Aerial Census of Manatees and Boats over the Lower St. Johns River and the Intracoastal Waterway in Northeastern Florida

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Table of Contents

List of Figures

List of Tables

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Above all, I offer special thanks to J. Powell who trained me as an aerial surveyor and developed my eye for spotting manatees some eight years ago.

INTRODUCTION

West Indian manatees (Trichechus manatus) occur throughout the year in rivers, estuaries and coastal areas of Florida (Moore 1951, Hartman 1974, Irvine and Campbell 1978, Irvine et al. 1981). Manatees are widely dispersed along the Gulf and Atlantic Coasts of the southeastern U.S. during the summer months and aggregate at traditional warm water wintering sites during cooler months (Hartman 1974, Powell and Waldron 1978, Rose and McCutcheon 1980, Rathbun et al. 1982, Powell and Rathbun 1983, Shane 1983). Their winter range on the east coast of Florida extends as far north as Jacksonville (Hartman 1974, Rathbun et al. 1983, Kinnaird and Valade 1983) but manatees are sighted most frequently in the northeastern region of the peninsula during the summer months (Moore 1951, Hartman 1974, Irvine and Campbell 1978). Recent evidence suggests that manatees in northeastern Florida are not discrete subpopulations and that manatees make seasonal north/south migrations along the eastern coastal waterways (Hartman 1974, Shane 1983, Rathbun et al. 1983, Kinnaird and Valade 1983).

Northeastern Florida has the highest known manatee mortality in the state, including the highest incidence of deaths due to collisions with boats, particularly in the St. Johns River and Brevard County (O'Shea et al. in prep.). It is difficult to develop wise management policies for this region because spatial and temporal use of northeastern Florida by manatees has not been fully documented. The nature and extent of boat traffic also has not been described.

Partial surveys of manatees in northeastern Florida have been conducted by Hartman (1979), Irvine and Campbell (1978) and Rose and McCutcheon (1980). All of the studies were seasonal and surveys were not conducted throughout one entire year. Seasonal changes in local distribution and abundance in northeastern Florida have been documented only for Brevard County (Shane 1983) and the upper St. Johns River (Bengston 1982).

Aerial surveys are the only cost-effective means to census marine mammals over large areas (Irvine et al. 1981). However, counts from aerial surveys must be viewed with caution because the number of animals undetected during a survey is never known (Hartman 1974, Irvine and Campbell 1978). Also, variability between surveys is high, and ground-truthing techniques have not been refined (Packard et al. 1983). Results of aerial surveys are therefore only an index of abundance at the time of the survey, but these counts are useful to document distribution, relative abundance, and patterns of habitat use (Irvine et al. 1981).

I conducted aerial surveys for one complete year over the lower reaches of the St. Johns River and the northeastern section of the ICW (southern Volusia County to Kings Bay, Georgia) to document the spatial and temporal patterns that characterize manatee use of northeast Florida, and to describe the nature and extent of boat traffic. The development of management practices based on these patterns should help minimize resource conflicts and possibly reduce manatee boat/barge mortality.

STUDY AREAS

Lower St. Johns River

The study area incorporates the lower 78 kilometers of the St. Johns River, including major tributaries (Fig. 1). The southern border of the study area is delineated by the Shands Bridge in the city of Green Cove Springs, approximately 230 kilometers north of Blue Spring. The northern border lies at the confluence of the St. Johns River and the Atlantic Ocean. The study area was divided, for the purpose of data analysis, into ten arbitrary zones, delineated by bridges and other geographical features recognizable during low level flights.

The northern two-thirds of the study area (zones 1-7) fall under the jurisdiction of Duval County. The southern one-third (zones 8-10) is divided by St. Johns County to the east and Clay County to the west.

The St. Johns flows in a northward direction until the river bisects the heavily industrialized riverfront city of Jacksonville, where it turns east (zone 3) and flows towards the coast. Two additional cities, Orange Park and Green Cove Springs, are located on the western shore of the St. Johns River. Mayport US Naval Air Station is located at the mouth of the river on the southern bank. The St. Johns River is bisected by the ICW approximately five kilometers west of Mayport.

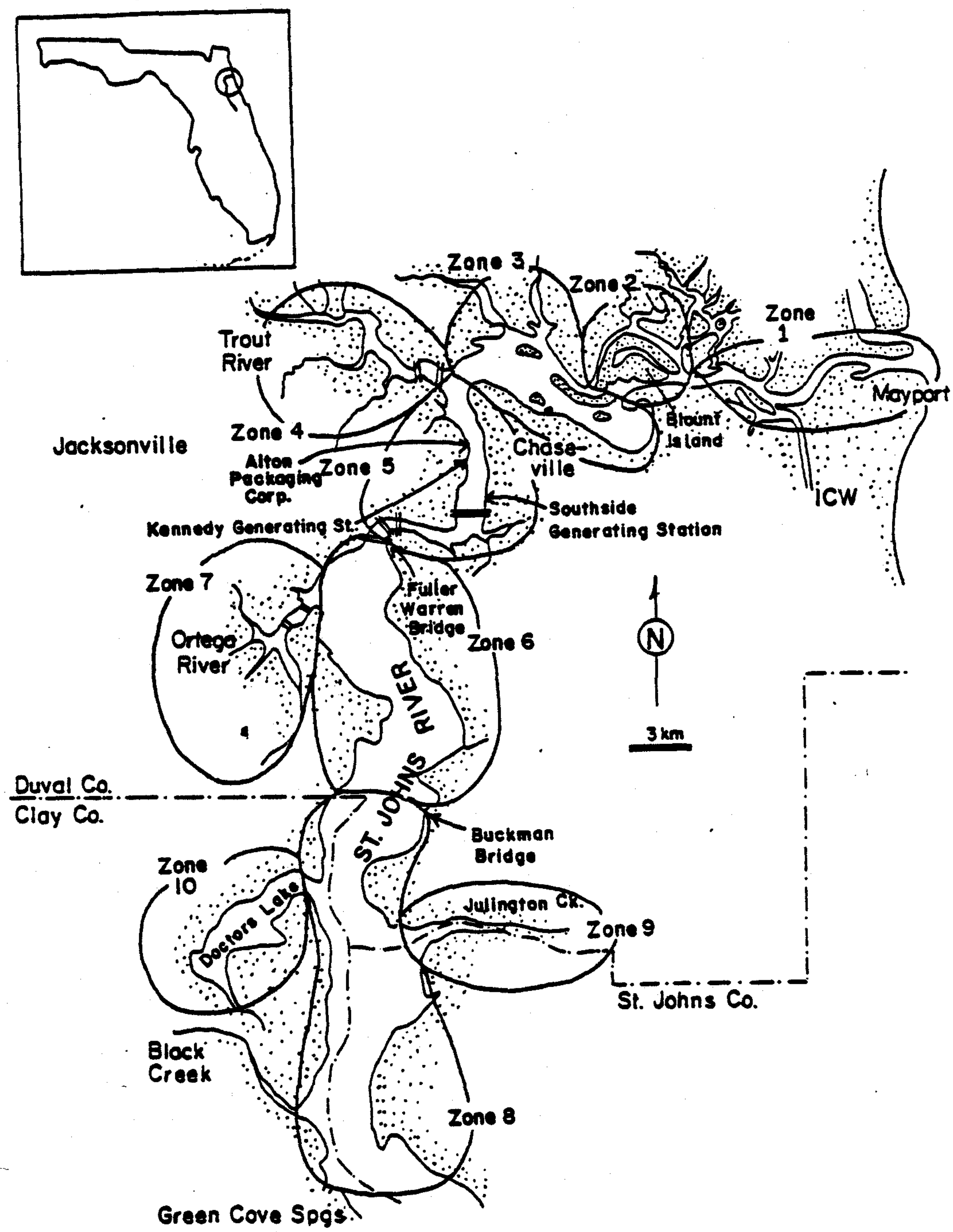
The Port of Jacksonville, located in the heart of the city of Jacksonville, is the largest and most active shipping port along the Atlantic coast south of Hatteras, NC (Jacksonville Port Handbook 1981/82). During 1980 alone, approximately 17,000 vessel trips were logged in Jacksonville Harbor (U.S. Army Corps of Engineers).

Water depth in the study area varies from 24 meters in the dredged ship-channels north of the Fuller-Warren bridge (zones 1, 2, 3, & 5) to one meter in major tributaries and associated lakes (zones 4, 7 & 9-10). Mean tidal range is 1.22 m (Southern Waterway Guide, Inc. 1983). Water currents average approximately 5.5 km/hr near the mouth of the river, increasing up to 9.3 km/hr where the river narrows at the city bridges (zone 5) and decreasing to less than 2 km/hr south of the bridges (Southern Waterway Guide 1983).

Water clarity is extremely poor throughout the study area and decreases dramatically north of the Fuller Warren Bridge in the industrialized section of the river (zones 1-7). A zone of transition between seawater and river water extends upstream from Jacksonville but chloride concentrations begin to weaken south of zone five (Anderson and Goolsby 1973).

Submerged aquatic vegetation, consisting primarily of sparse beds of eelgrass (*Vallisneria americana*), is found on the east and west banks south of the Buckman Bridge (zone 8) and throughout Doctor's Lake (zone 10). Little aquatic vegetation other than floating mats of water hyacinth (*Eichhornia crassipes*) and cordgrass (*Spartina bakeri*) is present north of the Buckman Bridge.

Figure 1. St. Johns River study area.



Several artificial warm water sources are present within the study area: the Alton Packing Corp. (APC) and the Jacksonville Electric Authority's (JEA) J. D. Kennedy (KGS), Southside (SGS) and Northside Generating Stations (NGS).

Intracoastal Waterway (ICW)

This study area includes a 263 kilometer stretch of the ICW extending from just north of Kings Bay, Georgia, south to Oak Hill, Florida (Fig. 2). The mainland borders the ICW on the west; barrier islands to the east separate the waterway from the Atlantic Ocean. Three inlets and the mouths of three rivers link this stretch of the ICW to the Atlantic Ocean.

The study area was divided into eight arbitrary zones for the purpose of data analysis. These zones are 20 to 40 kilometers in length, delineated by bridges and other geographical landmarks recognizable during low level flights.

This region includes many communities on both banks of the ICW. Major communities are: Fernandina Beach, Jacksonville Beach, St. Augustine, Ormond Beach, Daytona Beach and New Smyrna Beach. Tomoka and Anastasia State Parks, Matanzas National Monument, and Cumberland Island National Seashore are located within the study area.

The ICW is used by commercial vessels and tows unable to navigate long stretches in the open ocean, and by pleasure craft. Small boat and recreational facilities are found throughout the northeast section of the waterway (NOAA 1982).

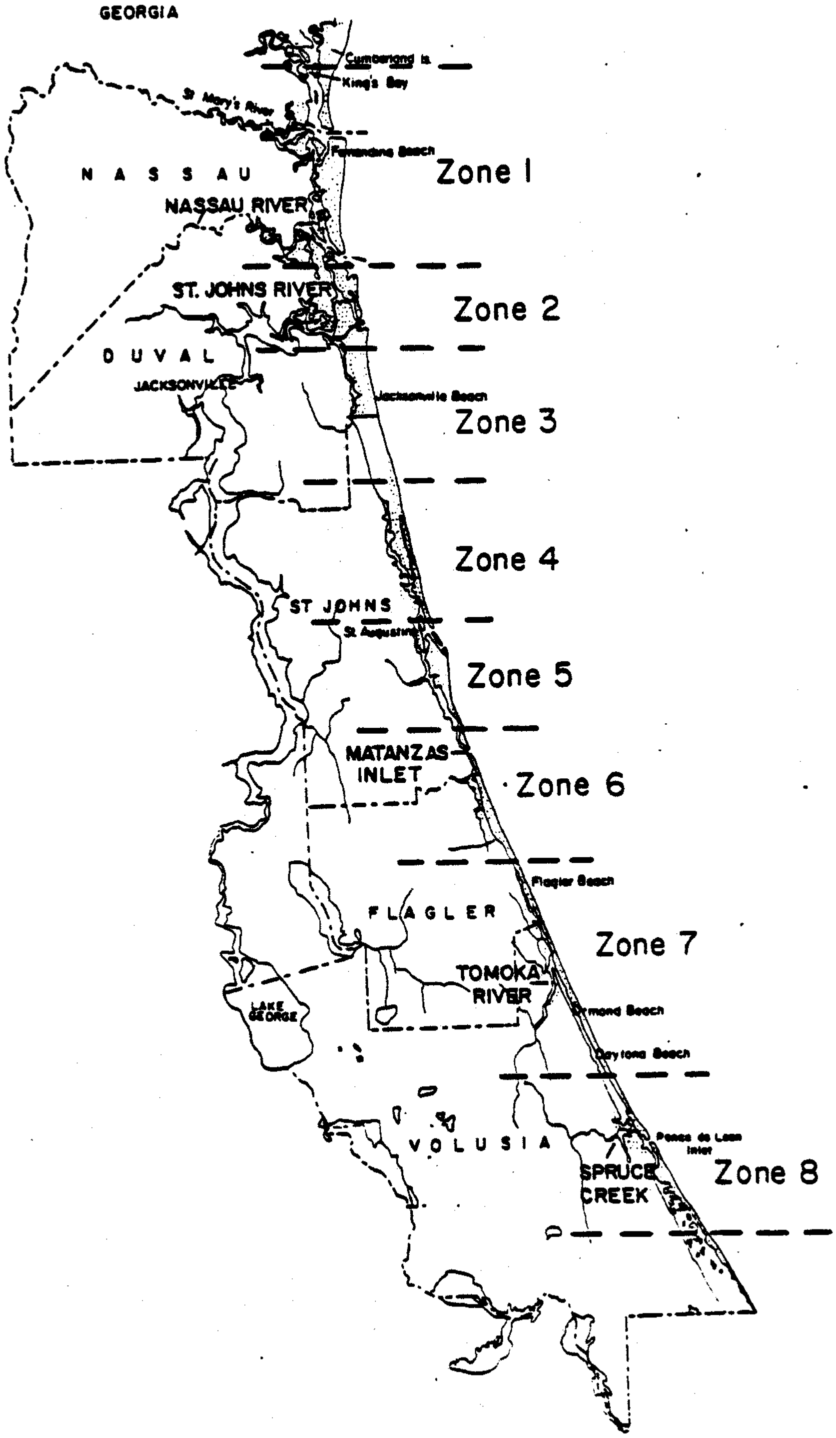
With the exception of the Fernandina and Daytona Beach areas (zones 1 and 7), the waterway is generally narrow, sheltered, protected from strong winds and usually free of rough water. Depths of 3.6 m are reported throughout the length of the waterway but significant shoaling and shifting occurs, particularly around inlets and river mouths. Currents up to 7.4 km/hr may be encountered. Mean tidal ranges vary from 2 m at Fernandina Beach (zone 1) to less than 1 m at Ponce de Leon Inlet (zone 8) (Southern Waterway Guide 1983). Habitat varies from salt marsh (zones 1 and 2) to subtropical mangrove estuaries (zone 8). Waters are turbid and generally void of aquatic vegetation with the exception of inlets and the southern extremes of the study area (zones 7 and 8).

Three pulp mills and one generating station are located within the study area: Container Corporation of America, Fernandina Beach, FL; ITT Rayonier Mill, Fernandina Beach, FL; Gillman Paper Co., St. Marys, Georgia; and New Smyrna Utilities, Ponce de Leon, FL. All of the these companies discharge warm water into the ICW. The Ponce de Leon generating plant is presently being phased out and was not operating during the course of this study.

METHODS

Aerial surveys were flown over both study areas between 8 July 1982 and 16 June 1983. Surveys were conducted twice monthly for each study area; generally once during the week and once over the weekend. Only one survey

Figure 2. Intracoastal Waterway study area.



was conducted over the ICW and one over the St. Johns River during the months of November and December, respectively, because of inclement weather.

Flights were initiated and terminated at the Gainesville Regional Airport. Surveys were conducted from a Cessna 172[1] at altitudes of 150-170 meters and speeds between 128-150 km/hr. On 41 of 46 total surveys, the right door was removed to provide an increased field of observation. The same flight paths were followed over each study area during every census (Figs. 3 and 4). The east and west banks of the St. Johns River were surveyed separately. Only one pass was made over the ICW; generally both banks were visible at once. The direction of the flight path (N-S vs. S-N) over the ICW varied according to wind direction. Circles were made over all inlets, over the discharge areas of power plants during the winter and over all manatee sightings.

A principal observer sat in the right front seat and recorded the number, activity and location of manatees in each designated zone. Manatees within three body-lengths of each other were recorded as a group. Photographs were taken of groups that were too large to count accurately. Activity was recorded as feeding, resting, traveling or cavorting. Feeding could be recognized by the presence of a manatee in a grassbed and a nearby plume of suspended sediment in the water. Motionless manatees were recorded as resting and swimming manatees as traveling. A group of manatees ($\geq$ 3 animals) rolling, splashing or swimming in tight circles were considered to be cavorting. The number of calves (animals one-half or less the size of an average adult) was noted. A second observer sat in the back seat and recorded boat traffic. Boats that were anchored or moving were tallied for the period that the plane was over a particular zone. Docked and moored boats were not counted. Direction of travel, boat type (recreational, sail, commercial fishing, barge/tug, oceanliner or other) and size class ($<$ 7.3 m and $\geq$ 7.3 m) were noted for each observation. The size classification was chosen based on findings by Beck et al. (1982) that these boat sizes generally are powered by different engine types (outboard and stern-drive vs. inboard for boats $<$ 7.3 m and boats $\geq$7.3 m, respectively) and may have differential impact on manatee injury and death.

Ambient air temperature, wind speed and direction, water turbidity, cloud cover and glare were also recorded at the beginning of each survey. Each flight was rated as excellent, good, fair or poor based on a subjective evaluation of the latter four conditions. The percent bottom cover by grassbeds for each zone was evaluated from sketches made every three months during aerial surveys.

Patterns of relative manatee and boat abundance, boat type, manatee group size and manatee behavior were evaluated using chi-square (Siegel 1956) and analysis of variance (ANOVA) (Sokal and Rohlf 1969) procedures. Multiple comparisons among means were made using Duncan's multiple range test for means (Snedecor and Cochran 1980). An arcsine transformation was performed on proportions (Snedecor and Cochran 1980). The Kendall's Tau rank correlation coefficient and the Pearson product-moment correlation

[1]References to trade names do not imply Government endorsement of commercial products.

Figure 3. Flight path over the St. Johns River.

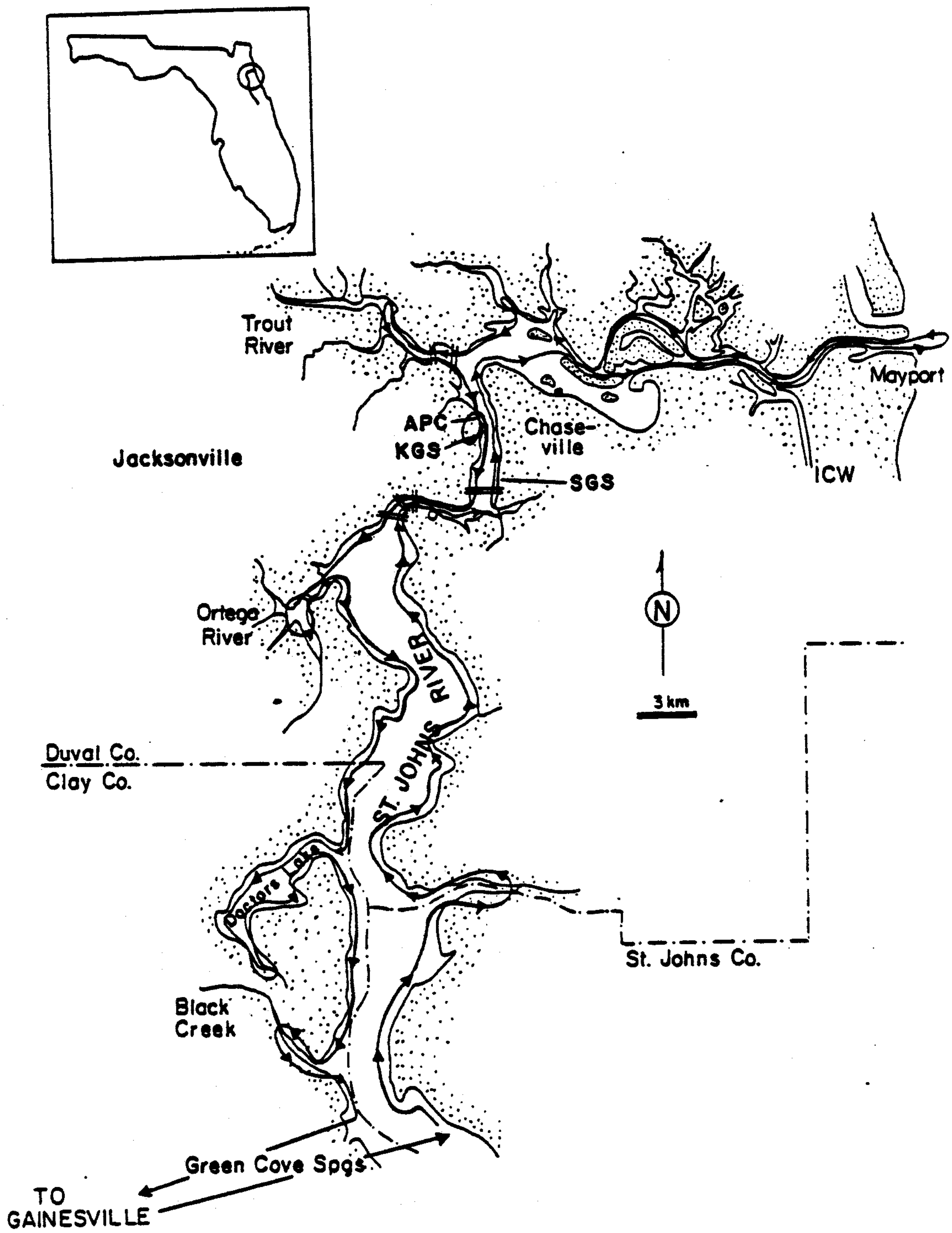
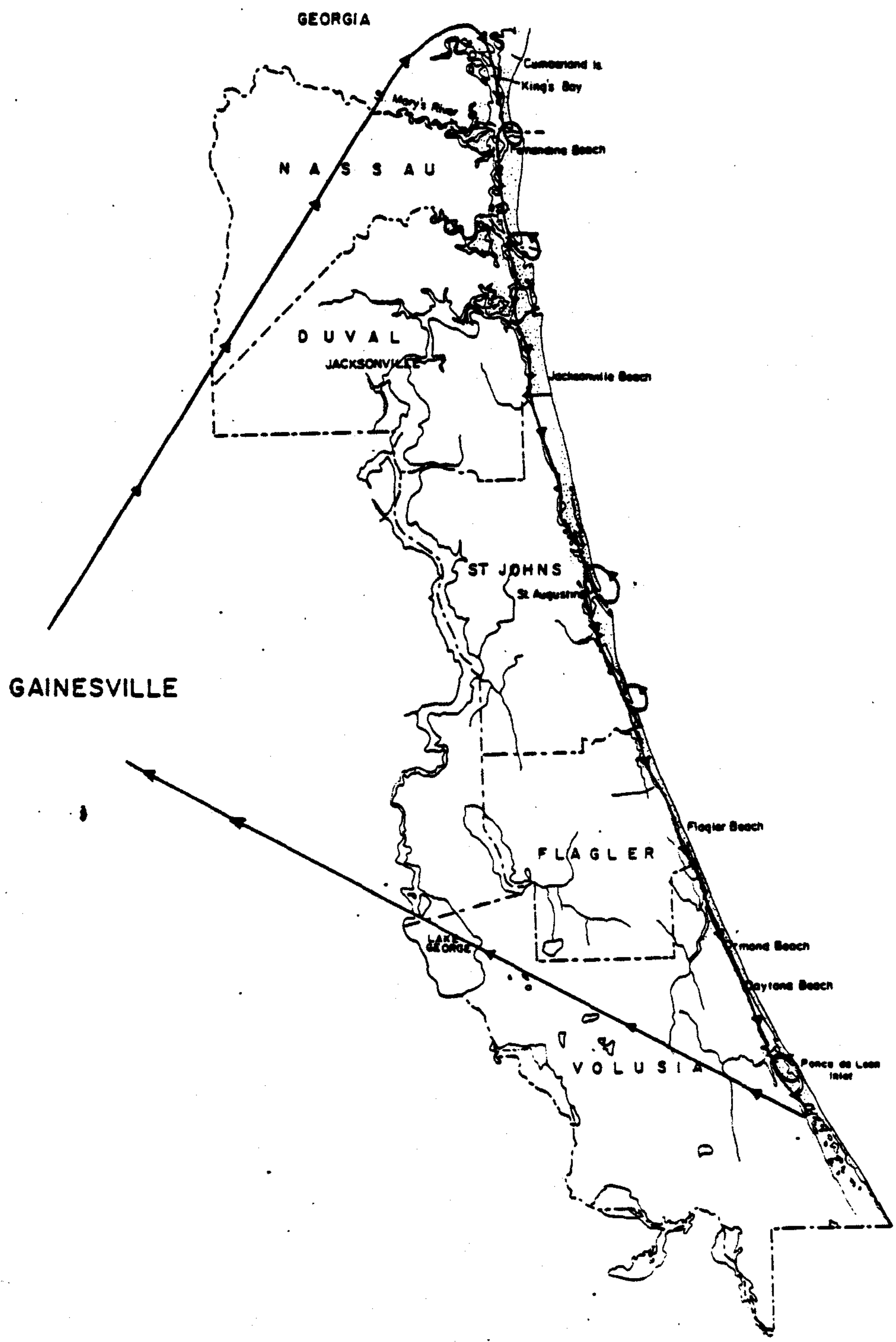


Figure 4. Flight path over the Intracoastal Waterway.



coefficient (Siegel 1956) were used to test for associations between pairs of independent samples. The Mann-Whitney U Test (Siegel 1956) was used to determine independence between means. Computations were performed with resources of the Northeast Regional Data Center, University of Florida, Gainesville, Florida.

RESULTS

The Lower St. Johns River

Manatee Abundance

A total of 420 manatees were observed during 23 surveys. Manatee abundance varied significantly among months ($X^2 = 138.6$, $N = 12$, $P = .0001$) and quarters of the year ($X^2 = 116.0$, $N = 4$, $p = .0001$) (Fig. 5). Peak manatee counts were made in July 1982 and May 1983; the lowest numbers occurred in February and March 1983. Counts were higher than expected during the spring and summer months (April-September) and lower than expected during the winter months (January-March).

The ratio of calves to total manatees sighted per survey varied from 0.0 to 0.18. The ratio of calves to adults for all surveys combined was 0.07. Twenty out of twenty-nine (69%) total calf sightings were made during the spring and summer months. No calves were sighted from December to mid May (Table 1).

Manatees were most frequently sighted alone or in pairs (Fig. 6). Groups of up to nine animals were seen cavorting along the river banks; the largest aggregations (11 animals) were at industrial warm water outflows. Group size did not vary significantly among months ($F = 1.24$, $N = 12$, $p = 0.266$) or quarters of the year ($F = 0.65$, $N = 4$, $p = 0.58$).

Seasonal temperature change influenced total manatee counts (Fig. 7). The number of manatees counted during each survey was positively correlated with ambient air temperature ($r = 0.67$, $N = 22$, $p = 0.006$).

There was no significant relationship between the survey conditions and the number of manatees sighted ($r = 0.29$, $N = 22$, $p = 0.18$). The number of manatees counted was also independent of the day of the week (weekday vs. weekend) on which the survey was conducted (Mann Whitney $U_{14,8} = 43$, $p > 0.1$). The total number of manatees counted during each survey was independent of the total number of boats counted ($r = 0.25$, $N = 22$, $p = 0.25$).

Manatee Distribution in the Study Area

Manatee counts (Fig. 8) and manatee densities (Table 2) varied within the study area. Actual counts were highest from Green Cove Springs to Buckman Bridge (zone 8), but the density of manatees (no. of manatees/linear flight distance) was greatest in Doctor's Lake (zone 10). Few sightings were made from Chaseville to the mouth of the river (zones 1-3); manatees were sighted only around Blount Island (zone 2). No manatees were sighted in the Ortega River (zone 7). There was a tendency for manatees sighted to the

Figure 5. Number of manatees counted by month and quarter of the year in the St. Johns River.

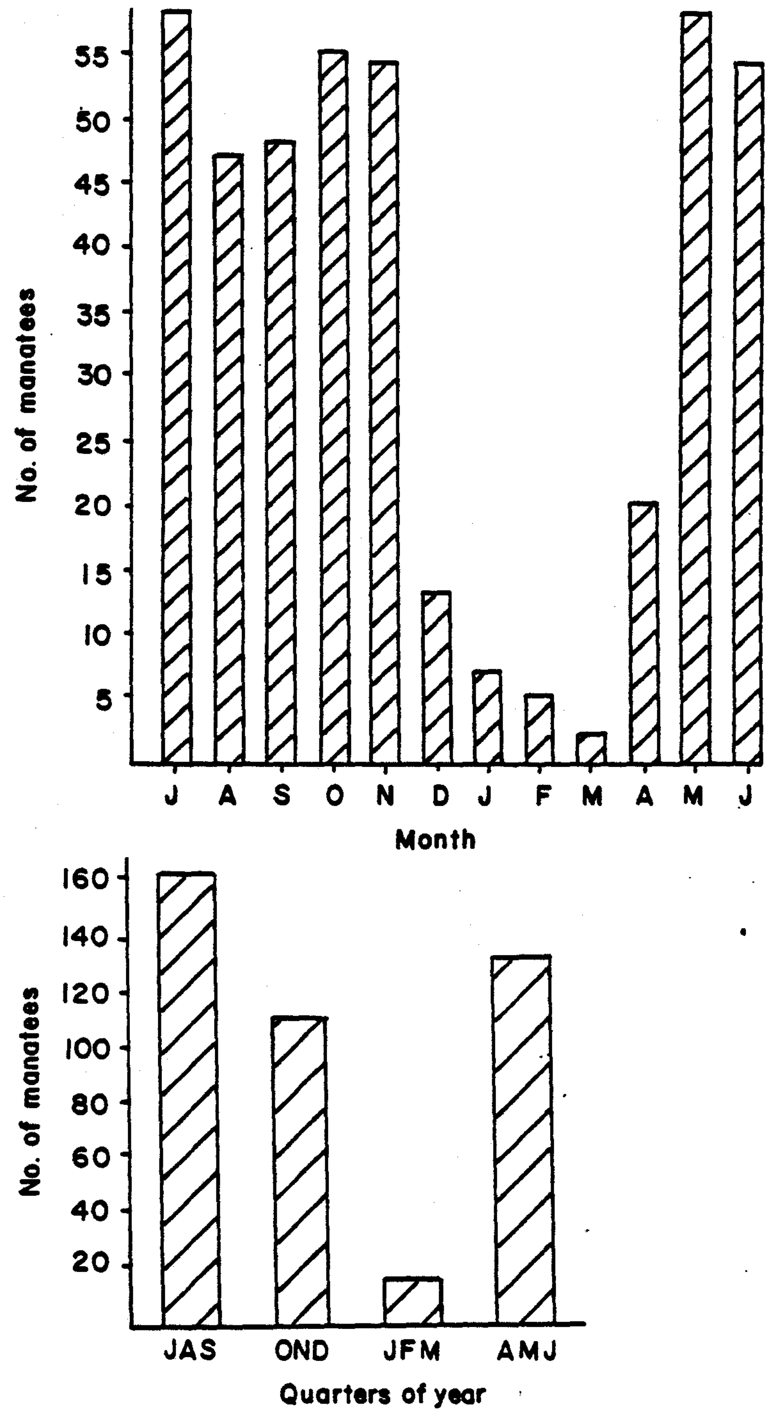


Table 1. Numbers and ratios of adults and calves sighted in the St. Johns River.

St. Johns River

Survey date	No. of adults (a)	No. of calves (c)	c/a	Total No. manatees
8 Jul	22	3	.136	25
21 Jul	31	2	.06	33
4 Aug	23	2	.08	25
28 Aug	22	0	0	22
14 Sep	32	6	.18	38
25 Sep	18	0	0	18
5 Oct	21	0	0	21
16 Oct	20	4	.2	24
2 Nov	34	2	.06	36
31 Nov	16	3	.18	18
18 Dec	13	0	0	13
4 Jan	1	0	0	1
25 Jan	6	0	0	6
9 Feb	4	0	0	4
25 Feb	1	0	0	1
9 Mar	0	0	0	0
26 Mar	2	0	0	2
16 Apr	15	0	0	15
21 Apr	5	0	0	5
14 May	9	1	.11	10
25 May	44	4	.09	48
11 Jun	20	1	.05	21
16 Jun	32	1	.03	33
TOTALS	390	29	.07	420

Figure 6. Frequency of group size in the St. Johns River.

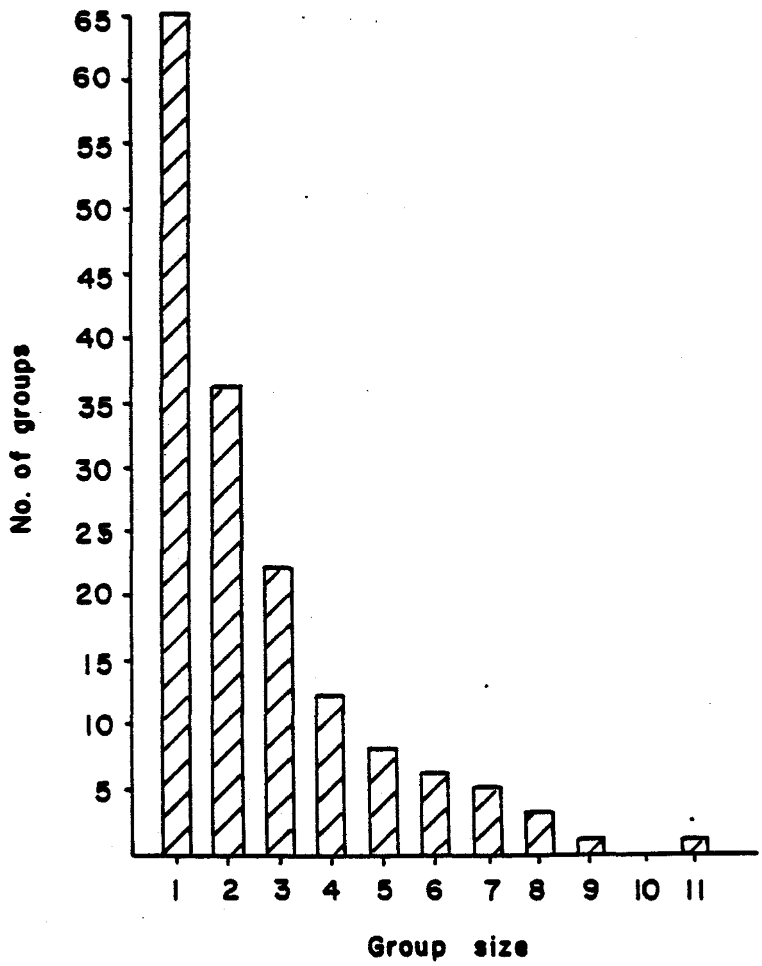


Figure 7. Relationship between temperature and manatee counts in the St. Johns River.

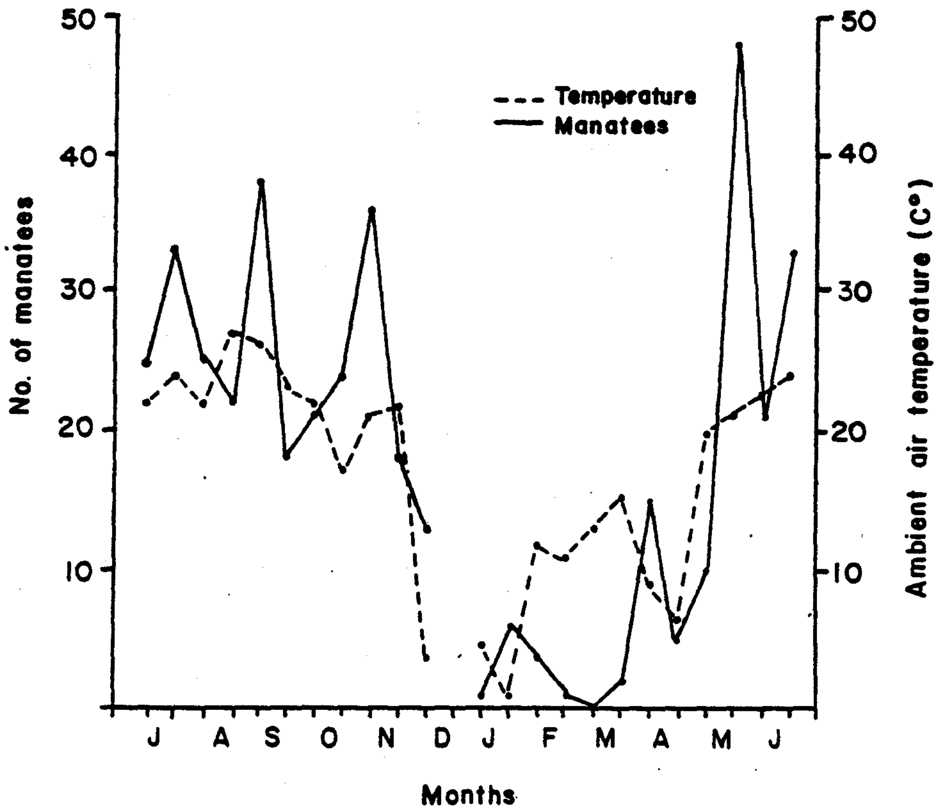


Figure 8. Number of manatees counted in ten zones in the St. Johns River.

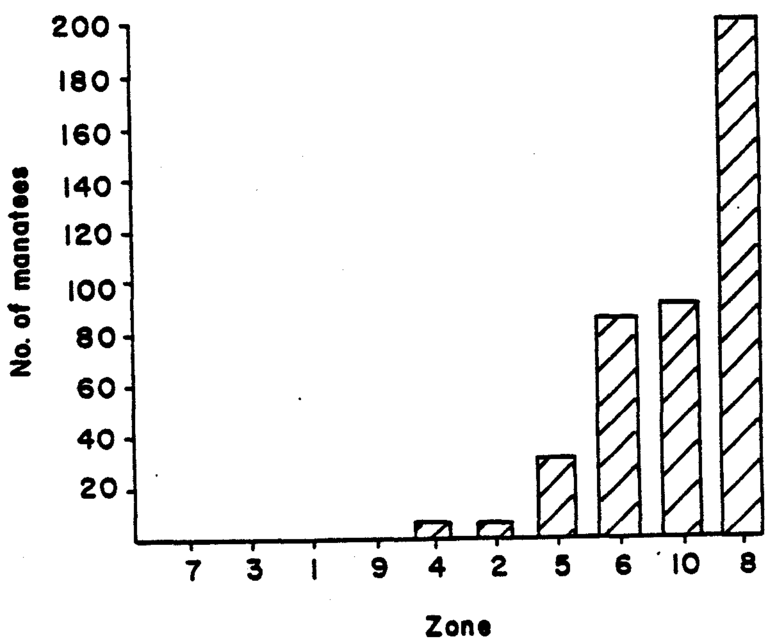


Table 2. Density of manatees in the zones of the St. Johns River. Density values were calculated by dividing the linear distance (km) of the flight path over each zone into the total number of manatees sighted in each zone during quarters of the year.

	Quarter of the Year				Total
Zone	JAS	OND	JFM	AMJ	Density
1	.07	.00	.00	.00	.07
2	.00	.00	.00	.38	.38
3	.00	.00	.03	.00	.03
4	.12	.00	.00	.24	.35
5	.00	.63	.45	.07	1.15
6	1.12	.95	.00	2.75	4.83
7	.00	.00	.00	.00	.00
8	3.35	2.08	.03	2.01	7.57
9	.00	.00	.00	.57	.57
10	4.85	2.57	.00	1.78	9.20
TOTALS	9.51	6.23	0.51	7.80	24.08

north (zone 6) and south (zone 8) of the Buckman Bridge to be on the east and west banks of the river, respectively.

There were seasonal changes in manatee distribution within the study area (Fig. 9, Table 2). Manatees were sighted in two zones in the east bend of the river (zones 2 and 4) only during the spring and fall. All but two of the sightings made between the Fuller Warren Bridge and Chaseville (zone 5) occurred from November to March and were in the immediate vicinity of one of three industrial, warm water outfalls located within the zone. The section of the river south of the Fuller Warren Bridge (zones 6-10), was used by manatees from spring to late fall (April-December); only one sighting occurred from January to March.

Where manatees were frequently sighted, the counts were correlated with changes in air temperature. The number of manatees increased significantly with temperatures in the zones south of the Fuller Warren Bridge ($r = 0.47$, 0.63, and 0.54 for zones 6, 8 and 10, respectively, $N's = 23$, $p < 0.05$). Manatee counts were negatively correlated with air temperature in the vicinity of the power plants (zone 5) ($r = -0.54$, $N = 22$, $p = 0.009$).

The percent bottom coverage by aquatic vegetation was the best predictor of manatee abundance (Kendall's Tau = 0.76, $N = 10$, $p = 0.004$). Manatees generally did not avoid zones with high boat traffic; the total density of manatees per zone was not significantly correlated with the density of boats per zone (Kendall's Tau = 11.0, $N = 10$, $p > 0.1$). However, within such zones manatees were generally sighted along the banks of the river, away from the center of traffic. When the relationship between manatee and boat densities was examined for each zone separately, only one zone (zone 5) showed a significant negative correlation (Kendall's Tau = -0.36, $N = 22$, $p = 0.03$) between the density of manatees and boats calculated for each survey.

Manatee Movements and Behavioral Patterns

Doctors Lake (zone 10) and the stretch of the river from Green Cove Springs to the Buckman Bridge (zone 8) were the major feeding and resting grounds (Fig. 10). A few animals were observed feeding on shoreline vegetation further down the river where no grassbeds were present. Warm water outfalls were the principal resting grounds during the winter months. Groups of cavorting manatees were sighted in tributaries, coves, marinas and isolated shorelines. Cavorting manatees were most frequently observed on the east bank of the river approximately eight kilometers south of the Ortega River near a residential section with little human activity. Traveling manatees were observed throughout the study area and were generally sighted along the banks of the river, away from boat channels.

Cavorting and traveling manatees comprised the greatest percentage of observations from April to June. Sightings of feeding manatees comprised the greatest percentage of observations from July to September. An overwhelming proportion of manatee activities observed from October to March was of resting animals (Table 3).

Figure 9. Seasonal distribution of manatees in the St. Johns River. Size of dot indicates the number of manatees per location: ○ = 1; ● = 2-5; ● = 6-10; ● = ≥ 11.

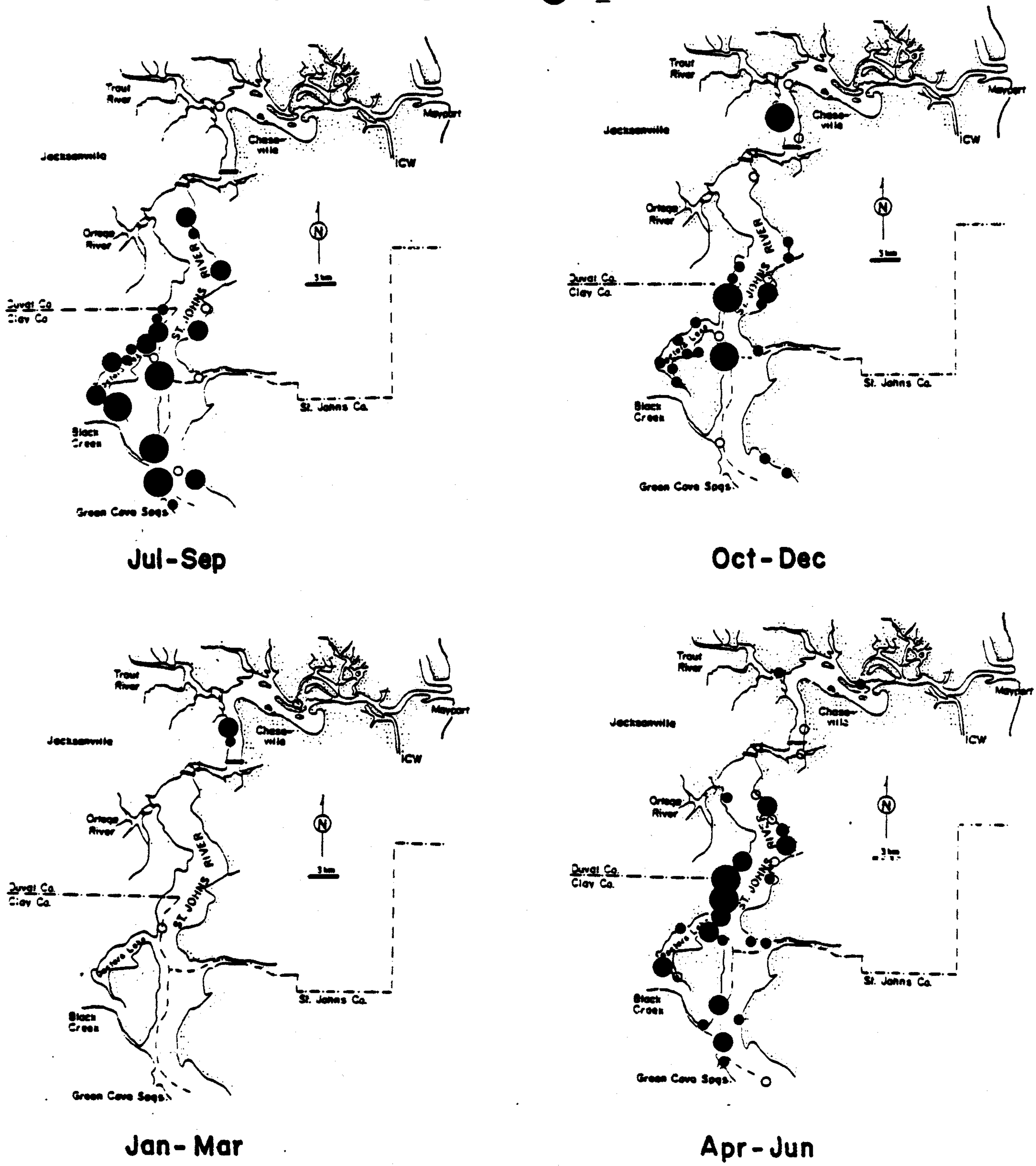


Figure 10. Activity of manatees in the St. Johns River. Size of dot indicates number of manatees per location: ○ = 1; • = 2-5; ● = 6-10; ⬤ = $\geq$ 11.

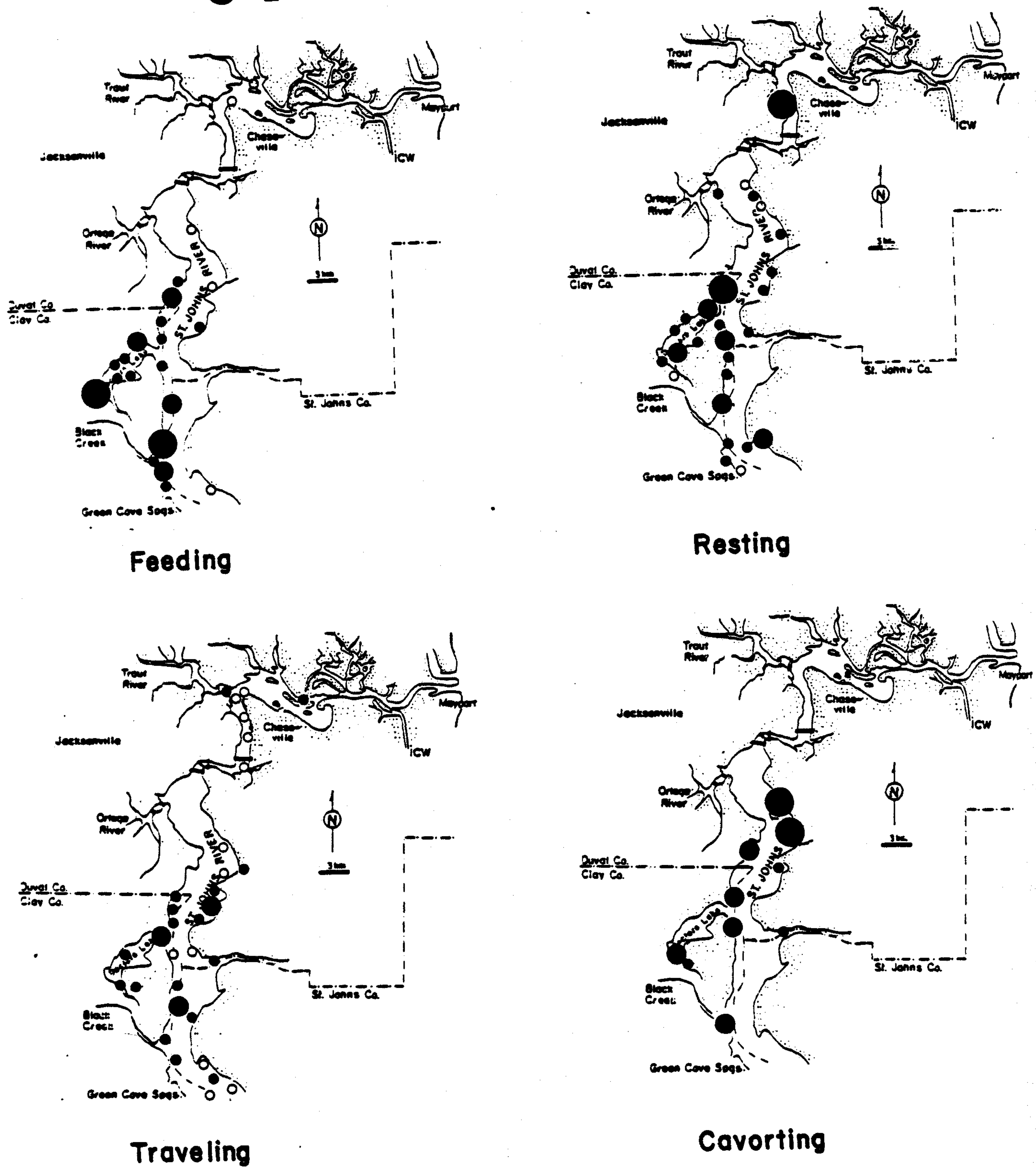


Table 3. Frequency and percent per season of manatee activity in the St. Johns River.

	BEHAVIORS									
SEASON	FEEDING		RESTING		CAVORTING		TRAVELING		TOTALS	
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
JUL-SEPT	67	(42)	38	(13)	38	(10)	16	(10)	159[1]	(100)
OCT-DEC	19	(17)	66	(58)	1	(0)	28	(25)	114[2]	(100)
JAN-MAR	1	(7)	11	(79)	0	(0)	2	(14)	14	(100)
APR-JUN	20	(15)	31	(23)	46	(35)	36	(27)	133[3]	(100)
TOTALS	107		146		85		82		420	

[1]Three individuals were tallied for two different behaviors.

[2]Behaviors were not determined for two individuals.

[3]Behavior was not determined for one individual.

Boat Traffic

A one-way analysis of variance showed that boat traffic varied significantly in abundance between months ($F = 34$, $N = 12$, $p = 0.26$) and quarters of the year ($F = 4.22$, $N = 4$, $p = 0.01$) (Fig. 11). Mean monthly boat counts for August and September were significantly higher than all other months and the mean boat count for the summer quarter (July-September) was significantly higher than all other quarters ($p = 0.05$). The mean number of boats counted over weekends was significantly higher than the mean number of boats counted during weekdays ($t = -2.34$, $N = 23$, $p = 0.04$). This relationship was accredited to a significant increase in small recreational boats over the weekends ($F = 7.24$, $N = 23$, $p = 0.01$).

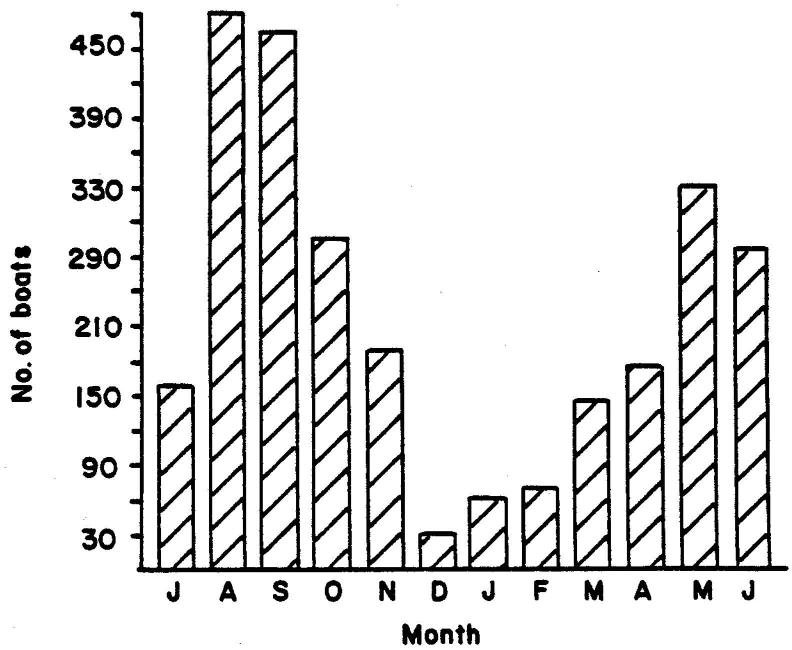
Eighty-five percent of all boat traffic was classified as recreational and eighty percent of the traffic was less than 7.3 m in length. The remainder of the traffic was comprised primarily of commercial fishing vessels, barges and motor-sailboats.

The frequency of seven boat types varied significantly among and within seasons ($X^2 = 80.8$, $N = 2713$, $p = 0.0001$) (Table 4). The greatest deviations from the expected frequencies came from the high number of small recreational boats counted during the summer and the low number counted during the fall and winter. In contrast to small boats, larger recreational boats were fewer in number than would be expected during the summer. Other large deviations from expected frequencies were due to a high amount of barge traffic from January to March and a low amount from July to September.

The distribution of boat traffic varied within the study area (Table 5). Boat density was highest at the mouth of the river (zone 1) and in Doctors Lake (Zone 10). The lowest boat densities were calculated for the Chaseville-Mill Cove area (Zone 3) and the Ortega River (zone 7). Boat type varied significantly within zones (ANOVA, $p < 0.05$); the mean number of small recreational boats was significantly higher than the means of all other boat types in every zone (Duncan's multiple range test, $p = 0.05$). Figure 12 summarizes the distribution of boat types (excluding sailboats) within the study area based on the relative density values of each boat type in all zones. Recreational boats are found throughout the study area with major concentrations occurring near the mouth of the river (zone 1), Doctors Lake (zone 10) and the Ortega River (zone 7). The density of commercial fishing boats is greatest around Blount Island (zone 2) and barges, oceanliners and other large industrial vessels are densest in the narrow region of the river from the Fuller Warren Bridge to Chaseville (Zone 5).

Boat activity varied significantly among and within seasons ($X^2 = 78.7$, $N = 2643$, $p = 0.0001$). The greatest deviations from the expected frequencies came from the large number of boats traveling north from July to September and a larger than expected number traveling south from January to March. Other large deviations were due to greater than expected numbers of anchored boats in the spring (April-June) and fall (Oct-Dec) and lower than expected numbers of anchored boats in the winter (January-March). The activity of boats varied significantly among and within all zones ($X^2 = 406.2$, $N = 2643$, $p = 0.0001$). The greatest deviations from the expected frequencies came from the large number of boats moving perpendicular to the channel in the industrial zone (zone 5) and the large number of anchored boats in zone 1.

Figure 11. Number of boats counted by month and quarter of the year in the St. Johns River.



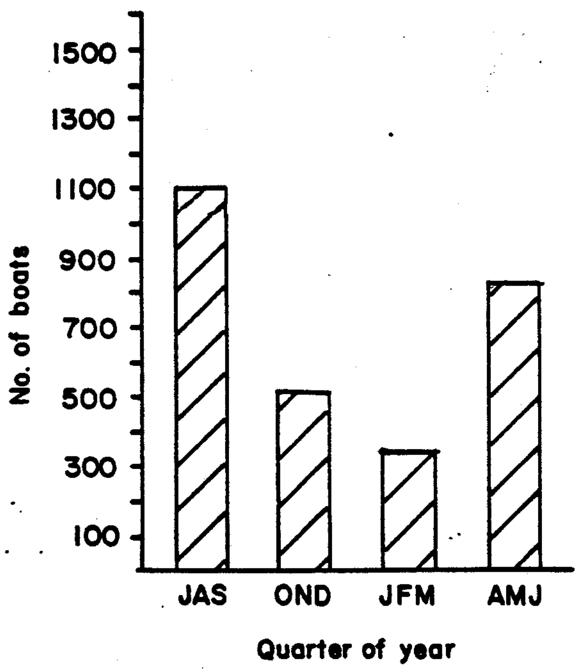


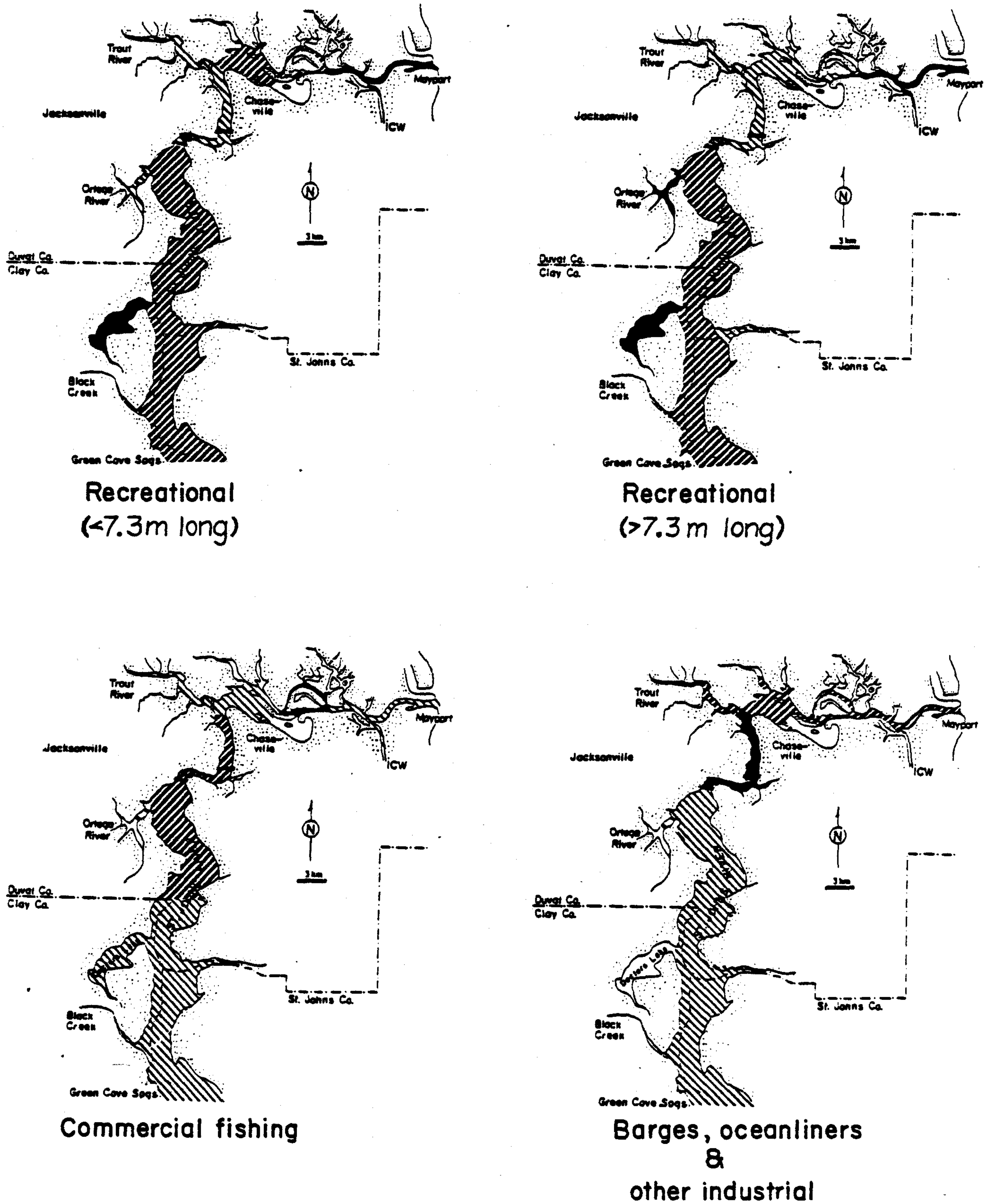
Table 4. Seasonal abundance of six boat classes in the St. Johns River.

SEASON	BOAT CLASS RECREATIONAL (< 7.3 m)	RECREATIONAL (≥7.3 m)	COMMERCIAL FISHING	MOTOR SAIL	BARGE TUG	OCEAN LINER & UNCLASSIFIED	TOTALS
Jul-Sep	914	46	47	56	24	15	1102
Oct-Dec	388	40	25	24	25	3	505
Jan-Mar	232	20	11	13	27	11	314
Apr-Jun	637	56	6	38	42	13	792
TOTALS	2171	162	89	131	118	42	2713

Table 5. Density of six boat classes in ten zones of the St. Johns River. Boat densities were calculated by dividing the linear flight distance (km) per zone into the total number of boats of each class counted in each zone.

	BOAT CLASS					
ZONE	RECREATIONAL (< 7.3 m)	RECREATIONAL (≥ 7.3 m)	COMMERCIAL FISHING	MOTOR SAIL	BARGE OCEANLINERS & OTHER INDUSTRIAL	TOTALS
1	22.7	1.51	0.38	0.48	1.23	26.3
2	15.6	0.54	1.5	0.78	1.08	19.5
3	9.1	0.63	0.35	0.48	0.84	11.4
4	4.2	0.47	0.23	0.27	0.23	5.4
5	5.6	0.59	0.85	0.76	2.2	10
6	10.5	1.06	1.0	2.21	0.33	15.1
7	5.5	1.27	0	0.43	0	7.2
8	13.7	0.97	0.07	1.08	0.48	16.3
9	15.1	0.85	0	0.55	0	16.9
10	21.4	1.38	0.19	0.93	0	23.9

Figure 12. Distribution of four boat classes in the St. Johns River. Shading intensity indicates the density of each boat class per zone: ■ = high; ▨ = med; ▧ = low.



Intracoastal Waterway

Manatee Abundance

A total of 134 manatees were observed during 23 surveys. Manatee abundance varied significantly among months (X^2 = 107.3, N = 6, p = 0.0001) and quarters of the year (X^2 = 72.2, N = 4, p = 0.0001) (Fig. 13). Manatee counts were highest during the spring and summer with peak counts in September 1982 and May 1983. The period of lowest utilization was during the late fall and winter months (October-March); only three manatees were observed from November to February.

The ratio of calves to total manatees observed per survey varied from 0.0 to 0.14. The ratio of calves to adults for all surveys combined was 0.04. All but one of the calf sightings were made within the spring months (April-June) (Table 6).

Manatees were most frequently sighted as singles (N = 43); however, the majority of the sightings were of manatees accompanying other manatees (N = 91) (Fig. 14). Larger groups (up to 11 animals) were observed at inlets to the Atlantic Ocean. As many as five animals were observed in groups in or around industrial warm water outfalls during the early spring months. One group of twenty manatees was sighted aggregated close to shore in zone eight, apparently drinking fresh water runoff.

Seasonal temperature change did not influence total counts (Fig. 15); the number of manatees counted during each survey was not significantly correlated with changes in ambient air temperature (r = 0.3, N = 23, p = .15).

There was no significant relationship between survey conditions and the number of manatees sighted (r = 0.24, N = 24, p = 0.24). On days when manatees were sighted, the number of manatees counted was independent of the day of the week (weekday vs. weekend) on which the survey was conducted (Mann Whitney $U_{12,5}$ = 18, $p > 0.1$). The total number of manatees counted per survey was also independent of the total number of boats counted (r = 0.15, N = 22, p = 0.49).

Manatee Distribution in the Study Area

Manatees were sighted throughout the entire study area but the number of sightings and the density of manatees varied among zones (Fig. 16 and Table 7). Manatee counts and densities were highest in the most southern and northern zones (zones 1 and 8, respectively), followed in number by the stretch of the ICW from Flagler Beach to Port Orange (zone 7). The majority of the sightings in the latter zone were made in the vicinity of the Tomoka River. The two most heavily used zones both had one or more inlets to the Atlantic Ocean.

There were seasonal changes in manatee distribution within the study area (Fig. 17, Table 7). Manatees were sighted throughout the ICW during the spring months (April-June). Manatee sightings in the northern zones (zones 1-5) were more frequent during the spring. Summer and fall sightings

Figure 13. Number of manatees counted by month and quarters of the year in the Intracoastal Waterway.

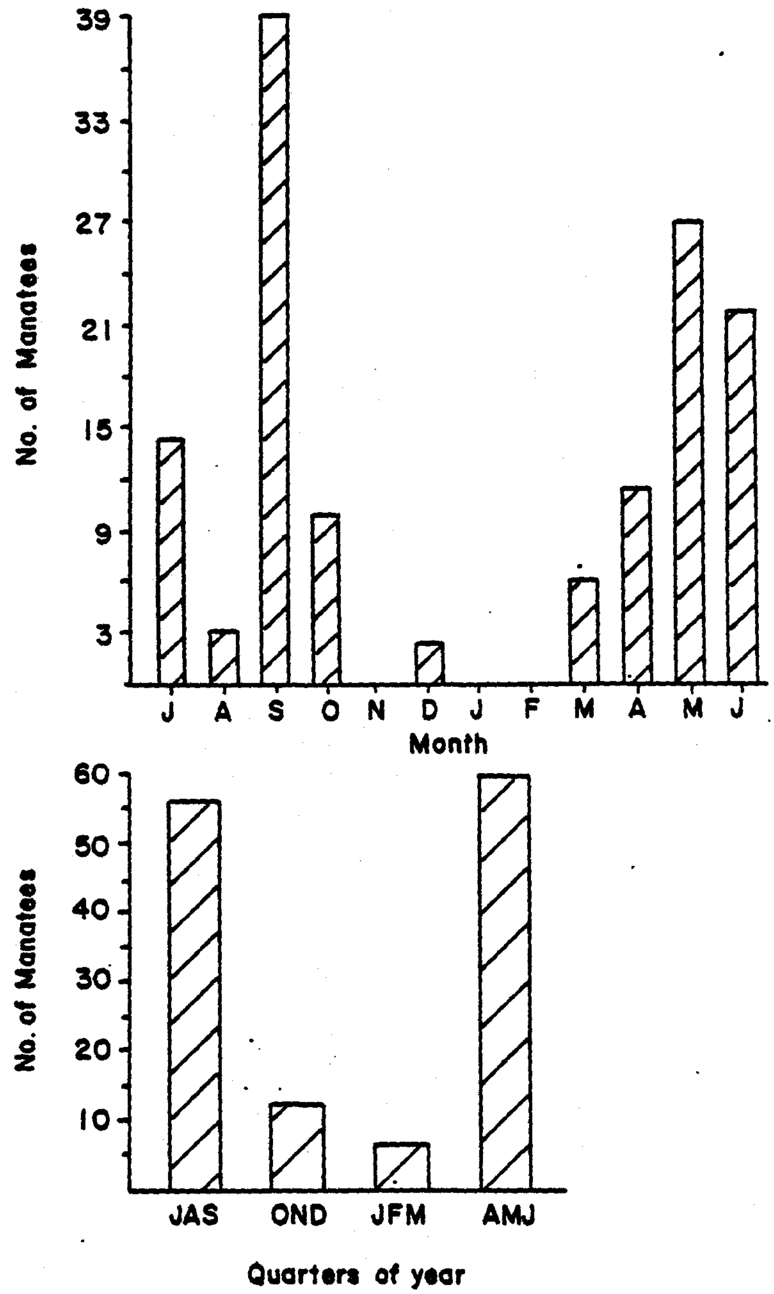


Table 6. Numbers and ratio of calves to adults sighted in the Intracoastal Waterway.

Survey Date	No. of Adults (a)	No. of calves (c)	c/a	Total No. Manatees
9 Jul	11	1	.09	12
23 Jul	2	0	0	2
9 Aug	1	0	0	1
28 Aug	2	0	0	2
16 Sep	38	0	0	38
28 Sep	1	0	0	1
7 Oct	9	0	0	9
17 Oct	1	0	0	1
6 Nov	0	0	0	0
2 Dec	2	0	0	2
19 Dec	0	0	0	0
6 Jan	0	0	0	0
29 Jan	0	0	0	0
12 Feb	0	0	0	0
29 Feb	0	0	0	0
14 Mar	1	0	0	1
29 Mar	5	0	0	5
5 Apr	7	1	.14	8
17 Apr	3	0	0	3
10 May	15	2	.13	17
15 May	9	1	.11	10
1 Jun	17		0	17
11 Jun	5	0	0	5
TOTALS	129	5	.04	134

Figure 14. Frequency of group size in the Intracoastal Waterway.

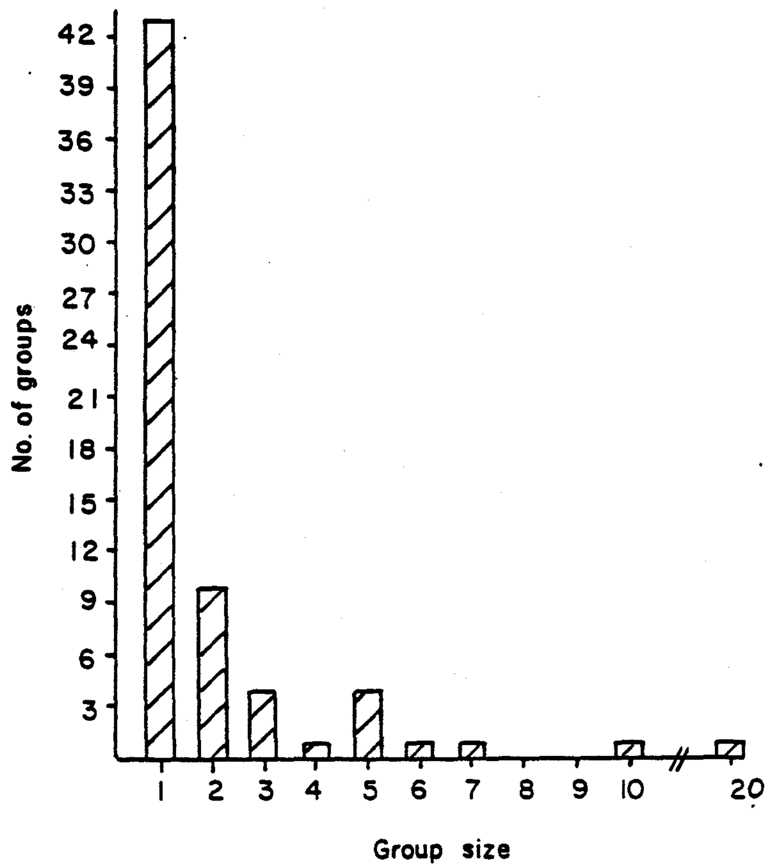


Figure 15. Relationship between temperature and manatee counts in the Intracoastal Waterway.

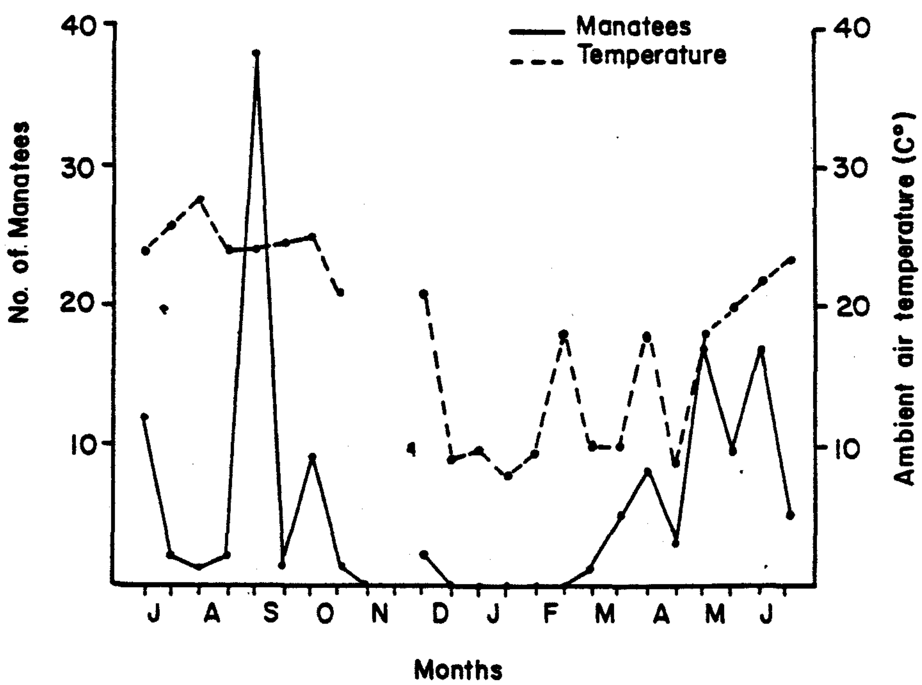


Figure 16. Number of manatees counted in eight zones of the Intracoastal Waterway.

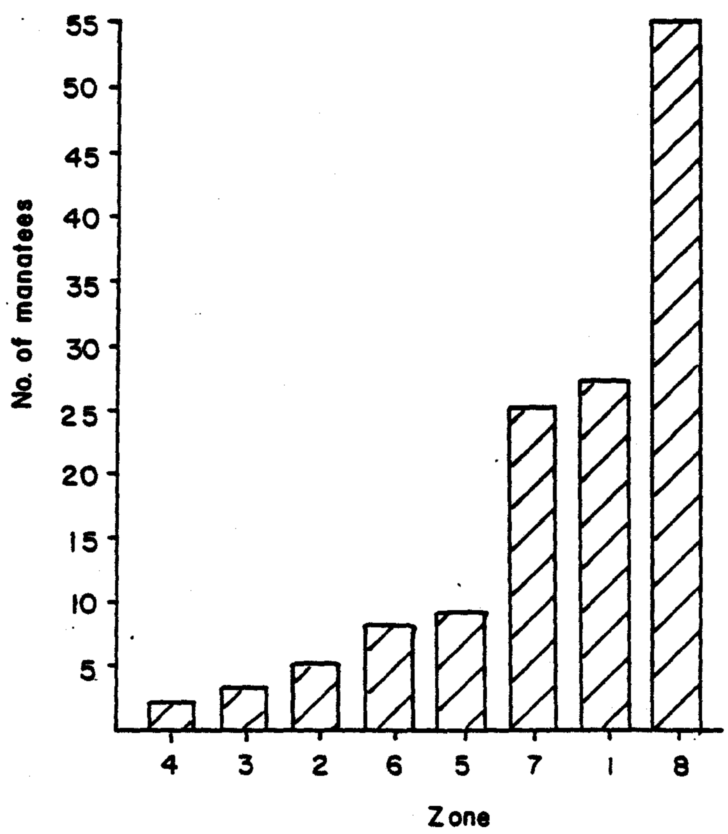
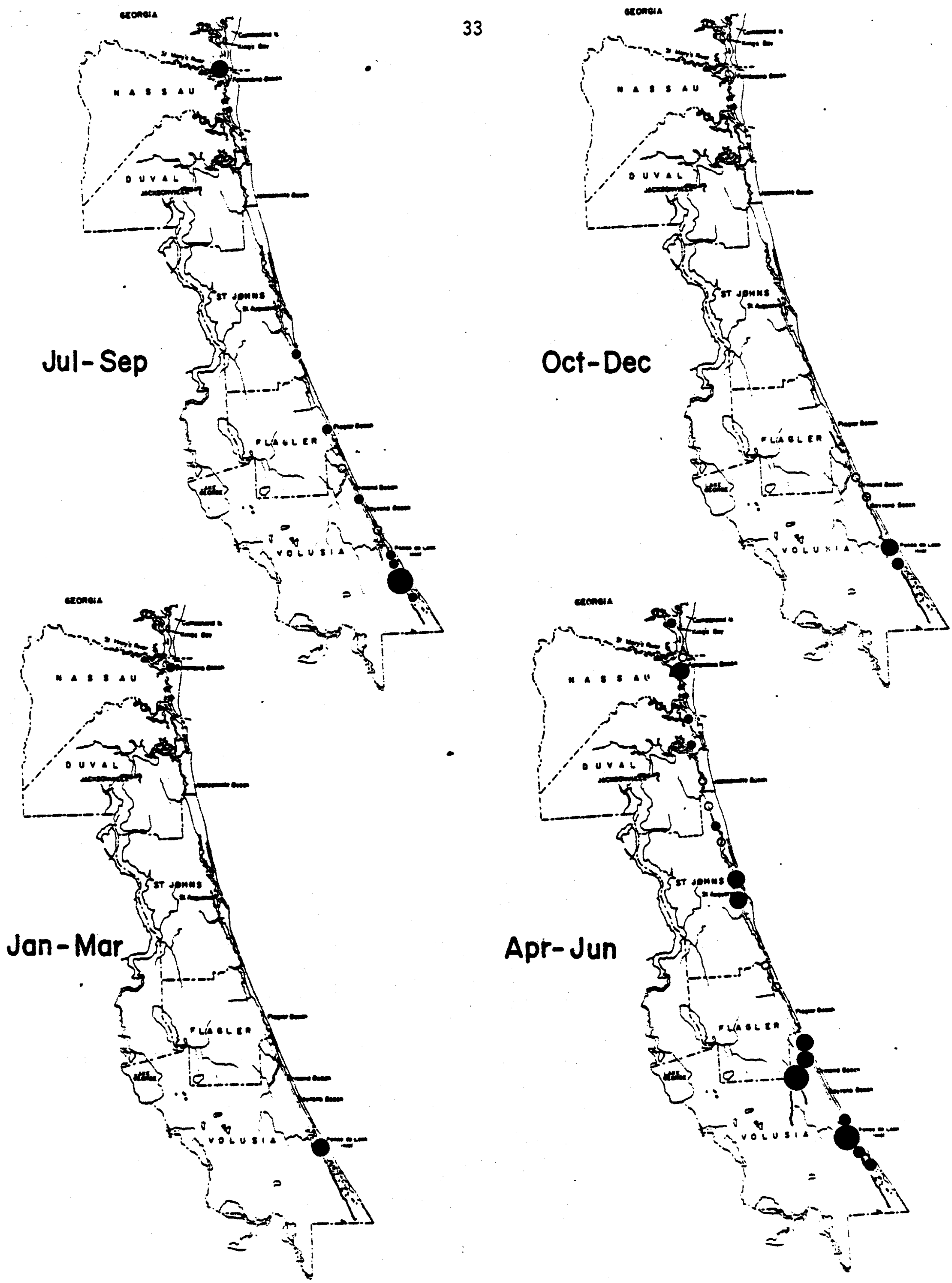


Table 7. Density of manatees in eight zones of the Intracoastal Waterway. Density values were calculated by dividing the linear distance (km) of the flight path over each zone, into the total number of manatees sighted in each zone during quarters of the year.

ZONE	JUL-SEP	OCT-DEC	JAN-MAR	APR-JUN	TOTAL DENSITY
1	.26	.00	.12	.26	.64
2	.00	.00	.00	.29	.29
3	.00	.00	.00	.11	.11
4	.00	.00	.00	.06	.06
5	.00	.00	.00	.46	.46
6	.11	.00	.00	.11	.22
7	.15	.05	.00	.41	.61
8	.84	.24	.02	.22	1.32
TOTALS	1.36	.29	.14	1.92	3.71

Figure 17. Seasonal distribution of manatees in the Intracoastal Waterway. Size of dot indicates the number of manatees per location: o = 1; • = 2-5; ● = 6-10; ⬤ = $\geq$ 11.


GEORGIA
NASSAU
DUVAL
JACKSONVILLE
ST JOHNS
FLAGLER
VOLUSIA
Jul-Sep
Oct-Dec
Jan-Mar
Apr-Jun

increased progressively to the south. Late fall and early spring sightings were most frequent in the vicinity of the Fernandina Beach industrial warm water outfalls (zone 1).

The number of manatees sighted in each zone varied with seasonal changes in air temperature. The number of sightings in each zone increased with air temperature; however, the relationships were not significant ($p > 0.1$).

Manatees did not avoid areas with high boat traffic; the density of manatees per survey zone was not significantly correlated with the density of boats (Kendall's Tau = -3.0, N = 8, $p > 0.1$). When the relationship between manatee and boat densities was examined for each zone separately, one zone (zone 8) showed a significant positive correlation between the number of manatees and boats (Kendall's Tau = 0.36, N =23, $p = 0.03$).

Manatee Movements and Behavioral Patterns

Manatees used the ICW for traveling more frequently than for any other behavior (Table 8). Observations of resting and cavorting manatees were infrequent and feeding manatees were noted only five times. The greatest percentages of animals observed traveling were during the spring and late summer. Manatees were observed traveling throughout the entire study area (Fig. 18). However, the majority of the sightings, with the exception of those animals observed in and around the Tomoka River (zone 6), were in the vicinity of inlets connecting with the Atlantic Ocean. Eighty-two percent (N = 110) of all traveling manatees were sighted within five meters of the shoreline, the remaining 18 percent (N = 24) were observed in the middle of boat channels. Of the few manatees observed resting or cavorting, all were sighted in cut-offs, small tributaries or in shallow areas near the waterway banks. In all but one observation of feeding manatees, the animals were feeding on shoreline vegetation with the upper half of their body hauled out of the water.

Boat Traffic

A one-way analysis of variance showed that boat traffic did not vary significantly in abundance between months ($F = 0.77$, N = 12, $p = 0.66$) and quarters ($F = 1.9$, N = 4, $p = 0.16$) of the year (Fig. 19). However, boat counts peaked in April and May and there was a trend towards higher boat counts during the summer quarter. The mean number of boats counted on weekends was significantly higher than the mean number of boats counted during the week (Student's t-test = 2.7, N = 23, $p = 0.01$).

Eighty-one percent of all boat traffic was classified as recreational and 66 percent of the traffic was less than 7.3 m in length. The remainder of the traffic was comprised primarily of large motorsail vessels ($\geq$7.3 m) and, to a lesser degree, barges and commercial fishing vessels (Table 9).

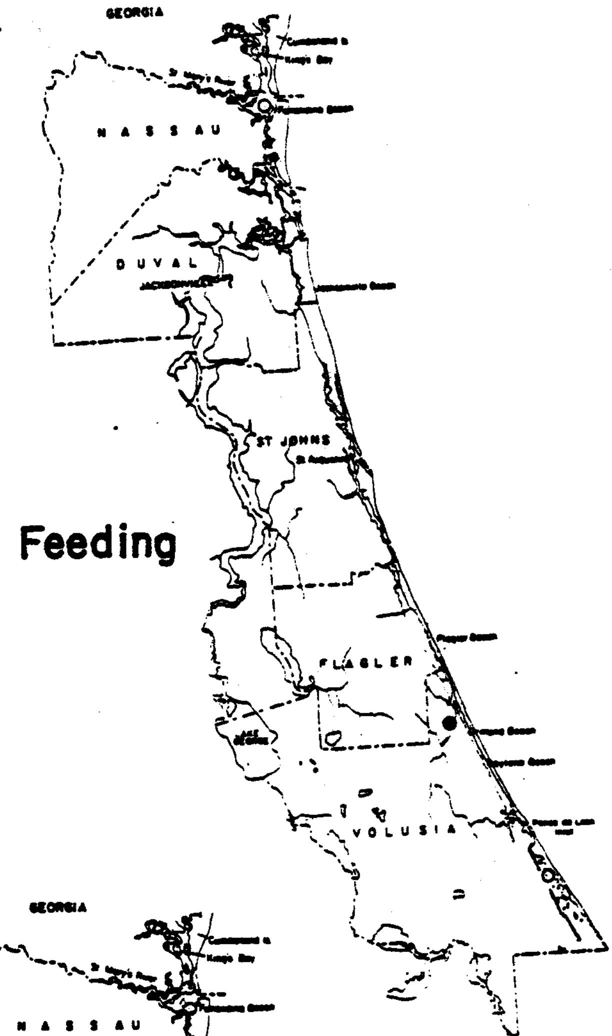
The frequency of seven boat types varied significantly among and within seasons ($X^2 = 215.7$, N = 4563, $p = 0.0001$). The greatest deviations from the expected frequencies were due to a the large number of small recreational boats in the summer and the low number in the spring. In contrast to small

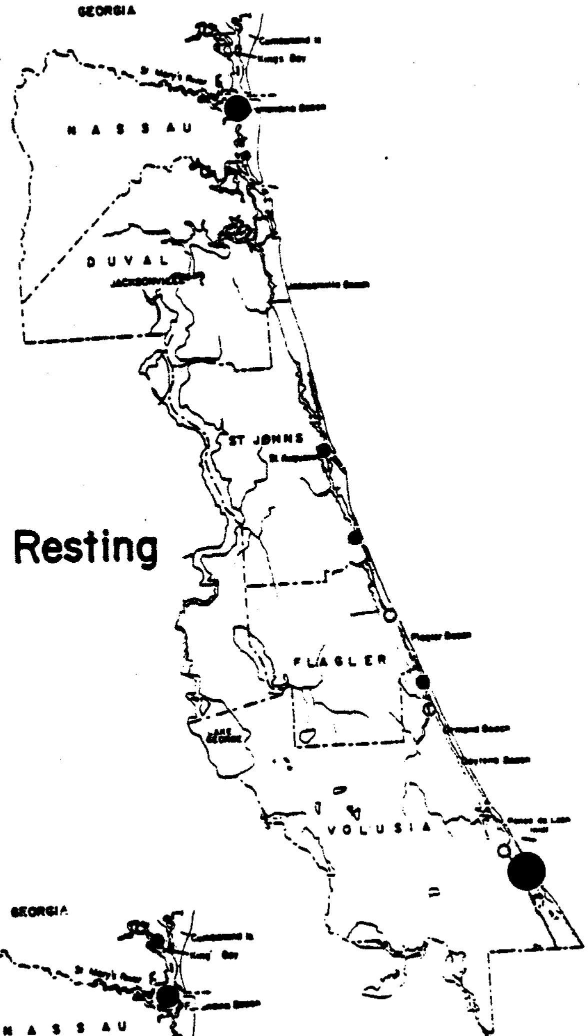
Table 8. Frequency and percent per season of manatee activity in the Intracoastal Waterway.

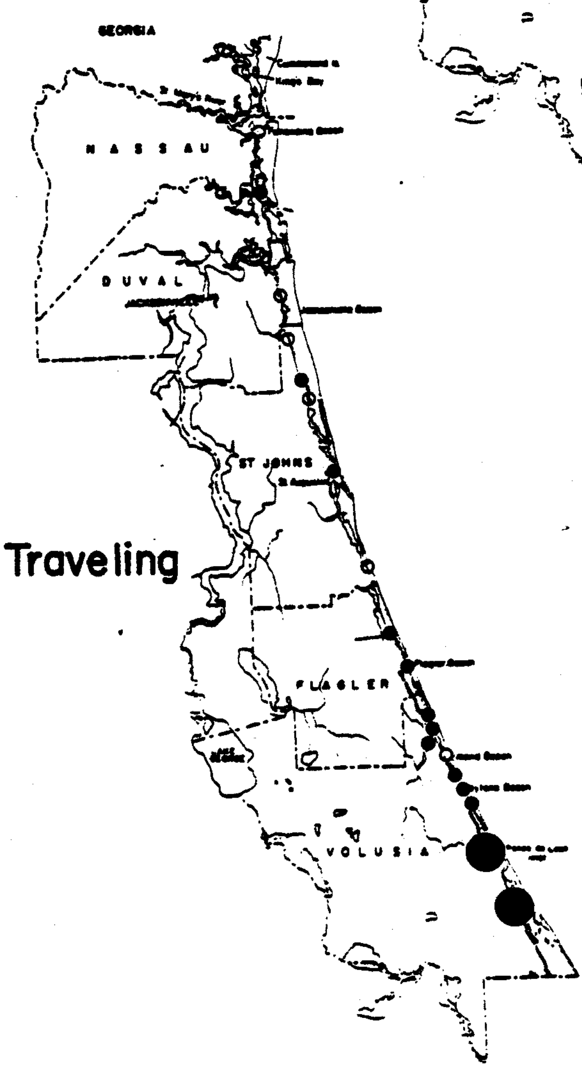
	BEHAVIOR									
SEASON	FEEDING		RESTING		CAVORTING		TRAVELING		TOTALS	
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
JUL-SEP	1	(0)	25	(45)	10	(18)	21	(37)	57[1]	(100)
OCT-DEC	1	(8)	0	(0)	0	(0)	11	(92)	12	(100)
JAN-MAR	0	(0)	4	(67)	0	(0)	2	(33)	6	(100)
APR-JUN	3	(5)	11	(18)	14	(23)	33	(54)	61[1]	(100)
TOTALS	5		40		24		67		136	

[1]One individual was tallied for two different behaviors.

Figure 18. Activity of manatees in the Intracoastal Waterway. Size of dot indicates the number of manatees per location: ○ = 1; ● = 2-5; ● = 6-10; ● = $\geq$ 11.


GEORGIA
NASSAU
DUVAL
ST JOHNS
Feeding
FLAGLER
VOLUSIA


GEORGIA
NASSAU
DUVAL
ST JOHNS
Resting
FLAGLER
VOLUSIA


GEORGIA
NASSAU
DUVAL
ST JOHNS
Traveling
FLAGLER
VOLUSIA

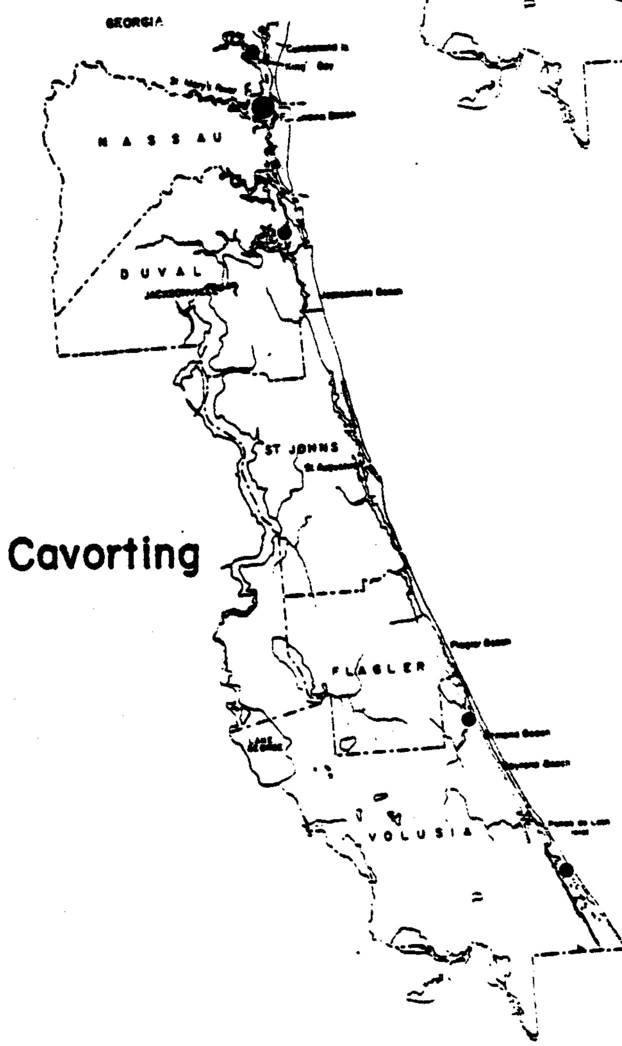

GEORGIA
NASSAU
DUVAL
ST JOHNS
Cavorting
FLAGLER
VOLUSIA

Figure 19. Number of boats counted by month and quarter of the year in the Intracoastal Waterway.

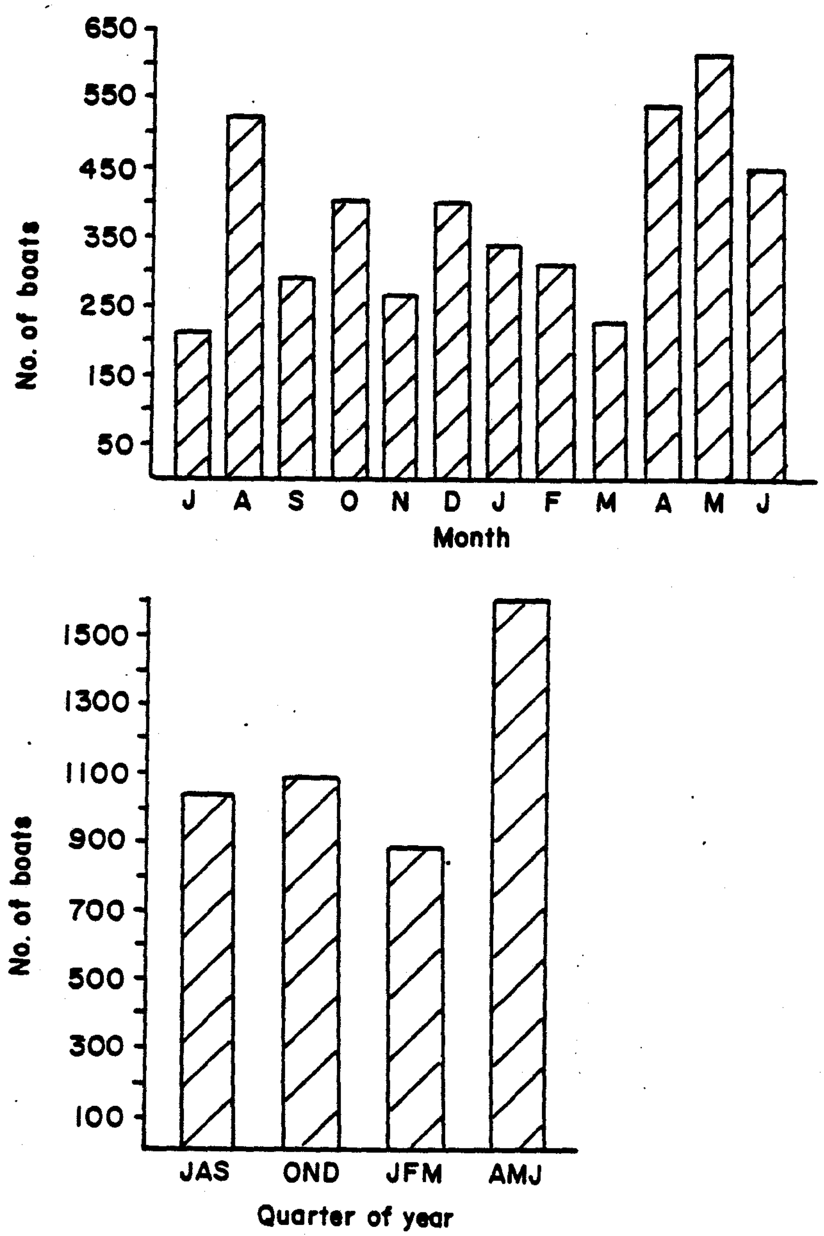


Table 9. Seasonal abundance of six boat classes in the Intracoastal Waterway.

	BOAT CLASS						
SEASON	RECREATIONAL (<7.3 m)	RECREATIONAL (≥7.3 m)	COMMERCIAL FISHING	MOTOR SAIL	BARGE TUG	OCEANLINER & UNCLASSIFIED	TOTALS
JUL-SEP	780	117	26	93	17	3	1036
OCT-DEC	652	153	20	226	8	5	1064
JAN-MAR	624	98	22	105	16	12	877
APR-JUN	954	336	21	184	67	24	1586
TOTALS	3010	704	89	608	108	44	4563

boats, large recreational boats were observed in greater numbers than expected during the spring. Other large deviations from expected frequencies resulted from a large number of motor-sail boats during the winter months.

The distribution of boat traffic varied within the study area (Table 10). Boat densities were highest in the vicinity of Ponce de Leon Inlet (zone 8), St. Augustine Inlet (zone 5), and the intersection of the ICW and the St. Johns River (zone 2). The lowest boat density was between Flagler Beach and Port Orange (zone 7), the only zone without a nearby inlet. Boat type varied significantly within each zone (ANOVA, $p < 0.05$); the mean number of small recreational boats was significantly higher than the means of all other boat types in each zone ($p = 0.05$). When small recreational boats are excluded from the analysis, the mean numbers of large recreational boats and motor-sailboats are significantly higher in all but the two most northern zones. Figure 20 summarizes the distribution of four boat classes (excluding sailboats) within the study area based on the relative density values of each boat type in each zone. Major concentrations of recreational traffic are found in the three zones (2, 5 and 8) responsible for the highest density of boat traffic. The density of both fishing and industrial vessels are the greatest in the two most northern zones of the study area (zones 1 and 2).

Boat activity varies significantly among and within seasons ($X^2 = 132.9$, $N = 4037$, $p = 0.0001$). The greatest deviations from the expected frequencies were due to a high number of boats moving north in the spring and a low number moving north in the fall. In contrast, a much greater than expected number of boats were moving south during the fall and a lower number than expected were moving south during the spring. The activity of boats varied significantly among and within zones ($X^2 = 168.6$, $N = 4037$, $p = 0.0001$). The greatest deviations from the expected frequencies came from large numbers of boats anchored in those zones with inlets and large numbers of traveling boats in those zones without inlets.

DISCUSSION

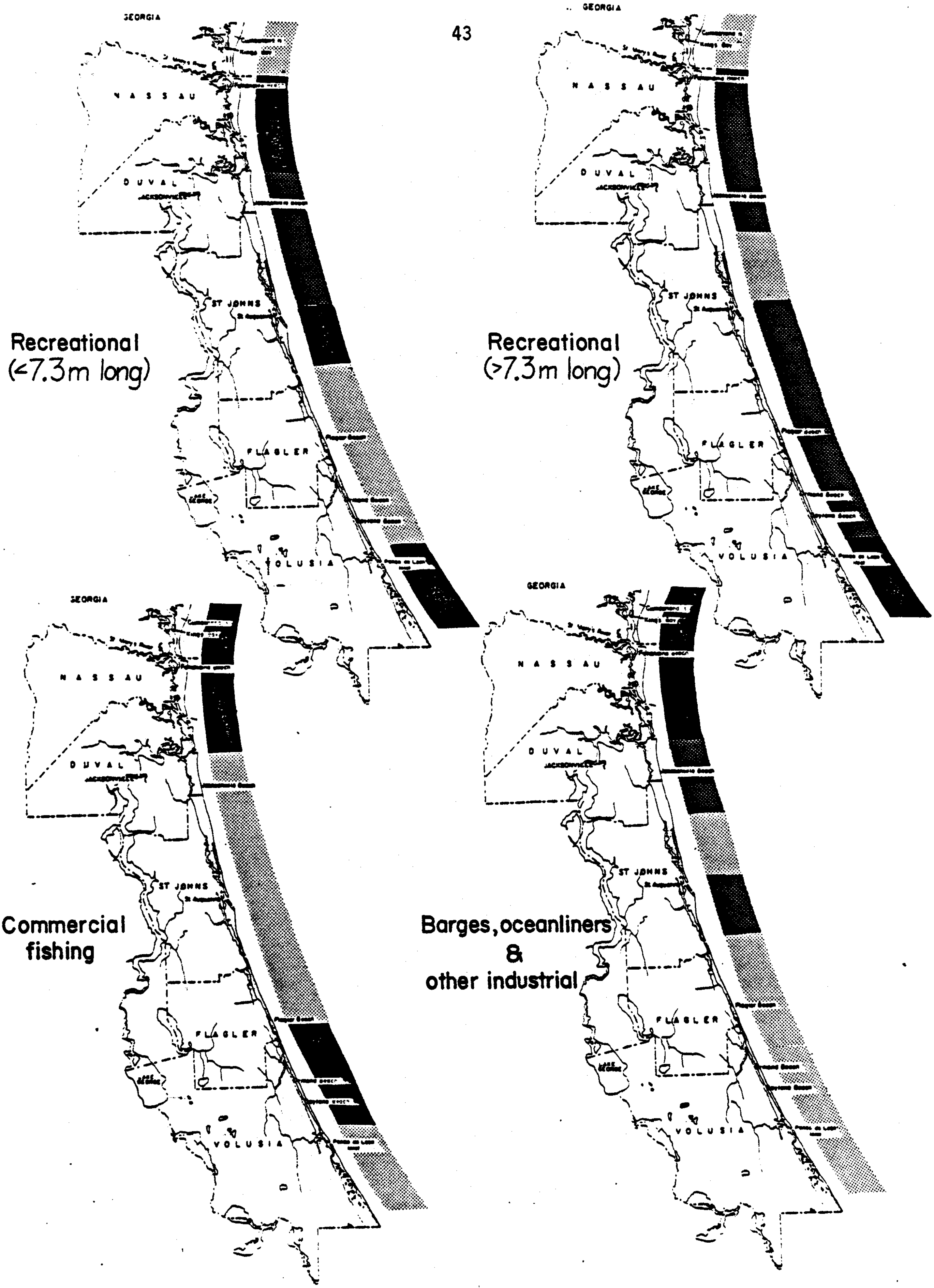
The Lower St. Johns River

Results of the present study support Hartman's (1974) observation that manatee abundance and distribution in the lower St. Johns River are correlated with water temperatures and food resources. Manatees were most abundant in the study area during the summer months when air and water temperatures are highest. Manatee intolerance to cold (Irvine 1983) limits their use of the river during winter months when ambient river water temperatures average below 19 to 16°C, the range often cited as the threshold of tolerance (Allsopp 1969, Campbell and Irvine 1981). Increased winter manatee counts were recorded only for zone five, where aggregations of manatees (up to 13 animals) were sighted in the warm water outfalls of two generating stations and one industrial plant. These aggregations also are limited by the low winter river water temperature; the aggregations are unstable and composed primarily of transient individuals (Kinnaird and Valade 1983).

Table 10. Density of six boat classes for eight zones in the Intracoastal Waterway. Boat densities were calculated by dividing the linear flight distance (km) per zone into the total number of boats of each class counted in each zone.

	BOAT CLASS					
ZONE	RECREATIONAL (<7.3 m)	RECREATIONAL (≥7.3 m)	COMMERCIAL FISHING	MOTOR SAIL	BARGE OCEANLINER OTHER INDUSTRIAL	TOTALS
1	6.4	1.7	0.81	1.87	1.02	11.8
2	16.8	2.7	0.75	2.13	1.22	23.6
3	11.4	2.9	0.55	2.0	0.25	17.1
4	11.2	1.7	0.09	2.22	0.09	15.3
5	16.5	2.8	0.51	3.14	0.35	23.3
6	10.1	2.6	0.16	1.97	0.37	15.2
7	8.8	2.4	0.19	2.04	1.07	14.5
8	17.2	4.7	0.23	3.46	0.31	25.9

Figure 20. Distribution of four boat classes in the Intracoastal Waterway. Shading intensity indicates the density of each boat class per zone: ■ = high; ■ = med; ▒ = low.


GEORGIA
NASSAU
DUVAL
JACKSONVILLE
ST JOHNS
FLAGLER
VOLUSIA
Recreational
(<7.3m long)
Recreational
(>7.3m long)
Commercial
fishing
Barges, oceanliners
&
other industrial

The increase in the number of manatees during the summer months represents an influx of animals from elsewhere into the study area. It is not known where these animals spend the winter. However, a few winter residents from Blue Spring, a natural warm water refuge approximately 170 km to the south, have migrated as far as the city of Green Cove Springs during the summer (Bengtson 1981). Perhaps some Blue Spring residents were involved in this influx. However, there are only about 35 Blue Spring residents (as of 1982/1983) and most of those winter south of this area (Bengtson 1981, Sirenia Project, unpubl. data). It has been speculated that animals ranging up and down the east coast of Florida may frequent the lower St. Johns during their annual north/south migration (Kinnaird and Valade 1983). This idea is supported by the greater number of manatees sighted traveling up and down the river during the spring and fall, respectively. I believe most of the manatees which summer in the lower St. Johns River winter at the Jacksonville power plants or the lower east coast of Florida.

Manatee distribution during the summer months was correlated with the location of submergent aquatic vegetation. Doctors Lake (zone 10) and the section of river from the Buckman Bridge south to the city of Green Cove Springs (zone 8) are bordered by beds of eelgrass (*Vallisneria americana*) and constitute important feeding and resting grounds for manatees. Manatees showed a preference for the west bank of zone eight and the southwest edge of Doctors Lake where grassbeds are more lush and fewer shoals are present than other sites. Food resources are extremely limited to the north of these two zones; no grassbeds were visible from the air although mats of floating vegetation were occasionally observed. Manatees in the lower St. Johns River are known to consume cordgrass (*Spartina bakeri*) (Sirenia Project, FWS unpubl. data). The few manatees observed feeding outside of zones with grassbeds were consuming overhanging shoreline vegetation which was presumed to be cordgrass.

Summer distribution within the study area also may be influenced by salinity. Hartman (1974, 1979) observed a preference by manatees for the mouths of rivers and other fresh water runoffs. During this study manatees were rarely sighted north of the zone of transition between fresh and salt water and those sighted beyond the zone were generally near the mouths of fresh water tributaries (i.e. Arlington and Trout Rivers) or during the winter in the warm water outfalls.

The fact that very few sightings were made from the mouth of the river to Mill Cove (zones 1-3) may be due to the extremely high water turbidity of the area or because manatees are generally traveling through the area, not stopping to rest or feed, thus making sightings less likely. Because manatees are traveling to and from the power plants during the cooler months and animals from outside the study area are moving into the Green Cove Springs zone during the warmer months, manatees likely are present year-round in that stretch of the river.

The proportion of calves sighted (7%) is somewhat lower than that reported by other researchers. Campbell and Irvine (1978) observed 9.6% and 14.4% calves during winter and summer aerial surveys respectively over the entire state of Florida. Calves made up 5.2% of the animals sighted by Odell (1979) in Collier and Monroe Counties but Campbell and Irvine (1978) reported 10.2% of their sightings were calves from surveys over the same area.

Leatherwood (1979) and Shane (1983) reported 9.9% and 8.9% calves, respectively from aerial surveys over the Indian and Banana Rivers. Rose and McCutcheon (1980) reported 9% calves on winter surveys over power plants on both coasts of Florida. Packard (1981) estimated that 14% of all manatees sighted during the winter in the Hobe Sound area were calves. Irvine et al. (1981) reported the only figure for the percentage of calf sightings that is lower than the figure reported here; the total percentage of calves estimated by the authors ranged from 0.9% to 4.9% in different months.

The relatively low proportion of calves reported for this study may be affected, in part, by the absence of calves from the study area during the cooler months. O'Shea et al. (in prep.) suggest that small dependent calves may be restricted to traditional warm water sources by their mothers and therefore avoid the cold induced mortality prevalent among subadults. The lower St. Johns River constitutes marginal winter habitat for manatees (Kinnaird and Valade 1983) and therefore may not be favored by females with calves. Odell (1979) suggested that the tendency of calves to stay close to their mothers might result in fewer calf sightings. It is possible that calves, by virtue of their size and the tendency to associate closely with their mothers, may have been oversighted in the turbid water characteristic of the St. Johns River. However, many of the above studies reporting a high percentage of calves have been conducted under turbid conditions. Also, there are several reasons why calves are more likely to be seen (i.e. synchronous breathing with their mothers and side-by-side traveling). Therefore, I believe that the proportion of calves reported represents a sound estimate.

Some authors (Moore 1951, Irvine and Campbell 1978, Shane 1981) have suggested that a spring peak in calving may occur. Too few calves were sighted in this study to indicate seasonal reproductive trends. The high proportion of animals observed cavorting from April through June may indicate a spring mating season; this is inconsistent with data presented by Bengston (1981) who observed a greater percentage of cavorting and mating behavior during the later summer and early fall in the upper St. Johns River. Both studies indicate however that winter mating/cavorting is minimal which suggests that mating occurs primarily in the warmer months.

Bengston (1981) estimated the manatee population of the entire St. Johns River at 50-75 animals, a figure that Eberhardt (1982) states is not consistent with the high mortality rate in the river and the increasing numbers of manatees wintering in Blue Spring. I believe the effective manatee population of the river (i.e. that population of animals that is not necessarily resident but utilizes the river during part of the year) is much greater than the above estimate. Manatee counts in the high thirties were not uncommon during this study and a peak count of 48 animals was recorded over three zones (6, 8 and 10) in one survey. Many animals probably move in and out of the river during the warmer months and it is likely that these counts reflect different individuals. Also, these figures represent relative numbers and are most likely underestimates. Although daily survey conditions did not influence manatee counts, turbid waters and limited visibility throughout the duration of the study probably lowered the chance of sighting manatees. Also, relative to the entire river, only a limited amount of shoreline was surveyed for this study. Additional animals that winter at Blue Spring remain south during the summer (Bengtson 1981) and very few could have contributed to the numbers recorded in these surveys. Considering these factors and the likely use of the river by many transient animals, it is highly probable that the effective manatee population of the St. Johns River is at least 150 animals.

The seasonal and weekend peaks observed in boat traffic are consistent with data collected by Hanni (1978) showing that two-thirds of the non-commercial boating activity in the Jacksonville area takes place from July through September with most activity occurring over the weekends. These high summer figures may be attributed, in part, to an influx of tourists from outside the state (Bell et al. 1982). However, the majority of boats using the St. Johns River are operated by residents within the northeastern region of Florida (Bell et al. 1982).

Hanni (1978) also found that the number of boats with offshore destinations was much less in the Jacksonville area than in areas farther south (i.e. Dade Co. and St. Augustine) and attributed this to the fact that tributaries and estuaries of the St. Johns River offer significant alternative destinations for fishing and recreation. This may help explain the high boat densities in Doctors Lake, the Ortega River and other zones away from the mouth of the river. The majority of large recreational boat traffic occurred near the mouth of the river (Mayport, zone 1). This distribution is consistent with observations that the majority of boats traveling offshore are typically larger than those remaining inland (Hanni 1978, Ditton et al. 1982). The distribution of recreational traffic is also influenced by the distribution of docking facilities (Kinnaird 1983). The high density of docking facilities in the Ortega River (zone 7) (where no manatees were observed) and the Mayport area (zone 1) may also concentrate boating activity.

Commercial fishing and industrial traffic was distributed, as expected, from the mouth of the river to Port Jacksonville, with major concentrations occurring near industrial plants, terminals and generating stations. Although commercial fishing was determined to be the heaviest in zone 2, the majority of commercial fishing boats was concentrated in zone 1 where the unloading docks are located. Survey results may have been biased by the fact that commercial fishing traffic, unlike other boat-class traffic, occurs primarily in the early morning and late evening, before and after the surveys were conducted. In reference to manatees, zones 1 and 2 are the most appropriate locations for commercial fishing vessels. By placing docks near the ocean, the distance traveled on the river by vessels is minimized and the probability of colliding with a manatee is reduced.

In general, the abundance, distribution or size class of boat traffic did not appear to influence manatee distribution. However, the negative correlation between manatee and boat counts in zone five, a zone characterized by heavy industrial traffic suggests that manatees will avoid, if possible, such areas when large, industrial craft are abundant. Also, boat distribution and activity may have influenced manatee distribution within zones of heavy traffic. Manatees tended to travel outside of boat channels, avoid shoaled areas and restrict cavorting activities to sites with low boat activity. In addition, the limited food and seasonal warm water resources available to manatees and the distribution of these resources within zones of high to moderate boat traffic, may not give manatees the option of choosing alternative, low boat density zones.

Based on survey results, zones of major overlap between manatee and boat use are Doctors Lake and Green Cove Springs (zones 8 and 10). These zones therefore constitute areas of high manatee vulnerability to collisions with boats and boating activity in these areas are a cause of concern. Data collected by the Sirenia Project, FWS, Gainesville, Field Station, from 1976 to July 1983, on the distribution of manatee boat/barge mortality within this study area, identify the industrial zones of the river (1,2,3 and 5) as the zones of greatest conflict. Eighty-four percent (N = 16) of all boat/barge related manatee deaths occurring within the study area (N = 19) were recovered within these zones. The carcasses were severely mutilated (2 animals were cut almost entirely in half) and bore wounds of a size which could only have been made by vessels with large propellers (Beck et al. 1982). Based on this fact, and the boat classes characteristic of these zones, it appears that large industrial and commercial traffic is most likely responsible for the majority of manatee boat/barge mortalities in the St. Johns River. The narrow width of the river and the non-linear pattern of traffic flow in these zones may also contribute to the problem (Kinnaird 1983). Other factors, such as the increased barge traffic during the winter months when manatees aggregate at the power plants, may also augment the problem. Although manatee boat/barge deaths occurred in all seasons in the study area (O'Shea et al. in prep.), five of seven boat kills recovered in the immediate vicinity of the power plants occurred during the cooler months (Sirenia Project, unpubl. data). Animals traveling to and from food resources to the south are extremely vulnerable to collisions with boats when passing through this lower river conflict zone. Because animals ranging up and down the entire east coast may frequent the lower St. Johns River, the problem of boat/barge mortalities must be considered one of regional impact (Kinnaird and Valade 1983).

Intracoastal Waterway (ICW)

Survey results from the Intracoastal Waterway support Hartman's (1974) idea that this stretch of waterway is used by manatees primarily as a migratory route along the east coast of Florida and south Georgia. This northeastern section of the ICW is likely an important route between the St. Johns River and Brevard County. These are the only two areas in northeast Florida known to have significant numbers of manatees on a year-round basis (Hartman 1974, Shane 1983). Manatees sighted during the surveys were almost always traveling and observations were most frequent in the spring and late fall, time periods that coincide with patterns of migration (Moore 1951, Hartman 1974, 1979, Shane 1983, Rathbun et al. 1983). Increases in manatee sightings in the ICW were generally staggered one month ahead of increases in the number of sightings in the St. Johns River, supporting the idea that manatees wintering outside the St. Johns may migrate to the river from more southerly coastal regions during the spring via the ICW (Hartman 1974, Kinnaird and Valade 1983). The opposite pattern was not observed during the fall, but the warm fall weather of 1982 may have caused a less well-defined peak in movement. Long distance movements by manatees between the St. Johns River and power plants on the ICW in Brevard and Broward Counties (Rathbun et al. 1983, Kinnaird and Valade 1983) are also consistent with the idea that the ICW is a major migratory route. Some migration may occur through oceanic waters along the Atlantic coastline, but Hartman (1974) noted that the four kilometer detour necessary to navigate the jetties at the mouth of St. Johns River, the extreme shoaling and turbulent waters of some coastal areas, and the lack of fresh water may discourage manatees from traveling along the coast. It is likely that manatees utilize both the coastline and the ICW, moving in and out between inlets. This would be consistent the tendency for sightings to be clumped around inlets.

Data are also consistent with Hartman's (1974) observation that manatee use of the ICW is limited by cold weather and by the lack of fresh water and an adequate food supply. The occurrence and frequency of manatee sightings generally decrease to the north. Manatee sightings are restricted to fewer months of the year and peaks in sightings shift from spring to summer in the more northern zones. Rathbun et al. (1982) noticed the same pattern of manatee occurrence along the southeast coast of the U.S. north of Florida. Fresh water run-off may be responsible for manatee concentrations in and around Tomoka River and for other sightings near the confluence of fresh water sources and the ICW, especially Spruce and Bulow Creeks. Food resources become progressively scarcer north of Volusia County (Hartman 1974) as do manatee sightings. The only manatees observed feeding in this study were forced to forage on shoreline vegetation. Rathbun et al. (1982) also cite limited food supply as a major factor restricting manatee movements up the southeast coast of the U.S.

An exception to the northern decline in manatee observations throughout the study area is found in the vicinity of Fernandina Beach (zone 1). The warm water resources available to manatees from ITT Rayonier and the American Container Corporation are responsible for the high spring counts in this zone. Interestingly, Hartman (1974) did not observe manatees at these outfalls during aerial surveys in 1974, nor were sightings reported by the local residents interviewed. Industrial warm water outfalls have been cited as being partly responsible for the recent expansion of the manatees winter range up the northeast coast of Florida (Rathbun et al. 1983). Although manatees were not observed at these warm water outfalls during the winter, the plants appear to offer refuge for manatees during the cold snaps of early spring and late fall, thereby possibly allowing manatees extended time to range farther north during the summer months. A claim that manatees appear at the Gillman Paper Company on the North River (zone 1) was not confirmed.

Of six cause-of-death categories defined for manatees salvaged statewide (Bonde et al. in prep), dependent calf deaths are disproportionately high in the northeastern section of the ICW (O'Shea et al. in prep.). O'Shea et al interpret this to be largely a statistical result of lower boat mortality in the area and lower calf mortality in other parts of northeastern Florida, but also suggest it may reflect the use of quiet, shallow areas off the ICW as birthing places by female manatees. The Tomoka River may be one such area used by calving females. Complications or accidents during parturition may account for many of these deaths (O'Shea et al.in prep.). Four of thirteen (31%) perinatal and dependent calf deaths occurring from May 1976 through July 1983 in the northeastern ICW were recovered in the Tomoka River (Sirenia Project, unpubl. data). Although absolute numbers are not great, this is the highest number of small calf deaths recorded for any river of similar size in the state (Sirenia Project unpubl. data). The Tomoka River is also the site of the only witnessed birth of a free-ranging manatee (McNerney 1982). Although all tributaries were not surveyed in detail (due to overhanging vegetation that often obscures isolated waterways), the extremely low percentage of calves observed throughout the study does not suggest that birthing is frequent elsewhere in the ICW.

Boat traffic in the ICW was consistently high throughout the year. This may be due to the large number of small recreational boats that are able to use the waterway year-round because of its sheltered nature and usually calm waters (NOAA 1982). An increase in traffic during the spring and summer is attributed primarily to a rise in the number of larger recreational boats, most likely operated by non-residents moving north and south with the seasons.

Levels of boat traffic and boat density alone did not appear to be a determining factor influencing large-scale manatee migration, travel or distribution patterns. Areas of high manatee use overlapped with areas of high boat density. Boat density was heaviest in the south, particularly in the vicinity of Daytona Beach and Ponce de Leon Inlet (zones 7 and 8) and near other inlets such as St. Augustine, Matanzas and the St. Johns River that are utilized by manatees. High densities of large boats (i.e. recreational boats $\geq$ 7.3 m long, tugs and commercial fishing boats), which may pose greater threats to manatees than smaller boats (Beck et al. 1982), were concentrated, near these inlets as predicted by Ditton et al. (1982).

At the local level, the effect of boat traffic and boat densities may be more substantial. Manatees appeared to avoid heavy boat traffic within these zones by traveling close to shore or by resting in oxbows or isolated tributaries. A significant number of manatees were sighted in the Tomoka River and associated bay and mosquito control canals relative to the rest of the ICW. Manatees may use this tributary not only because of its fresh water supply but also because of the very low density of boat traffic relative to that in the portion of the ICW immediately adjacent.

Presently, manatee boat/barge mortality is extremely low in the ICW relative to other areas on the east coast (O'Shea et al. in prep.). This may be due to overall lower manatee numbers or, more likely, to the fact that manatees in general do not spend much time in the waterway. However, an increase in deep-draft vessels (i.e. tugs, barges and large recreational boats) could be expected to increase boat/barge mortalities. The shallow waters of the ICW do not provide sufficient room for a manatee to pass safely underneath the hull of deep draft boats and the restricted canal width through much of the ICW does not allow much leeway for escape in the event of two boats passing simultaneously. Increased boat traffic may also limit manatee movement up and down the east coast. Residents in Volusia county claimed that increased boat traffic between the 1960's and 1970's was responsible for a decline in manatee sightings (Hartman 1974).

Flagler County (zones 6 and 7) was the fastest growing county on the east coast of Florida in the 1970's and a large portion of Florida's burgeoning population is expected to continue to settle in Flagler County and areas along the coast of the peninsula (Fernald 1981). Recreational and commercial traffic are increasing throughout the northeastern ICW along with the demand for docking facilities to accommodate these vessels (DNR 1983). Such an increase will undoubtedly have a negative effect on manatees. Therefore, wise marina siting policies and other management strategies designed to protect manatees must be considered before the problem grows.

Finally, one critical question remains in the interpretation of the data presented here: Is the manatee population in northeastern Florida declining? One possible scenario is based on the following facts: 1) the low percentage of calves in the St. Johns River and ICW relative to other areas, 2) the number of boat/barge kills in the adult size class and 3) decreased winter manatee counts at Brevard County power plants (Reynolds 1983). Taken together, these facts translate into a textbook example of a declining population. Chronic boat/barge mortality is occurring with more adults being killed because of a top-heavy, unstable age distribution. Such an age distribution has occurred because of the loss of a large number of subadults from northeastern Florida in 1977 (O'Shea et al. in prep.) that would normally have been recruited into the breeding population by the time of this study. Therefore, less reproduction is seen relative to other regions because the population is unstable and declining.

Another possible, but less likely scenario, is that the population is at its greatest possible size given the available resources. Reproduction is suppressed and the population is stable but top-heavy with adults. Because manatees would no longer be reproducing as quickly as a population at a size lower than carrying capacity, boat/barge deaths would be biased towards adults and the percentage of calves in the population would be low relative to other areas.

It is also possible that avoidance of northern regions by females with young may influence low calf counts. Shifts in the use of Brevard County power plants by manatees could also describe other scenarios. However, I believe that until the population status of manatees in northeastern Florida is better understood, we must err conservative and develop management policies and strategies for northeastern Florida that deal with a potentially declining population.

Management Recommendations

1) It would be prudent to continue aerial surveys for manatees with an intensity equal to this study to better understand the spatial and temporal patterns of manatees in northeast Florida, to gain knowledge about the annual variation of these patterns and to help determine if regional populations are declining.

2) Formal agreements should be drawn up between industry officials and the USFWS Manatee Coordinator to begin or to continue monitoring and photographing individual manatees frequenting the Jacksonville and Fernandina Beach power and industrial plants. Consideration should also be given to the initiation of a program to tag and radio-track summer aggregations in the St. Johns River. Such programs would help increase knowledge of manatee movements up and down the east coast.

3) Signs warning boaters of manatee presence and where to call in the event of a dead manatee should be installed at all marinas, fish camps and boat ramps throughout the lower St. Johns River and the ICW in northeastern Florida. Locations of particular importance for posting are Doctors Lake, the grassbeds near Green Cove Springs, the Jacksonville and Fernandina Beach industrial and power plants and inlets along the ICW. Informational and educational material should be distributed to all marinas and fish camps in the study areas. This task could be accomplished by the Coast Guard Auxillary, local Boy Scout troops or volunteer groups and should be organized by the USFWS Manatee Coordinator.

4) Efforts should be made to limit boating facilities and dredging activities in the Doctors Lake/Green Cove Springs area until more information is available on the importance of this area to manatees. Boating facilities should also be limited in and around Tomoka River and other shallow fresh water tributaries in the ICW thought to be important to manatees. Facilities for larger, deep-draft boats (i.e. commercial fishing vessels and off-shore recreational boats $\geq$ 7.3 m long) should be located as near as possible to inlets in order to minimize the distance traveled through manatee habitat to the ocean.

5) Tomoka State Park should be given status as a summer sanctuary zone for manatees. The size class of boats entering the state park waters should be limited to those less than 7.3 m in length and idle boat-speed zones should be established. Other state and federal lands bordering waterways used by manatees should include considerations for manatees in their management plans. State and Federal lands included within these study areas are: Cumberland Island National Seashore, Fort Clinch State Park, Castillo de San Marco National Monument, Frank B. Butler State Recreation Area, Fort Matanzas National Monument and Flagler Beach State Park.

6) Manatee populations at Brevard County power plants should be monitored in the winter and possibly elsewhere in Brevard County during the summer. This may be a critical step towards understanding whether the population of manatees in northeastern Florida is presently declining and is essential in documenting long distances movements by animals from the St. Johns River and ICW that may winter in Brevard County.

7) The research and management responsibilities of local, state and federal agencies should be integrated and coordinated. This could be accomplished while drafting plans for the siting of marinas, the control of boat traffic, the reduction of manatee mortality and harassment, the protection of grassbeds and critical resources and other issues such as weed control and sewage disposal.

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