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HABITAT PREFERENCES, MOVEMENT, SIZE FREQUENCY PATTERNS AND REPRODUCTIVE SEASONALITY OF THE LESSER ELECTRIC RAY, *Narcine brasiliensis*

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ABSTRACT: The lesser electric ray, *Narcine brasiliensis*, is often used in neurochemical studies of cholinergic neurons. Data on habitat preferences, seasonal movements, growth rates and reproductive seasonality are presented. *Narcine brasiliensis* is highly localized within an area, concentrating in surf zones adjacent to barrier beaches and on offshore sand bars in warm months and moving offshore in winter. Females larger than 29 cm total length are reproductively active and give birth to less than 20 young in August and September. Young are estimated to attain a size of 20 - 29 cm TL at the end of their first year. This species is potentially vulnerable to overharvest as a result of its low rate of reproduction and localized distribution.

Over the past decade there has been a growing use of electric rays of the family Torpedinidae, order Rajiformes, in neurophysiological and biochemical research. From 1980 to 1984, over 900 papers dealing with the biochemistry and neurophysiology of *Torpedo californica* and *Torpedo nobiliana* were cited in Biological Abstracts. *Torpedo* are large (approximately 2 m total length), deep water, cold temperature rays that are difficult to keep in the laboratory.

The lesser electric ray, *Narcine brasiliensis*, which is roughly one third the size of *Torpedo*, is perhaps more suitable as a laboratory animal. Occurring in shallow warm water from Argentina to North Carolina, it is locally common in the Gulf of Mexico and off the southeastern coast of the United States, making it potentially available for a routine and dependable supply to researchers. Unlike *Torpedo* a refrigerated sea water system is not necessary. It provides a neurophysiological preparation comparable to *Torpedo* in that both genera have electric organs densely innervated with exclusively cholinergic neurons and has been the model used in 45 neurochemical studies reported in Biological Abstracts since 1968.

In view of the importance of *Narcine* in the neurophysiological laboratory, the dearth of information on its life history and ecology is remarkable. Bigelow and Schroeder (1953) reported that polychaete annelids are its primary diet. It occurs inshore during the summer months in Mississippi Sound in the vicinity of passes between barrier islands (Funicelli, 1975; Migdalski & Fichter, 1976). The taxonomy of the family has most recently been reviewed by Fechhelm and McEachran (1984).

Studies of behavior and electric organ discharge using various species of the genus *Torpedo* are reported by Bray and Hixon (1978), Belbenoit (1986, 1977), Michaelson *et al.* (1979) and Mellinger *et al.* (1978). However, these larger, cold water species of electric ray are piscivorous. A recent review of the evolution and function of electric organs in fishes is provided by Bass (1986).

This two year investigation of population characteristics and movement patterns of *Narcine brasiliensis* was part of an exploration of the feasibility of routinely providing *Narcine brasiliensis* for biomedical laboratories. Methods developed for maintaining *Narcine* in laboratory are reported elsewhere (Rudloe, 1989).

STUDY AREA

The study was conducted in coastal waters from Alligator Point, Franklin County, Florida, to Cape San Blas, Gulf County, Florida. Four offshore stations were used, one in a depth of 10 m and one in 16 m several miles south of St. George Island, one at West Pass between St. George Island and St. Vincent Island, and one at Cape San Blas, Gulf County, Florida.

The West Pass and Cape San Blas sites are both regions of sand bars and gullies at depths of 8-10 meters. The West Pass site ("ray bar") is perpendicular to the west end of St. George Island at West Pass between St. George and St. Vincent Island, and the other is part of a large complex of underwater bars south of Cape San Blas. They are offshore from passes between barrier islands that carry most of the outflow from estuarine Apalachicola Bay (Livingston, 1983) and are characterized by strong currents and high turbidity. Temperatures ranged from 14.6°C to 31°C and salinities varied from 22-35 ppt during the study.

One inshore station was located at Alligator Point, Franklin County, Florida, in and just beyond the surf zone. The stations were chosen based on preliminary sampling from December 1984, to February 1985, and during the preceding summer. Sampling was designed to include areas utilized by the species at various seasons as the fish move on and offshore through the year. In addition qualitative sampling was done in waters in and just beyond the surf zone at Dog Island, St. George Island and Little St. George Island, Franklin County, Florida (Figure 1) and at a site approximately 15 miles offshore from St. George Island in approximately 30 meters depth (C Tower site).

METHODS

A 21 m vessel pulling two 12 m trawls was used to sample offshore while a shallow drafted nine m trawler pulling one 12 m trawl was used for the inshore sampling. Trawling was the only feasible sampling method due to highly turbid conditions and the necessity to sample at night when animals were active. Trawling was considered an efficient sampling method for this species in view of its sluggish swimming behavior and benthic feeding habits. The offshore stations south of St. George Island and at West Pass were sampled twice a month from March 1985 to February 1986, except in August 1985 (equipment failure). The Cape San Blas station was sampled twice a month from June 1985, to January, 1986. The inshore station at Alligator Point was sampled once a month from April 1986 to March 1987. The other 3 beach sites were sampled qualitatively a total of 13 times between June 1985 and March 1987.

A one hour tow was made at each station. Stations which yielded rays were then sampled further using up to eight additional 1 hour tows per station. All electric rays captured were measured and sexed and all individuals longer than 20 cm TL were tagged with a plastic dart tag (FT-6) manufactured by Floy Tag and Manufacturing, Seattle, Washington. The barbed shaft was inserted into the musculature posterior to the body disc. In animals held in captivity, tagging did not

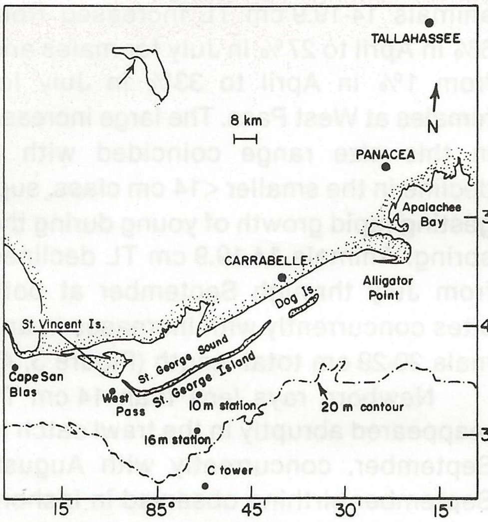

Figure 1. Sampling sites for electric rays, March 1985 - March 1987.

impede the fish, or cause infection or necrosis and <1% tag loss was observed. All body lengths are expressed as total length.

Surface water temperature and salinity, and wind and sea state were recorded at each station. Bottom temperatures were recorded in December 1985 and January 1986. Trawling began at dark and continued until shortly after dawn. The majority of animals were returned to shore with tag numbers used to track individuals in subsequent neurochemical or culture methods studies (Rudloe, 1989).

Animals not needed for laboratory research were released at the collection site. Posters offering a reward for returned tags were placed at seafood plants within 160 km of the study area. To determine reproductive seasonality 110 females were dissected and their ovaries weighed periodically from March 1985 through April 1986. Swollen claspers were noted on males.

RESULTS

A total of 3,913 rays were captured from March 1985 to March 1987 from all sites. Of these 3,229 were returned to shore, 455 tagged and released and 229 released untagged due to small size. Ten tagged rays were recaptured (Table 1).

OFF SHORE SITES

The catch per unit effort (CPUE) of the four offshore stations offshore from the barrier beaches is plotted Figure 2.

The CPUE at the sites ranged from 3-31 rays/hour. However, rays were concentrated over an extremely limited area on each bar. As little as several tens of meters change in position could determine whether there were two or 20 rays in the catch. CPUE of rays declined during the August-September birthing season (see section on Reproductive Seasonality) at these sites and then increased in October. Adults left the area in November. Only young of the year were present in December. The 10 m and 16 m stations were frequented primarily in November and February, periods immediately preceding and following the season of occupancy of the ray bars and beaches.

The length frequency distribution of rays taken at Cape San Blas and West

Table 1. Trawling Summary of animals collected, March 1985 - March, 1987.

	Offshore	Inshore	Total
Rays Caught	2,198	1,715	3,913
Rays Released, Tagged	335	120	455
Rays Released, Untagged	194	35	229
Rays Returned to Shore	1,669	1,560	3,229
Tag Recoveries	8	2	10 (2%)

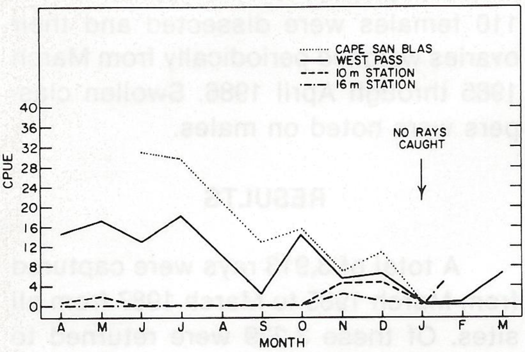

Figure 2. Catch per unit effort in rays per hour at four offshore stations, April 1985 - March 1986.

Pass from April 1985 to March 1986 expressed as percent of the sample in each size category for both males and females is given in Table 2. Females appear to attain larger sizes than do males. The proportion comprised of animals 14-19.9 cm TL increased from 6% in April to 27% in July for males and from 1% in April to 33% in July for females at West Pass. The large increase in this size range coincided with a decline in the smaller <14 cm class, suggesting rapid growth of young during the spring. Animals 14-19.9 cm TL declined from July through September at both sites concurrently with increases in animals 20-29 cm total length (Figure 3, 4).

Newborn rays less than 14 cm TL reappeared abruptly in the trawl catch in September, concurrently with August-September birthing observed in inshore rays, but peaked in November at West Pass and December at Cape San Blas (Figure 3, 4).

Females >30 cm TL with developed

Table 2. Size frequency of males and females by month as percent of total catch, April 1985 - March 1986.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
West Pass												
MALES n =	102	145	22	83		5	65	6	19	0	0	10
<14 cm	9	3	0	0		20	9	86	47	0	0	10
14-19.9 cm	6	17	23	27		0	6	0	42	0	0	20
20-29.9 cm	43	57	50	23		60	48	7	11	0	0	50
30-39.9 cm	42	23	27	29		20	37	7	0	0	0	20
>40 cm	0	0	0	4		0	0	0	0	0	0	0
FEMALES n =	94	98	25	78		3	52	20	14	0	2	10
<14 cm	10	4	0	1		0	6	75	43	0	50	20
14-19.9 cm	1	18	16	33		33	4	5	57	0	0	50
20-29.9 cm	26	59	48	53		67	44	10	0	0	50	10
30-39.9 cm	50	17	28	12		0	36	5	0	0	0	10
>40 cm	13	2	12	1		0	10	5	0	0	0	10
Cape San Blas												
MALES n =			65	63		25	27	19	23	0		
<14 cm			4	0		12	22	5	70	0		
14-19.9 cm			54	44		16	19	11	26	0		
20-29.9 cm			31	35		28	41	42	0	0		
30-39.9 cm			11	21		44	18	42	4	0		
>40 cm			0	0		0	0	0	0	0		
FEMALES n =			64	89		26	45	13	20	0		
<14 cm			5	1		15	2	8	65	0		
14-19.9 cm			65	65		8	15	31	35	0		
20-29.9 cm			17	22		27	55	23	0	0		
30-39.9 cm			5	4		27	24	23	0	0		
>40 cm			8	8		23	4	15	0	0		

ovaries (see Reproductive Seasonality section) declined in number at West Pass from an April peak of 63% of the females collected to a low of 0 in September and then increased in October to 46% of the females collected. Sampling at Cape San Blas from June-September 1985, however indicated that the occurrence of these females peaked 50% in September, suggesting that birthing females may have remained on the site.

WINTER DISTRIBUTION

Lesser electric rays remained on the offshore bars in all months except January and February. Larger animals disappeared from the catch at both sites in November, leaving predominately young animals at each site in December. During January and February 1986, no rays were caught at any of the offshore stations. However, 186 rays were caught in February at the C tower site. This area had been heavily trawled the preceding month but yielded no specimens. These rays were predominately 20-40 cm TL with no young of the year and only two animals less than 20 cm TL. No rays were caught at any site when bottom temperatures fell below 17°C.

A total of 132 rays were collected from December 1986 to February 1987. Rays were collected at the 16 m station through January. They again concentrated at the C tower site in February. They returned to the ray bar sites as in the previous year by March 1987. Males slightly outnumbered females in the catch at C Tower in winter 1987 with no young of the year (M/F ratio: 1.5/1).

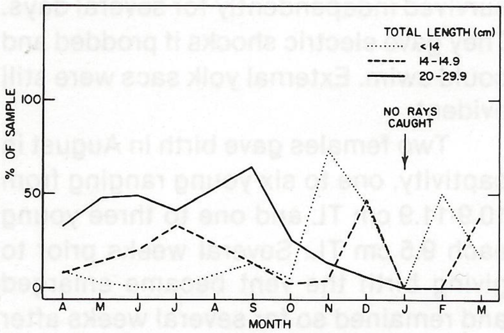

Figure 3. Size frequency of immature rays, (<30 cm total length), West Pass.

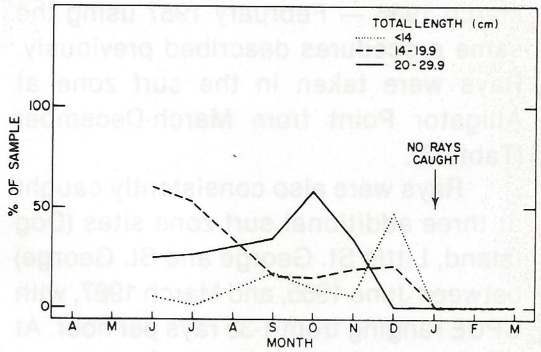

Figure 4. Size frequency of immature rays, (<30 cm total length), Cape San Blas.

In addition to the systematic sampling described above, 20 60 minute tows were made at a variety of other offshore locations from Dog Island to Cape San Blas throughout the study. No rays were found at any other site. Extensive interviews with commercial shrimp trawlers revealed few rays captured at any other sites. No tag returns were recovered from other sites.

BARRIER BEACH SITES

During August and September 1985, lesser electric rays were located in waters of less than three meters at two barrier beach sites: Alligator Point and Dog Island (Figure 1). Intermittent qualitative sampling continued until rays left the area in December 1985.

Routine monitoring of the Alligator Point surf zone by shrimpers working with us on other projects produced no rays in the area from December 1985 through February 1986. In March 1986 rays returned to these sites. Twelve months of monthly quantitative sampling at Alligator Point was conducted from

March 1986 — February 1987 using the same procedures described previously. Rays were taken in the surf zone at Alligator Point from March-December (Table 3).

Rays were also consistently caught at three additional surf zone sites (Dog Island, Little St. George and St. George) between June 1985, and March 1987, with CPUE ranging from 1-35 rays per hour. At all sites, samples taken in August and September had a predominance of newborn rays and large females. Animals greater than 29 cm were predominently females in the surf zone. Sex ratios at Dog Island in August and September 1985 reflected female dominance as did all surf zone samples at Little St. George Island (Table 4).

Lesser rays between 14-19.9 cm appeared on these sites in early spring and grew into the 20-29 cm TL range over the summer. These rays were then joined in August and September by large pregnant females and their newborn young. Pregnant females gave birth in August and September. Rapidly growing newborn rays dominated in the surf zone in September and grew into 14-19.9 cm size range during the fall. During January /February no rays were caught. In March, the young born the previous August reappeared in the trawls and grew to the 20-29.9 cm range during the following spring and summer. The changing proportions of immature (less than 30 cm TL) rays in these two size catagories at Alligator Point is plotted in Figure 5.

REPRODUCTIVE SEASONALITY

All dissected female rays above 20 cm (n = 81) had large well developed oocytes and all less than 29 cm (n = 29) did not. In March (N = 24) ovaries consisted of macroscopically undifferentiated yolk material and varied in weight

Table 3. Catch summary of rays adjacent to barrier beach at Alligator Point showing proportion of newborn rays, CPUE and sex ratio of mature rays.

Date	N	% <14 cm TL	CPUE Rays/hr	Male/Female >29 cm TL
3/86	29	8	—	7/0
4/86	101	0	—	—
5/86	51	0	4.0	10/1
6/86	jellyfish precluded sampling			
7/86	35	0	5.1	1.0/.6
8/86	jellyfish precluded sampling			
9/86	6	17	6.0	1/4
10/86	106	12	3.4	0/4
11/86	67	0	—	0/6
12/86	297	6	29.0	0/2
1/87	0	—	.7	0
2/87	0		.6	0

from 5.4-198.1 g wet weight. Ovaries ranged from 20-76 g wet weight in May 1985 (n = 20) and the tissue was now organized in all females examined into clearly defined segments with vascularization extending from the entire inner surface of the membrane into the ovary to a depth of approximately one cm.

Females examined in June 1985 (n = 9) had macroscopically visible embryos ranging from 9-17 in number, with a mean length of 4.5 cm (range 3.6-4.9 cm). By late July, all females larger than 29 cm both in captivity and collected from the field were visibly pregnant. Female rays >29 cm dissected in July (n = 4) carried embryos. Eight embryos surgically removed from a live female were all 8.7 cm in length and survived independently for several days. They gave electric shocks if prodded and could swim. External yolk sacs were still evident.

Two females gave birth in August in captivity, one to six young ranging from 10.9-11.9 cm TL and one to three young each 9.5 cm TL. Several weeks prior to giving birth the vent became enlarged and remained so for several weeks after birth. Thus pregnant and post birthing females were readily identified in the

Table 4. Summary of qualitative sampling at 3 additional barrier beach localities, showing proportion of newborn rays, CPUE and sex ratio of mature rays. Three samples had no trawl time, so CPUE could not be calculated: indicated by –.

Location / Date	N	% <14 cm TL	CPUE Rays/hr	Males/Females >29 cm TL
Dog Island				
6/85	4	0	2.7	1/0
8/85	17	29	7.1	0/6
9/85	32	91	—	0/5
4/86	25	4	5.0	1/3
5/86	17	6	17.0	1/3
7/86	6	50	—	0/1
Little St. George Island				
4/86	176	13	35.0	1/3.4
5/86	339	4	32.0	1/2.2
8/86	13	5	1.0	0/3
St. George Island				
5/86	59	7	27.5	1/.1
6/86	26	0	6.5	4/0
12/86	68	47	—	0/1
3/87	63	40	5.7	1/1.2

field by mid summer. Forty-one additional female rays >29.0 cm TL were collected from the field and dissected from October 1985 to April 1986, to complete twelve months of monitoring gonadal development. Female gonads totally regressed by February and were developing again in April 1986.

The only time during the total sampling period when females carried viable young was August and September. This was consistent with the field data indicating presence of young of the year in August and September.

Males above 22 cm TL had mature claspers. Nineteen males with swollen claspers suggestive of breeding activity were collected in December, 1985 in 18 meters depth south of the West Pass site. The mean size of these rays was 31.7 cm (range 28.0-38.1 cm TL).

TAGGING STUDY

A total of 455 *Narcine* was tagged and released at the point of capture between April 1985 and March 1987. Ten rays were recaptured, six females, three males and one of unknown sex. Four mature females moved from West Pass to Cape San Blas and were recovered between one and five months after release. Three (two males, one female) were recovered at the point of release after periods of one to two months at liberty. One moved from West Pass westward to Indian Pass. Two mature females tagged at Little St. George Island in May 1986 both moved offshore and were recovered offshore at West Pass and slightly south of West Pass after four and seven months respectively. Two rays recaptured by us and remeasured had grown 2.4 cm (a male after two months) and 5 cm (a female after five months) in total length, indicating summer field growth rates of approximately one cm per month for these two animals.

DISCUSSION

This study indicates that *Narcine brasiliensis* can be collected in most months of the year once specific localities occupied by the animal are located. The tag recovery locations plus the apparent general scarcity of rays in other areas, as indicated by our sampling and reported by fishermen, suggest that rays are localized in their habitats during

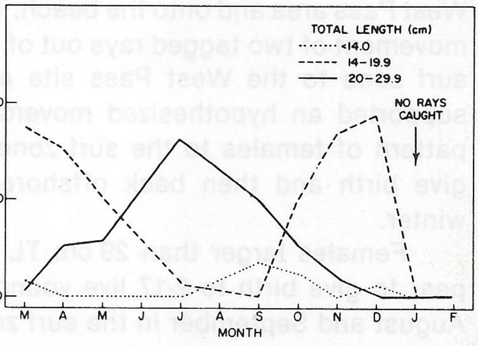

Figure 5. Size frequency of immature rays, (<30 cm total length), Alligator Point.

warm months at least, and move directly from one preferred locality to another or remain in one area over a period of weeks to months. They then move to deeper water in the winter. Since the 10 and 16 meter stations were occupied primarily during November and February, it is likely that animals taken there were transient, moving between ray bar or beach habitat in the warmer months and offshore in the winter.

Preferred habitats are in the vicinity of barrier beach surf zones and on bars adjacent to passes between estuarine barrier islands. This is consistent with summer distributions reported from the Mississippi Sound by Funicelli (1975). In addition, eight specimens were collected off a bar adjacent to the mouth of the Suriname River, Republic of Surinam, in South America in September 1978, suggesting that the habitat preferences described for the northern Gulf of Mexico are valid throughout the species' range. The period of winter inactivity at shallower sites might however be shorter or nonexistent in the tropical parts of the species' range and longer in more northerly water.

The presence of larger females and newborn rays in the surf zones in August and September, together with the decline in mature females but not mature males at West Pass in September suggests movement of females away from the West Pass area and onto the beach. The movement of two tagged rays out of the surf zone to the West Pass site also supported an hypothesized movement pattern of females to the surf zone to give birth and then back offshore to winter.

Females larger than 29 cm TL appear to give birth to 2-17 live young in August and September in the surf zone and at some but not all of summer offshore sites. Young are born at less than 14 cm TL, and growth is rapid in the fall. Growth is dormant over January and February and resumes in March. Thus a female ray born in August is estimated to grow to 15-19 cm by March of the next year, approximately 20-28 cm by September of that year, and to become a reproductively active adult (>29 cm) the following year at age two. Very large rays (>40 cm) might then be three to four years old.

If males become reproductively active at approximately 30 cm TL as is suggested by the limited sample of males with swollen claspers, this model would apply to them as well. However, the small sample size precludes definite conclusions. If mating does occur in December, sperm may be stored for some months prior to ovulation and fertilization, as is common with other elasmobranchs (Wourms, 1977). Whether thé birthing seasons or growth rates observed in this study are applicable to other parts of the species' range is not known at this point.

Data on mortality are not yet available, but the low birth rates as well as the potent defensive organs of this species suggest limited predation. Tagged rays released off trawlers were repeatedly observed to be actively avoided by both sharks and porpoises that fed heavily on other rays and bony fishes as they were culled overboard.

Whether the November and December peak in newborn rays at West Pass and Cape San Blas was a result of immigration of young from the beach is not clear. The absence of small animals at the "C" tower site in winter suggests that young may remain on the ray bar stations, but buried, over the winter when adults move offshore.

As was noted, additional trawls were made only if the first sample yielded rays. While the necessity to collect large numbers of animals for laboratory use in the limited time available demanded this approach, it nevertheless made comparisons of CPUE difficult and may underestimate numbers present.

The use of different size sampling gear at the inshore as compared to offshore stations precludes direct comparison of CPUE figures between inshore and offshore sites. The inshore CPUE values did however suggest larger numbers at Little St. George Island and St. George Island than east at Alligator Point and Dog Island. These sites are adjacent to the ray bar off West Pass, St. George Island, a major offshore ray site. Rays were also reported by fishermen to consistently occupy the surf zone in late summer at Cape San Blas, adjacent to the second major offshore ray site.

Estimates of population size or substainable yield cannot yet be made. However, it is likely that if this species is fished on a substained basis for laboratory use, its low rate of reproduction and localized distribution make it highly vulnerable to over fishing. In addition, its relative abundance might readily be over estimated depending on sampling sites chosen. Ongoing monitoring of catch per unit effort at each site and changes in size frequency on a site as well as spreading collecting efforts over as many collecting sites as possible will be essential to protect the long term future of this species as a marine resource.

The relation of the detailed topography of the ray bars to concentrations of animals as well as the orientational mechanisms used by these animals in their seasonal movements will be productive areas for future research.

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LITERATURE CITED

Bass, A. H., 1986. Electric organ revisited. Evolution of a vertebrate communication and orientation organ. *In* Bullock, T. H. and W. Heiligenberg (ED.). Electroreception. Wiley series in neurobiology, N.Y. 13-70.

Belbenoit, P. 1986. Fine analysis of predatory and defensive motor events in *Torpedo marmorata* (Pisces). J. Exp. Biol. 121:197-226.

Belbenoit, P., 1977. Electric organ discharge of *Torpedo marmorata* (Pisces): Basic pattern and ontogenetic changes. J. Physiol. (Paris). 75(4) 435-441.

Bigelow, H. B. and W. S. Schroeder, 1953. Fishes of the Western North Atlantic. Part 2. Sawfishes, quitar fishes, skates, rays and chimearoids. Mem. Sears Found. Mar. Res. (12) 588 pp.

Bray, R. N. & M. A. Hixon, 1978. Night shocker: predatory behavior of the Pacific electric ray, *Torpedo californica*. Science 200:333-334.

Fechhelm, J. D. & J. D. McEachran, 1984. A revision of the electric ray genus *Diplobatis* with notes on the interrelationships of *Narcinidae* (Chondrichthyes, Torpediniformes), Bull. Fla. St. Mus. 29(5):171-209.

Funicelli, N. A., 1975. Taxonomy, Feeding, limiting factors and sex ratios of *Dasyatis sabina*, *Dasyatis americana*, *Dasyatis say*, and *Narcine brasiliensis*. Ph.D. Diss. University of Southern Mississippi.

Livingston, R. J. 1983. Resource Atlas of the Apalachicola Estuary. Fla. Sea Grant College Program. Rep. No. 55.

Mellinger, J., P. Belbenoit, M. Ravaille, & T. Szabo, 1978. Electric organ development in *Torpedo marmorata* (Chondrichthyes). Dev. Biol. 67(1):167-188.

Michaelson, D. M., D. Sternberg, & J. Fishelson, 1979. Observations on feeding growth and electric discharge on new born *Torpedo ocellata* (Chondrichthyes, Batoidei) J. Fish. Biol. 15(2): 159-164.

Migdalski, E. C. and G. S. Fichter, 1976. The fresh and salt water fishes of the world. Knopf. New York, N.Y. 71-73 pp.

Rudloe, A., 1989. Captive maintenance of the Lesser Electric Ray, *Narcine brasiliensis* with observations of feeding behavior. Prog. Fish Cult. 51(1):37-41.

Wourms, J. P. 1977. Reproduction and development in chondrichthyan fishes. Am. Zool. 17:379-410.