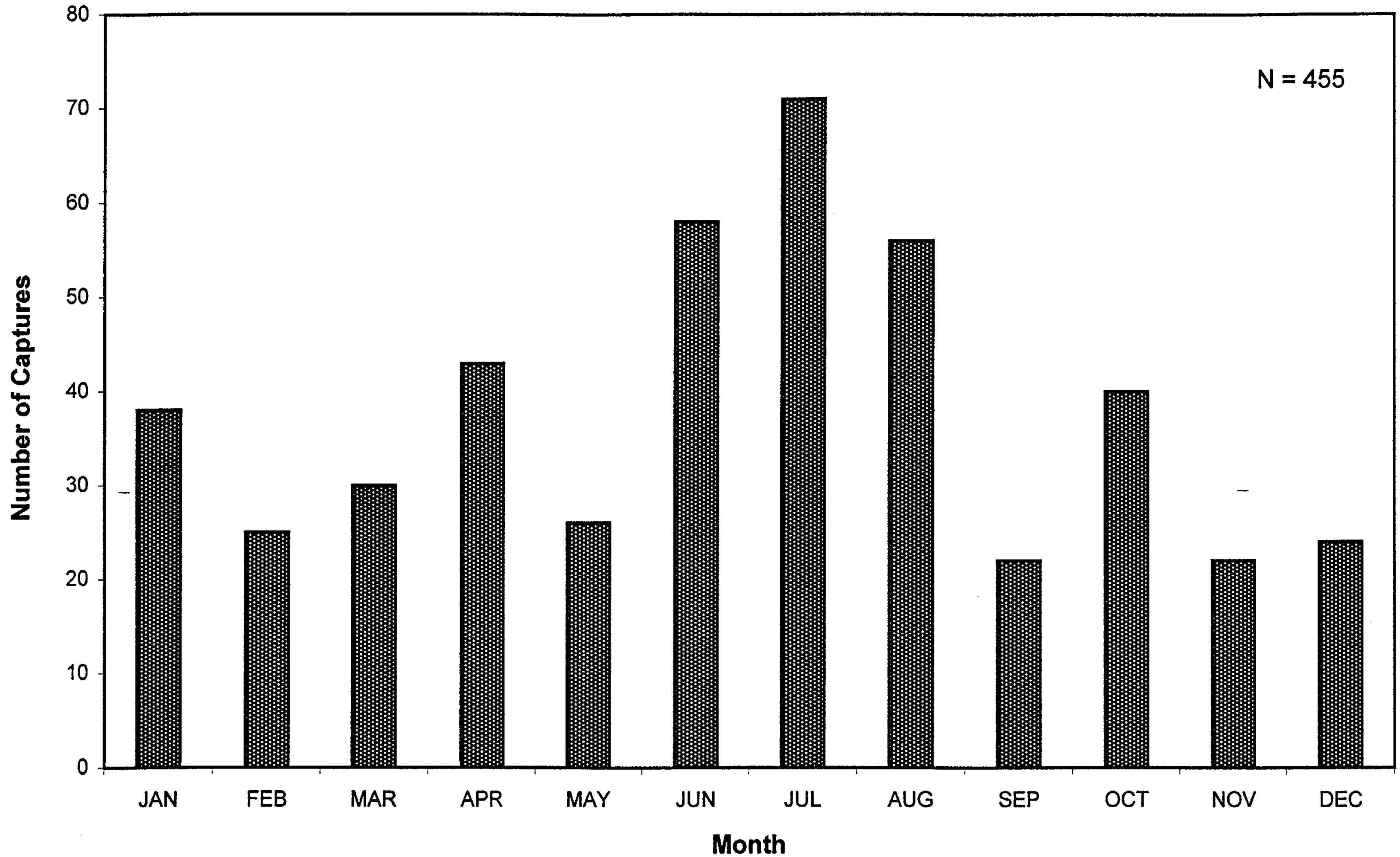

Figure 27. Number of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

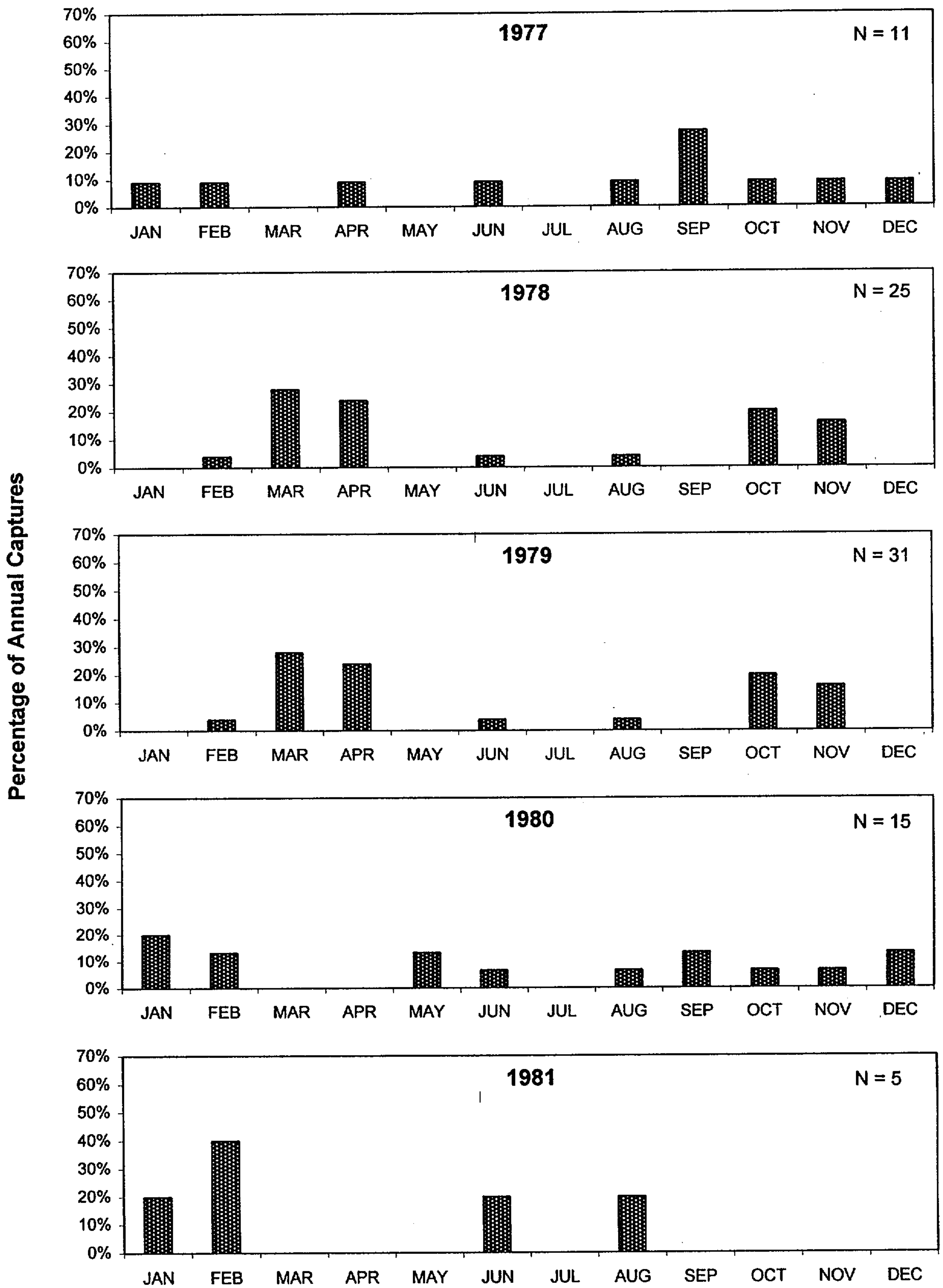

Figure 28. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

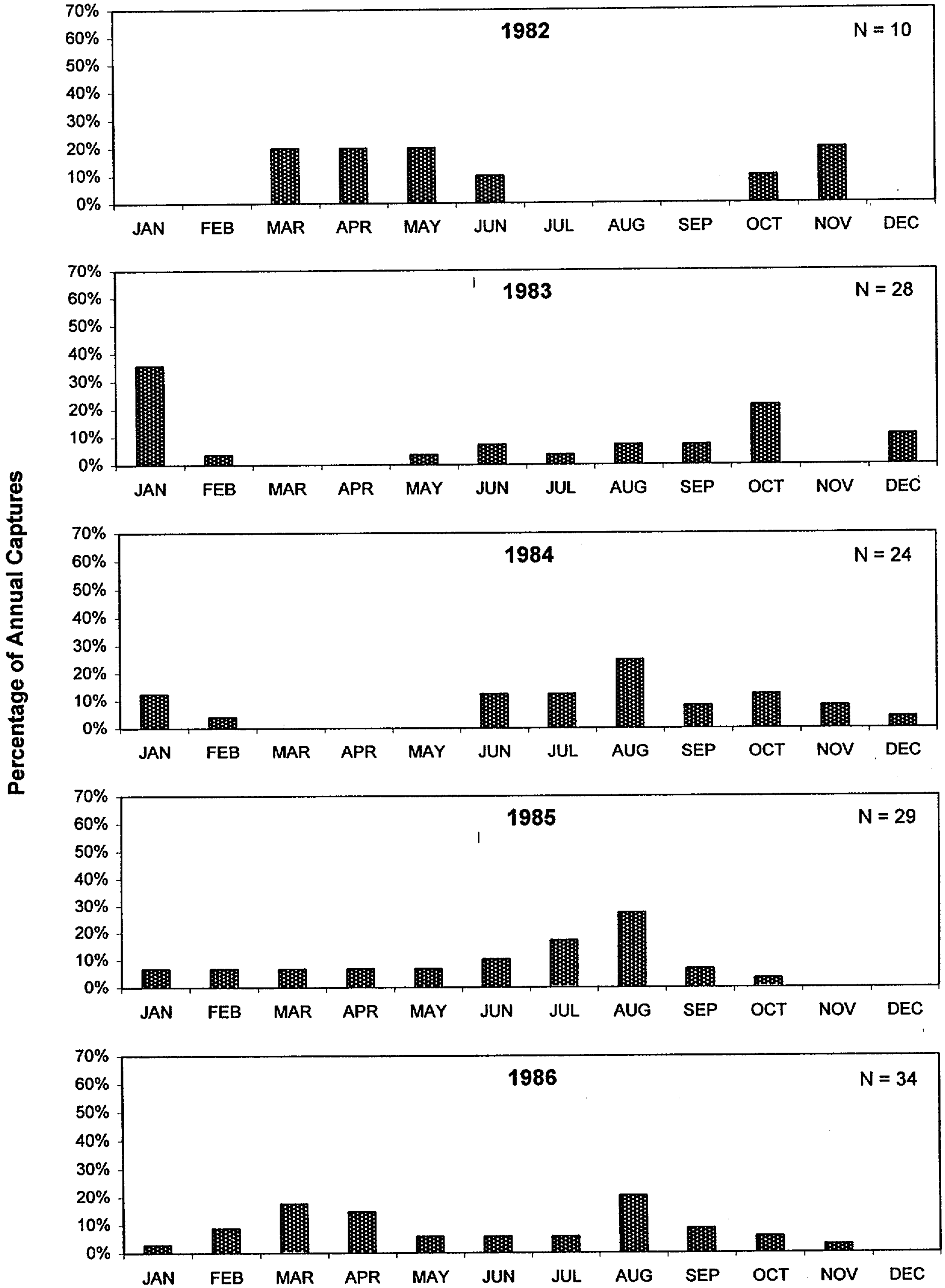

Figure 29. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

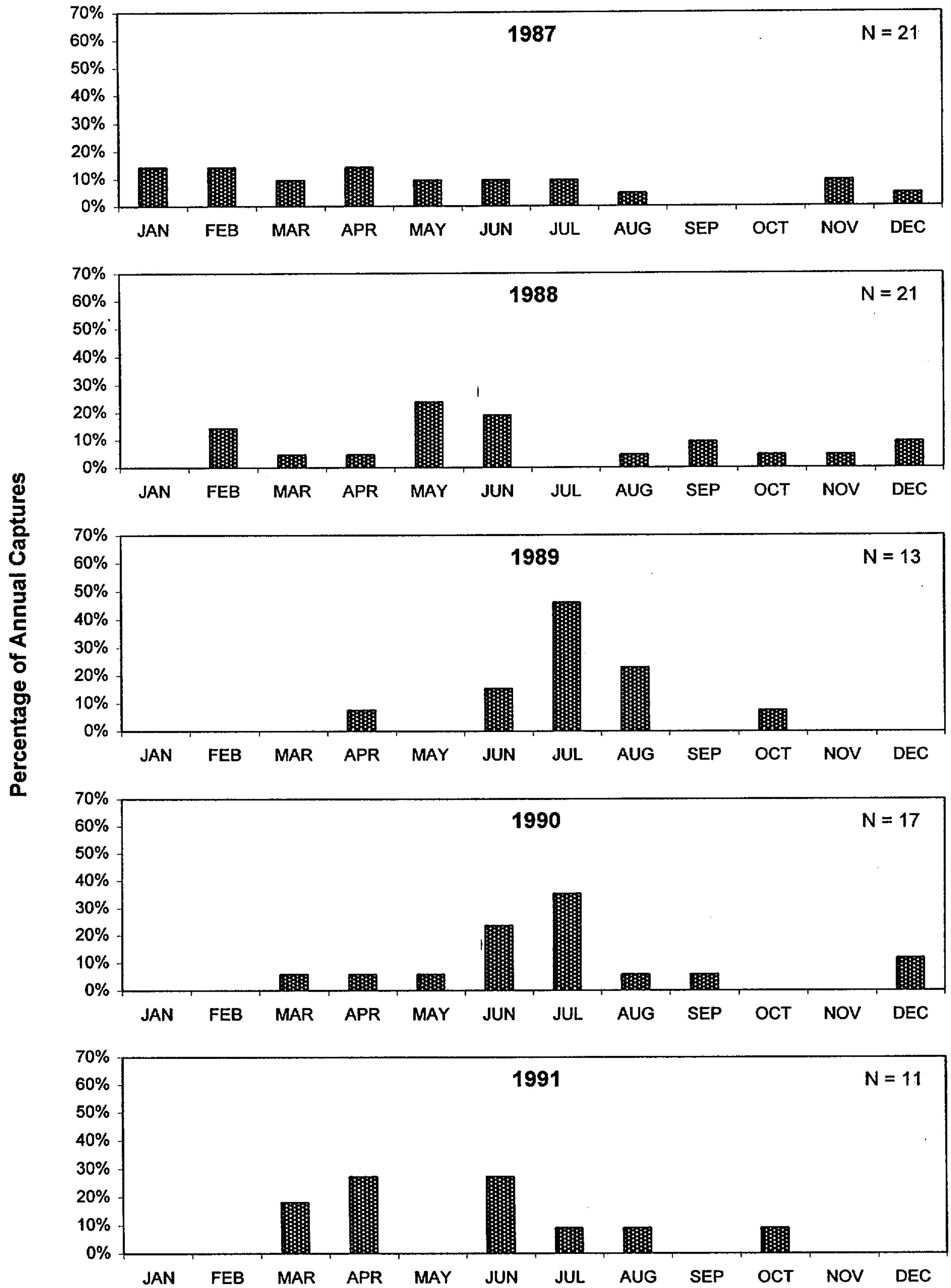

Figure 30. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

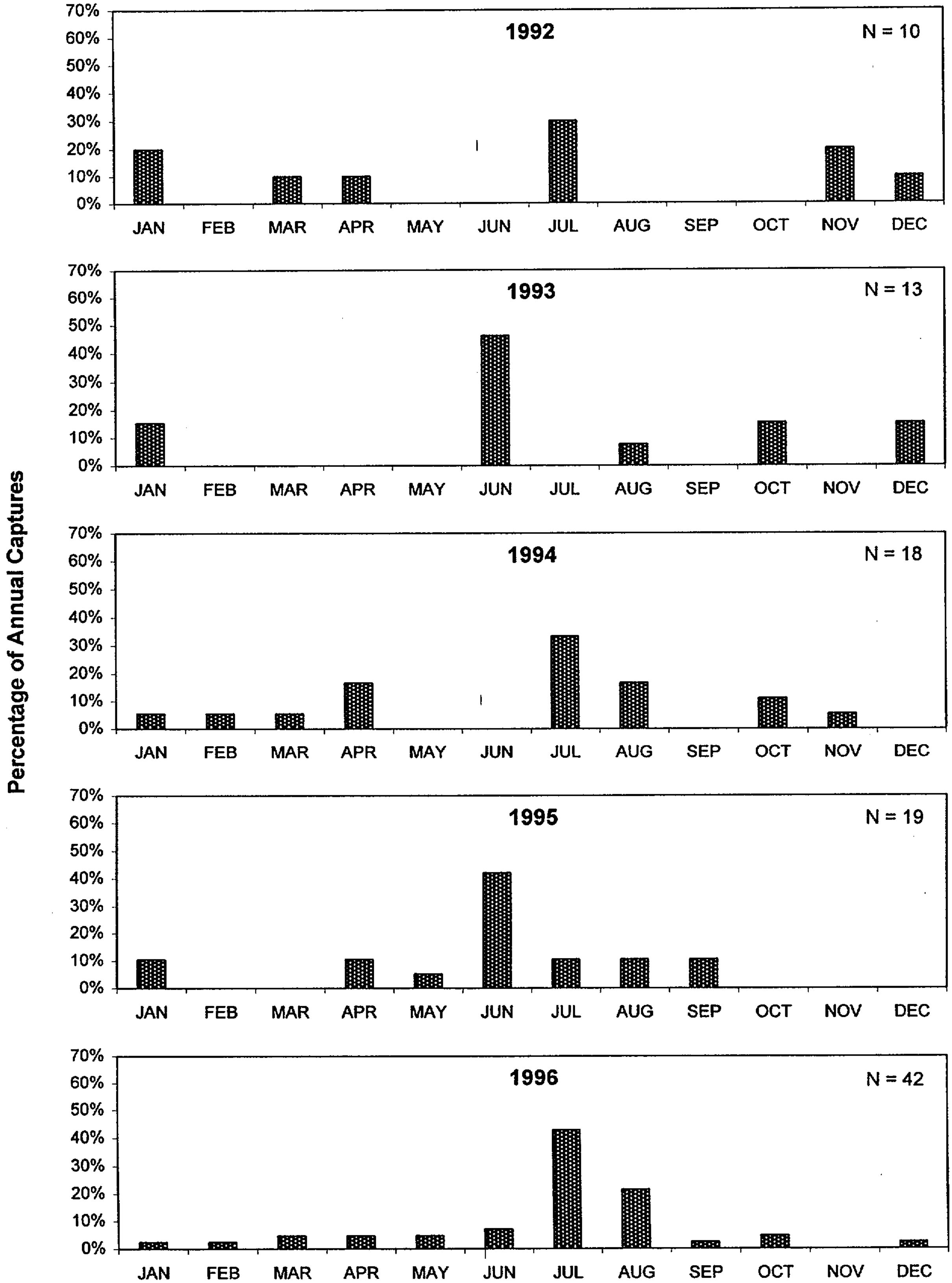

Figure 31. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

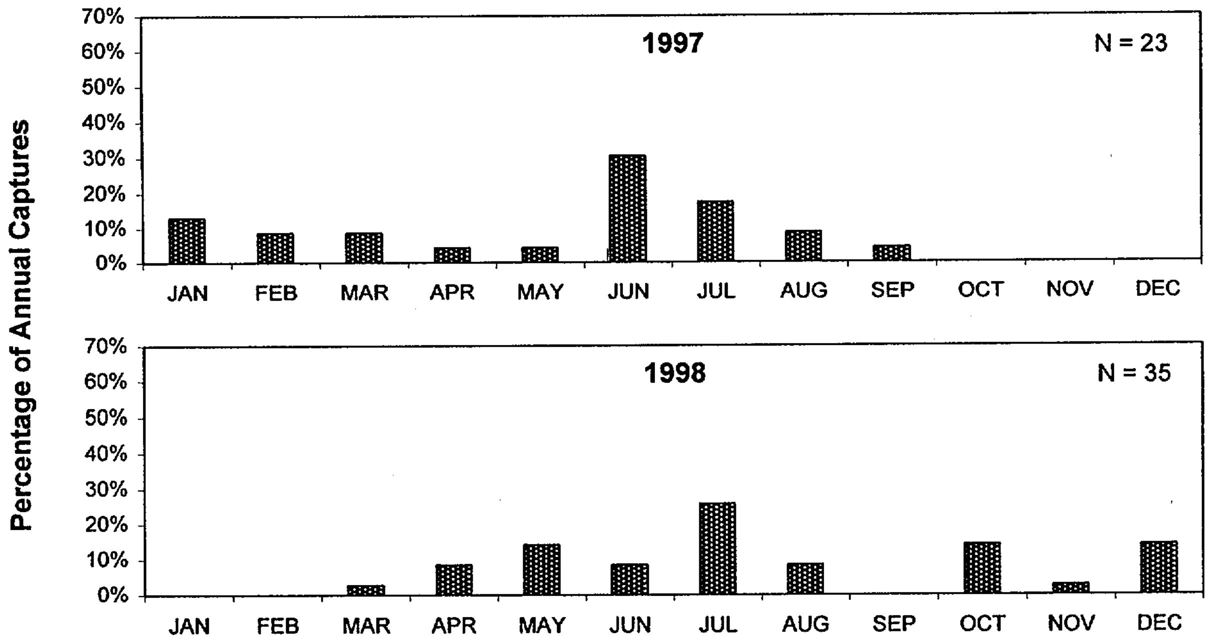

Figure 32. Percentage of subadult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

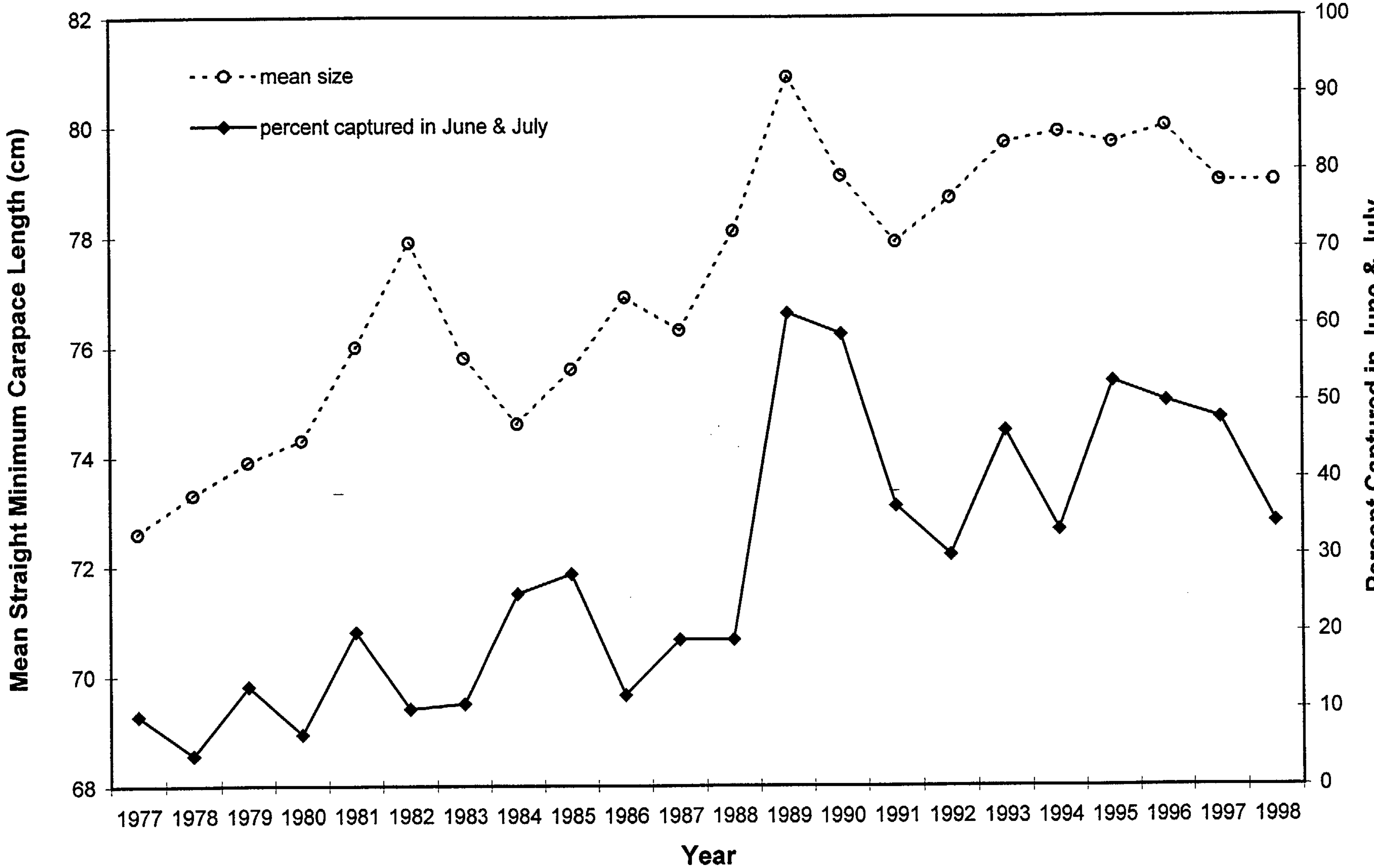

Figure 33. Mean size (straight minimum carapace length) of subadult loggerhead turtles compared to the percentage of annual subadult loggerhead captures that occurred during the months of June and July each year, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998.

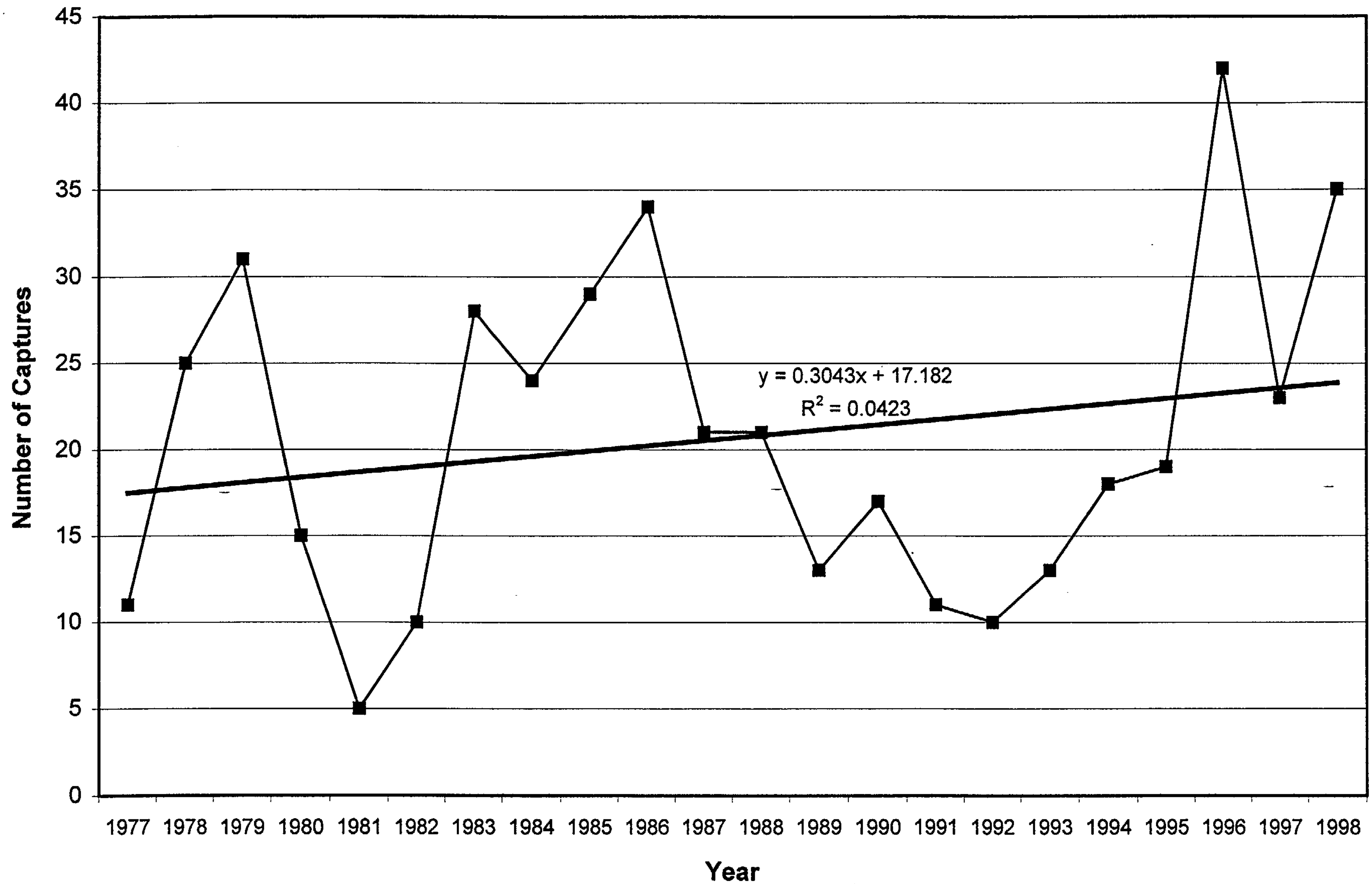

Figure 34. Annual number of subadult loggerhead captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

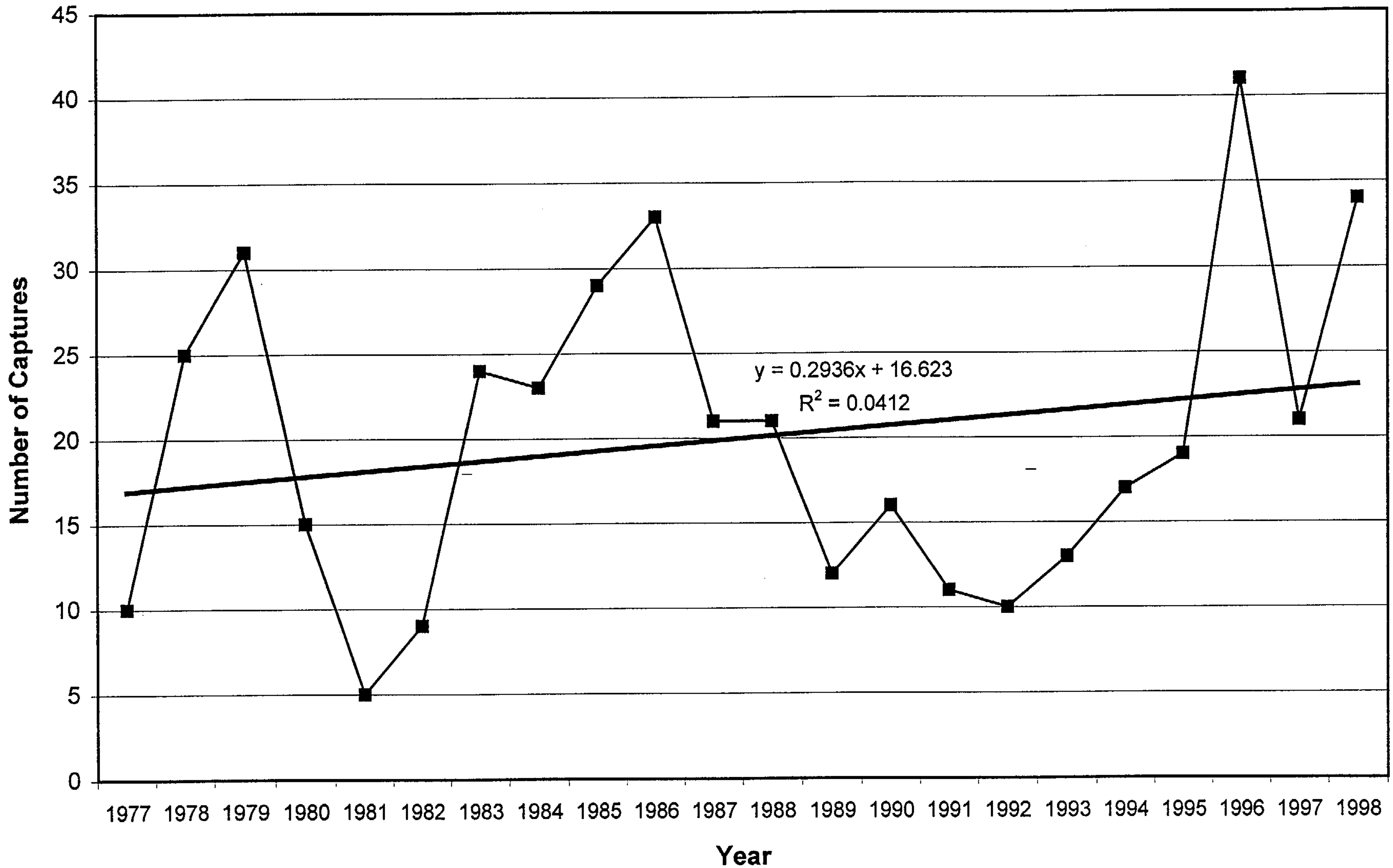

Figure 35. Annual number of subadult loggerhead captures (excluding recaptures), St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

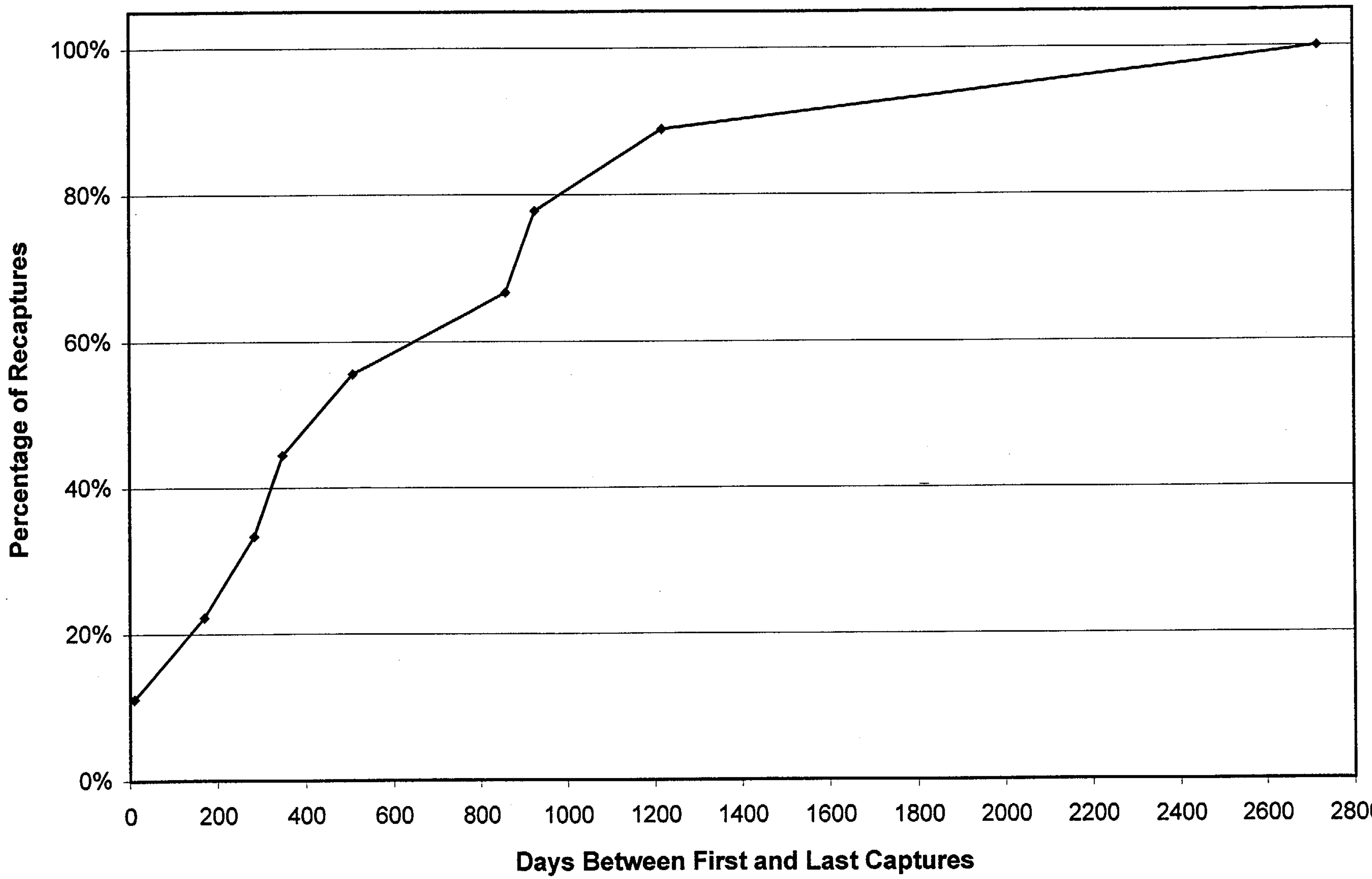

Figure 36. The percentage of subadult loggerhead recaptures that occurred within each time interval between first and last capture, St. Lucie Plant intake canal, Hutchinson Island, Florida.

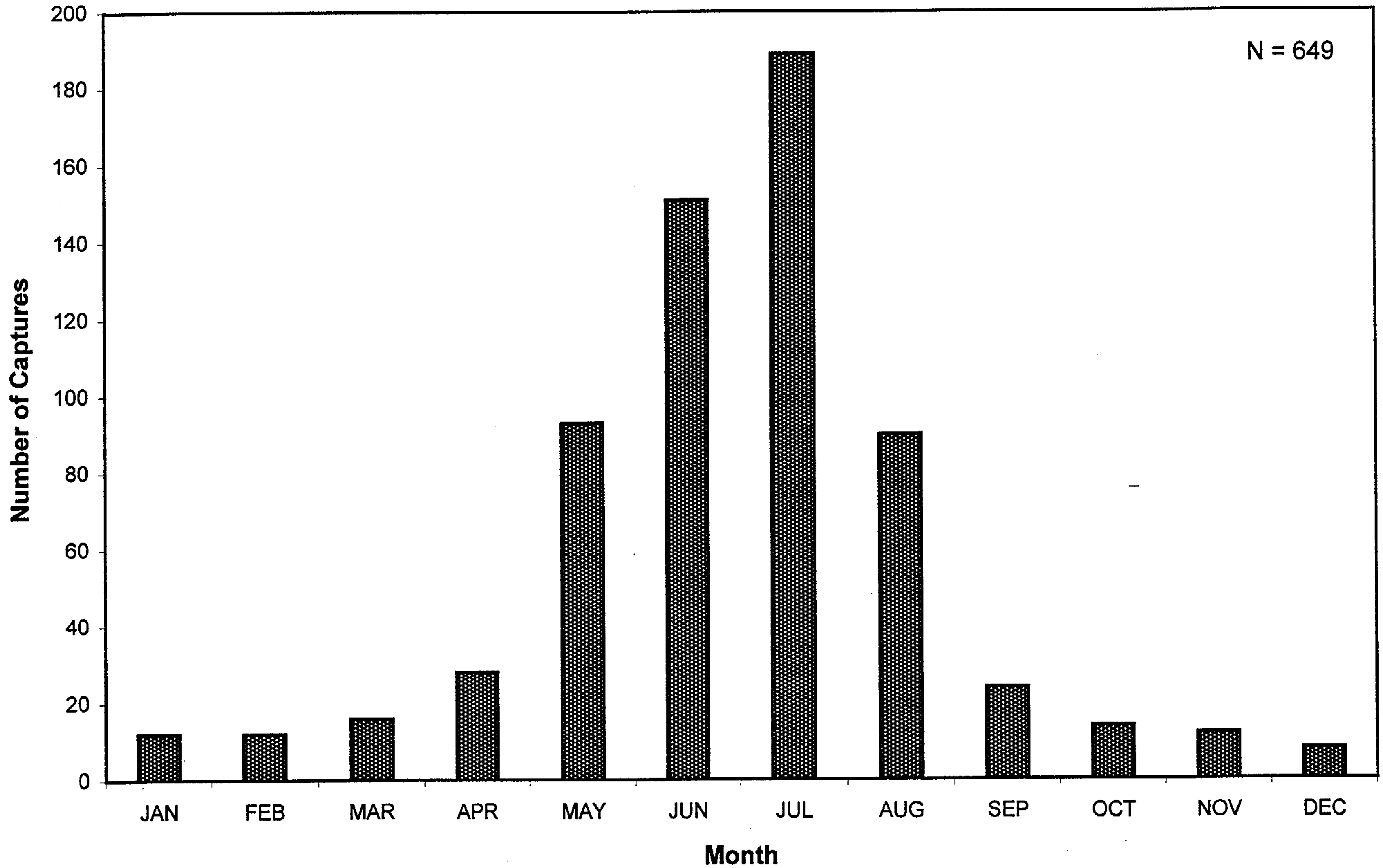

Figure 37. Number of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. The data set includes 562 females, 75 males and 12 adults for which sex was not recorded. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

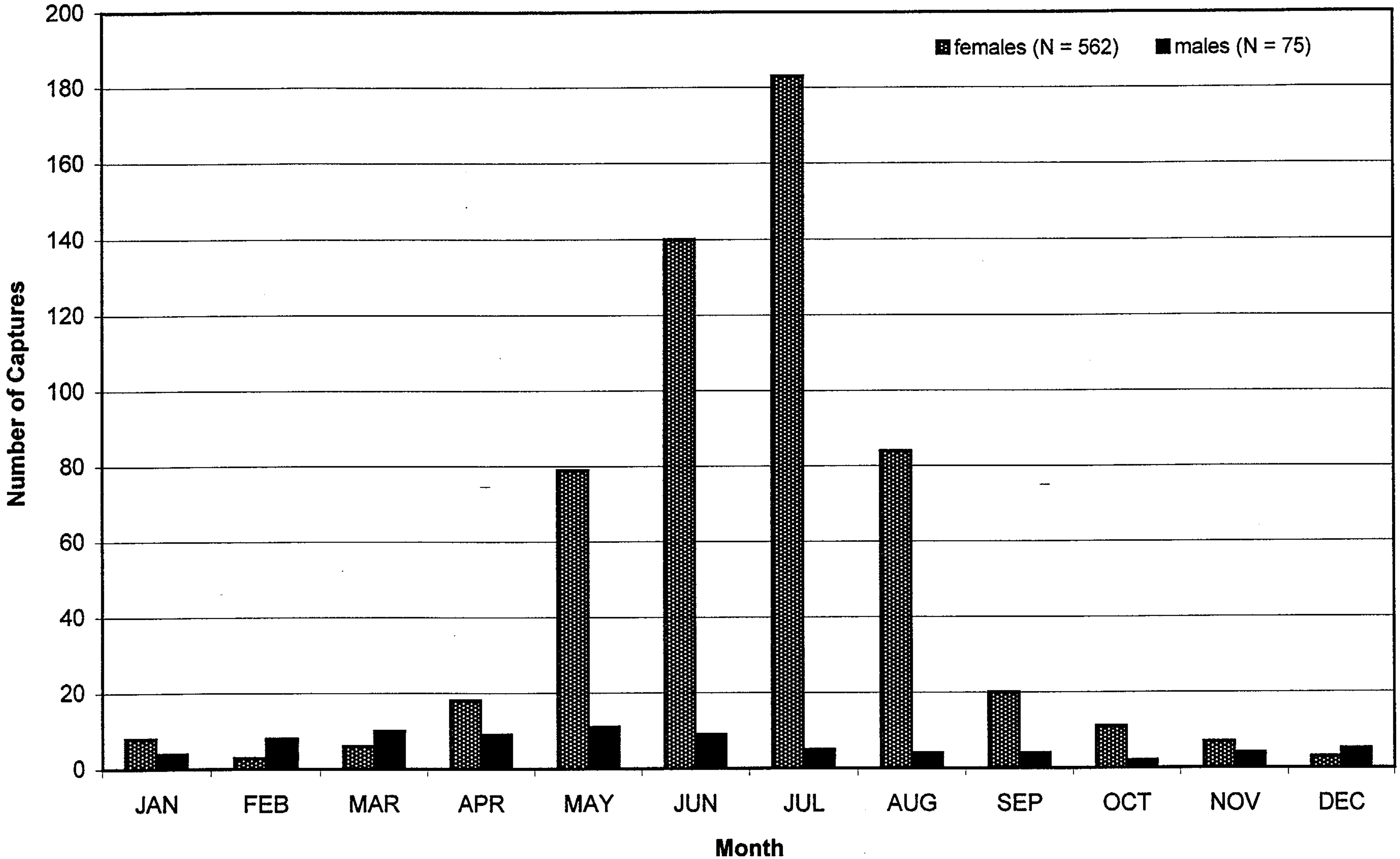

Figure 38. Number of adult male and female loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

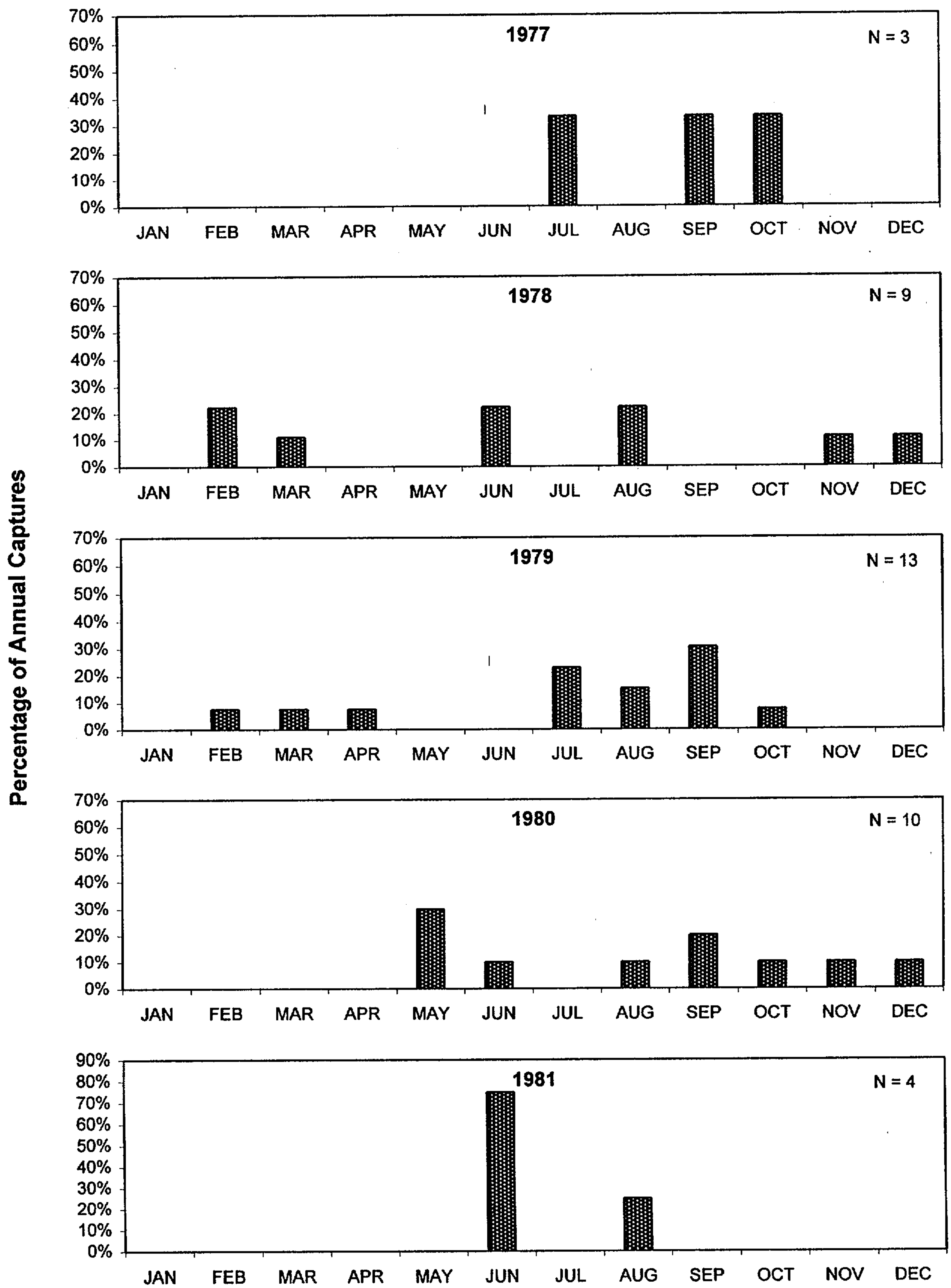

Figure 39. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

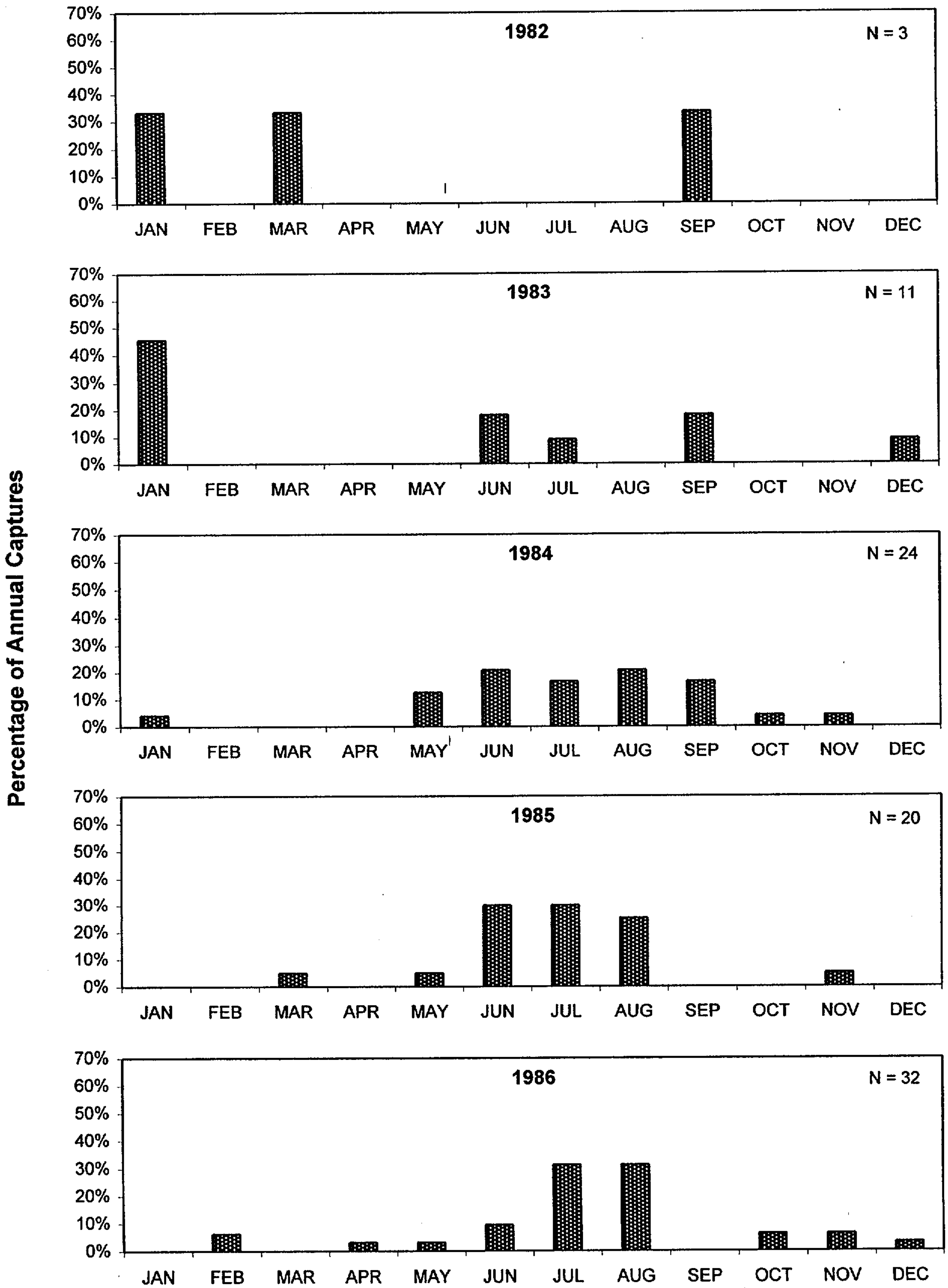

Figure 40. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

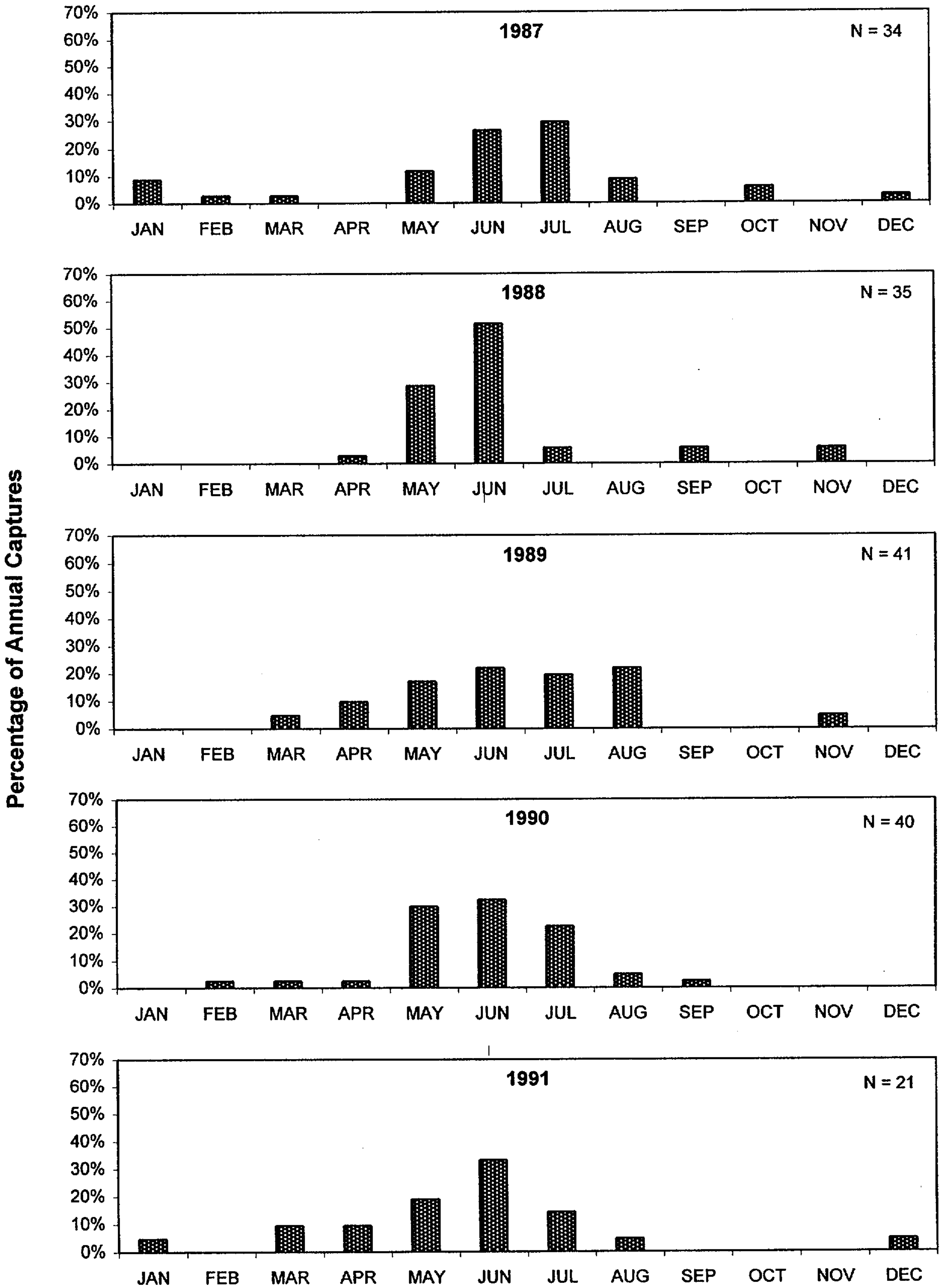

Figure 41. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

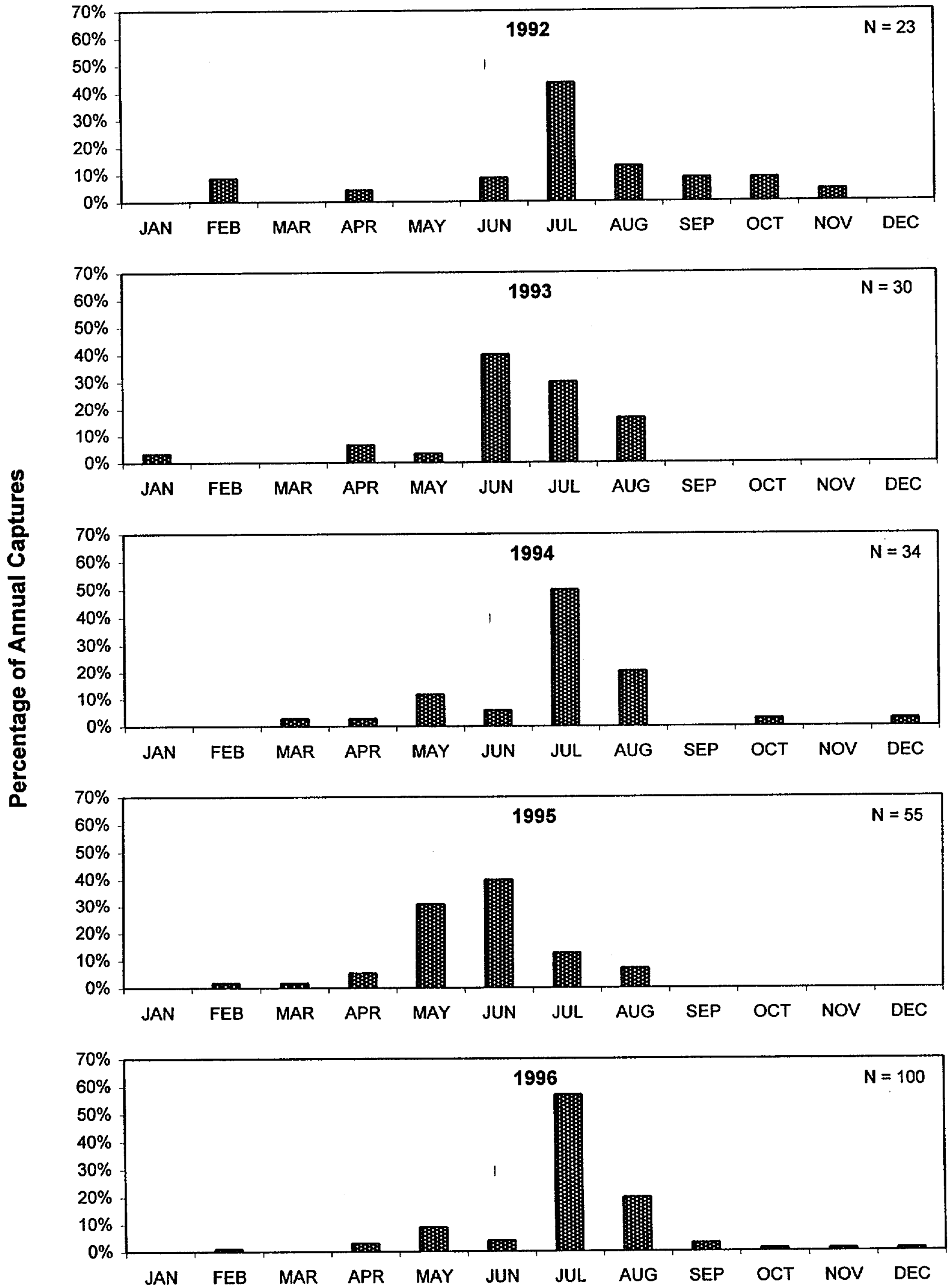

Figure 42. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

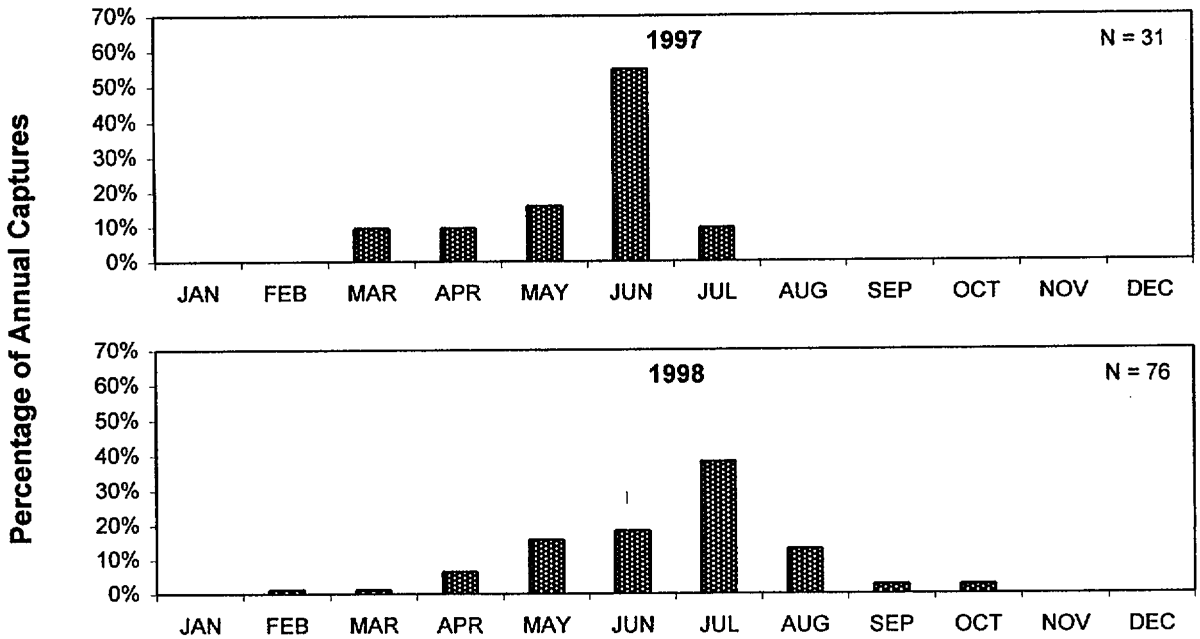

Figure 43. Percentage of adult loggerhead turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

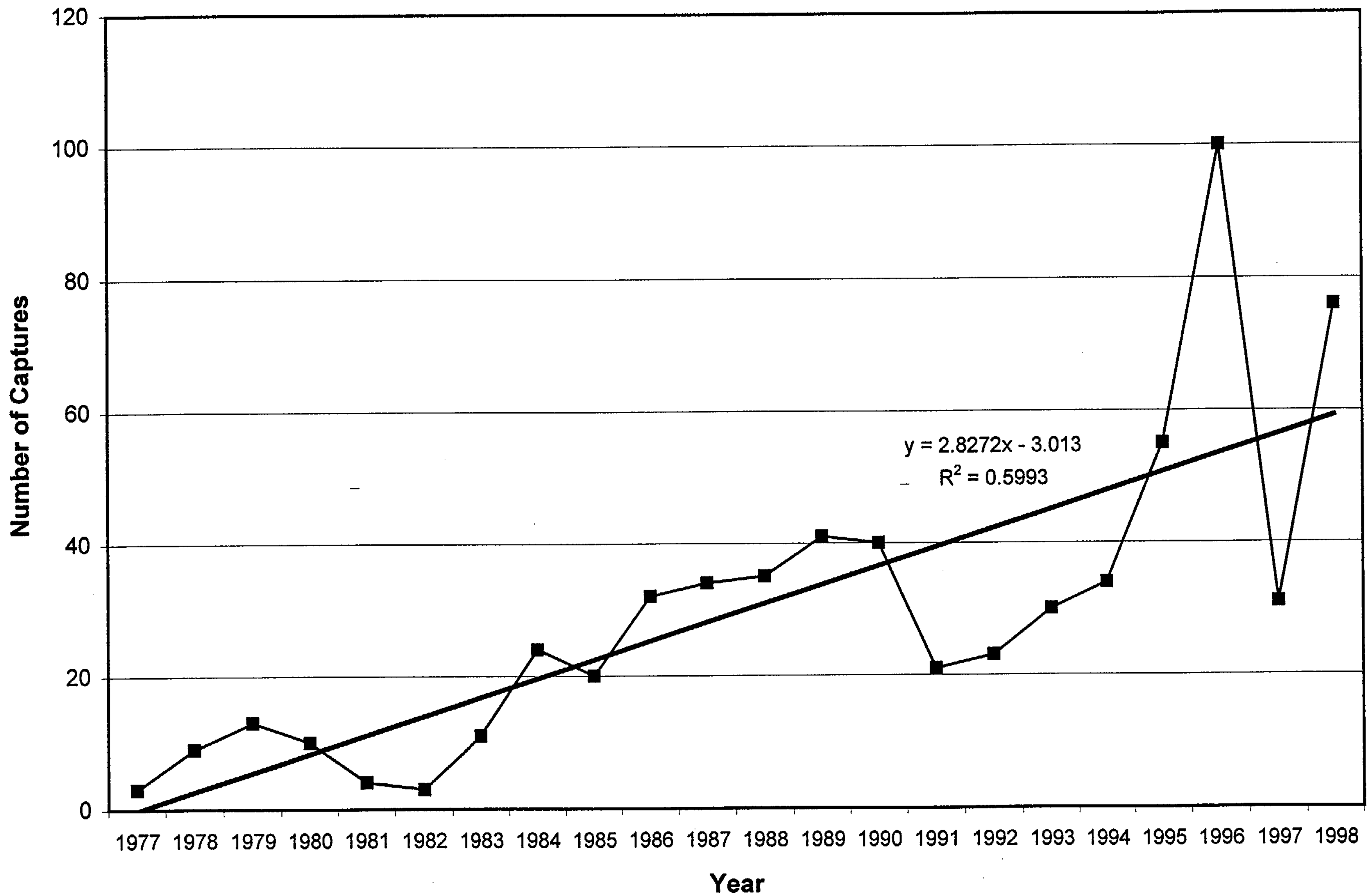

Figure 44. Annual number of adult loggerhead captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

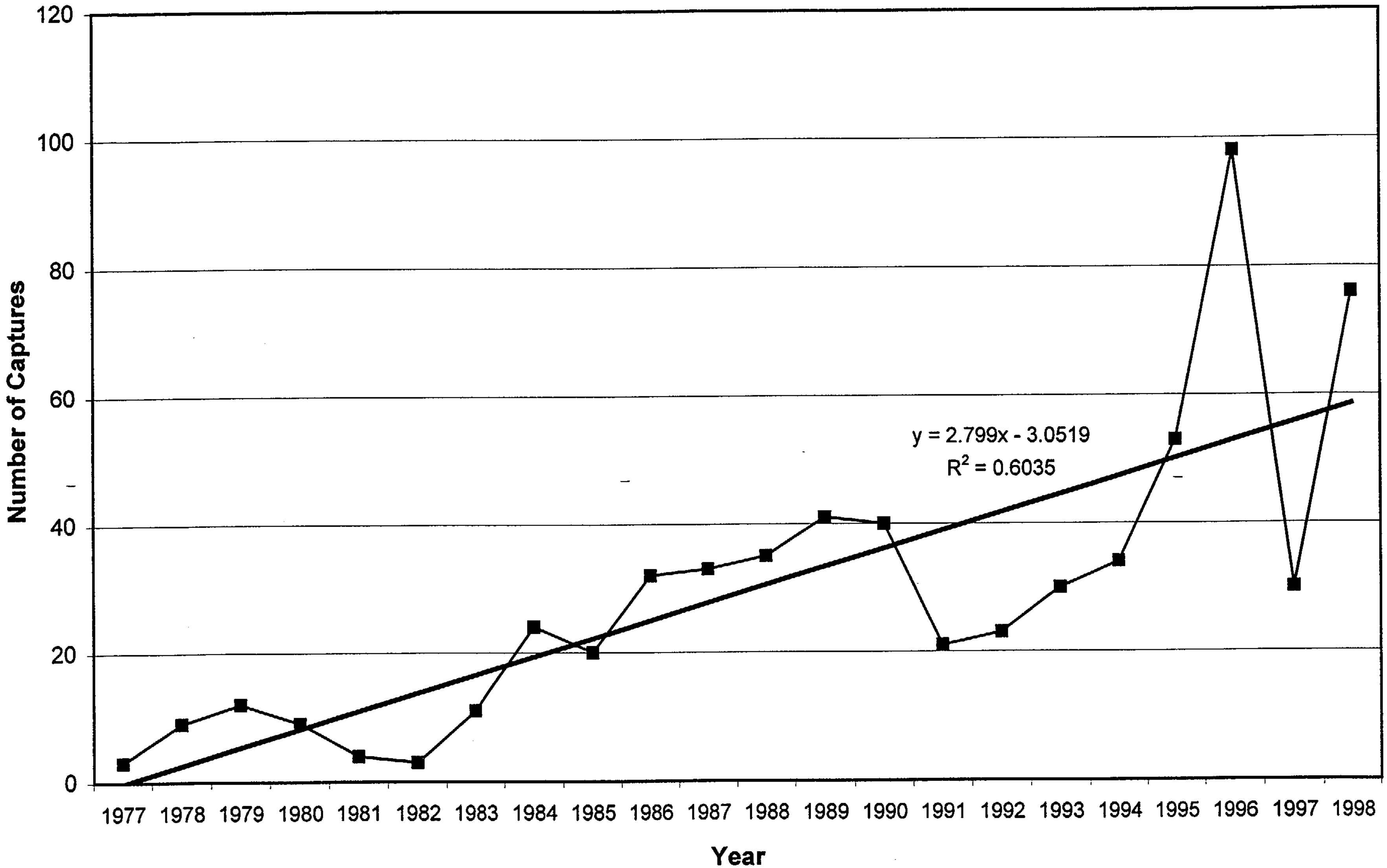

Figure 45. Annual number of adult loggerhead captures (excluding recaptures), St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

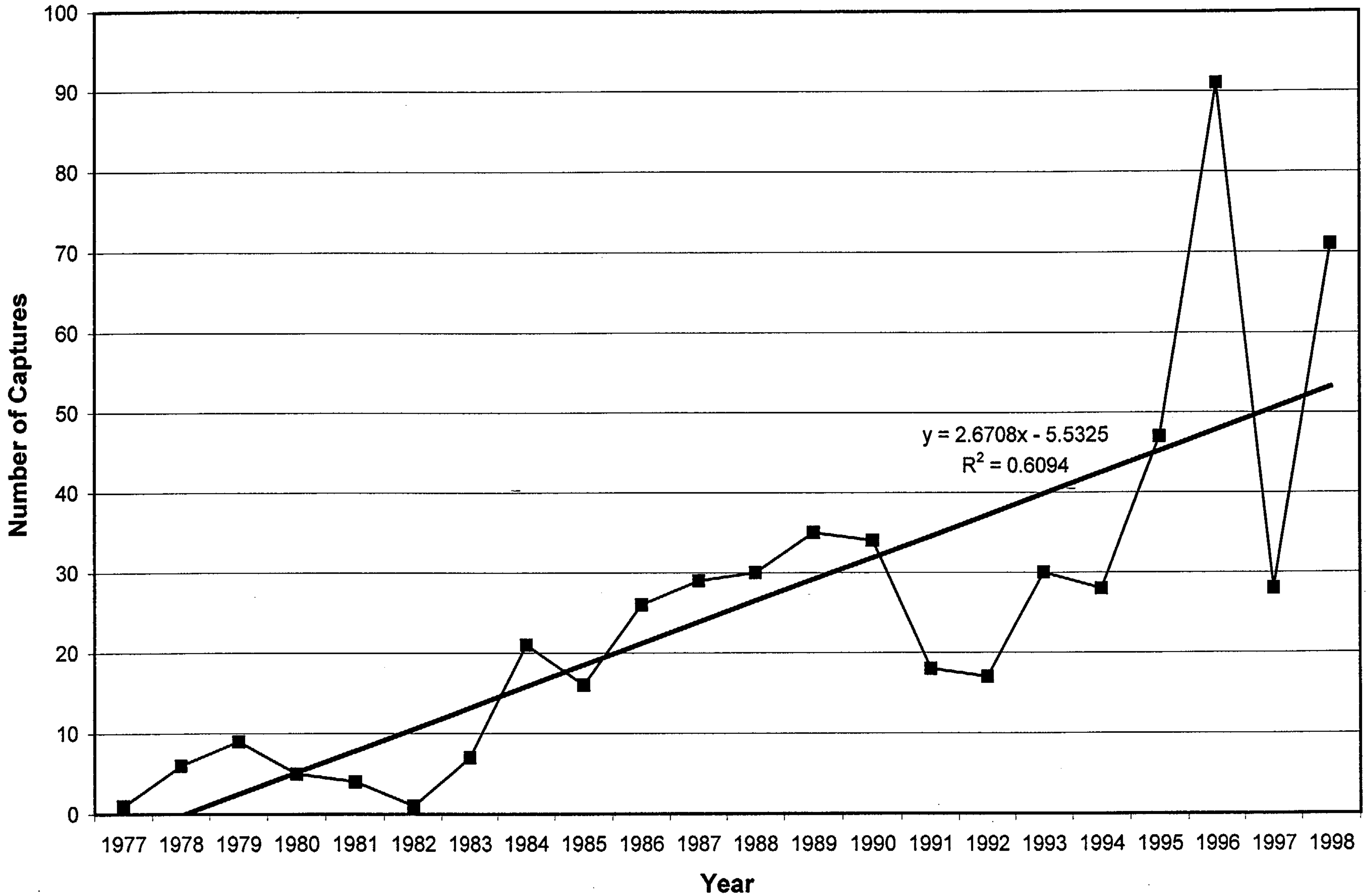

Figure 46. Annual number of adult female loggerhead captures excluding recaptures, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

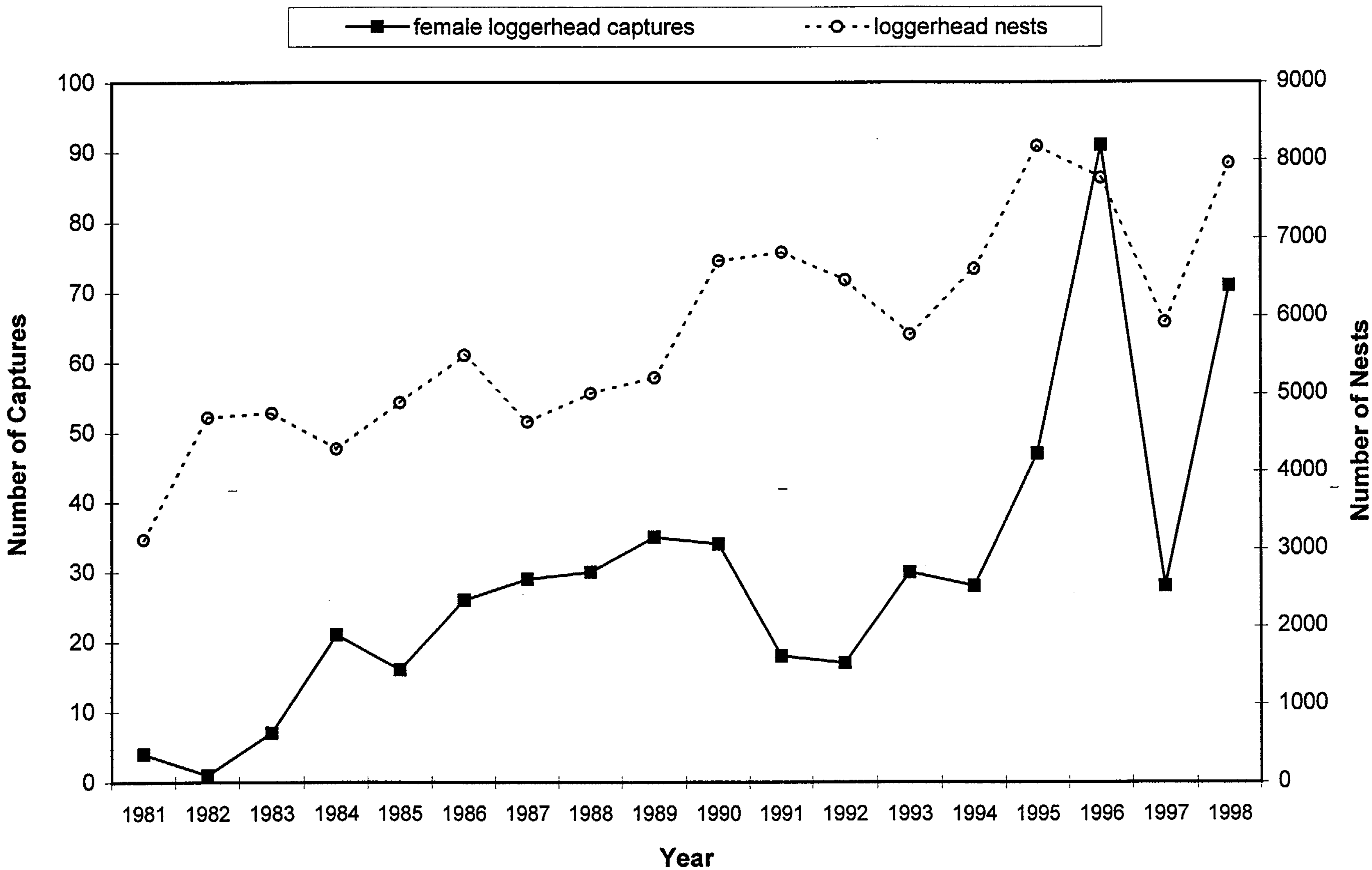

Figure 47. Annual numbers of adult female loggerhead captures at the St. Lucie Plant compared to the annual number of loggerhead nests on Hutchinson Island, Florida, 1981-1998. Annual nesting data are not available prior to 1981.

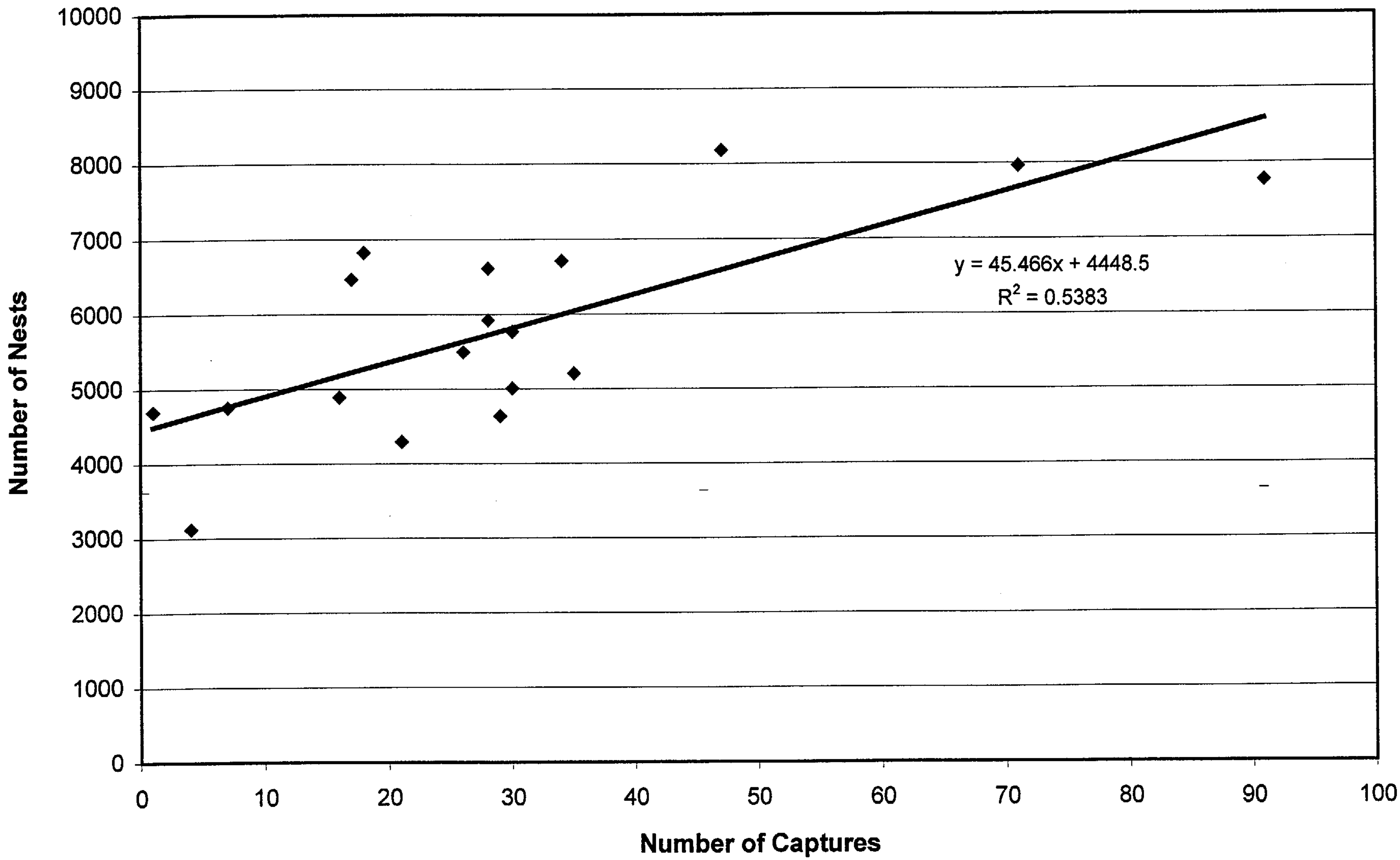

Figure 48. Relationship of annual numbers of adult female loggerhead captures at the St. Lucie Plant to the annual numbers of loggerhead nests on Hutchinson Island, Florida, 1981-1998. Annual nesting data are not available prior to 1981.

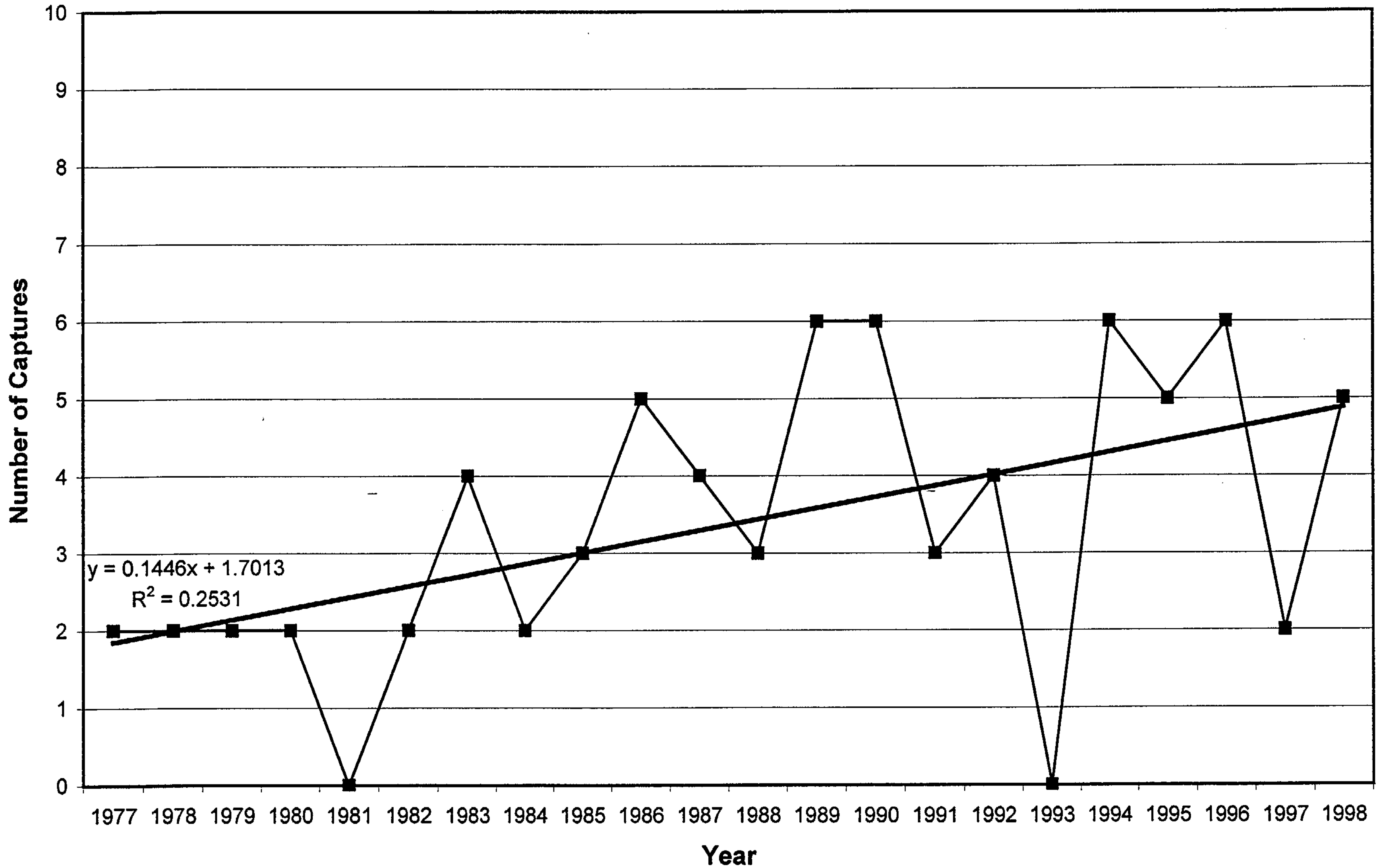

Figure 49. Annual number of adult male loggerhead captures excluding recaptures, St. Lucie Plant, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

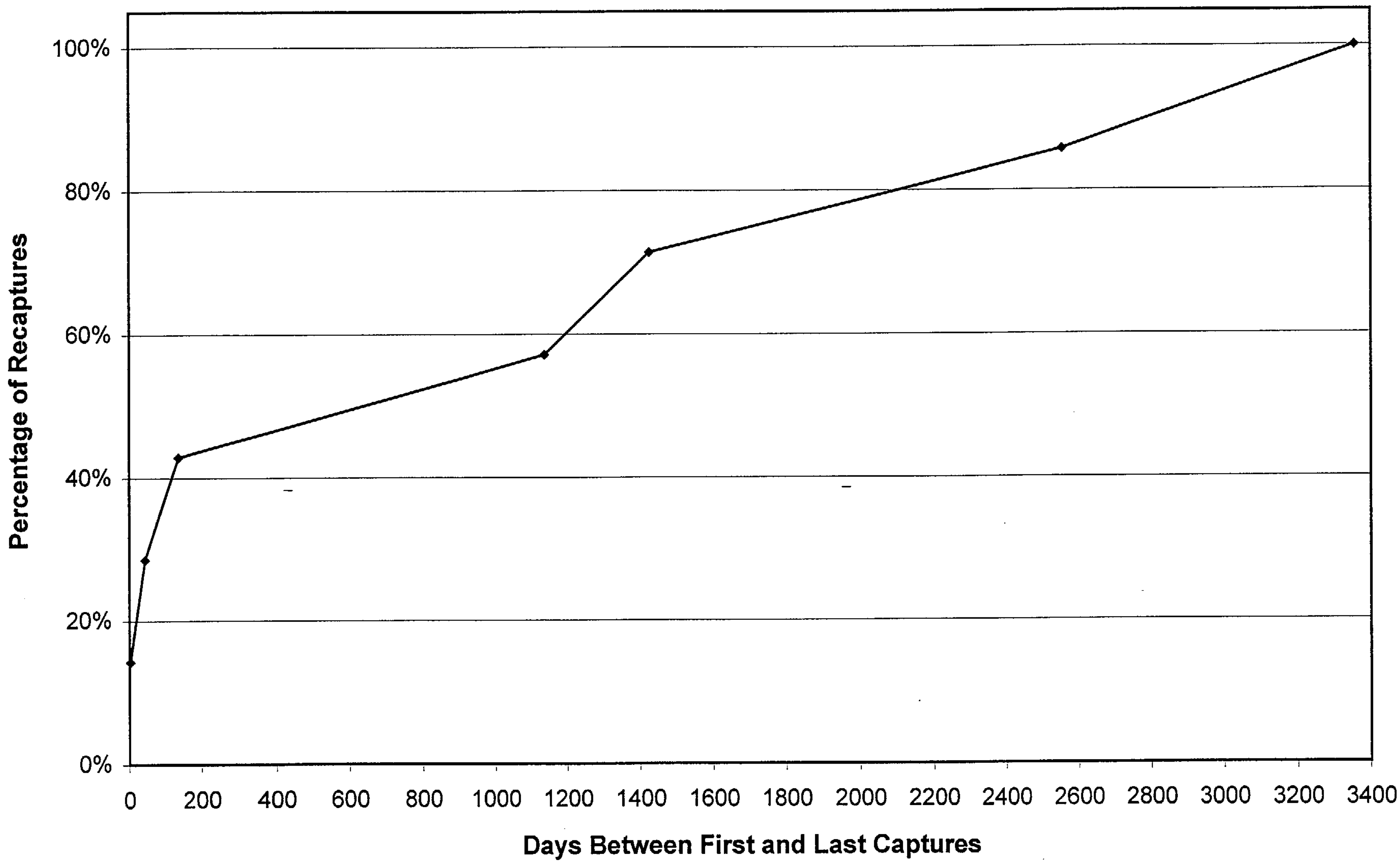

Figure 50. The percentage of adult loggerhead captures that occurred within each time interval between first and last capture, St. Lucie Plant intake canal, Hutchinson Island, Florida.

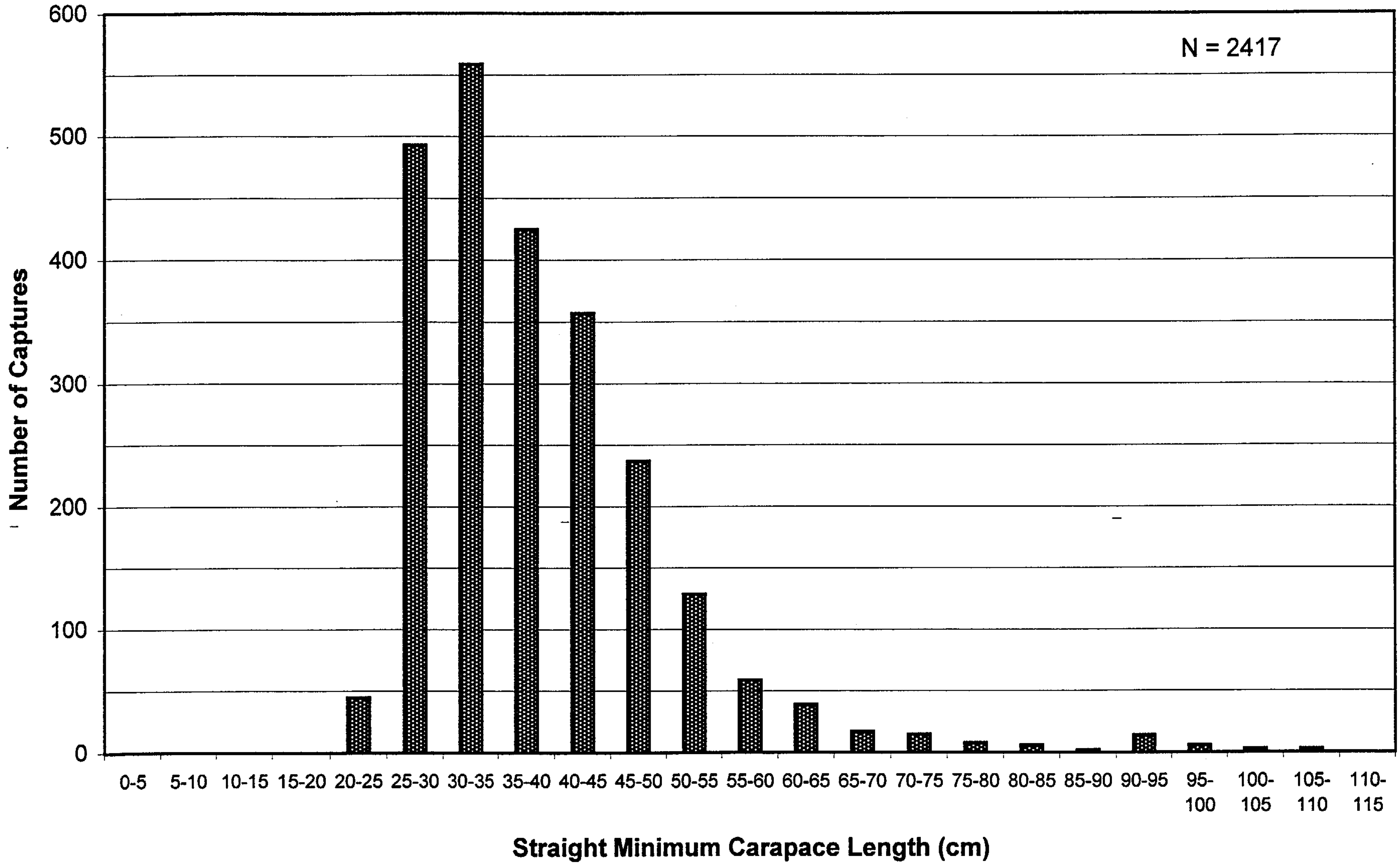

Figure 51. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1976-1998.

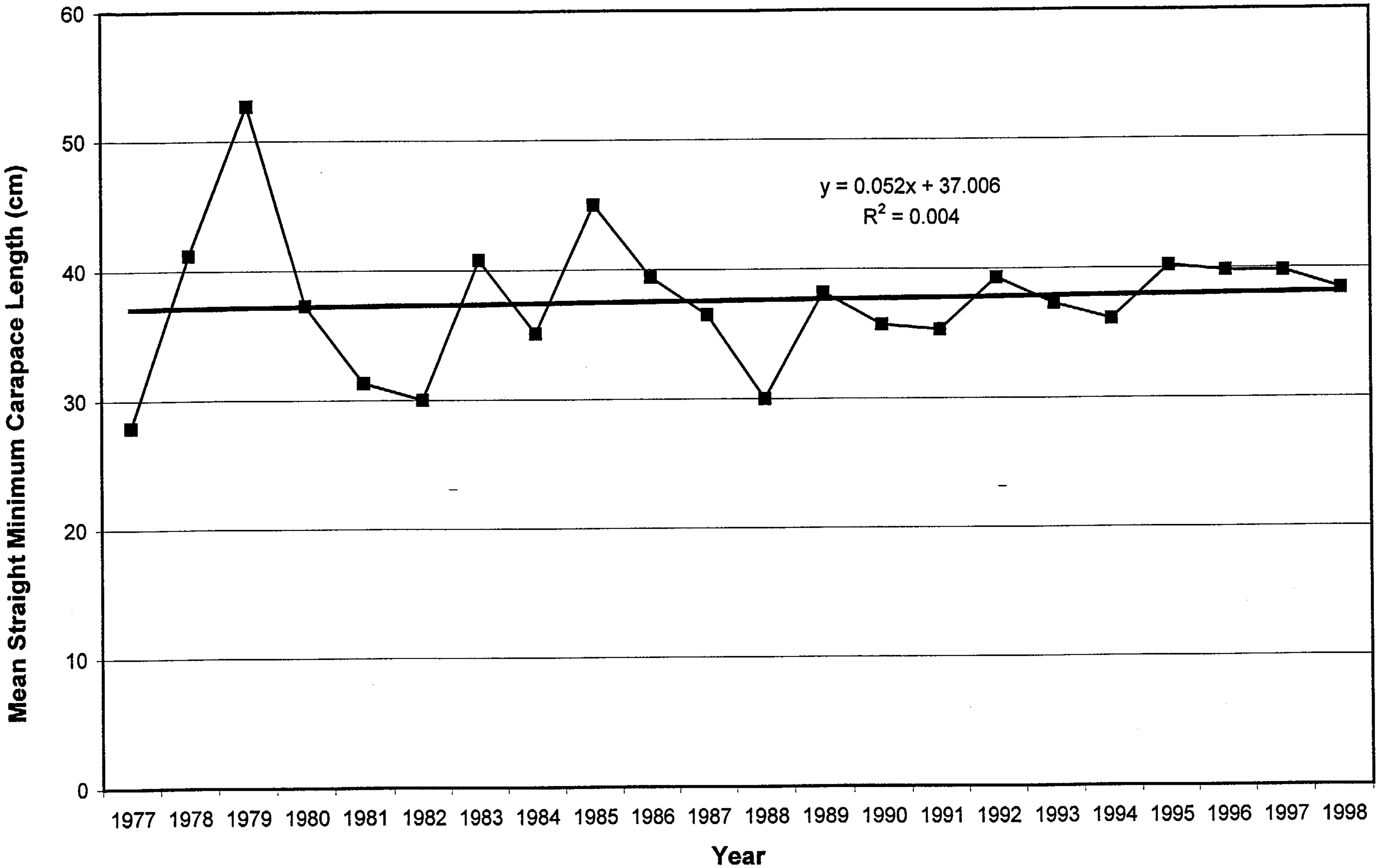

Figure 52. Mean size (straight minimum carapace length) of all green turtles captured each year in the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Note: no green turtles were captured during 1996.

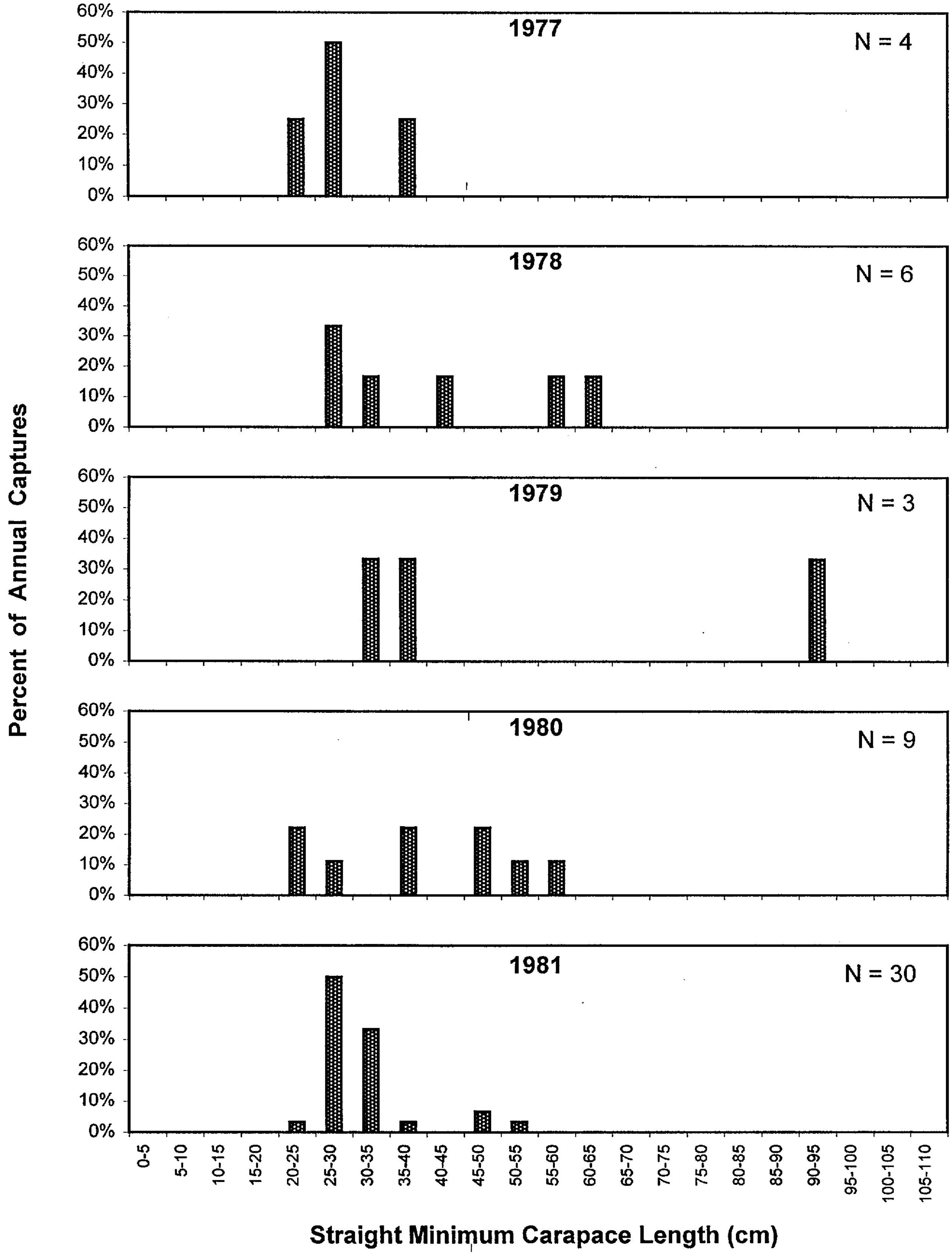

Figure 53. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Note: no green turtles were captured during 1976.

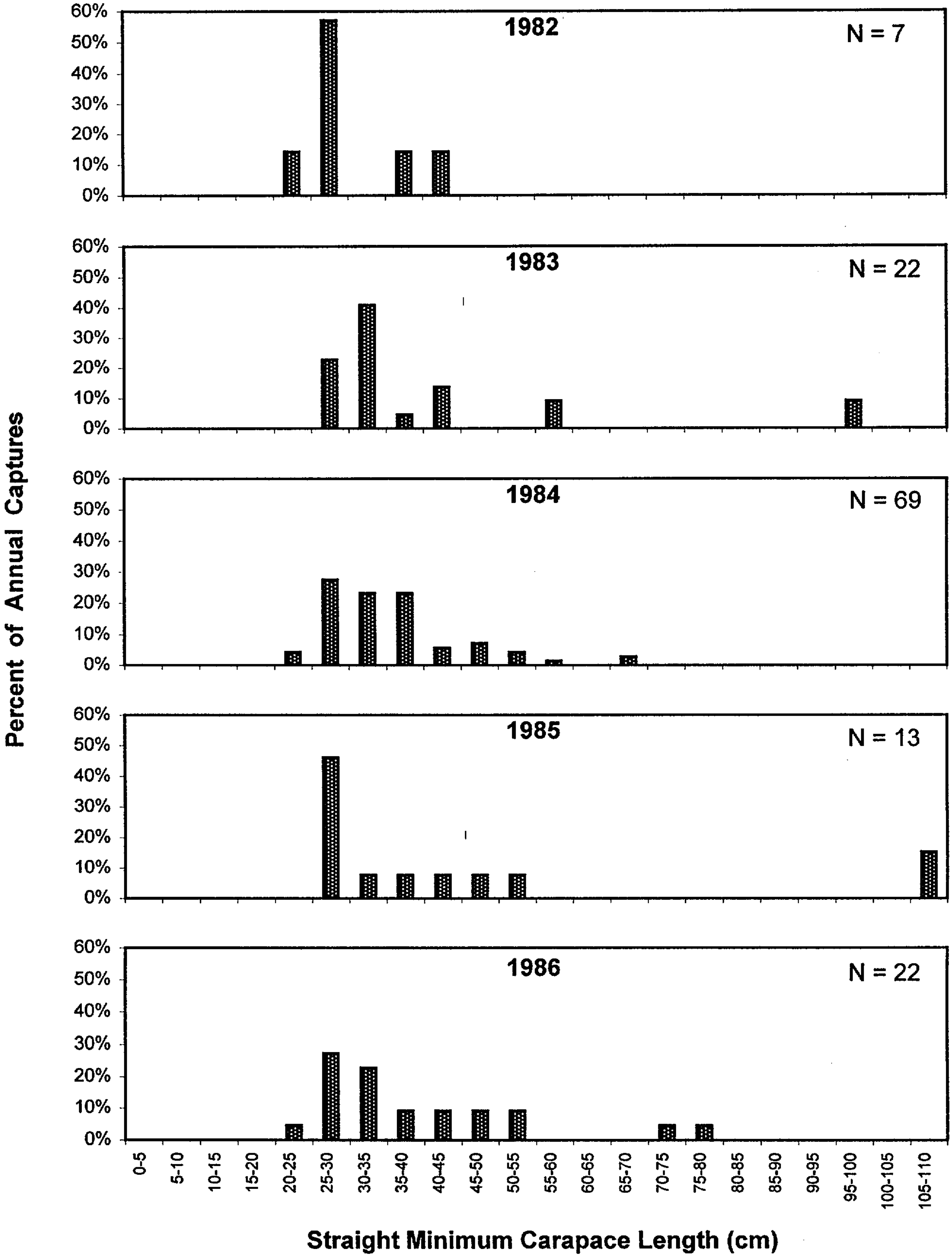

Figure 54. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

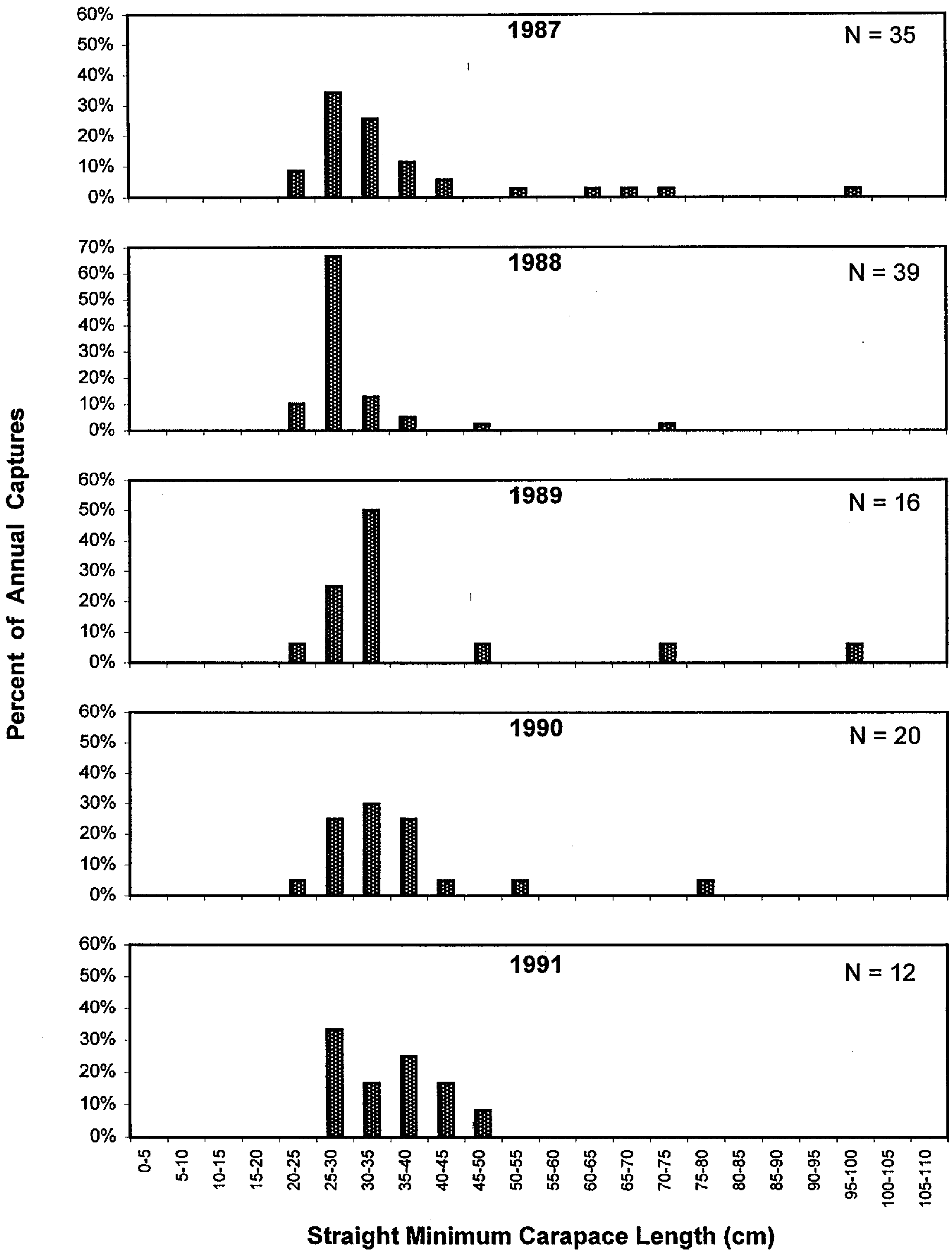

Figure 55. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

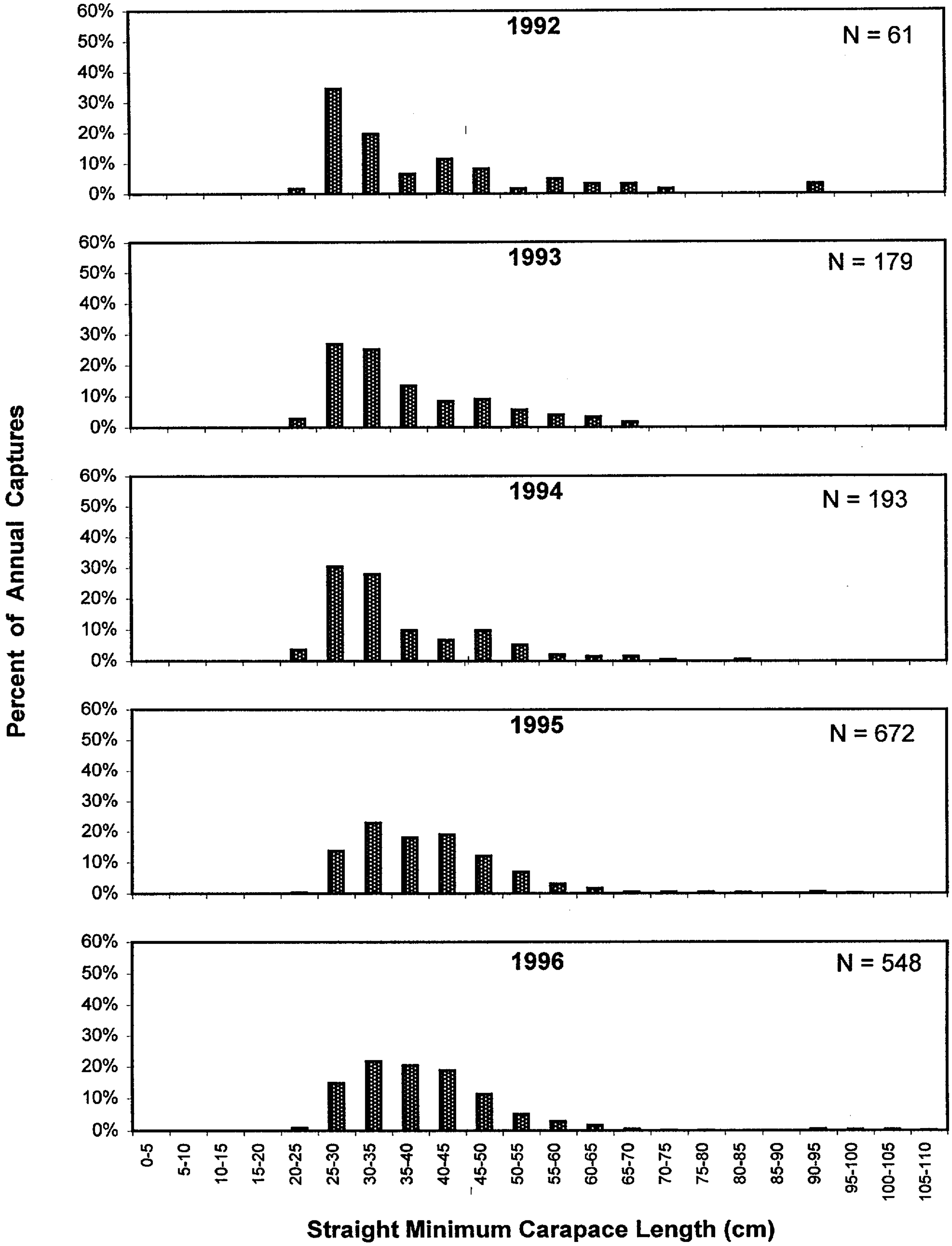

Figure 56. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

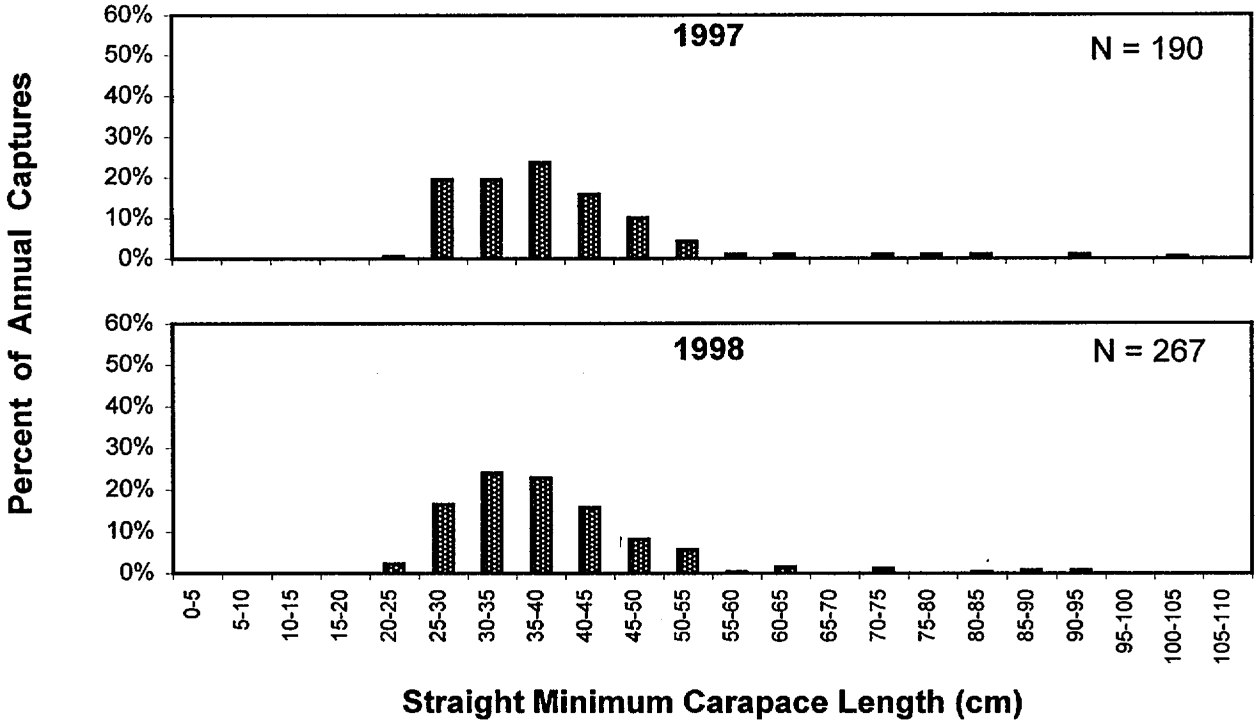

Figure 57. Distribution of straight minimum carapace length measurements for green turtles removed from the St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

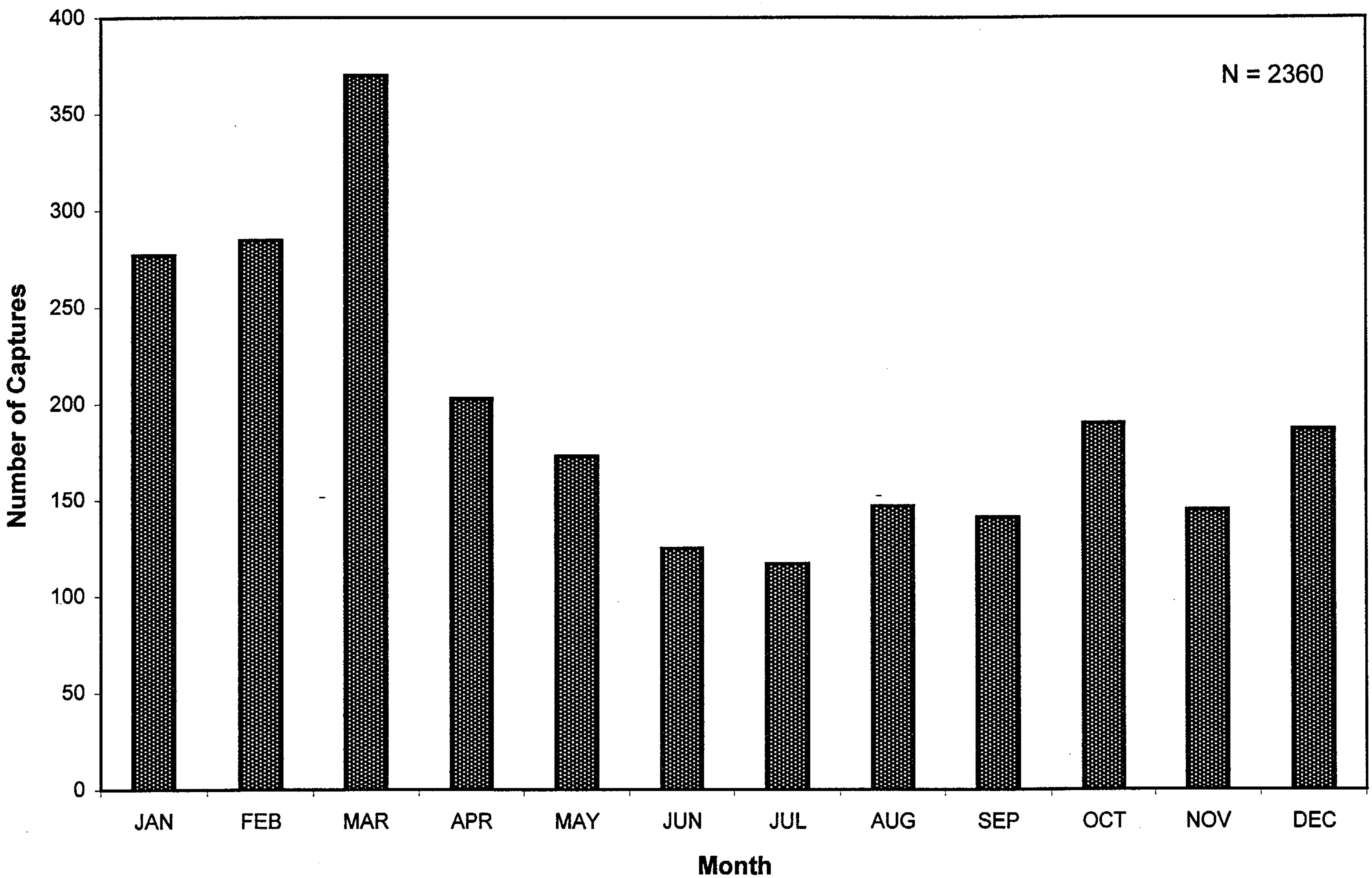

Figure 58. Number of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Note: no green turtles were captured during 1976.

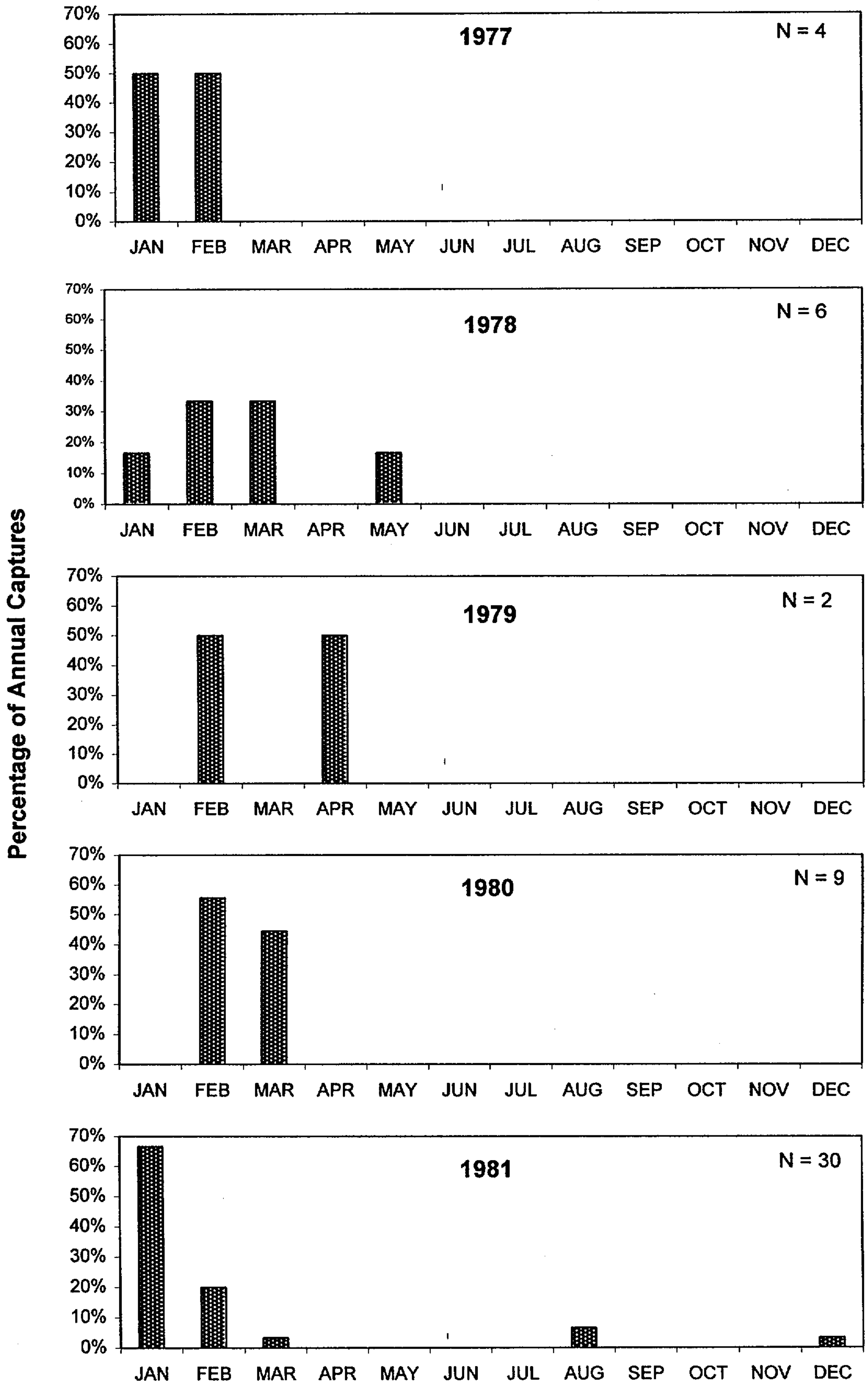

Figure 59. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1981. Note: no green turtles were captured during 1976.

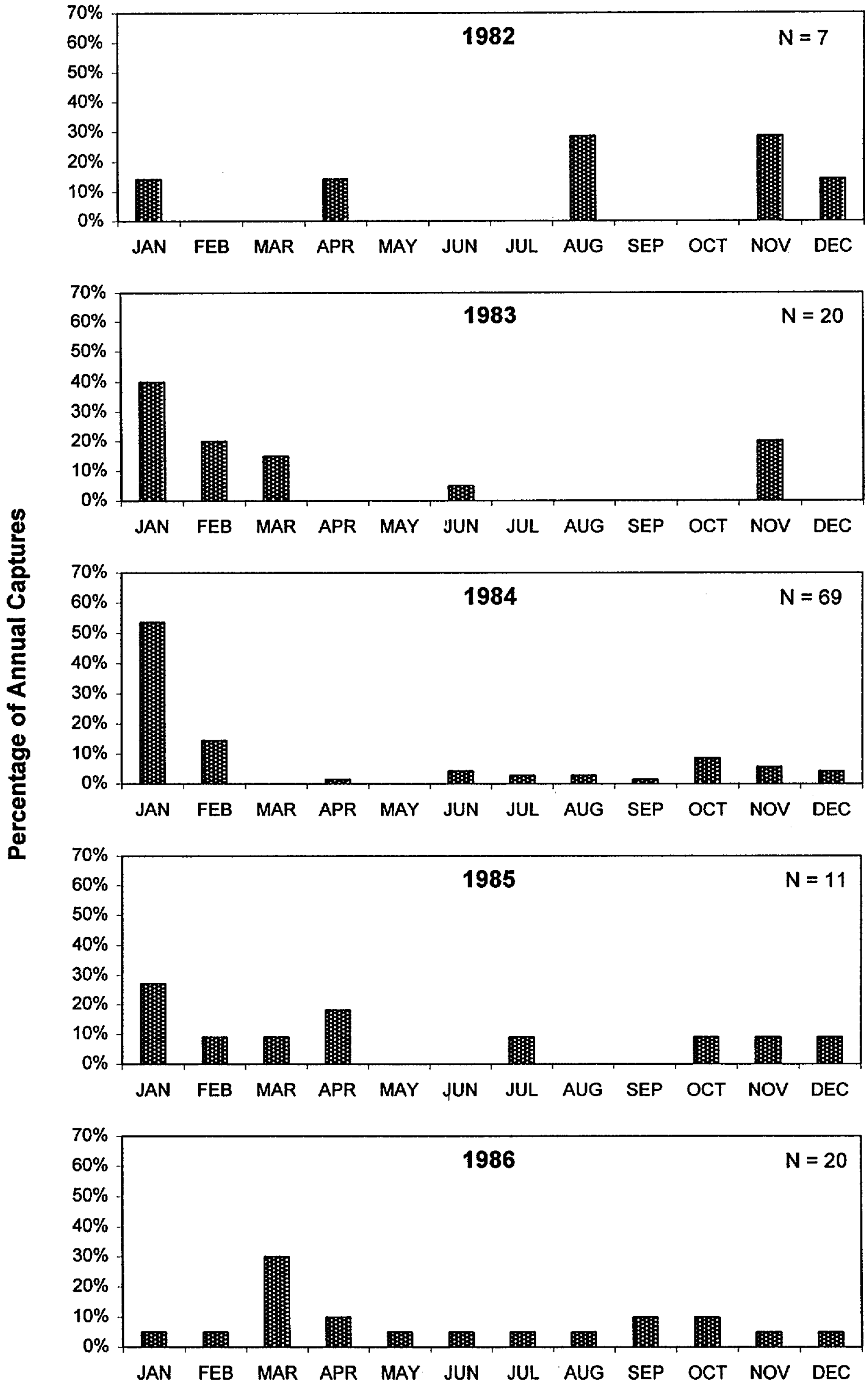

Figure 60. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1982-1986.

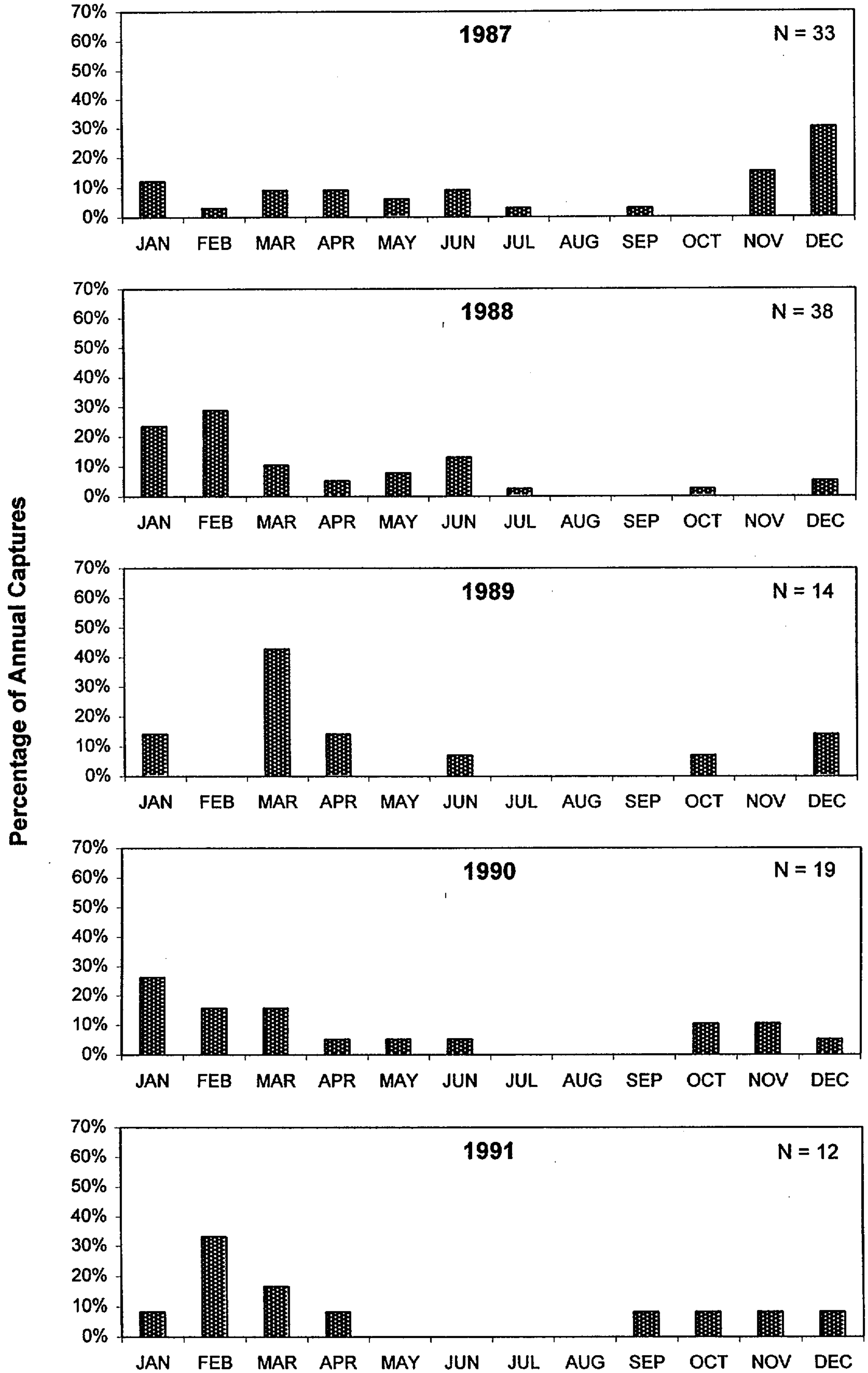

Figure 61. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1987-1991.

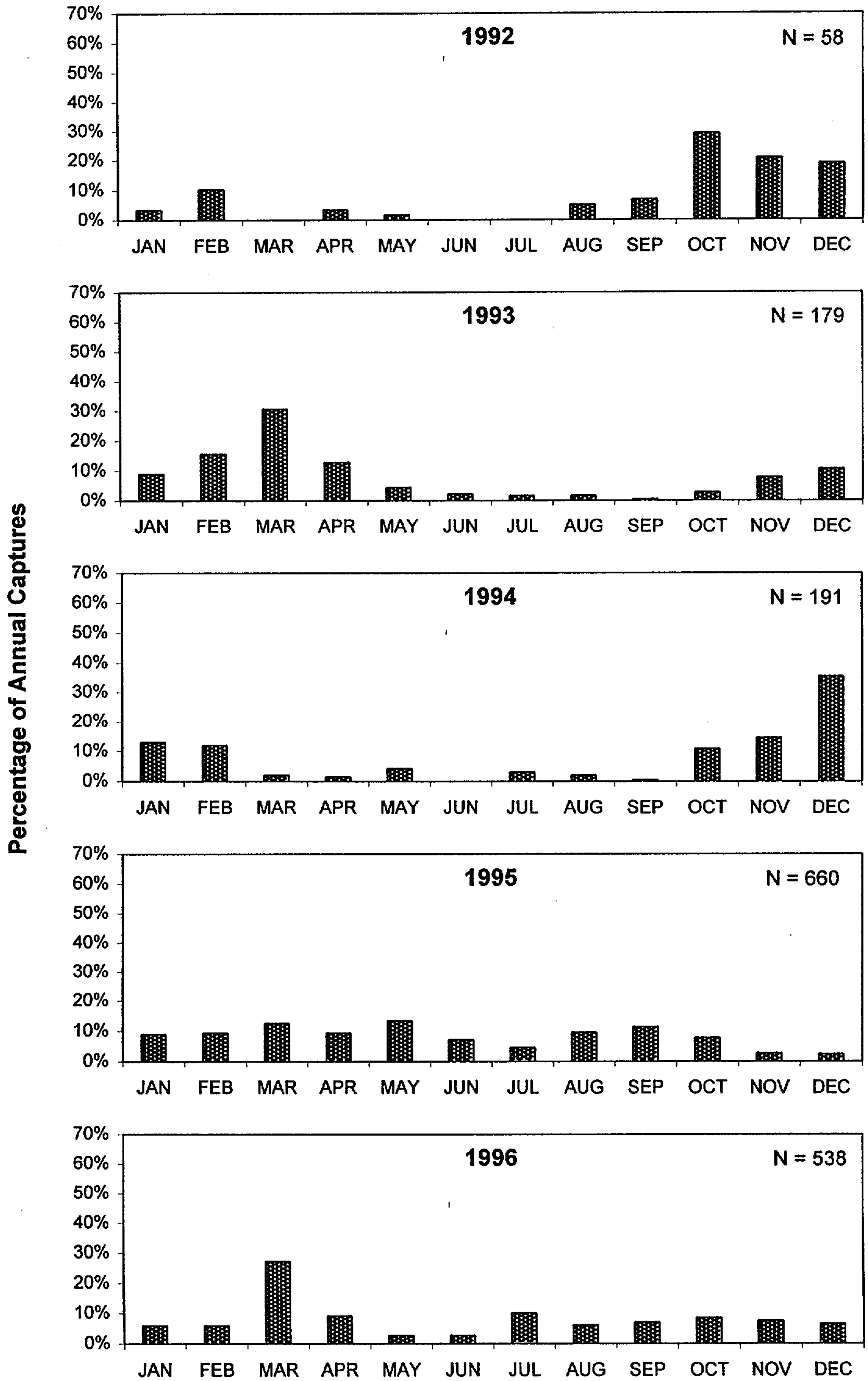

Figure 62. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1992-1996.

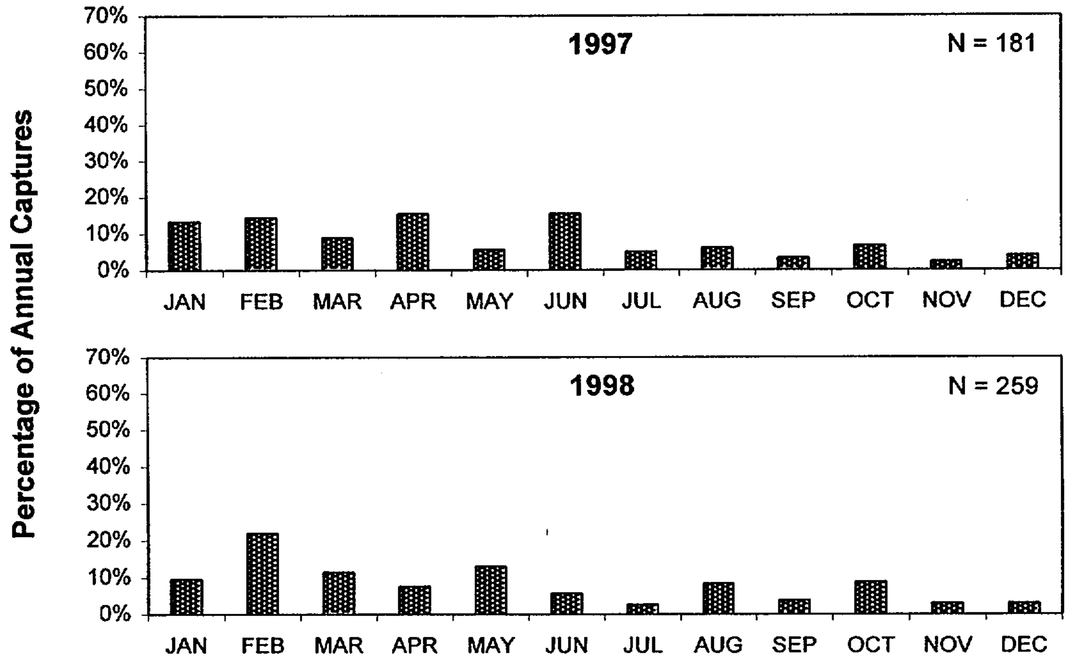

Figure 63. Percentage of juvenile green turtles captured each month, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1997-1998.

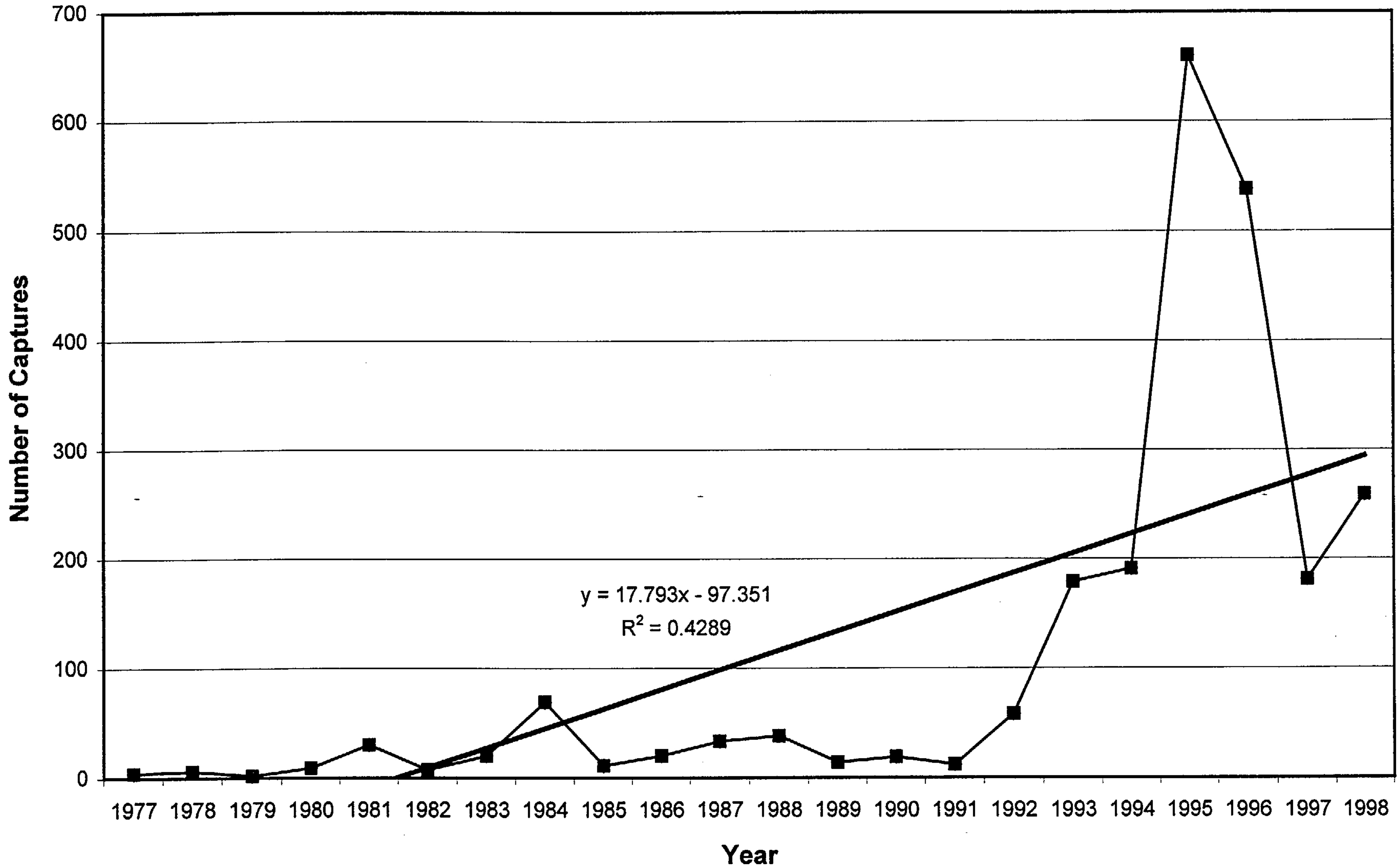

Figure 64. Annual number of juvenile green turtle captures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1996 were excluded since the power plant did not begin operation until May of that year.

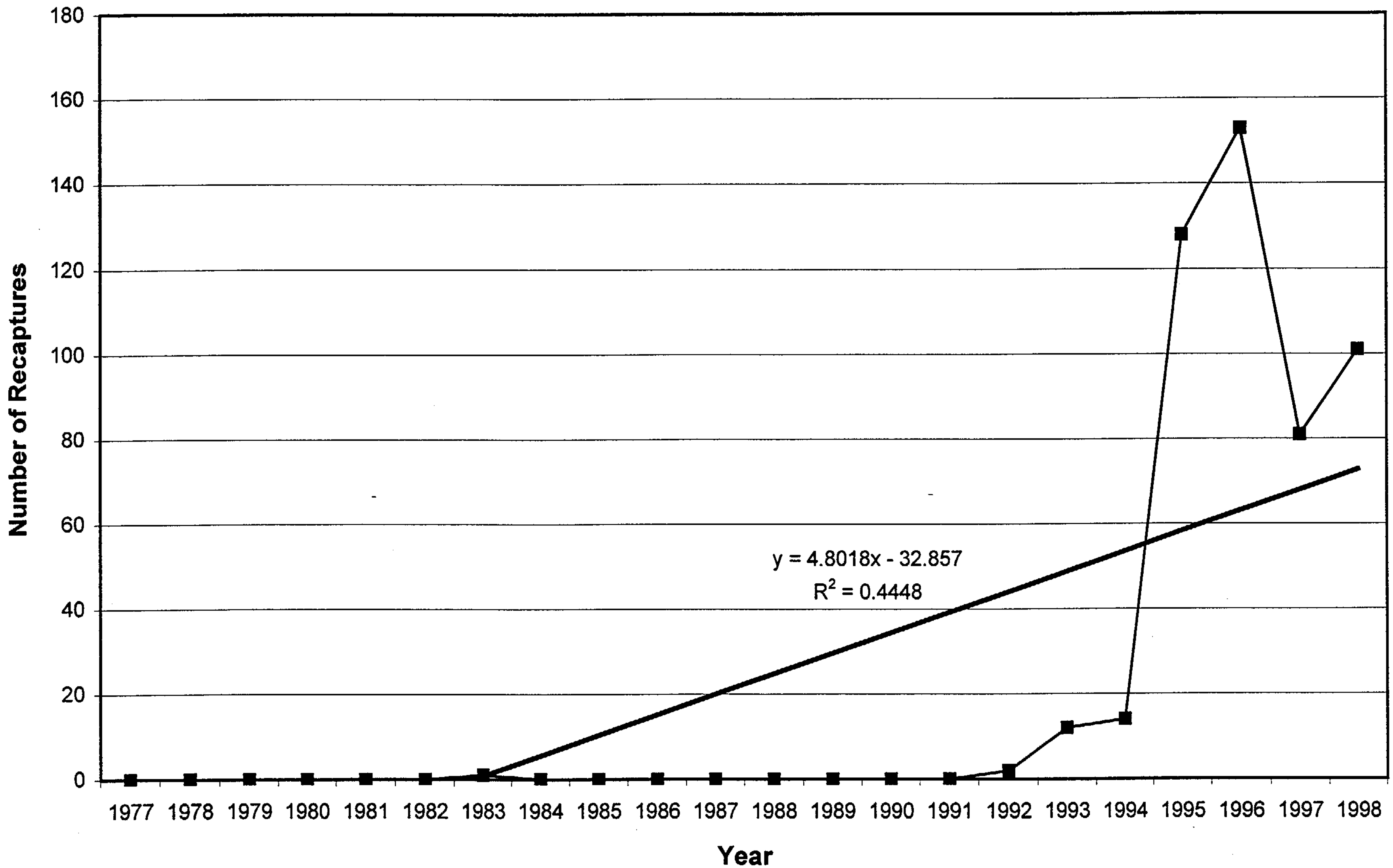

Figure 65. Annual number of juvenile green turtle recaptures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977 1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

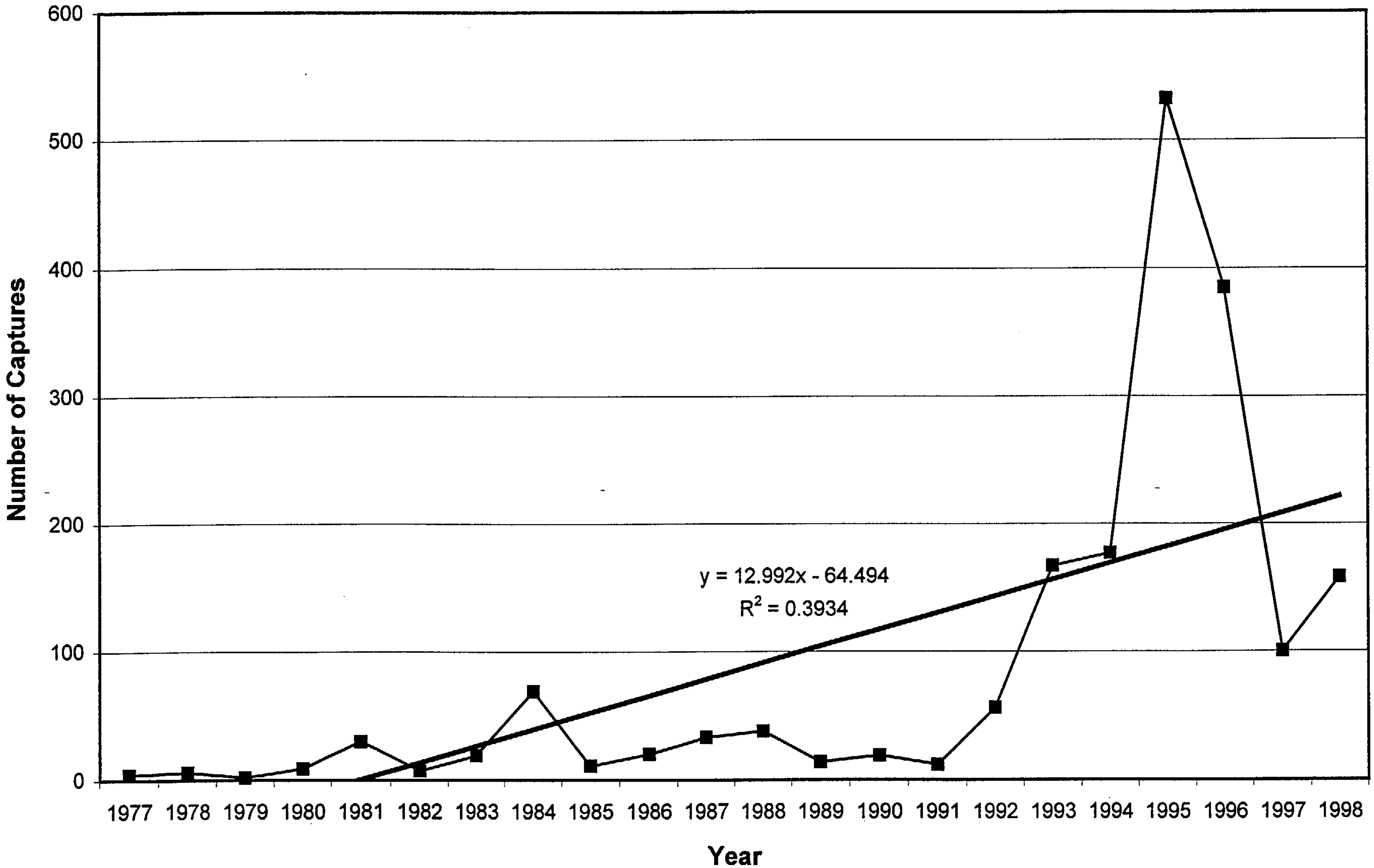

Figure 66. Annual number of juvenile green turtle captures excluding recaptures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1977-1998. Data for 1976 were excluded since the power plant did not begin operation until May of that year.

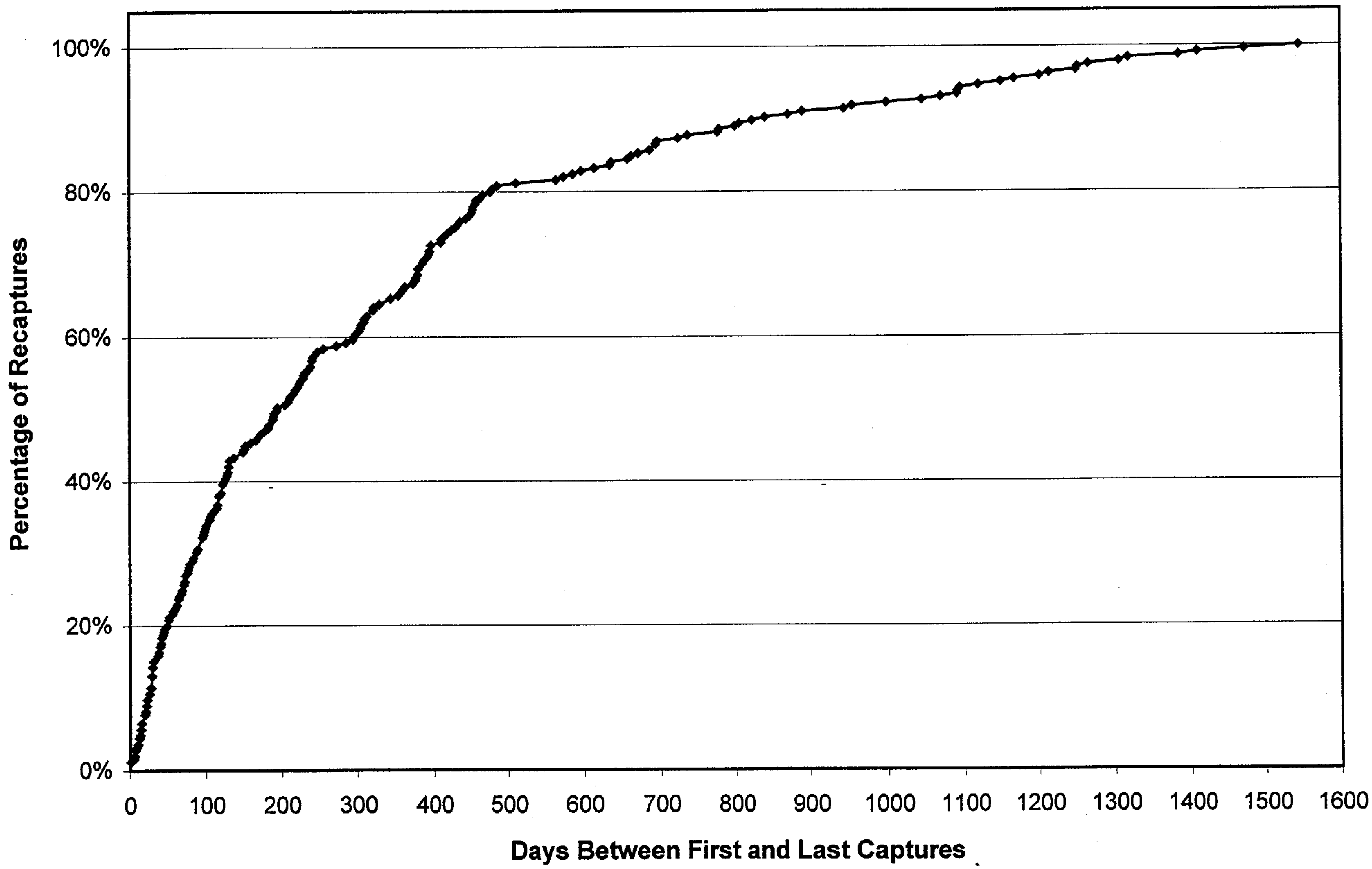

Figure 67. The percentage of juvenile green turtle recaptures that occurred within each time interval between first and last capture, St. Lucie Plant intake canal, Hutchinson Island, Florida.

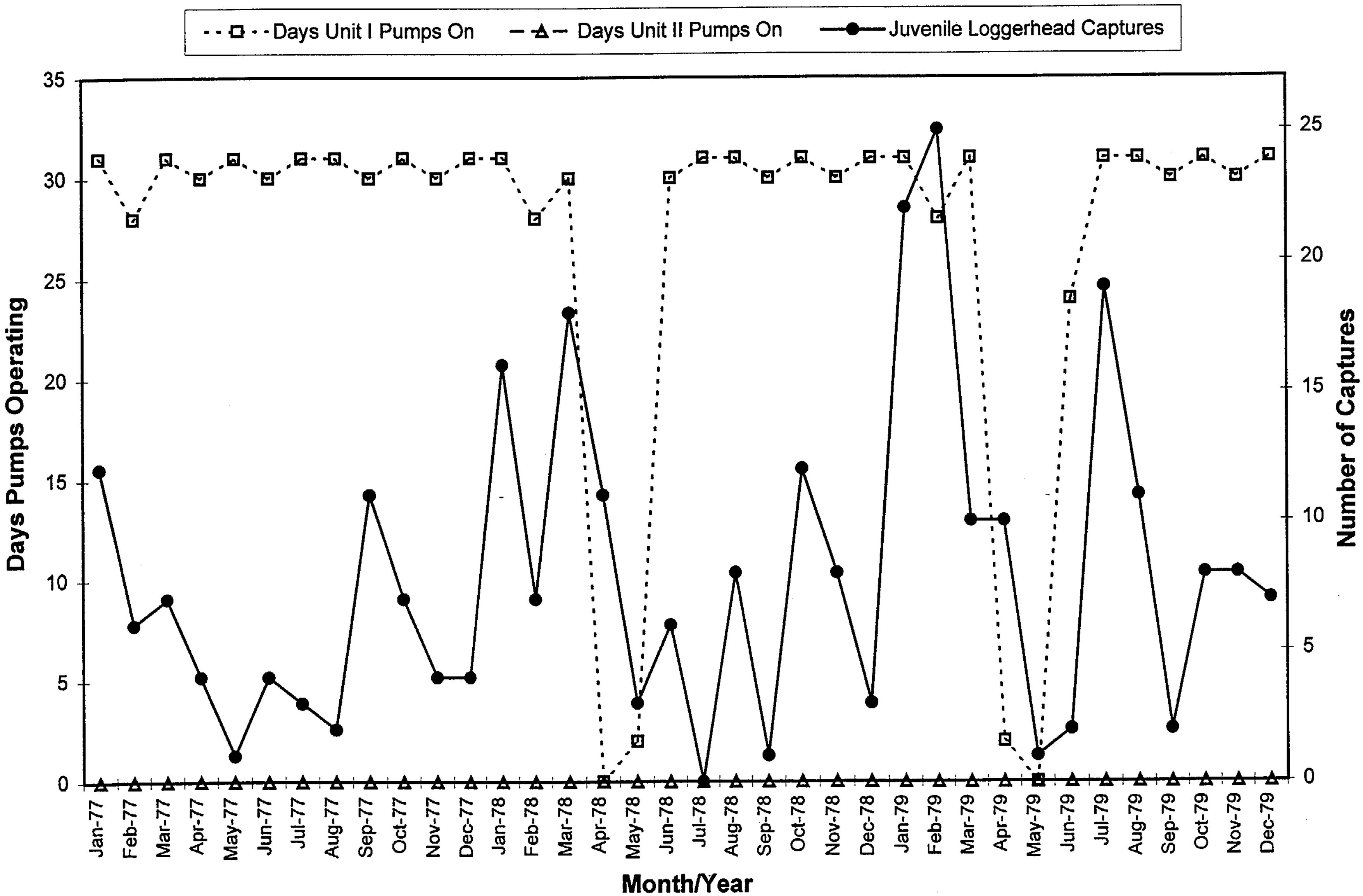

Figure 68. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1977 - December 1979.

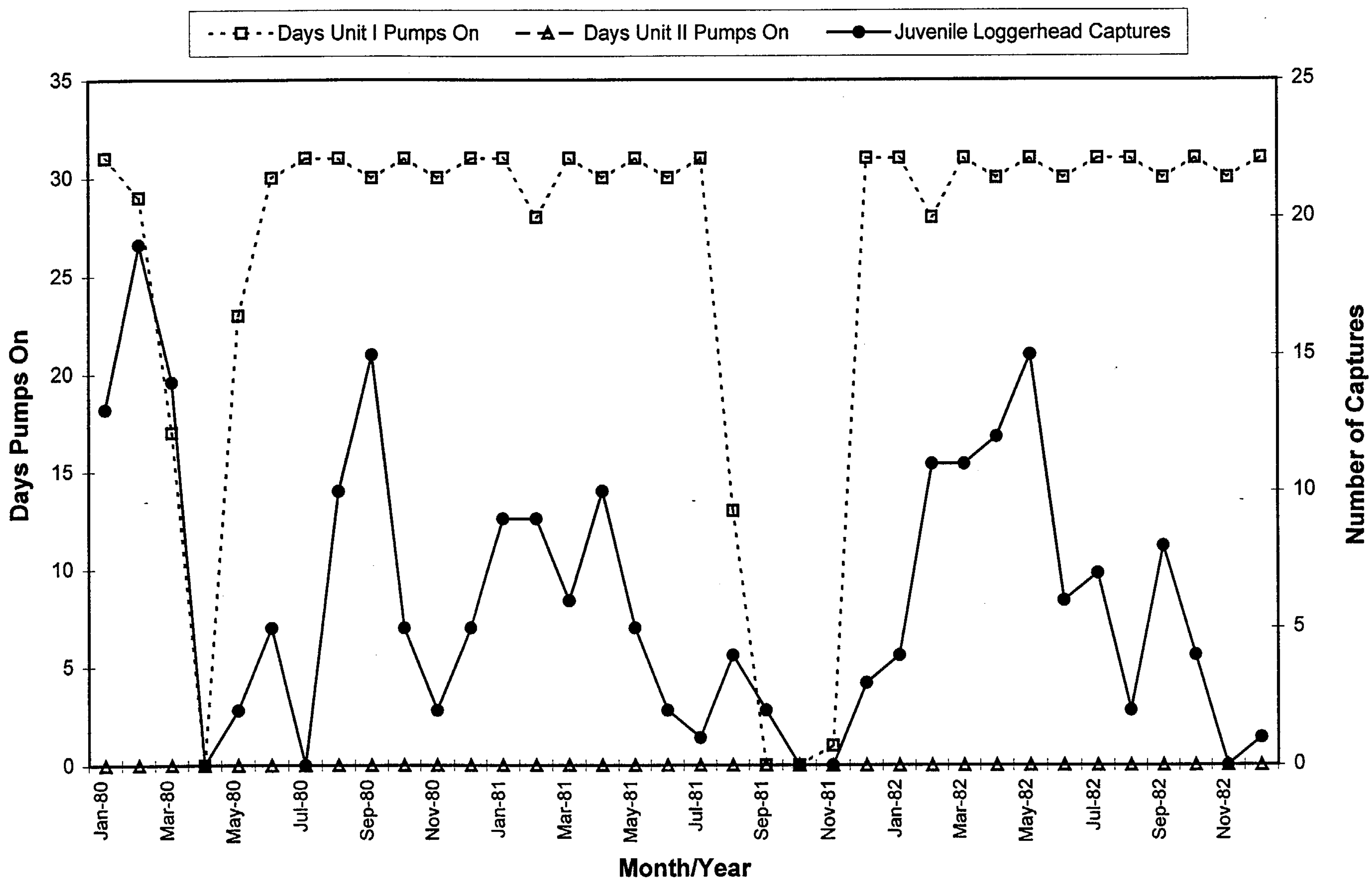

Figure 69. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1980 - December 1982.

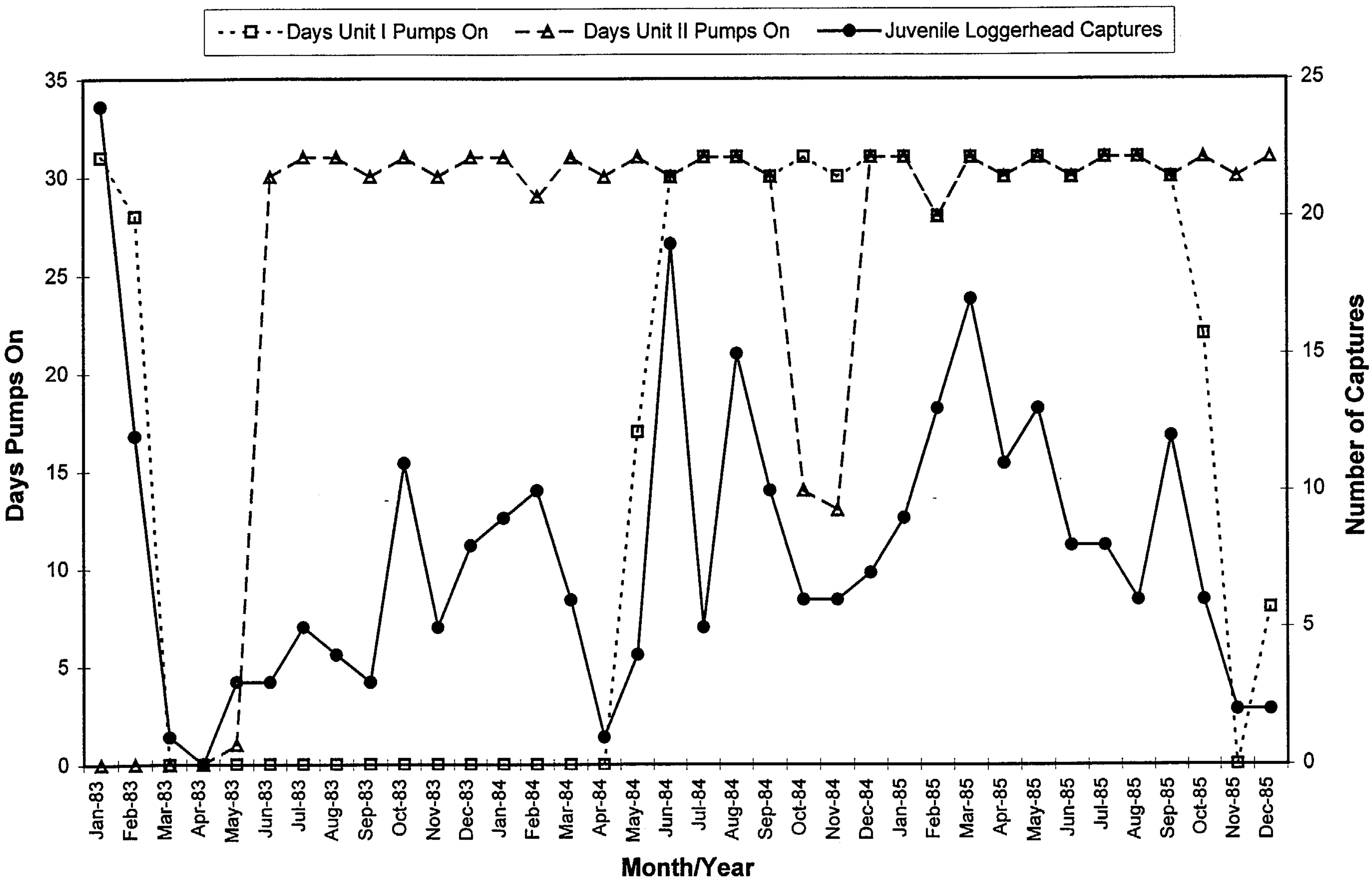

Figure 70. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1983 - December 1985.

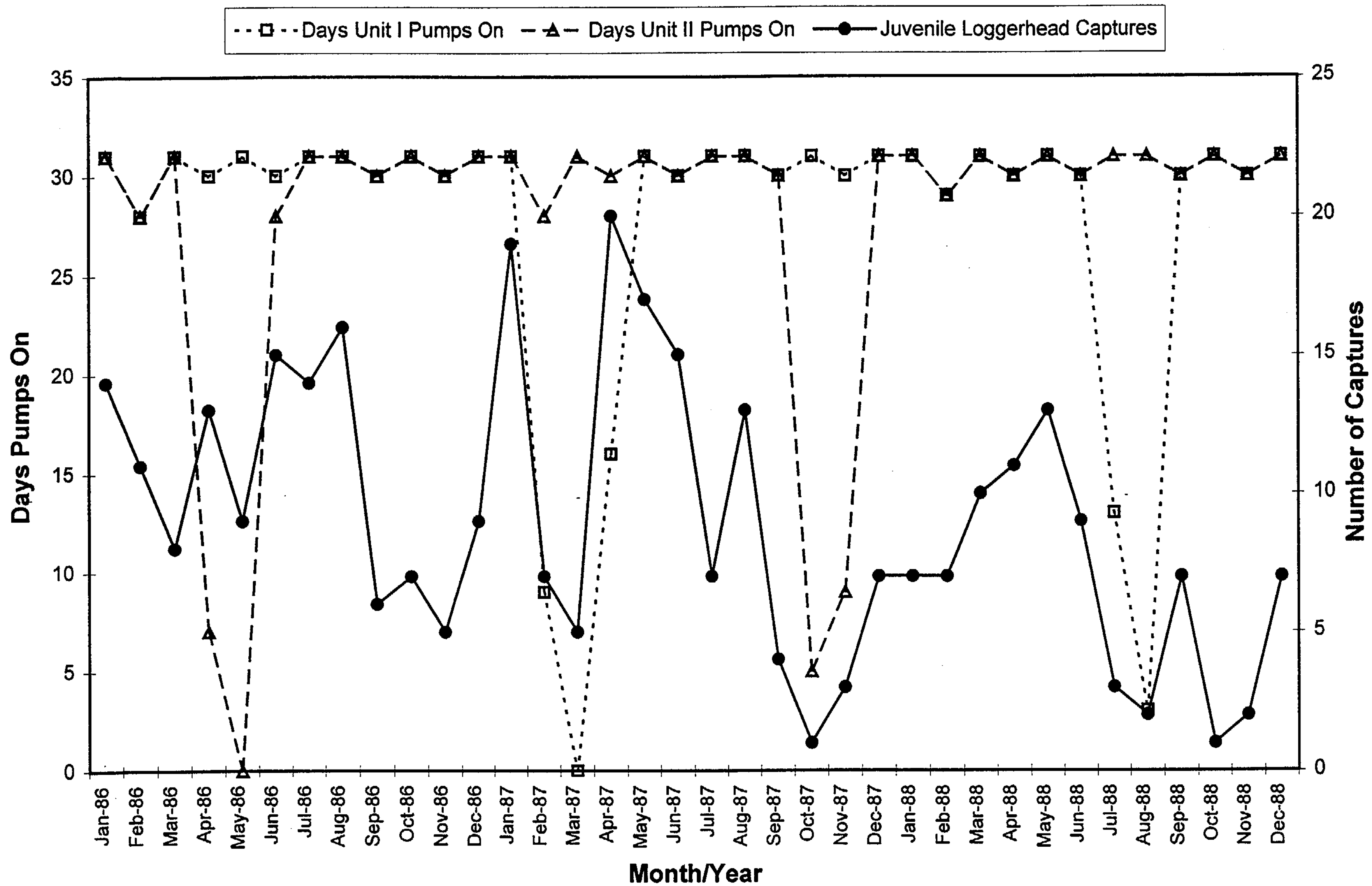

Figure 71. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1986 - December 1988.

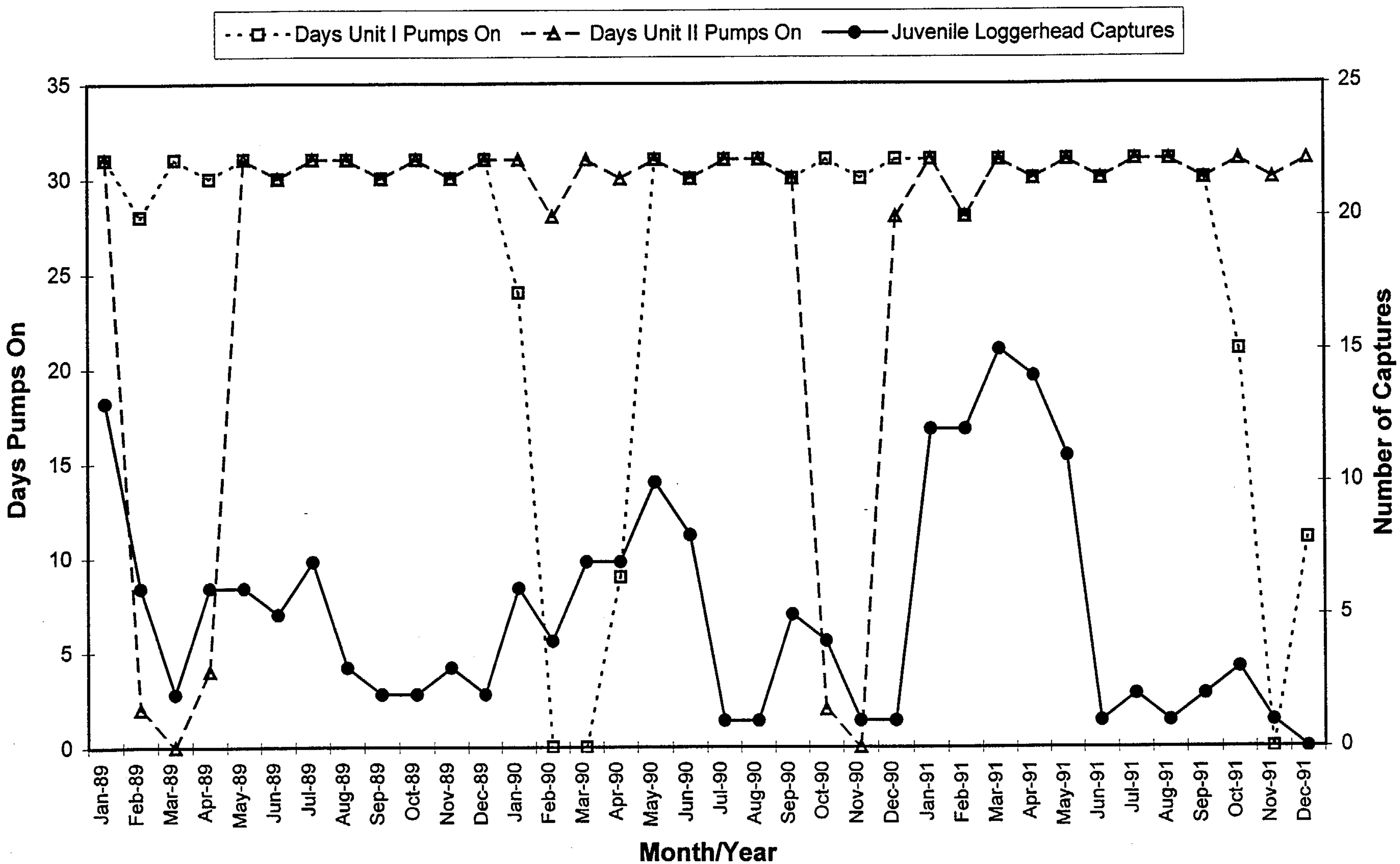

Figure 72. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1989 - December 1991.

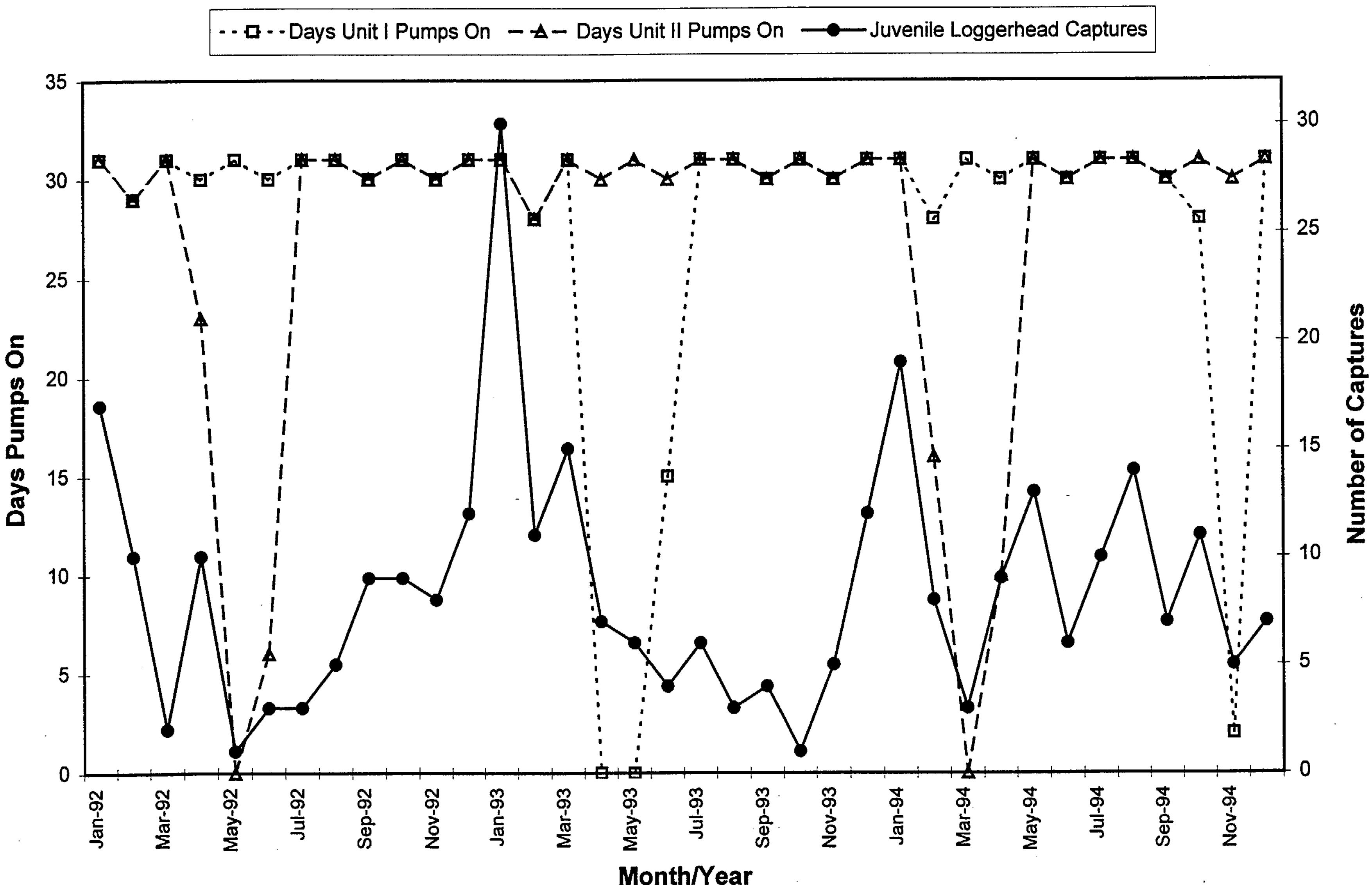

Figure 73. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1992 - December 1994.

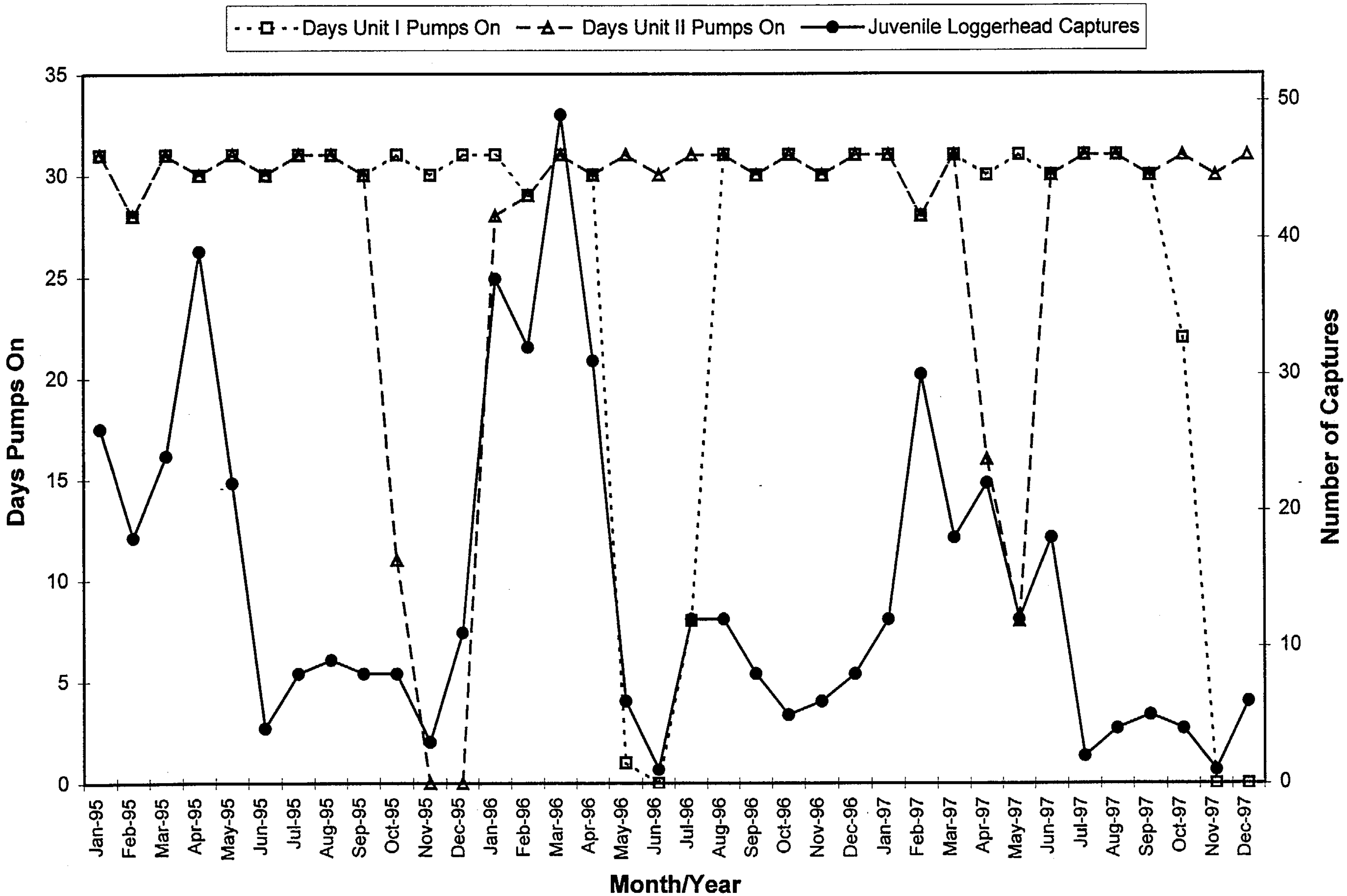

Figure 74. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1995 - December 1997.

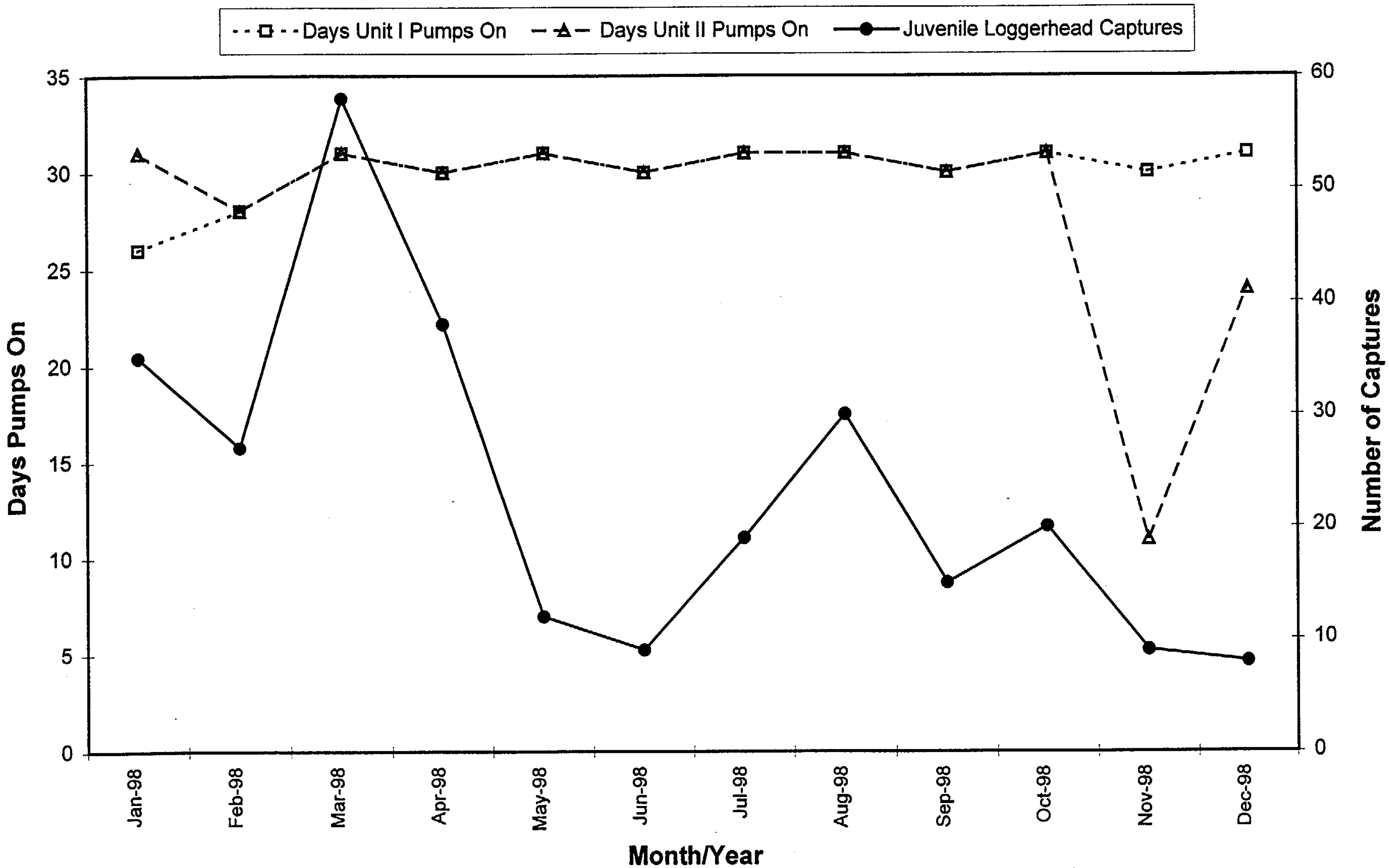

Figure 75. Monthly juvenile loggerhead captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1998 - December 1998.

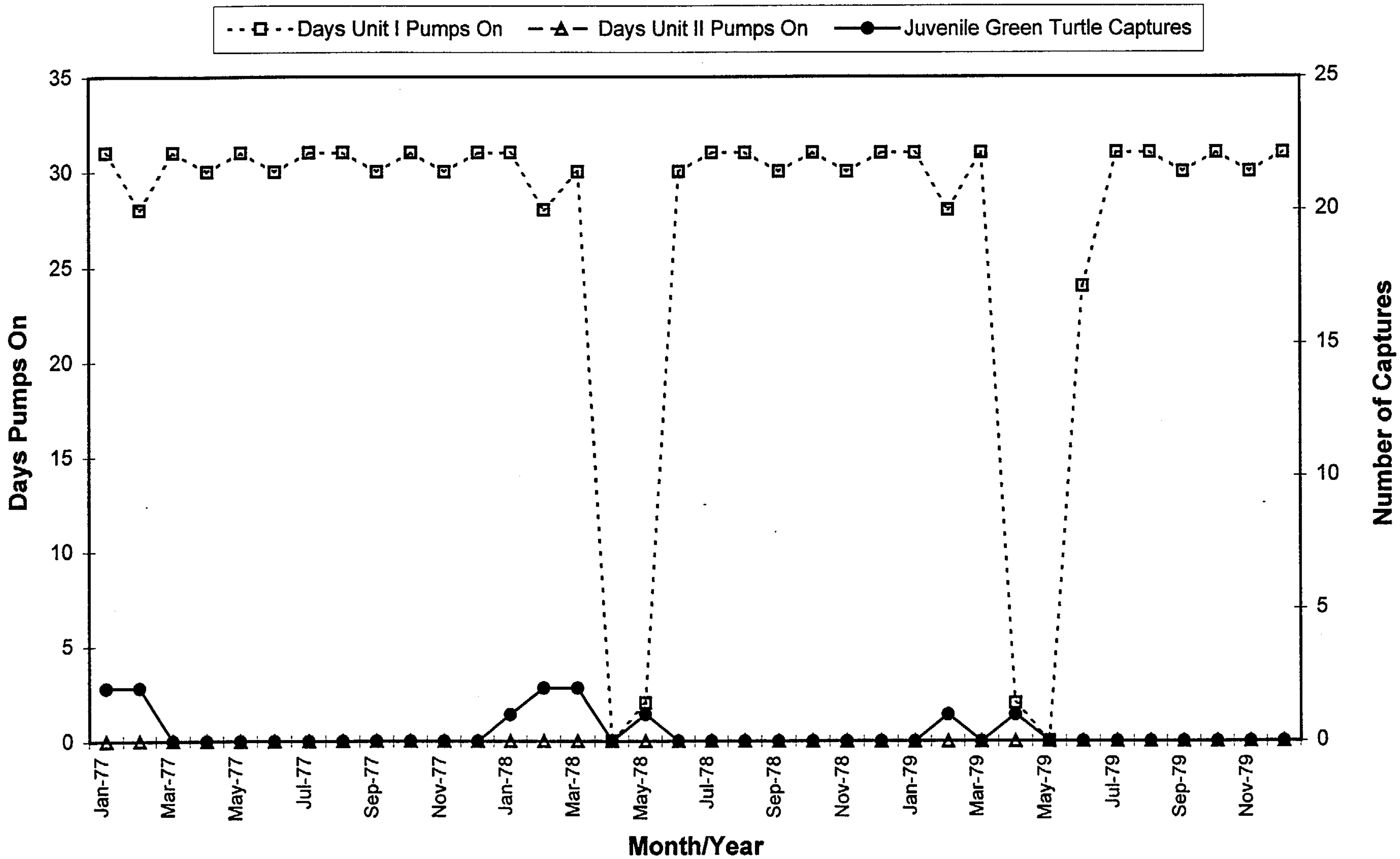

Figure 76. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1977 - December 1979.

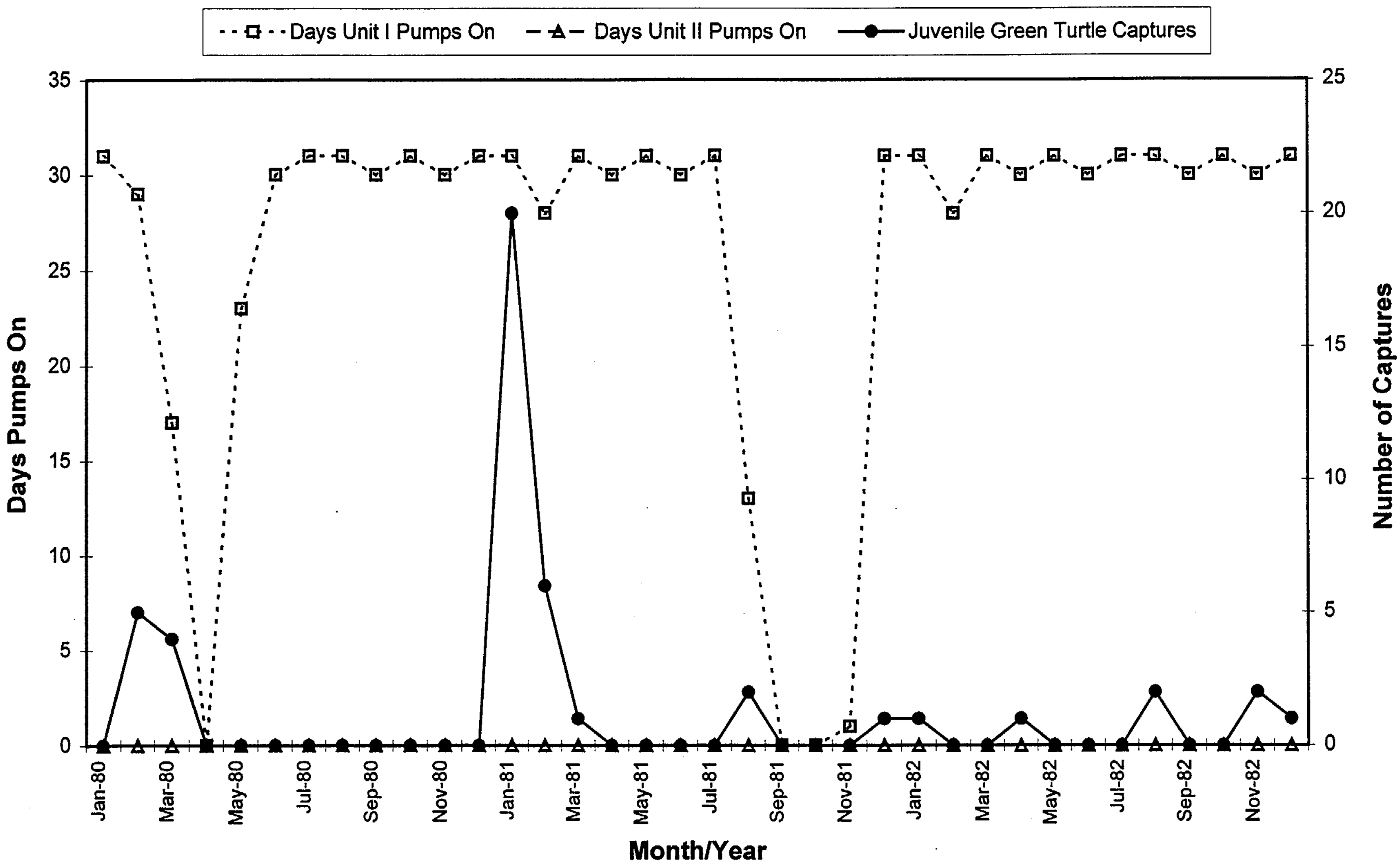

Figure 77. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1980 - December 1982.

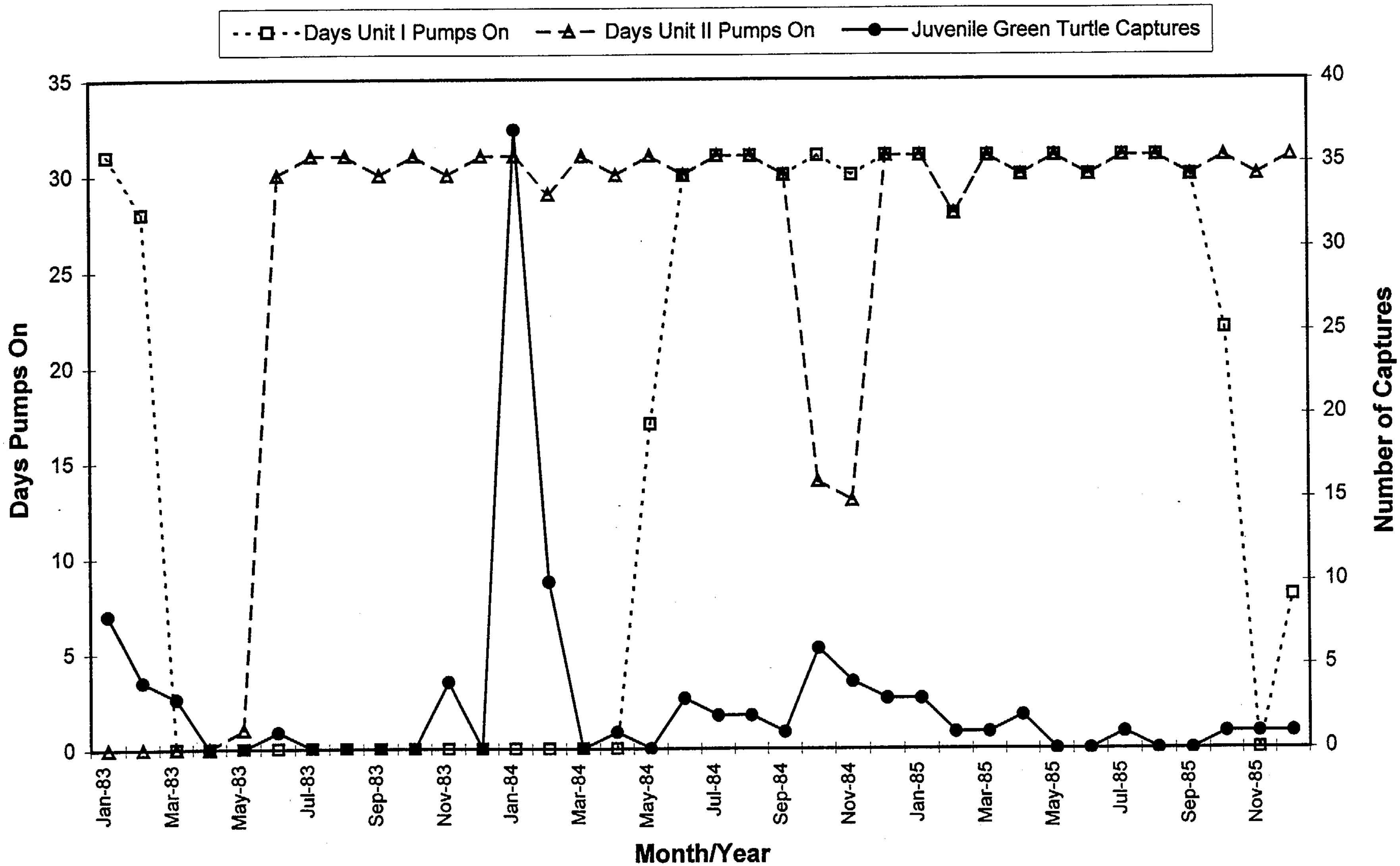

Figure 78. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1983 - December 1985.

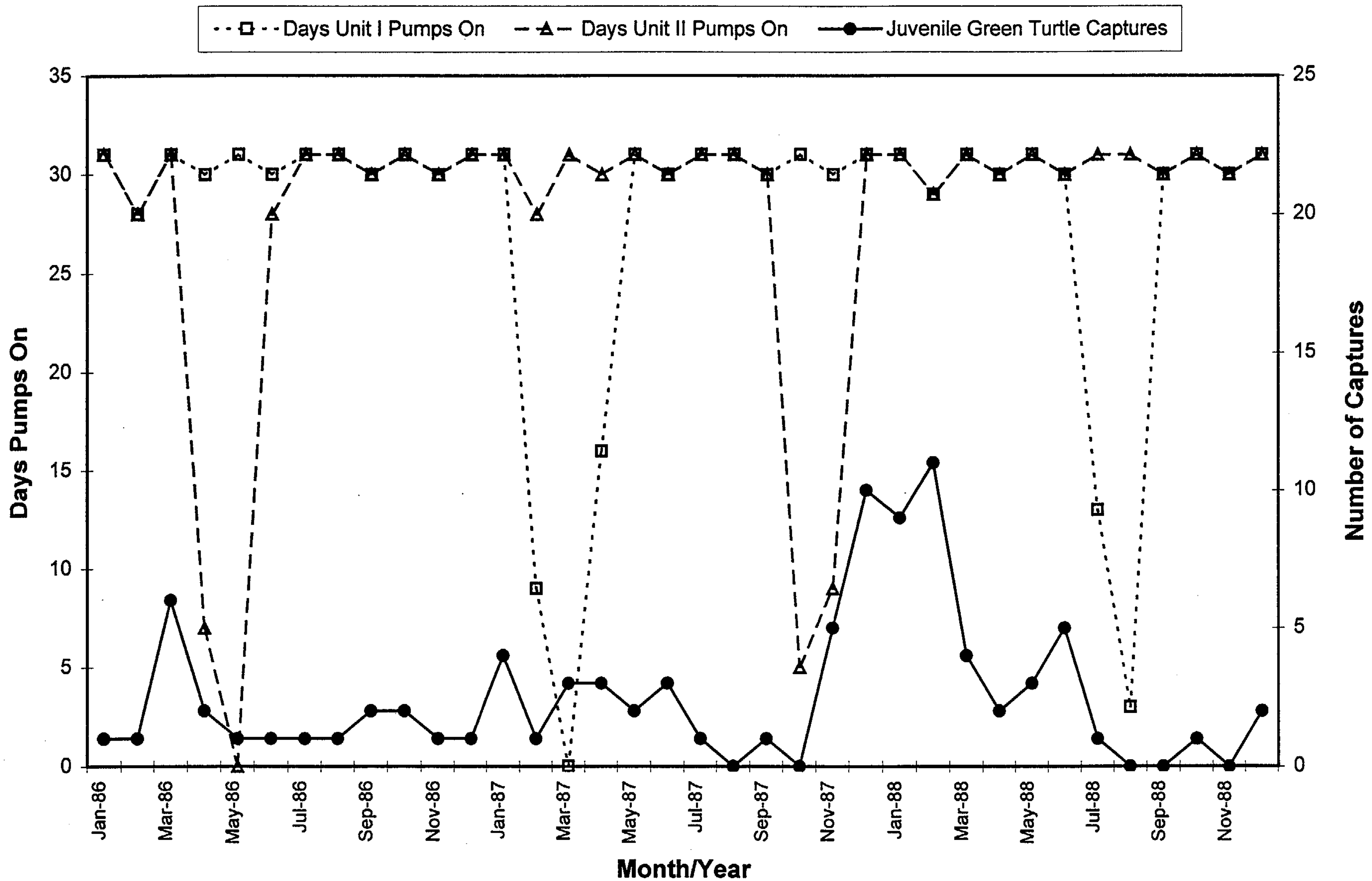

Figure 79. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1986 - December 1988.

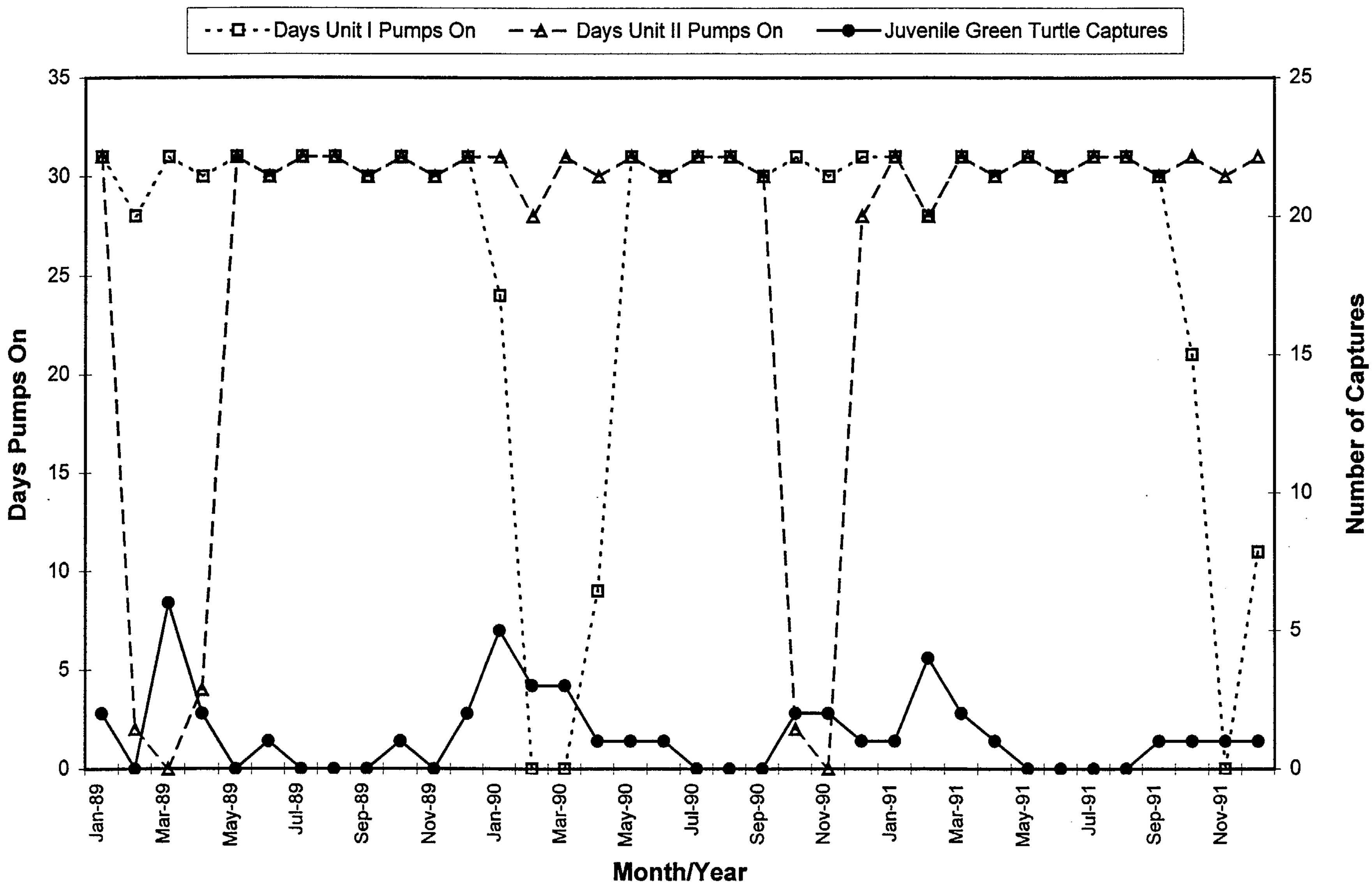

Figure 80. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1989 - December 1991.

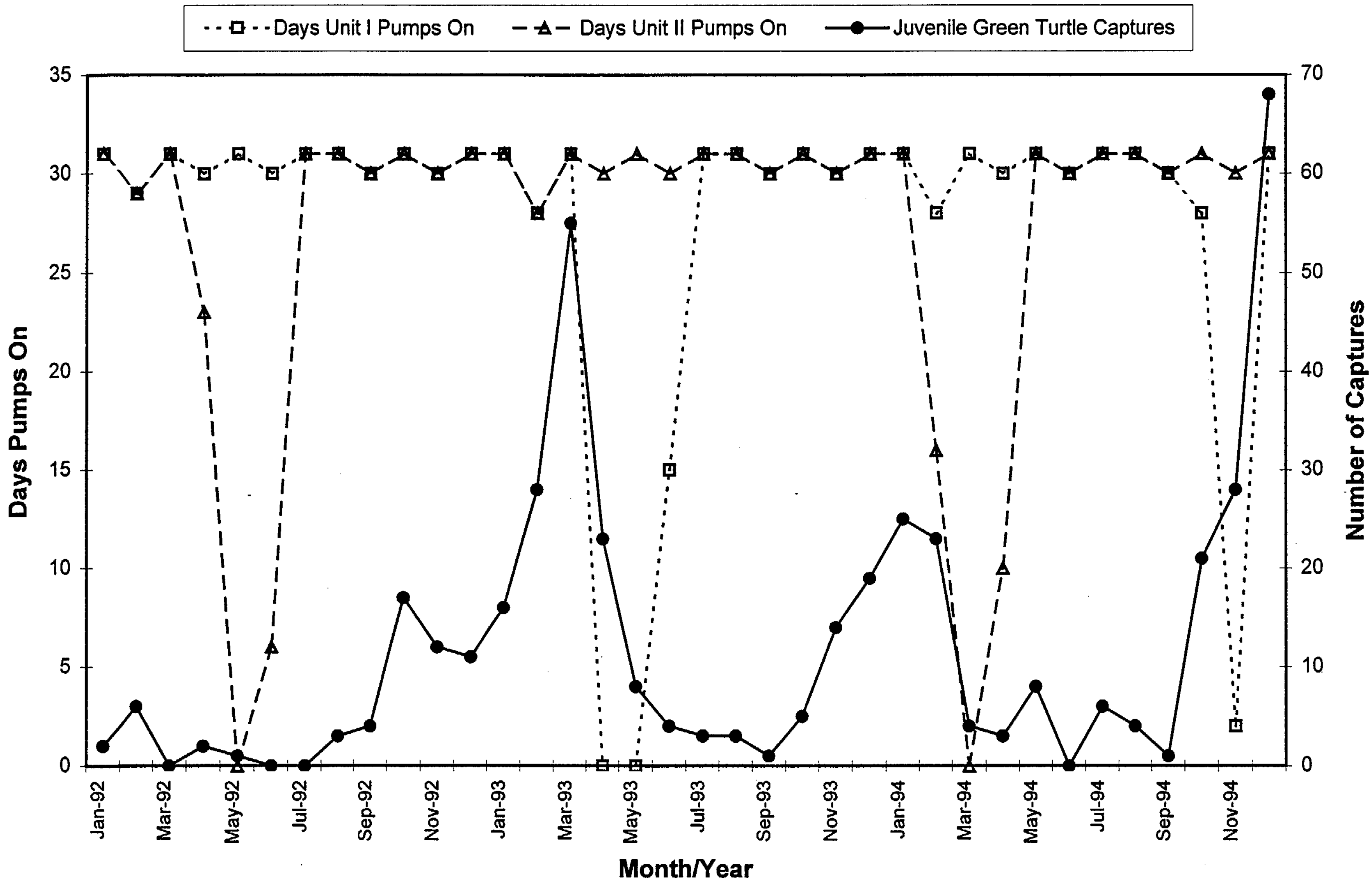

Figure 81. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1992 - December 1994.

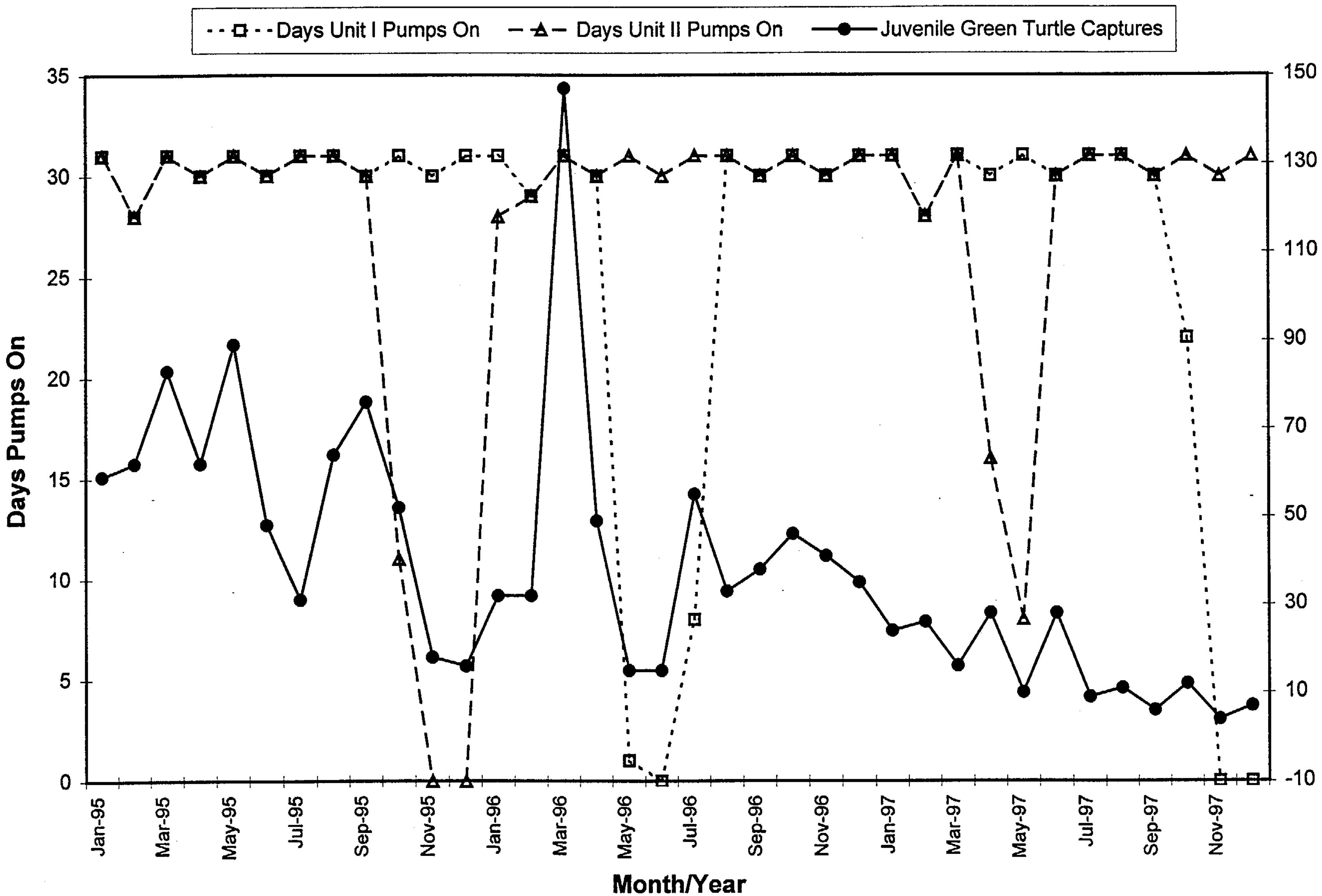

Figure 82. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1995 - December 1997.

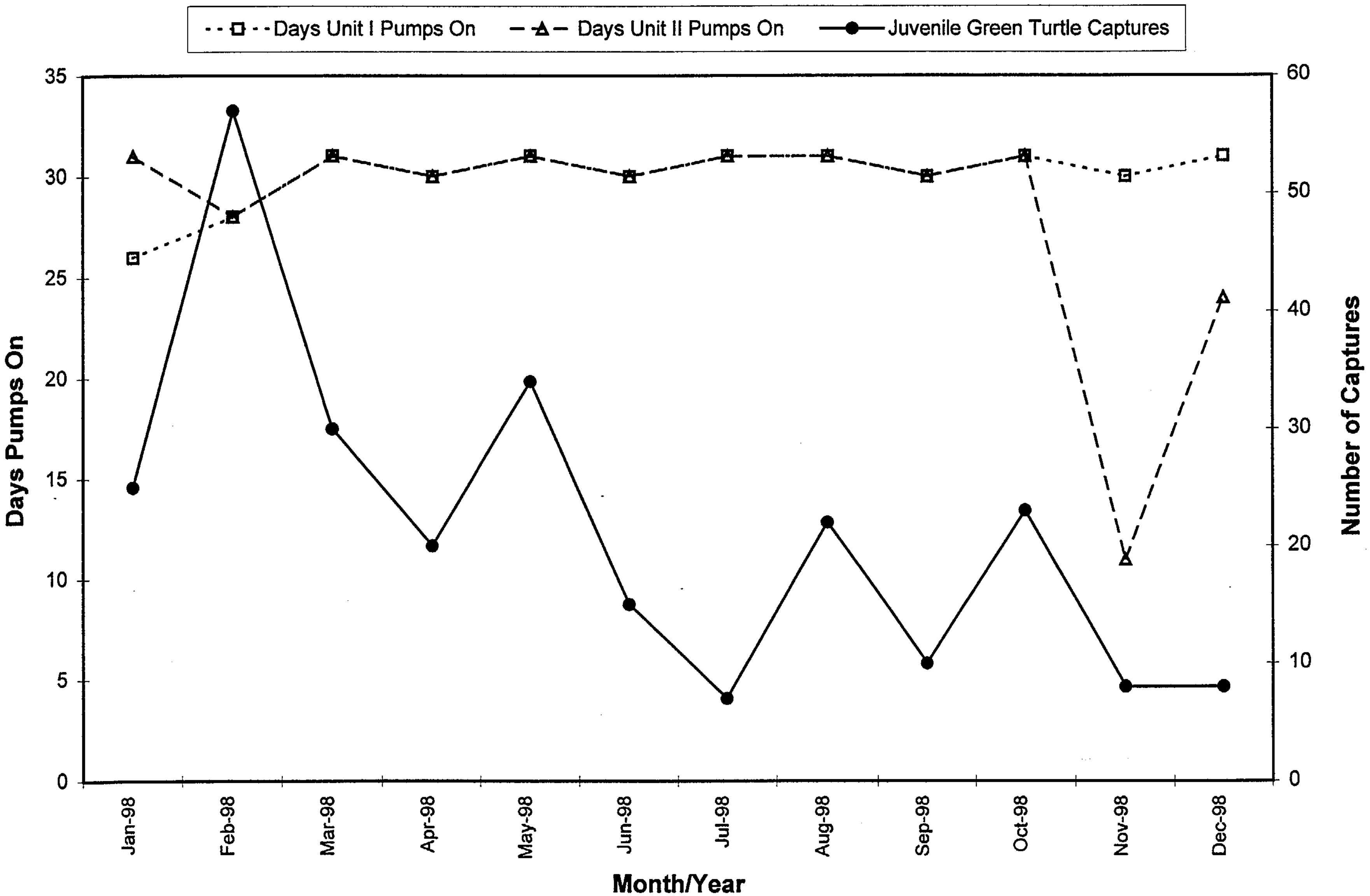

Figure 83. Monthly juvenile green turtle captures compared to St. Lucie Plant operating status (the approximate number of days per month that each unit's circulating water pumps were operating), January 1998 - December 1998.

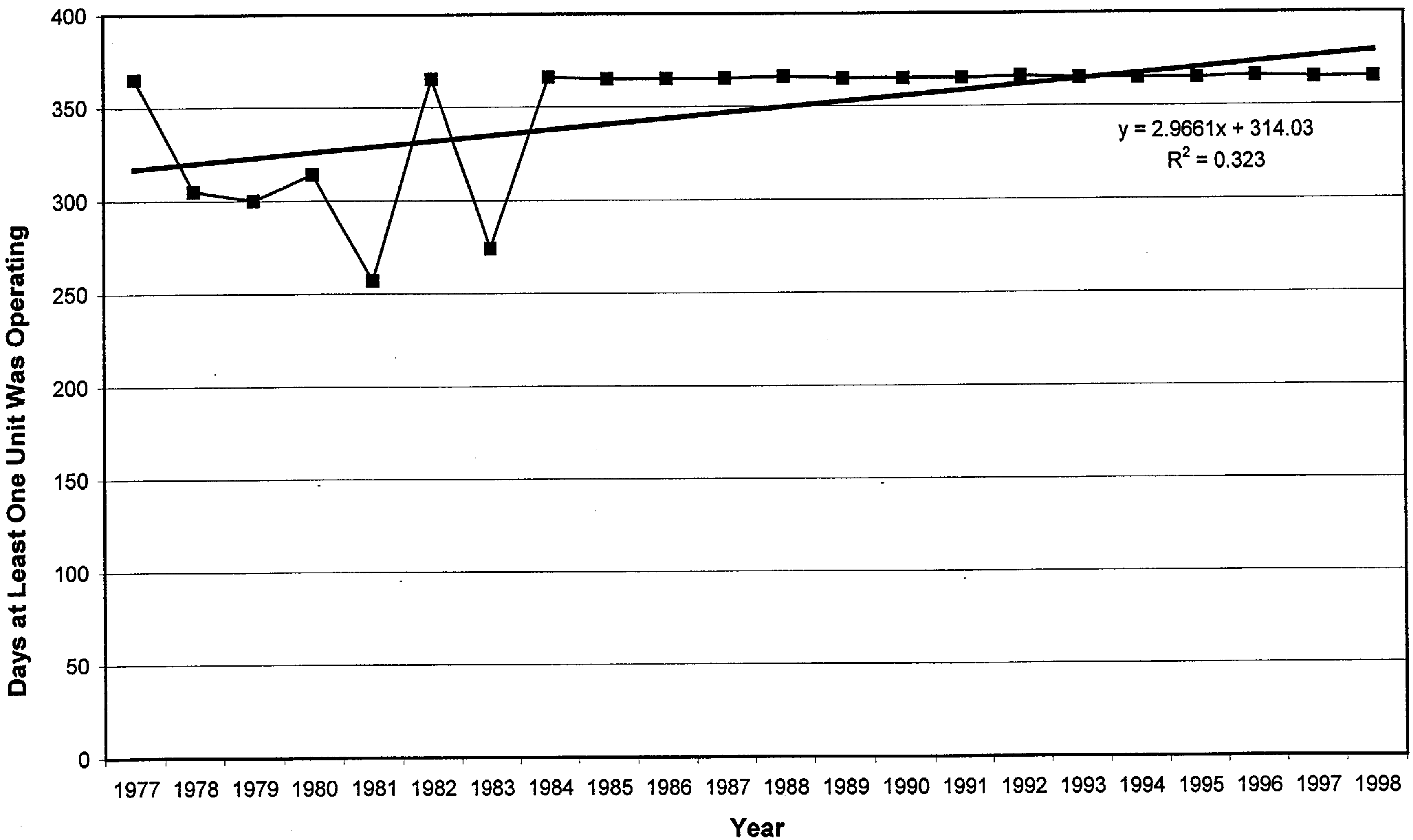

Figure 84. St. Lucie Plant operating status (the approximate number of days per year that at least one unit's circulating water pumps were operating), 1977-1998.

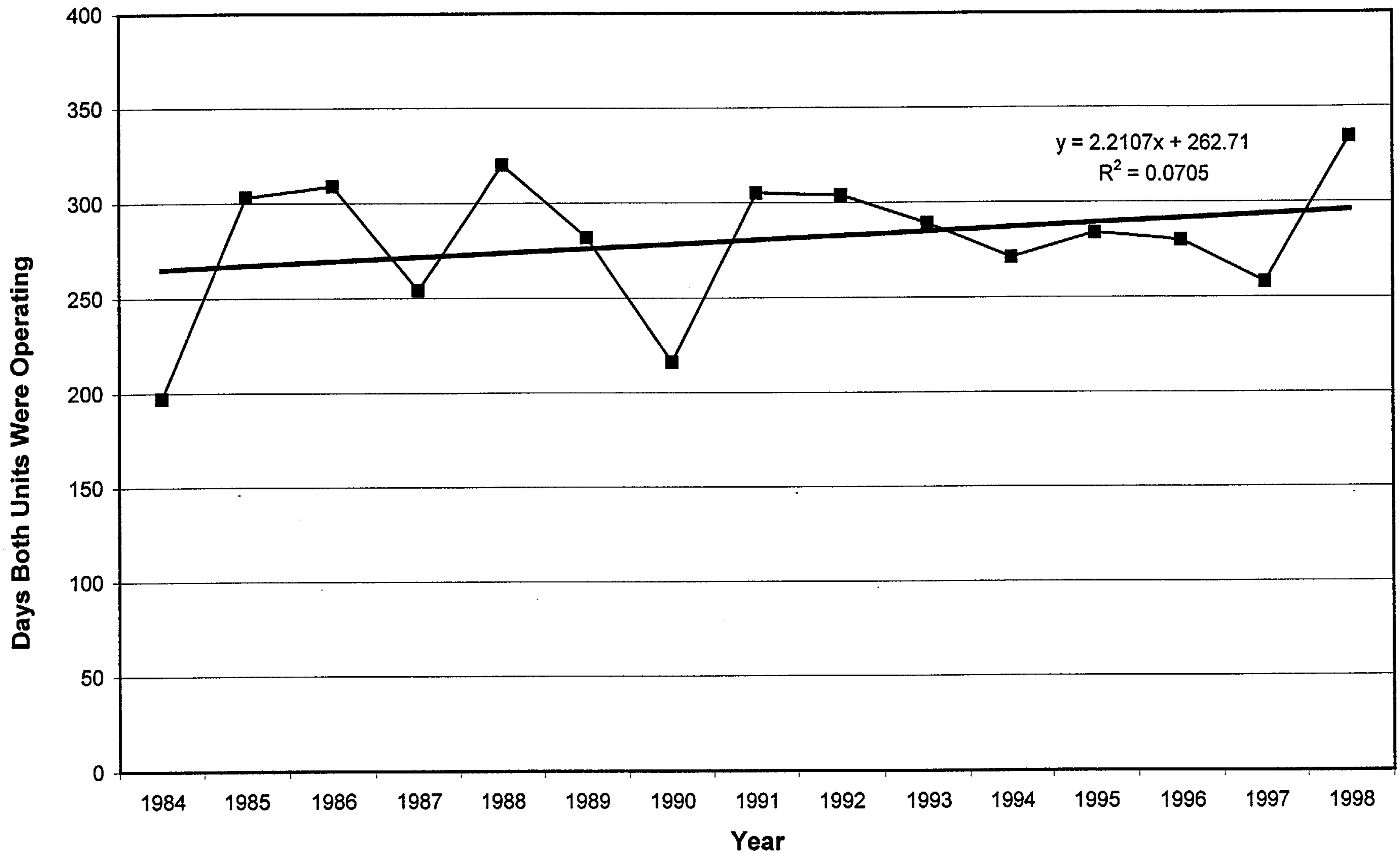

Figure 85. St. Lucie Plant operating status (the approximate number of days per year that circulating water pumps at both units were operating), 1984-1998.

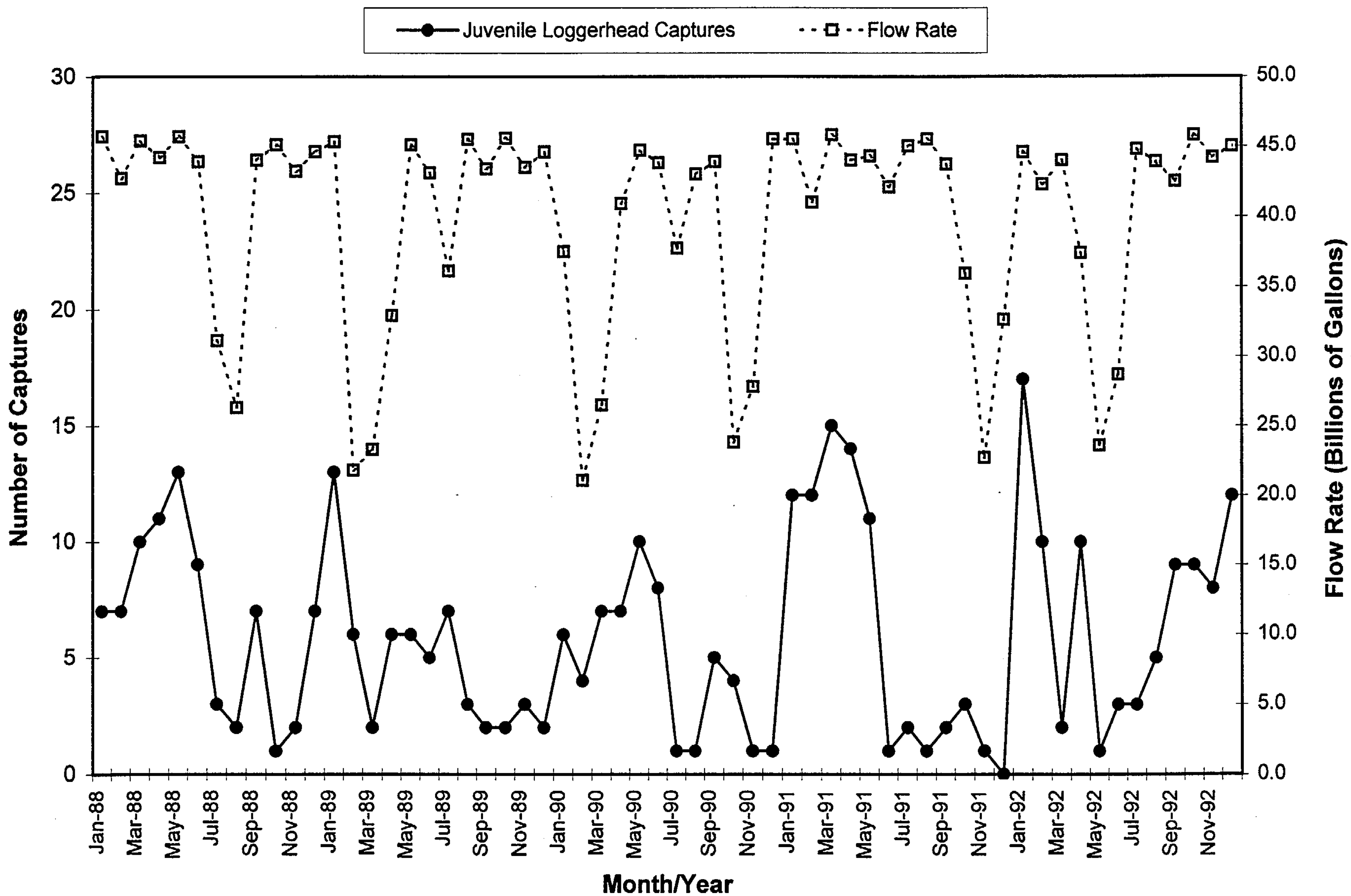

Figure 86. Monthly juvenile loggerhead captures compared to monthly flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1988 - December 1992.

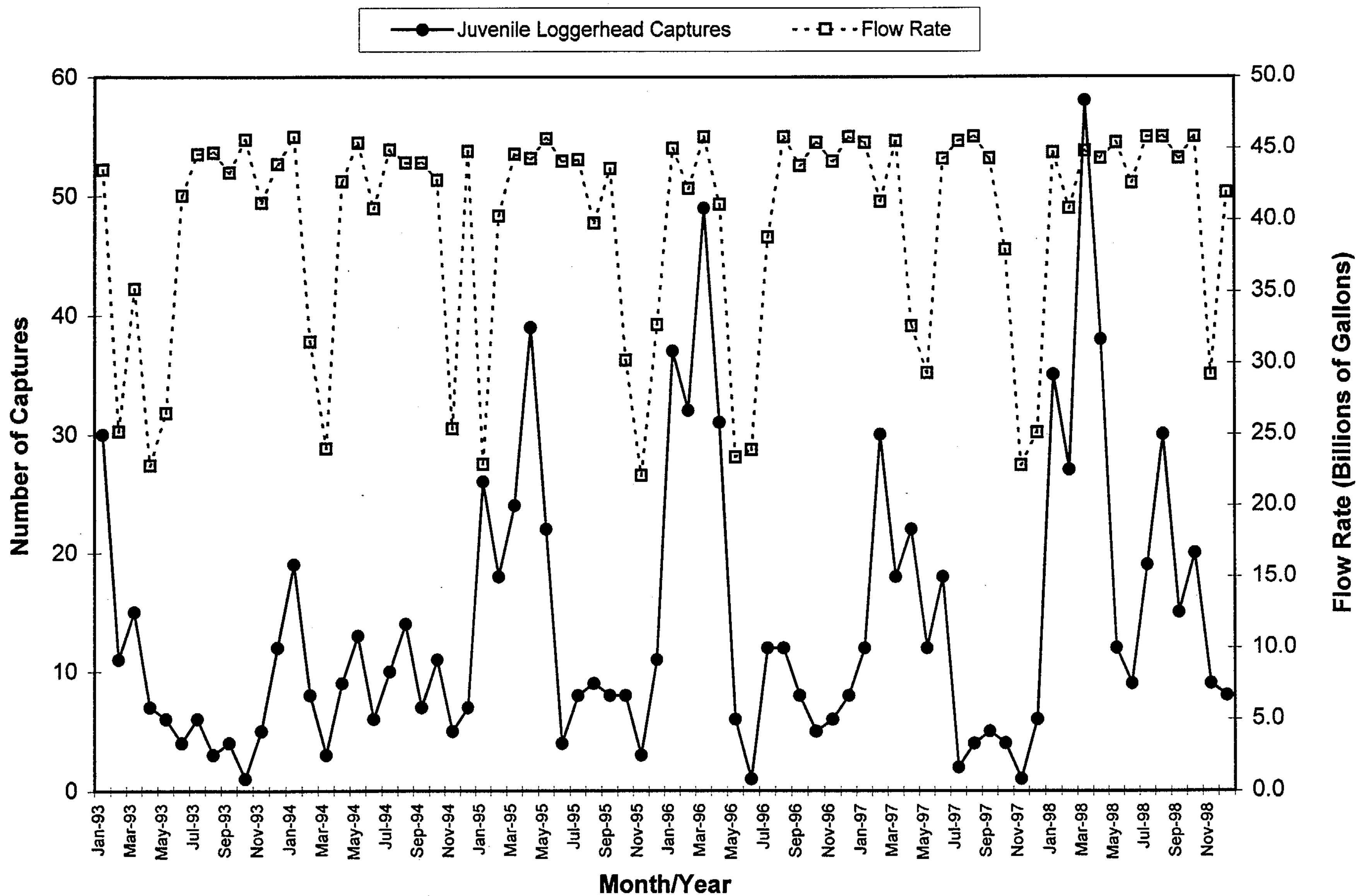

Figure 87. Monthly juvenile loggerhead captures compared to monthly flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1993 - December 1998.

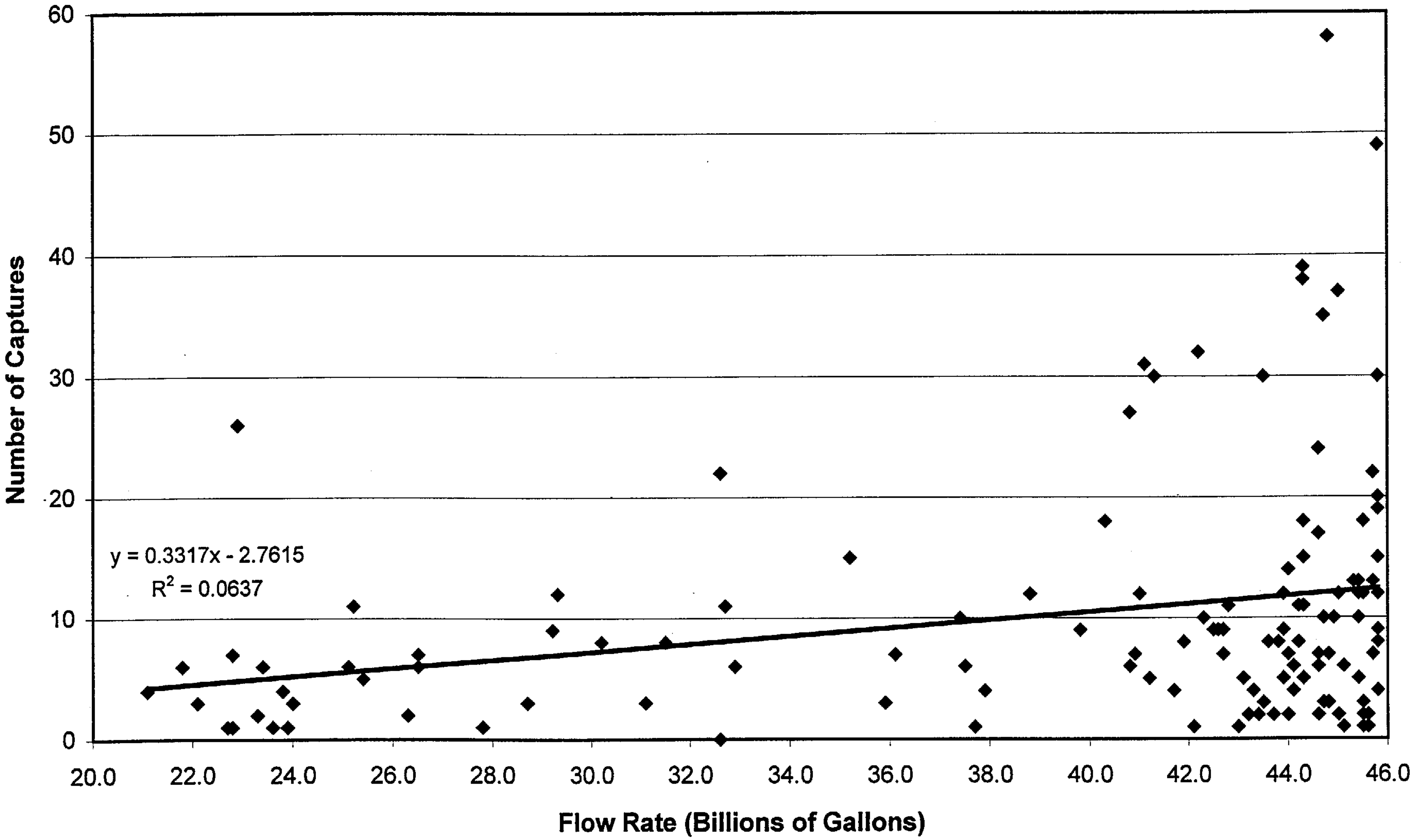

Figure 88. Monthly numbers of juvenile loggerhead captures versus monthly flow rates through circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1988 - December 1998.

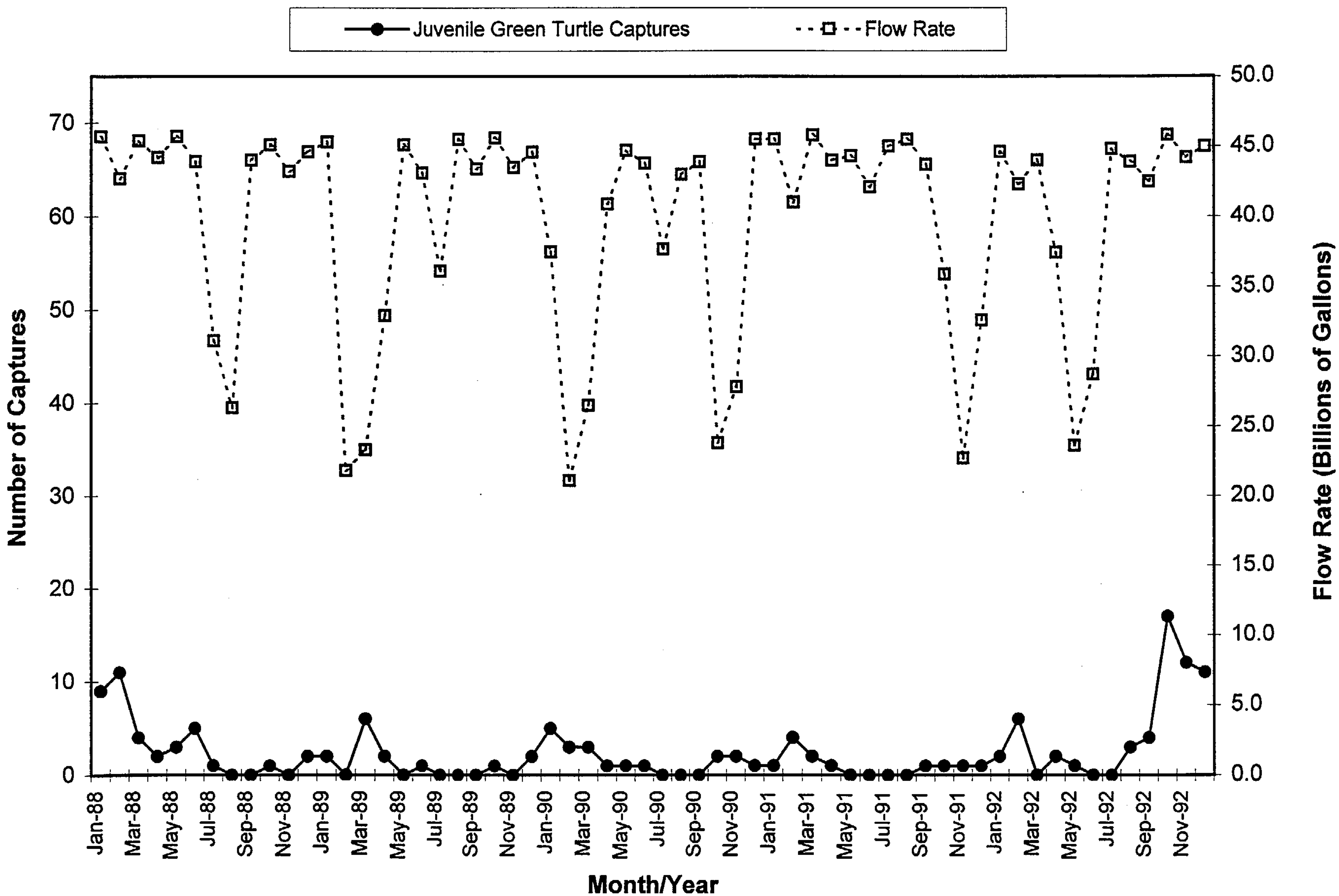

Figure 89. Monthly juvenile green turtle captures compared to monthly flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1988 - December 1992.

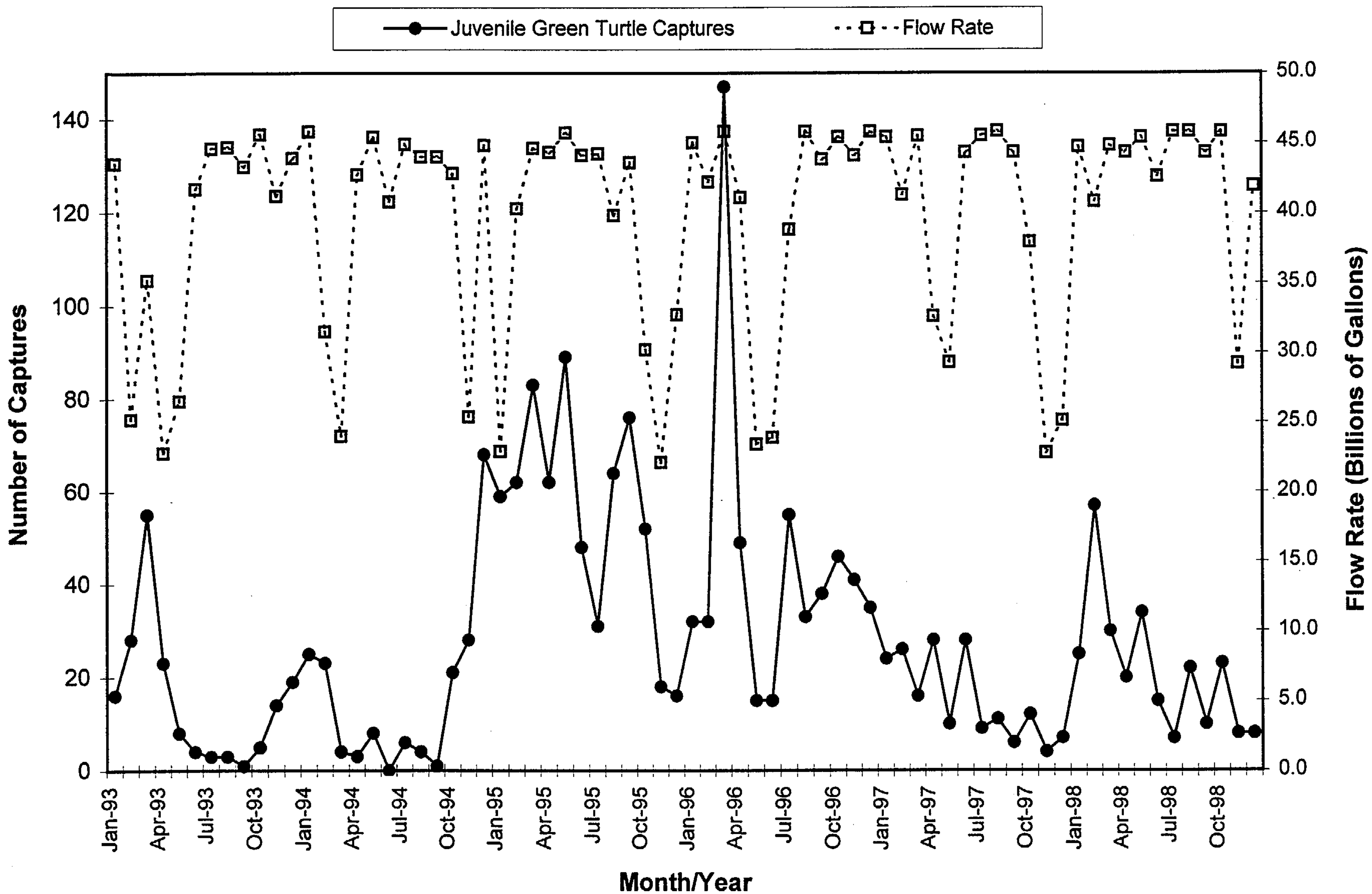

Figure 90. Monthly juvenile green turtle captures compared to monthly flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1993 - December 1998.

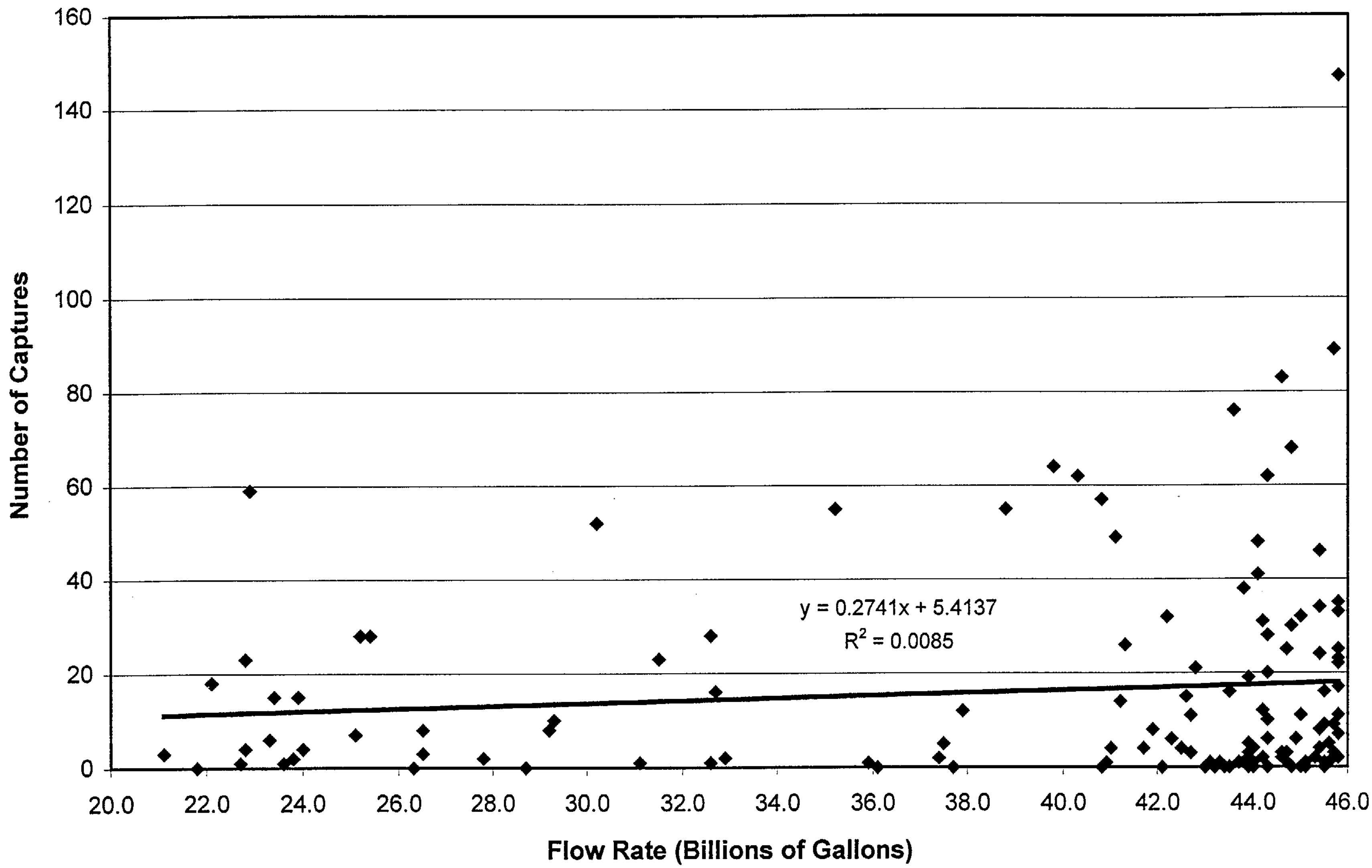

Figure 91. Monthly numbers of juvenile green turtle captures versus monthly flow rates through circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, January 1988 - December 1998.

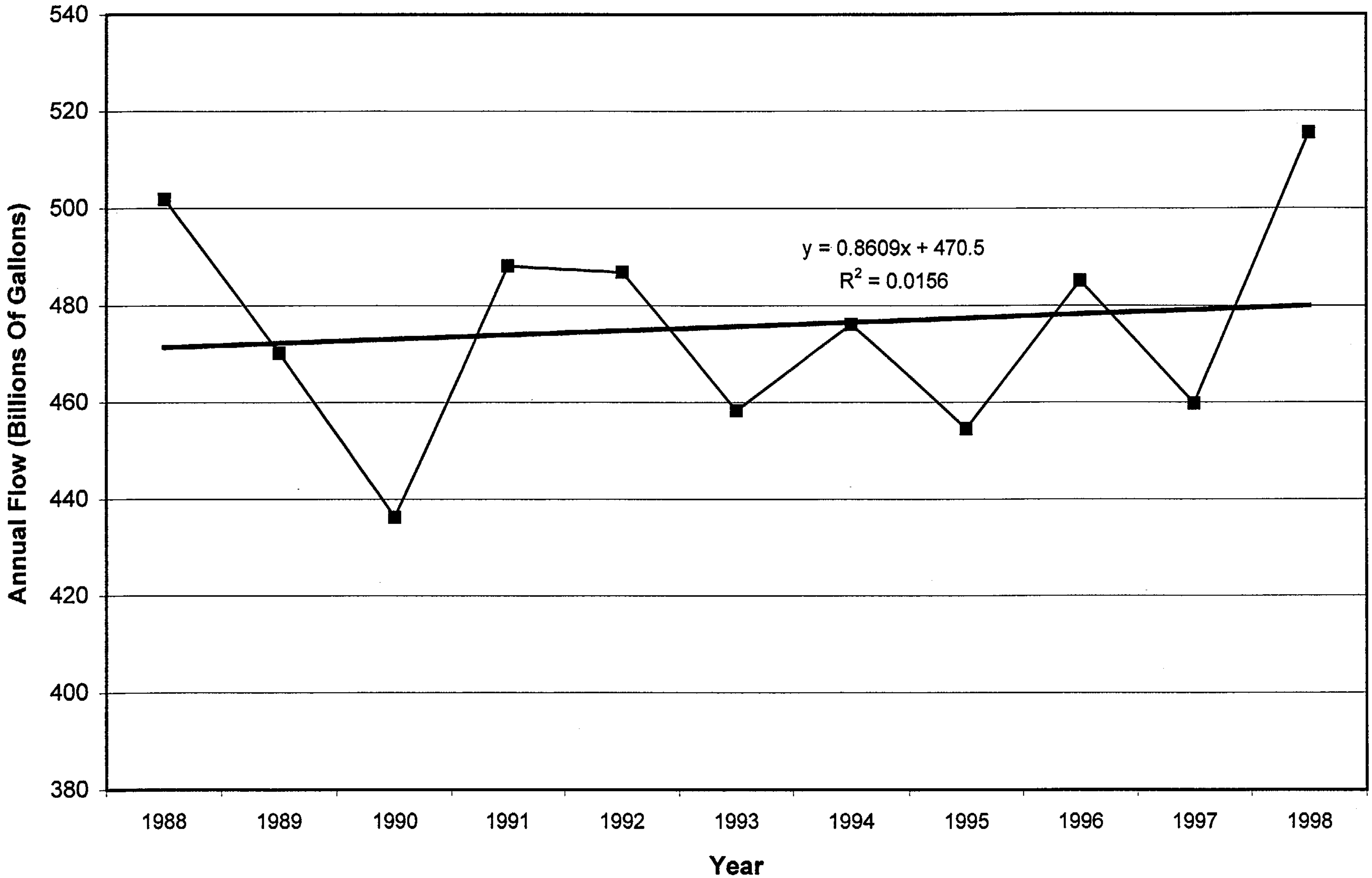

Figure 92. Annual flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, 1988-1998.

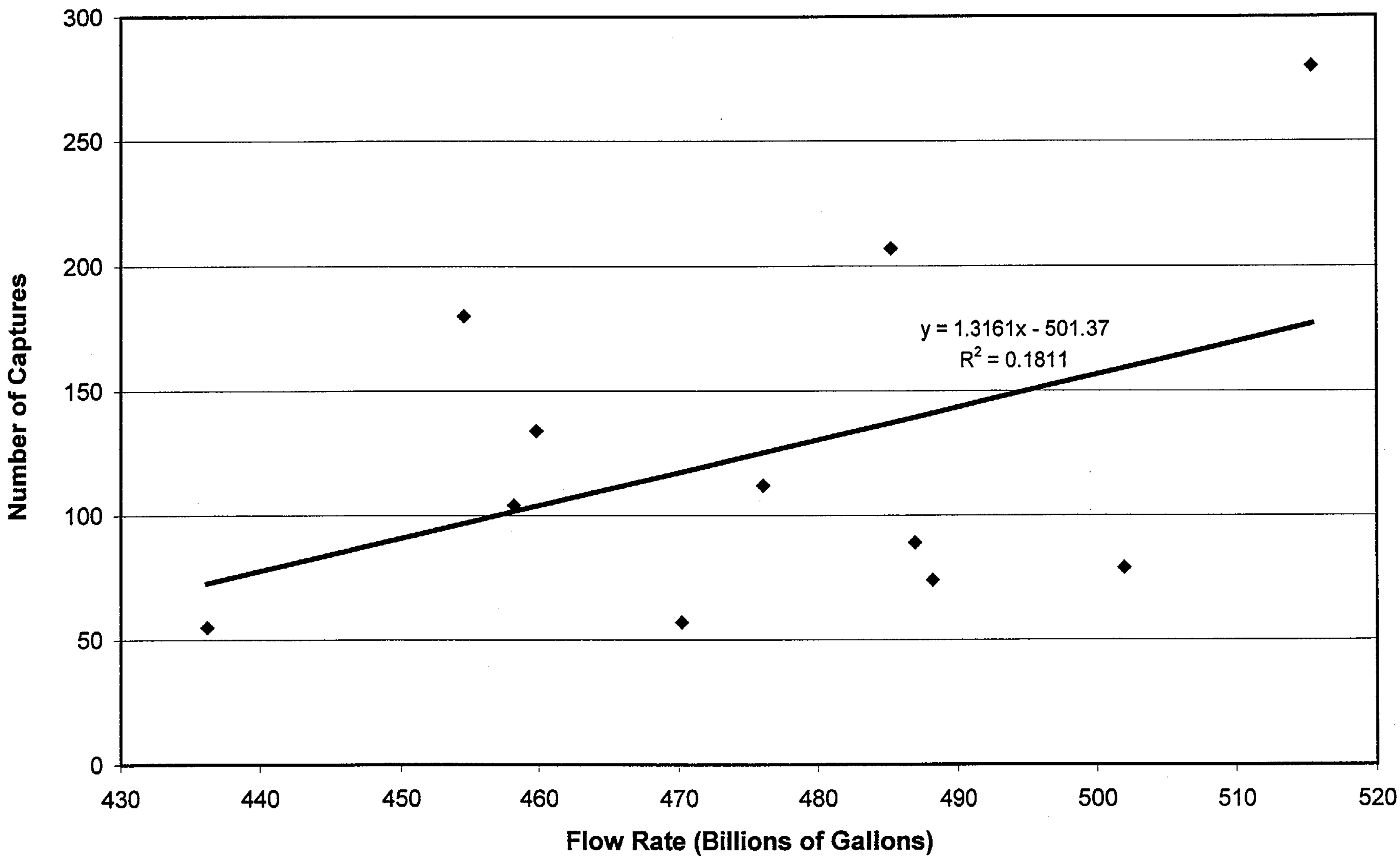

Figure 93. Annual juvenile loggerhead captures versus annual flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, 1988-1998.

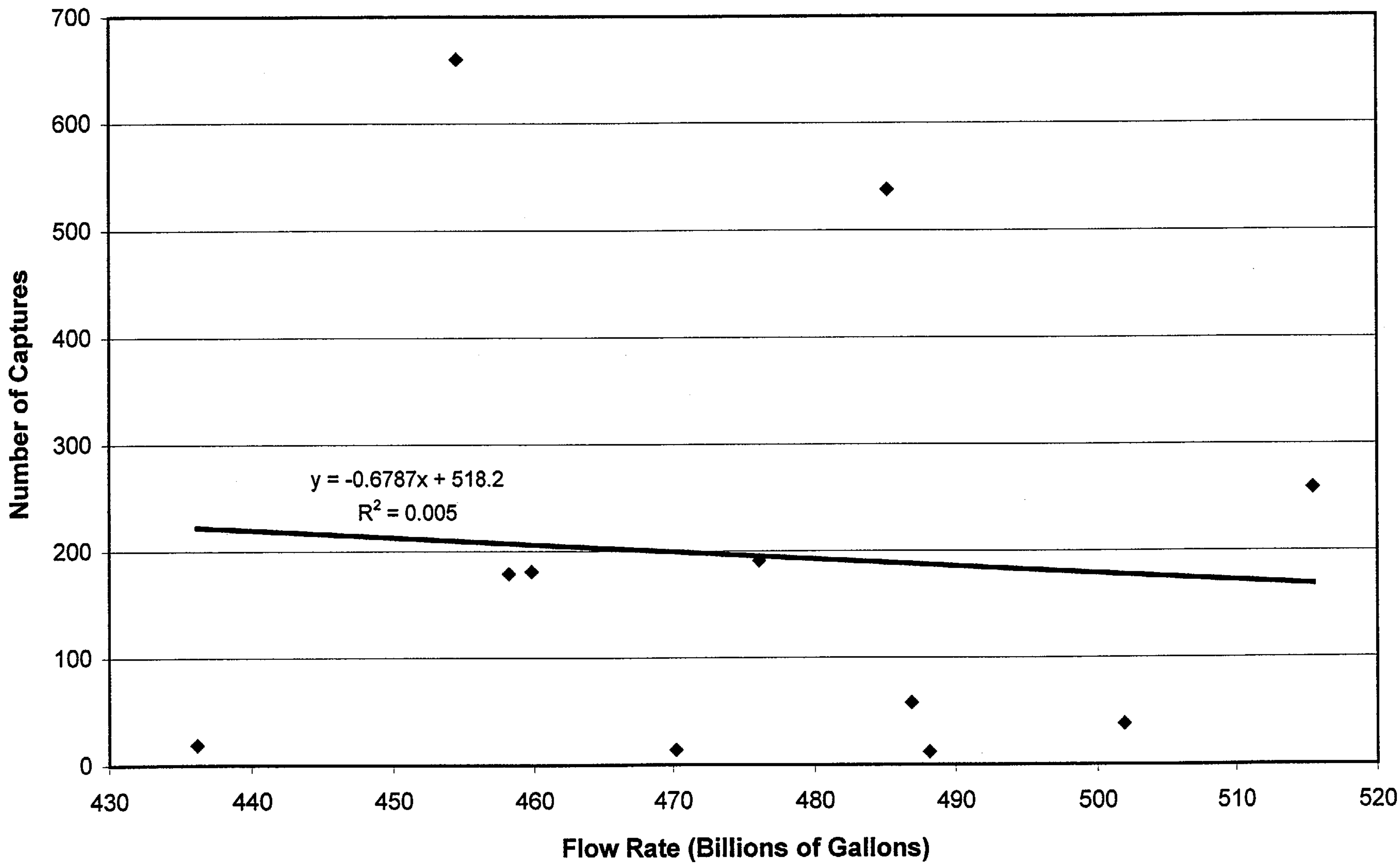

Figure 94. Annual juvenile green turtle captures versus annual flow rates through the circulating water pumps, St. Lucie Plant, Hutchinson Island, Florida, 1988-1998.

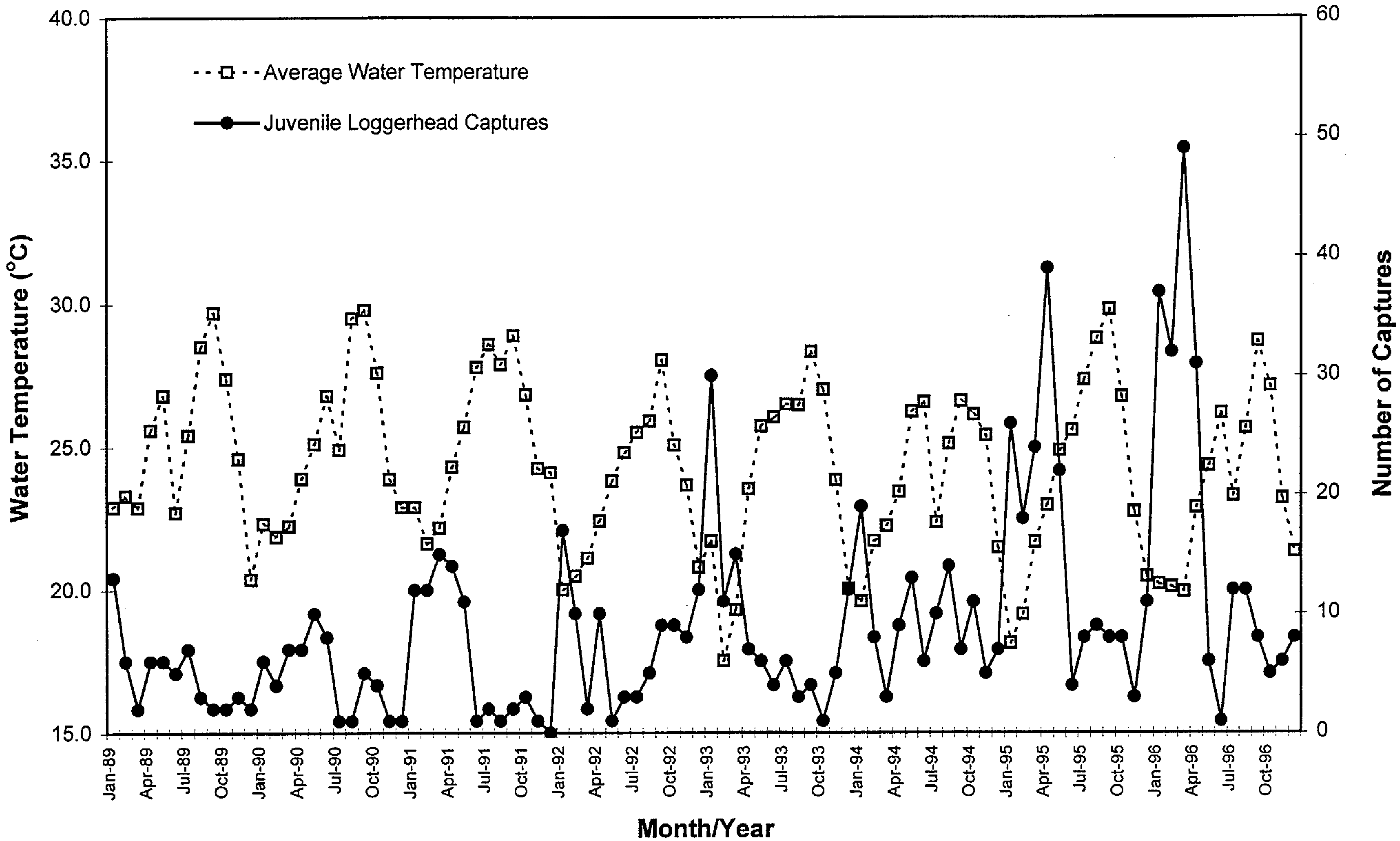

Figure 95. Monthly juvenile loggerhead captures compared to mean monthly water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, January 1989 - December 1996. Mean monthly water temperatures were based on daily water temperatures recorded at the power plant's circulating water pumps.

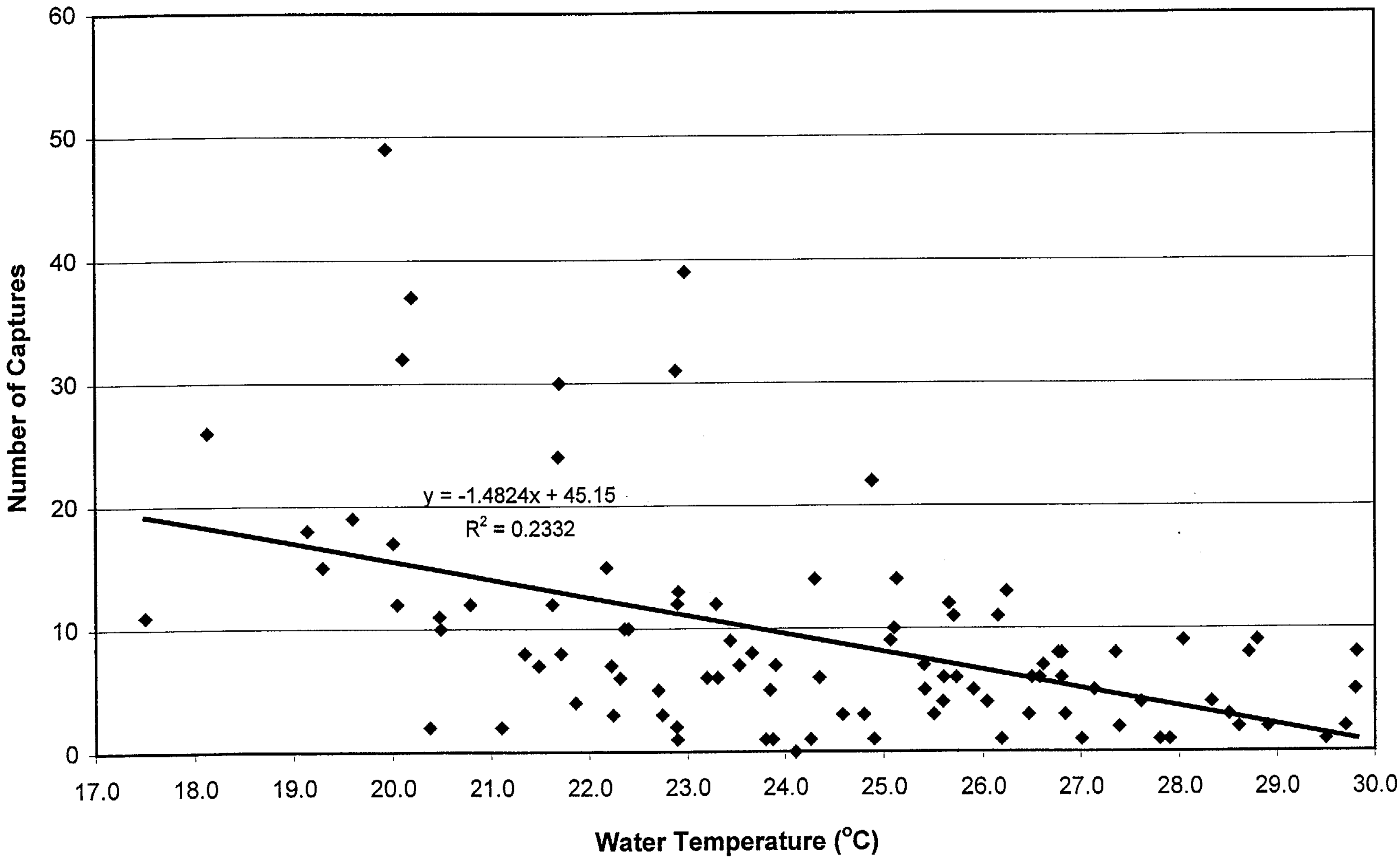

Figure 96. Monthly juvenile loggerhead captures versus mean monthly water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, January 1989 - December 1996. Mean monthly water temperatures were based on daily water temperatures recorded at the power plant's circulating water pumps.

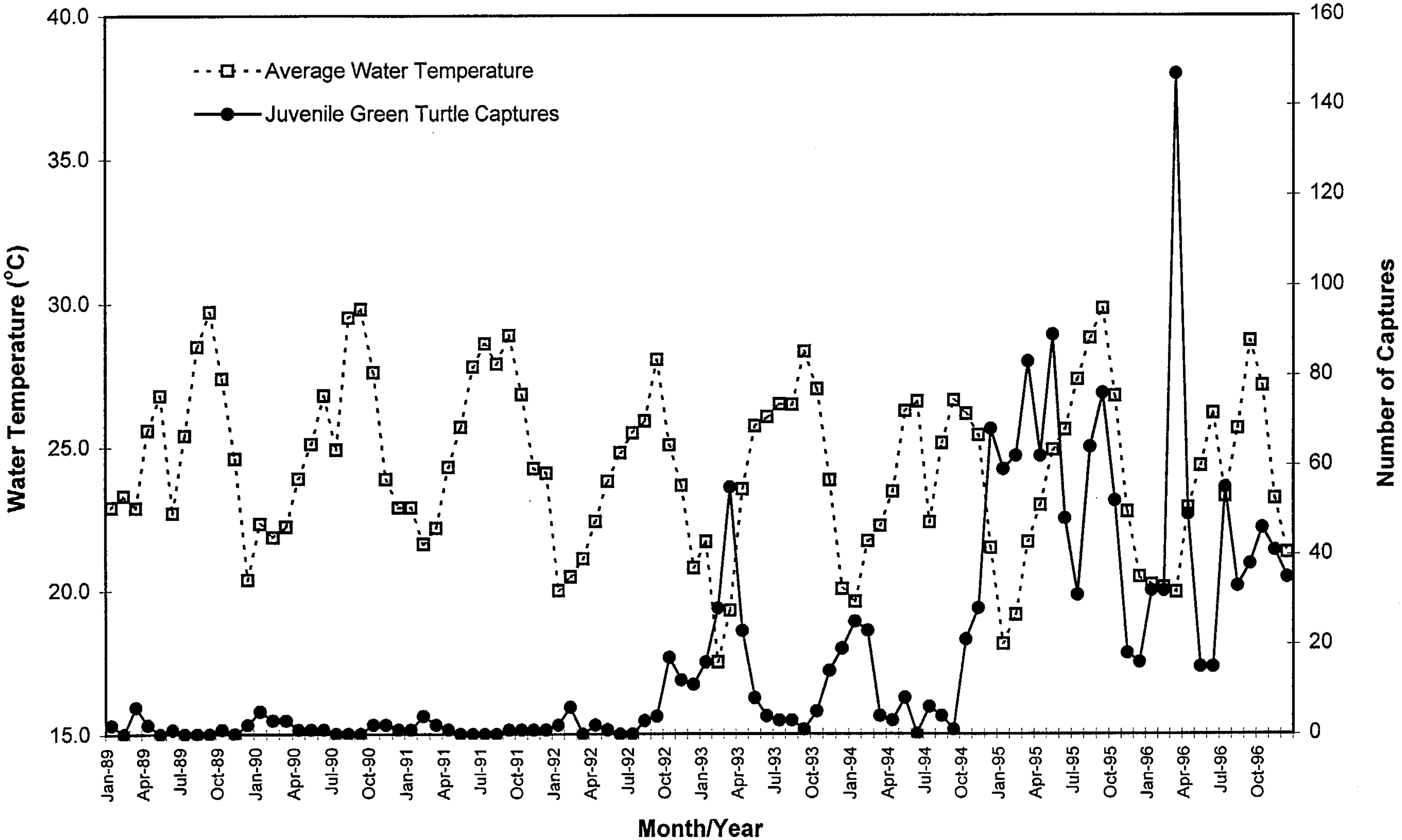

Figure 97. Monthly juvenile green turtle captures compared to mean monthly water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, January 1989 - December 1996. Mean monthly water temperatures were based on daily water temperatures recorded at the power plant's circulating water pumps.

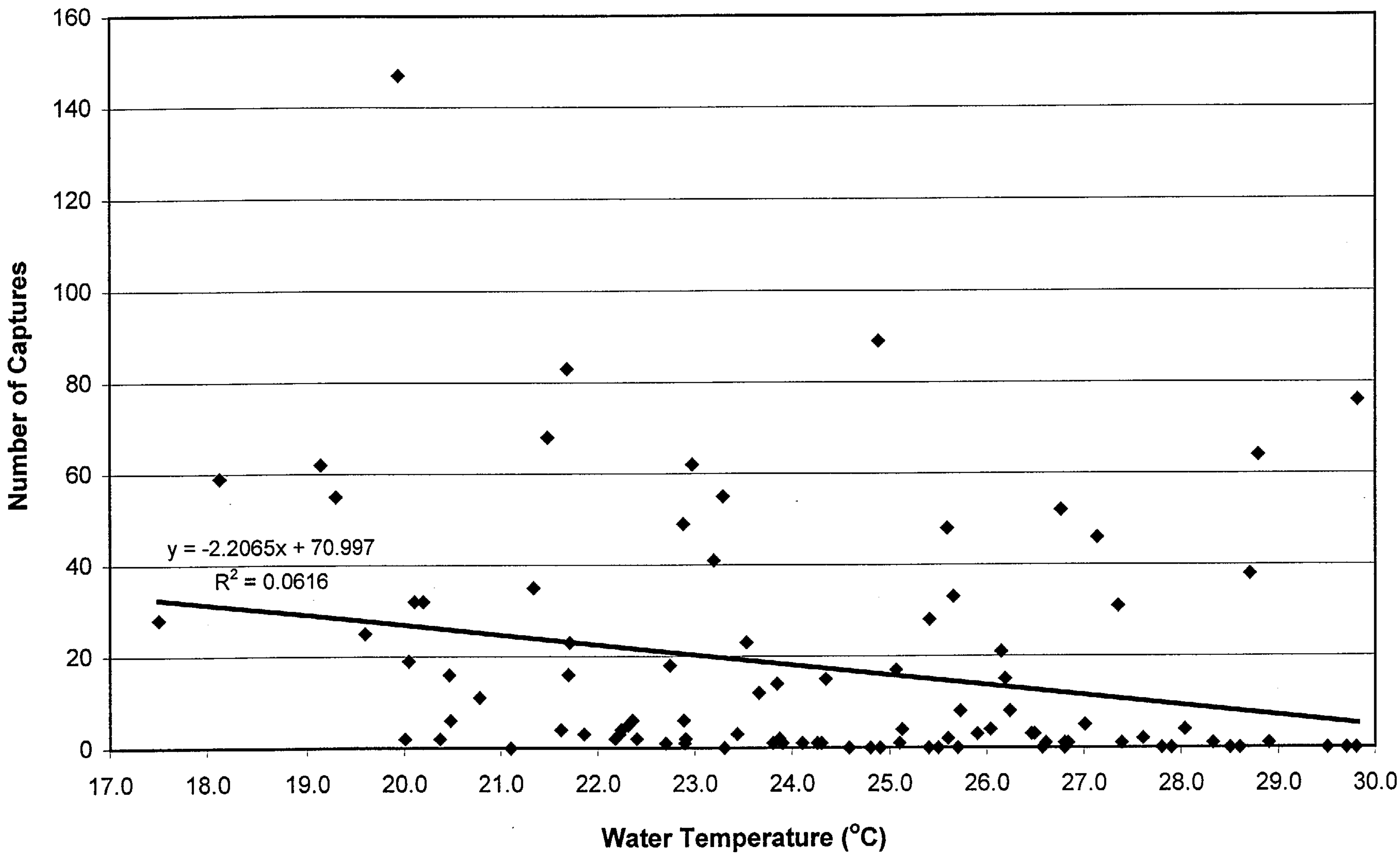

Figure 98. Monthly juvenile green turtle captures versus mean monthly water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, January 1989 - December 1996. Mean monthly water temperatures were based on daily water temperatures recorded at the power plant's circulating water pumps.

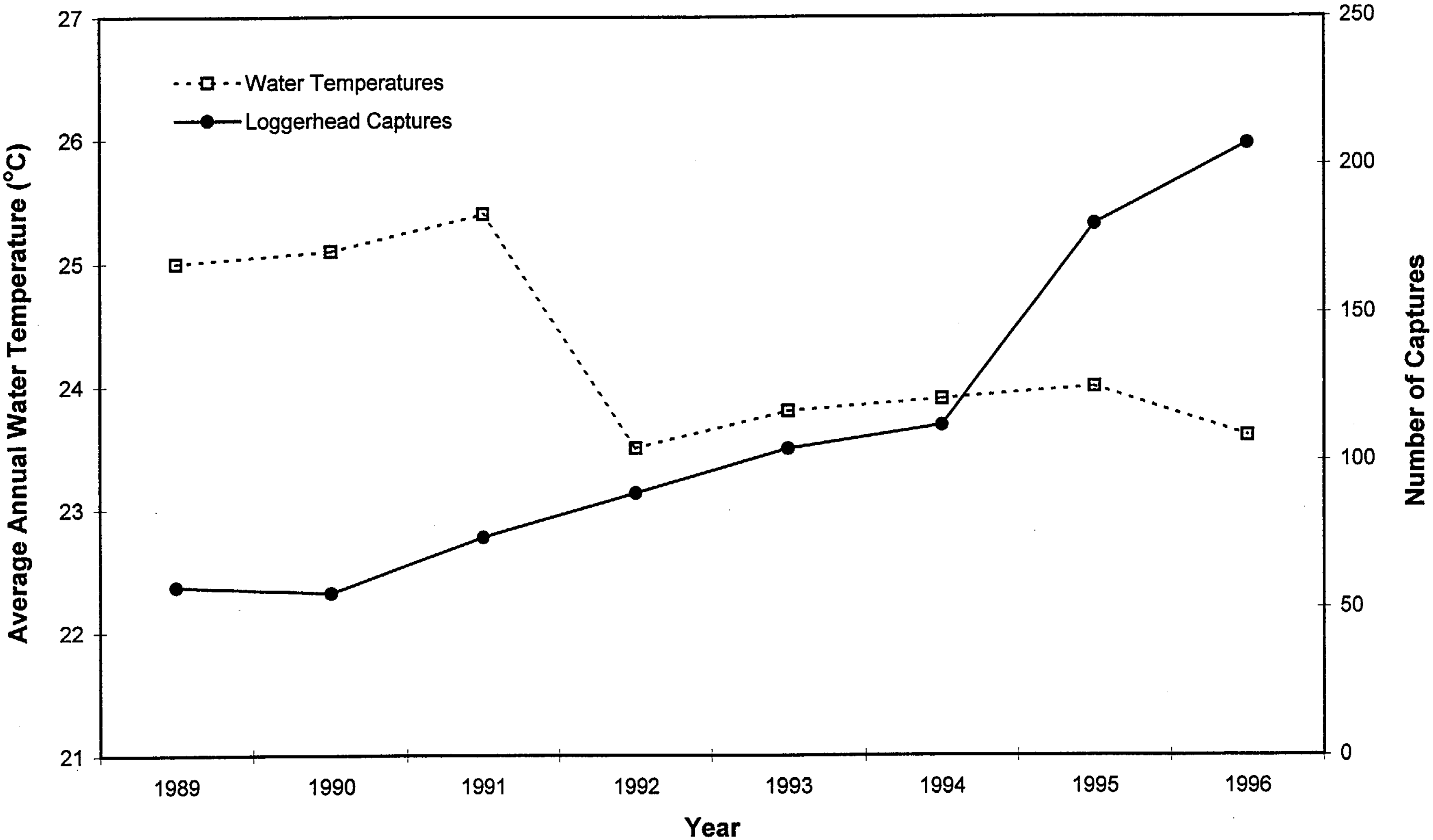

Figure 99. Annual number of juvenile loggerhead captures compared to average annual water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1989-1996.

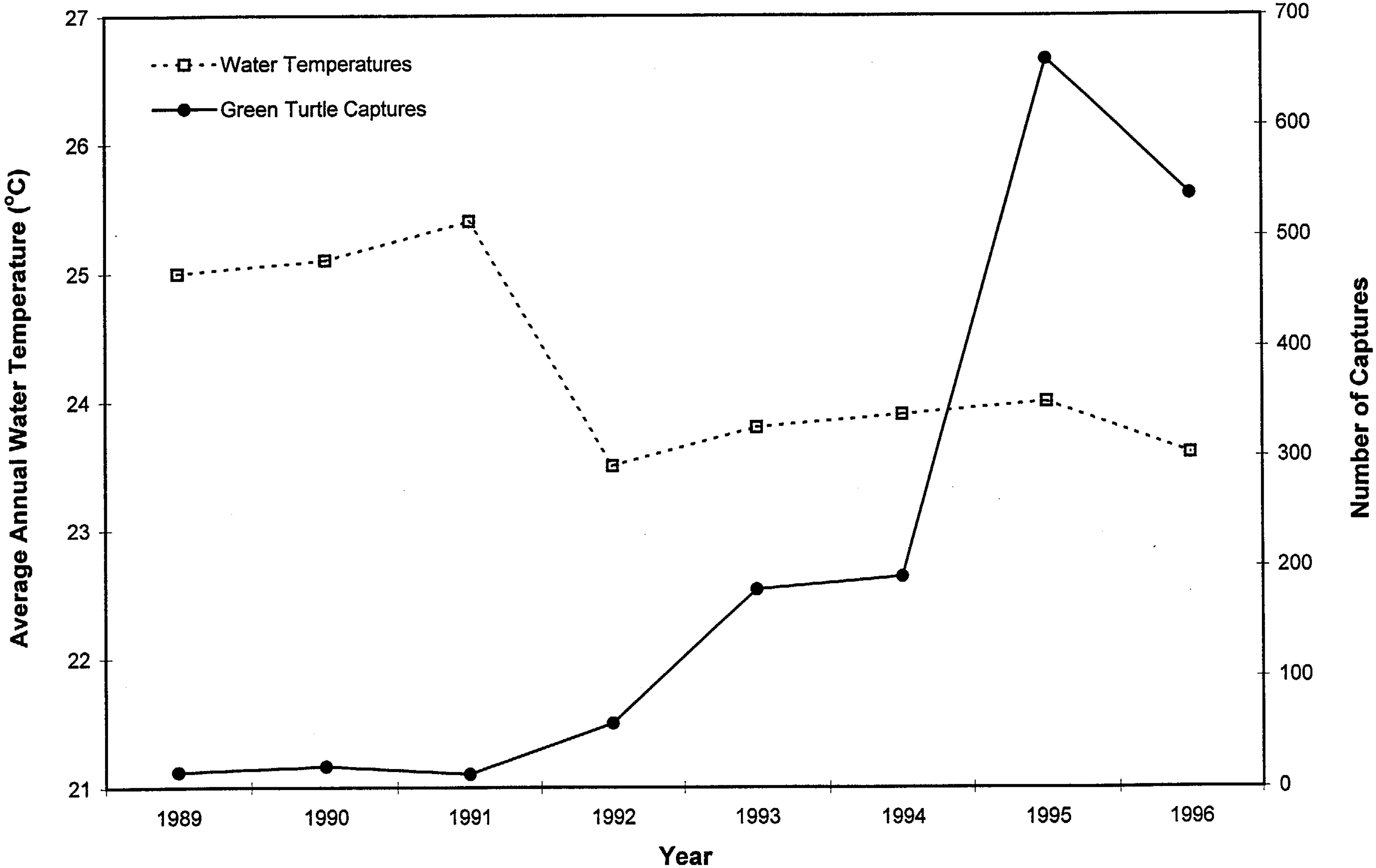

Figure 100. Annual number of juvenile green turtle captures compared to average annual water temperatures, St. Lucie Plant intake canal, Hutchinson Island, Florida, 1989-1996.

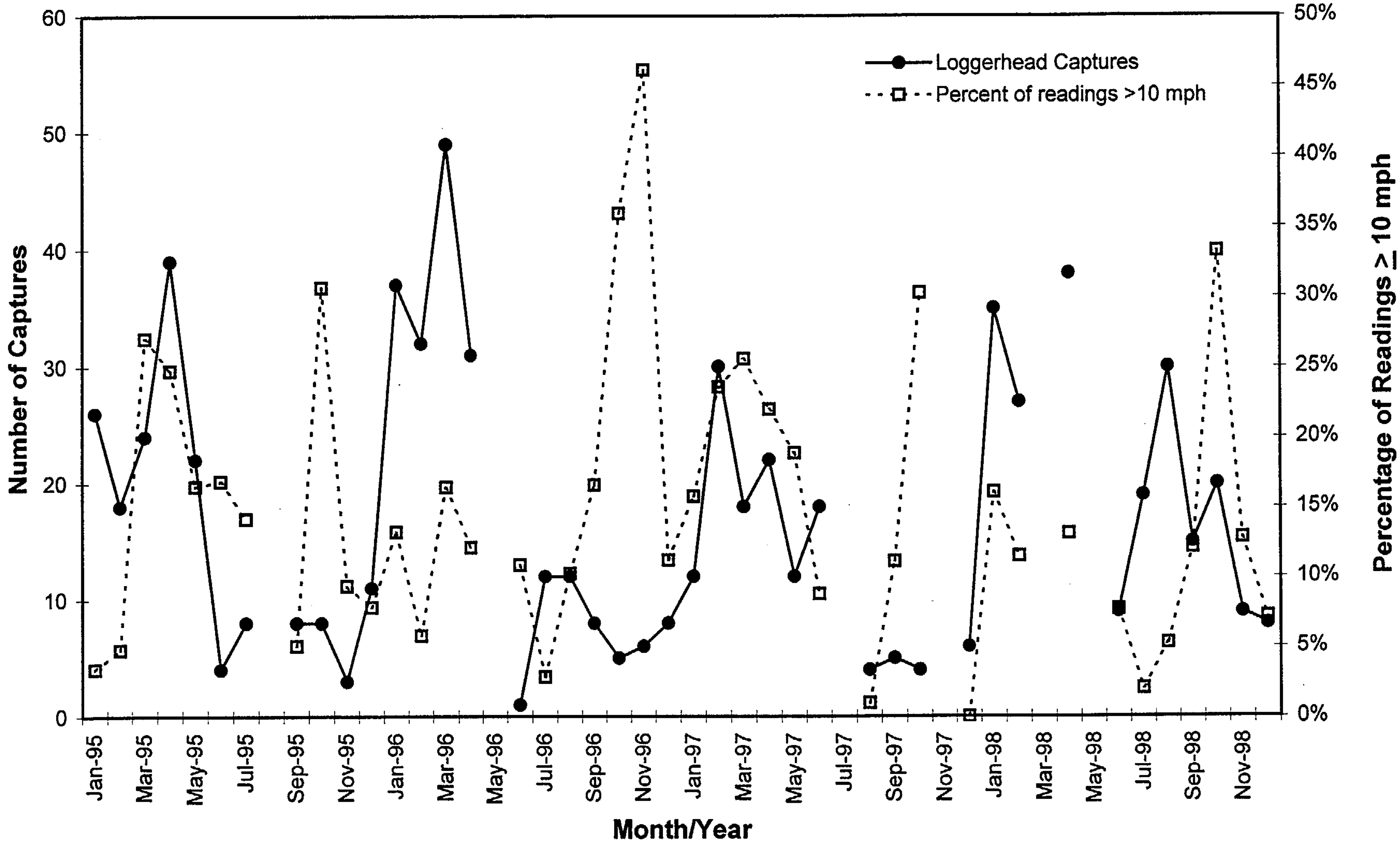

Figure 101. Monthly juvenile loggerhead captures compared to percentage of each month's wind readings with bearings between 0 and 140 degrees and velocities greater than or equal to 10 miles per hour, St. Lucie Plant, Hutchinson Island, Florida, January 1995 - December 1998. Wind direction and velocity were measured hourly at a height of 10 m just north of the discharge canal. Months missing more than 24 hourly wind readings were excluded.

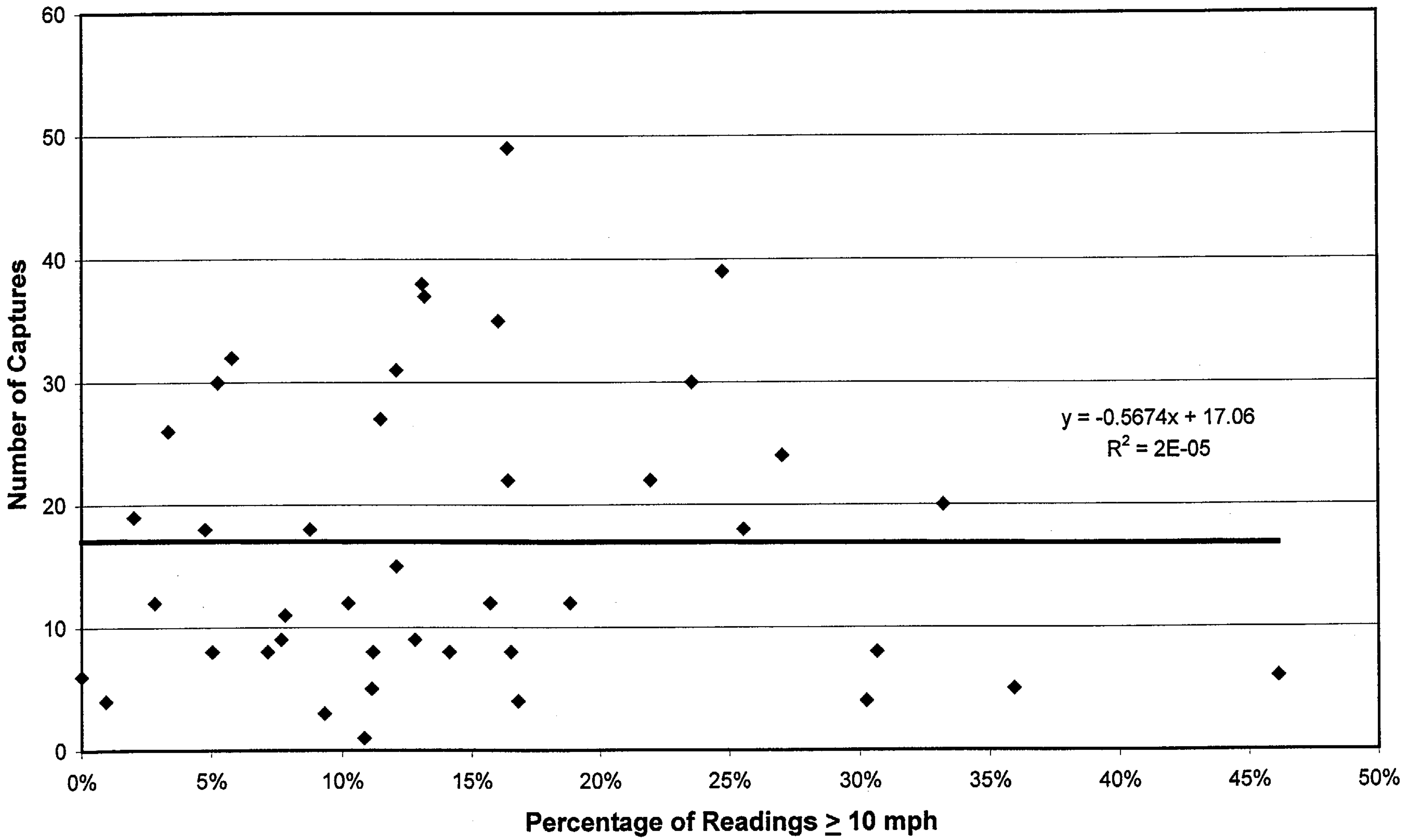

Figure 102. Monthly juvenile loggerhead captures versus percentage of each month's wind readings with bearings between 0 and 140 degrees and velocities greater than or equal to 10 miles per hour, St. Lucie Plant, Hutchinson Island, Florida, January 1995 - December 1998. Wind direction and velocity were measured hourly at a height of 10 m just north of the discharge canal. Months missing more than 24 hourly wind readings were excluded.

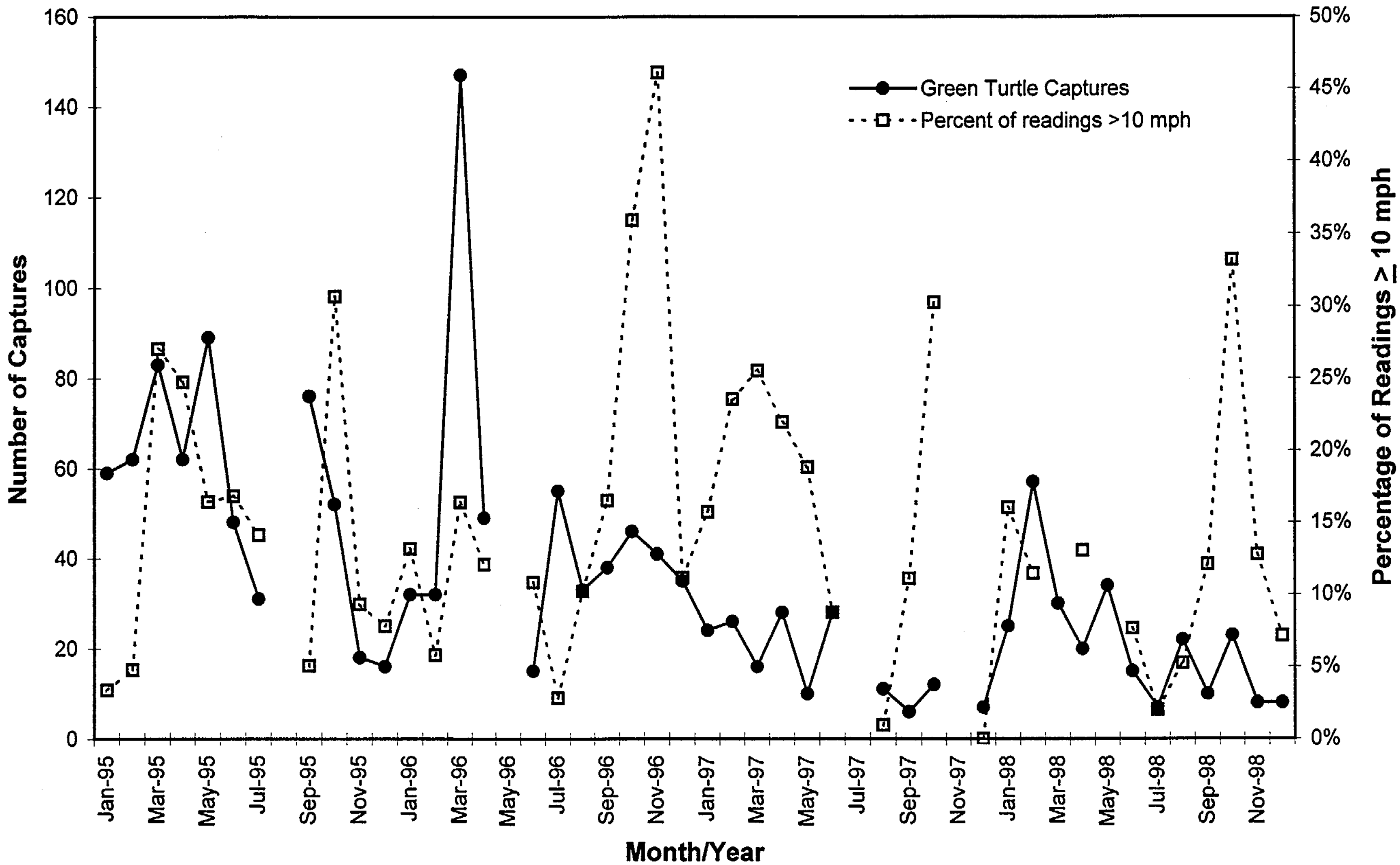

Figure 103. Monthly juvenile green turtle captures compared to percentage of each month's wind readings with bearings between 0 and 140 degrees and velocities greater than or equal to 10 miles per hour, St. Lucie Plant, Hutchinson Island, Florida, January 1995 - December 1998. Wind direction and velocity were measured hourly at a height of 10 m just north of the discharge canal. Months missing more than 24 hourly wind readings were excluded.

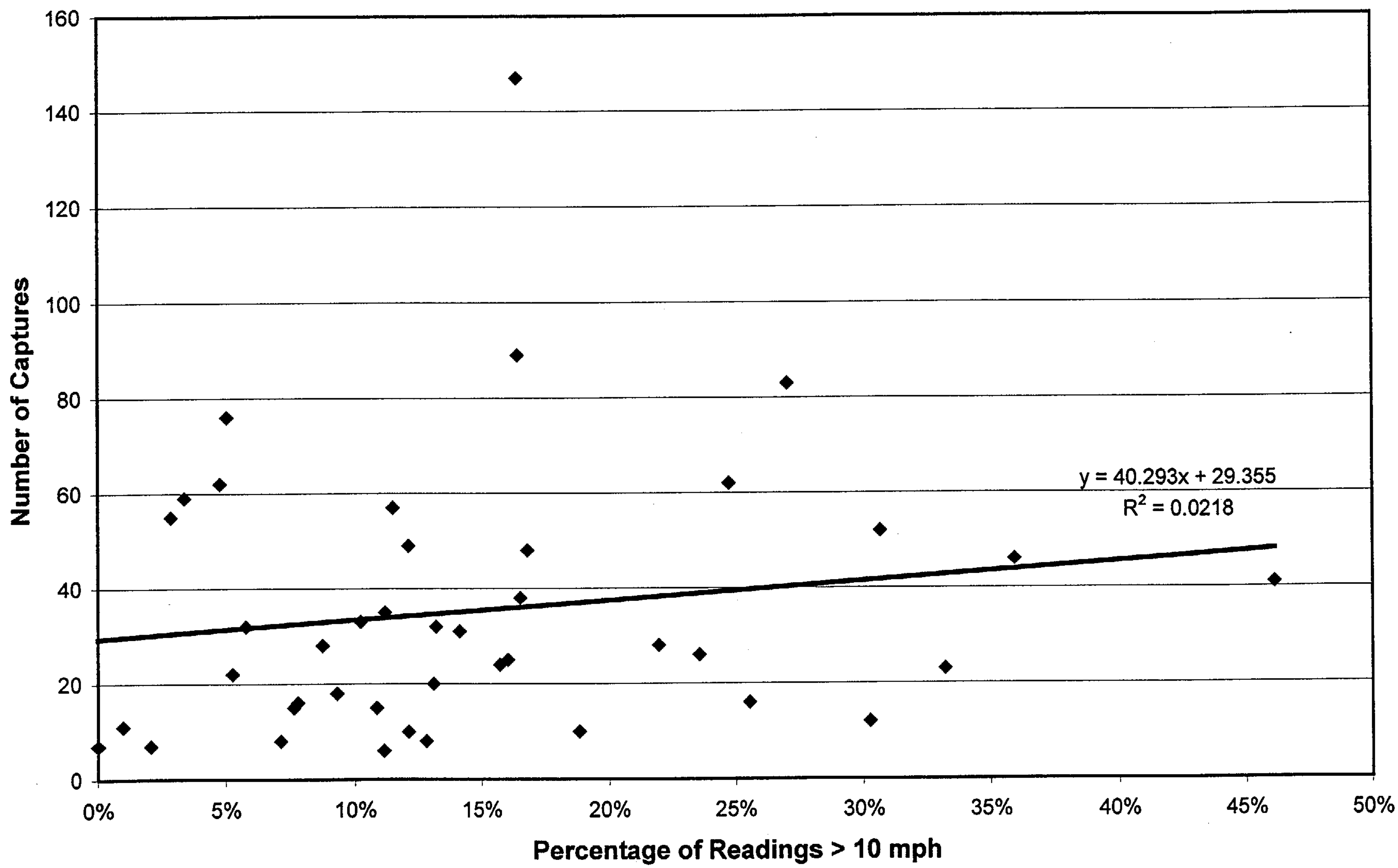

Figure 104. Monthly juvenile green turtle captures versus percentage of each month's wind readings with bearings between 0 and 140 degrees and velocities greater than or equal to 10 miles per hour, St. Lucie Plant, Hutchinson Island, Florida, January 1995 - December 1998. Wind direction and velocity were measured hourly at a height of 10 m just north of the discharge canal. Months missing more than 24 hourly wind readings were excluded.

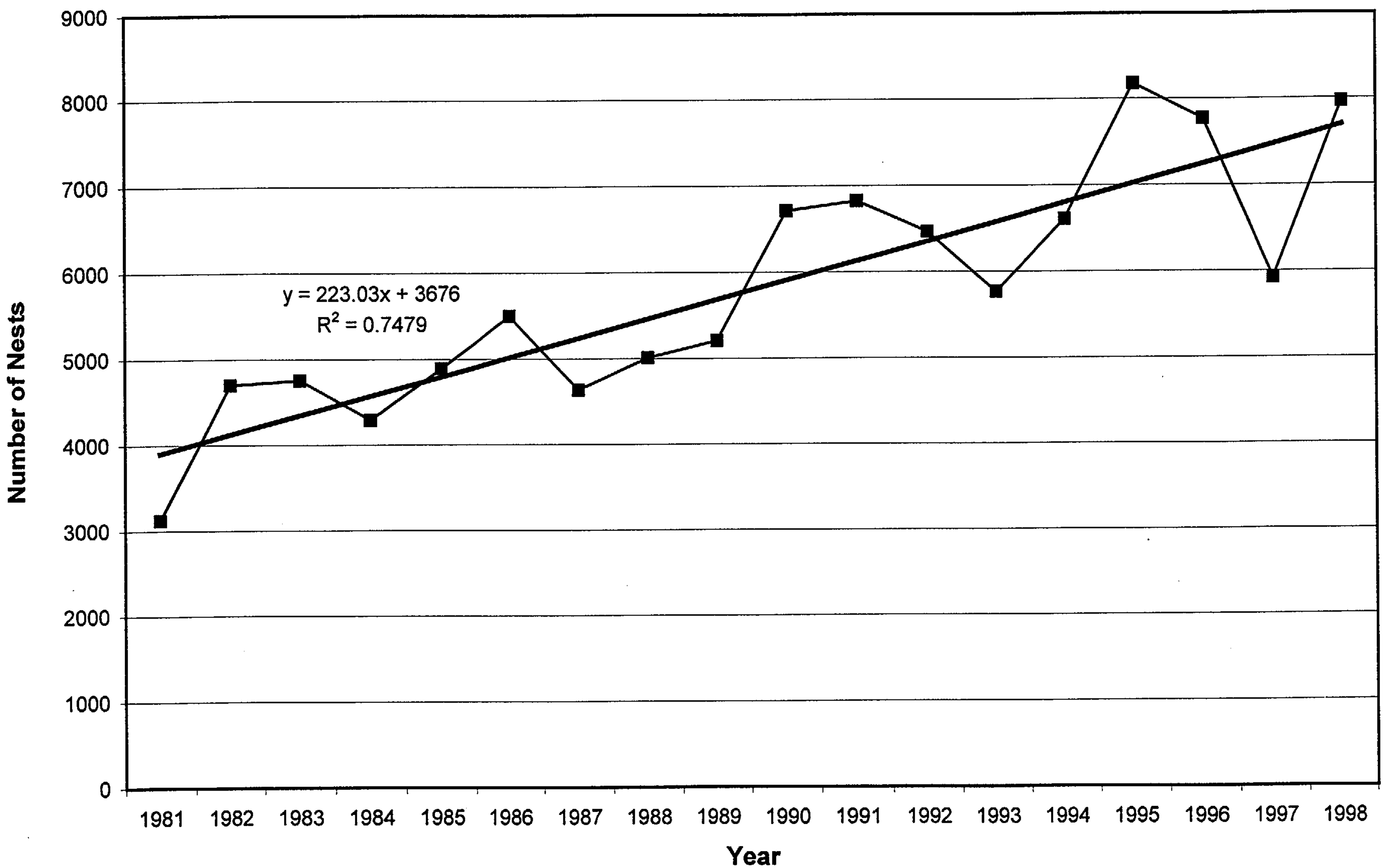

Figure 105. Annual numbers of loggerhead turtle nests recorded on Hutchinson Island, Florida 1981-1998.

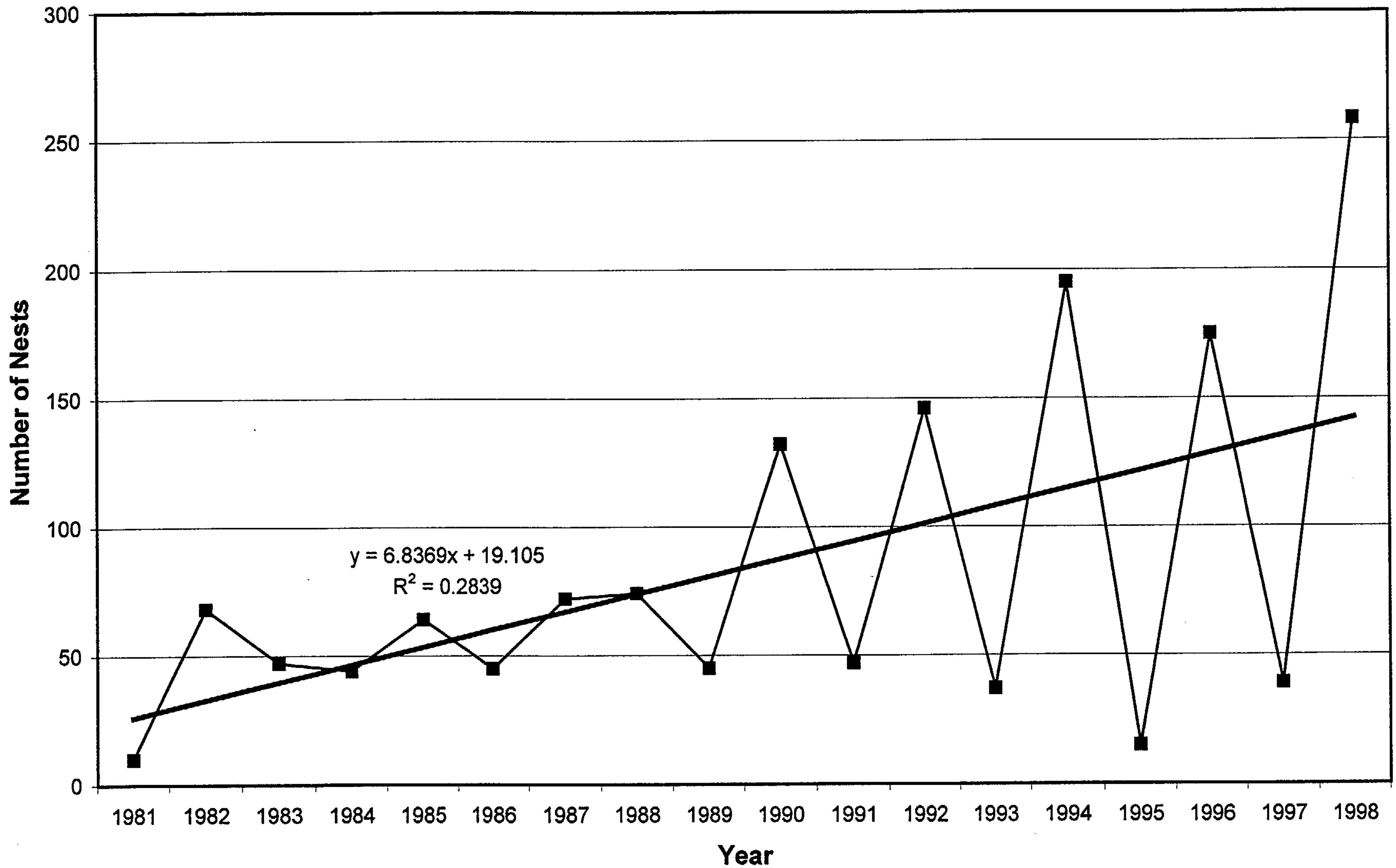

Figure 106. Annual numbers of green turtle nests recorded on Hutchinson Island, Florida, 1981-1998.