A TAGGING STUDY OF THE FRESHWATER ELASMOBRANCHS OF CENTRAL AMERICA

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April 1973

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University of Nebraska – Lincoln

FINAL REPORT

To: Office of Naval Research

Contractor: The University of Nebraska – Lincoln

Contract number: N00014-66-C0161

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INTRODUCTION

The bull shark, Carcharhinus leucas, occurs in relatively warm waters around the world, tends to congregate in shallow, brackish water about the mouths of large rivers and to make its way up some rivers, sometimes for great distances. This appears to be the case in the San Juan River between Nicaragua and Costa Rica, as well as in Lake Nicaragua which is drained by the San Juan, in both of which a sizable population of these sharks occurs. However, for many years it has been assumed that the sharks in the lake are landlocked by the occurrence of several rapids in the river, and it has only been in recent years that this theory has been challenged. A recent paper by my group (Copeia 1966(3):385-402) presents evidence against the theory, pointing out that the sharks are (as shown by morphometric data) of the same species throughout the system, as well as in the sea; that the rapids are navigable by barges and tugs of at least two feet draught; that sharks are taken both above and below the major rapids; and that the same species ascends rivers in other parts of the world. Although the circumstantial evidence is strong that sharks move up the Rio San Juan into Lake Nicaragua, definitive proof must come from sharks tagged at the mouth of the river and recovered in the lake.

The sawfish, Pristis perotteti, also occurs in the Lake Nicaragua-Rio San Juan system and the same question has arisen concerning its landlocked status.

OBJECTIVES

This study was designed

1. To demonstrate whether or not the bull shark and the sawfish

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13. ABSTRACT

From 1966 to 1972, 1634 adult and 1203 juvenile bull sharks (Carcharhinus leucas) and 345 sawfish (Pristis perotteti) were tagged in the Lake Nicaragua-Rio San Juan system. Recoveries by 1 January, 1973 have included 225 adults (13.8%), 206 juveniles (17.1%) and 153 sawfish (44.3%). Six adults have traversed the full length of the Rio San Juan upstream and twenty downstream, demonstrating conclusively that the species moves freely between Lake Nicaragua and the Caribbean Sea in both directions, and that the sharks and sawfish in the lake are not landlocked. The juvenile recoveries have in general been shorter term and have shown shorter movements, although one moved the full length of the river, downstream. Sawfish have been shown to move freely within the river and the lake. That they move between the lake and the sea has been clearly established by three individuals tagged in the lake and recovered at the river mouth. Tracking of sharks carrying ultrasonic transmitters disclosed a tendency for newly-caught and tagged sharks to move downstream and into the sea. Three sharks thus marked passed downstream the full length of the river in 5-7, 11+, and 12 days respectively. One of a group of 38 sharks was shown to pass the full length upstream in 2-25 days. The lack of recoveries long distances from the mouth of the Rio San Juan gives support to (although it does not prove) the idea that the Lake Nicaragua-Rio San Juan population of sharks is a relatively isolated population (accessory population of Stewart Springer).

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Carcharhinus leucas						
Bull shark						
Pristis perotteti						
Sawfish						
Shark tagging						
Sawfish tagging						
Elasmobranch tagging						
Ultrasonic tracking						
Tracking of sharks						
Freshwater elasmobranchs						
Rototags						
Petersen tags						
Lake Nicaragua						
San Juan River						
Rio San Juan						

move from the Caribbean Sea into Lake Nicaragua.

2. To determine whether or not they return to the sea after having been in the lake.
3. To establish their patterns of movement within the lake and the Rio San Juan.
4. To determine how long they stay in fresh water once they enter.

PROCEDURES

The original plan involved conventional tagging, to be conducted at the three major outlets of the Rio San Juan, at San Juan del Norte, Nicaragua, Barra del Colorado, Costa Rica (the major outlet, called the Rio Colorado, where the largest population of sharks occurs), and Samay Lagoon, Costa Rica; at various points on the river, particularly El Castillo and San Carlos, Nicaragua; and at the far end of the lake in the vicinity of Granada. Various circumstances prevented work at Granada, but extensive tagging was carried out at the other, more critical sites (see maps and Table 8 for geographic locations).

Petersen disk tags were employed in 1966 and 1967, but they proved unsatisfactory for such large fish as sharks and sawfish. They were rarely recovered more than four or five months after tagging, so they were replaced for the rest of the project by Jumbo Rototags, which have proven highly satisfactory.

Ultrasonic tags, emitting pulsed signals into the water, were used for four seasons. In 1967, sharks thus tagged were tracked, in the lower reaches of the river, with portable hydrophones and receivers from boats. In 1968, 1969 and 1970, passage of sharks was monitored with recording receivers installed at strategic points along the shores of the various

channels of the Rio San Juan. The tags and recorders have been described in an ONR Technical Report (Thorson, Esterberg and Johnson, 1969).

The sharks and sawfish were caught by local fishermen, who used hand lines with chain leaders and large hooks baited with chunks of freshly cut animal flesh, usually fish.

Most of the tagging occurred in the months of June, July and August, 1966 through 1970. In addition, a few were tagged in November, 1967, April, 1969, July, 1971, and July, 1972.

RESULTS

Shark Tagging

At the river mouths large numbers of juvenile sharks were taken (largely from about 50 to 80 cm. in length), as well as adults (as the term is used here, it includes sexually immature as well as mature individuals) from 110 to 240 cm. There were very few of the intermediate size range (80 to 110 cm.), suggesting that a part of the life cycle is spent elsewhere. The shark tagging records have therefore been separated into adult and juvenile categories. They are presented in Tables 1 and 2, which show numbers tagged, numbers recovered at least once, and percentage recovered, by year and by tag type, as of January 1, 1973.

A total of 1634 adults and 1203 juveniles were tagged. In both categories, appreciably lower percentages of Petersen tagged sharks were recovered than those tagged with Rototags. Only one of the former has been recovered within the past four years, its tags having been overgrown by cartilage and carried for 1022 days when the shark was caught. Recoveries of Rototags are still being made, and likely will be for a number of years. The overall recovery rate (13.8% for adults, 17.1% for

juveniles) seems remarkable, considering that each shark released has available to it the whole lake, the river, several large tributaries, coastal channels and the open sea.

Movements of adult sharks.

Table 4 summarizes movements made by adult sharks from each tagging site and gives ranges of time (in days) between tagging and recovery. The data are shown graphically in Figures 1, 2, and 3.

While most recoveries were made at the same locations where tagging took place, the sharks obviously moved freely back and forth between the coastal tagging sites as well as up the river for various distances. Six tagged at Barra del Colorado traversed the whole length of the river to San Carlos, and two of these continued on far into the lake (Isla Ometepe and Islas del Nancital).

Of the 145 adult sharks tagged at San Carlos, twenty have been recovered to date at the various mouths of the Rio San Juan. The free movement of sharks through the full length of the river, in both directions, has thus been positively established.

Movement within the lake has also been demonstrated by two sharks tagged at San Carlos and recovered at the far end of the lake at Los Cocos and the mouth of the Rio Tipitapa.

The length of time the sharks stay in fresh water cannot be established with complete certainty, since we cannot be sure that a shark both tagged and recovered in fresh water has not returned to the sea during the interim. However, the distances involved and the frequency of captures and recaptures, both in fresh water, argue strongly for virtually unlimited tolerance to fresh water.

To date, no recoveries have been reported in the Caribbean Sea farther from the coastal tagging sites than Tortuquero to the south and San Juan del Norte to the north. It seems probable that sharks of the Lake Nicaragua-Rio San Juan system range farther than known recoveries indicate. There may well be tags in the possession of fishermen at more distant points that have not reached me. However, the possibility also exists that we are dealing with a more or less isolated population. Nothing is known of the coastal movements of this species, nor is it known where the missing size range (80 to 110 cm.) spends that part of its life cycle.

Movements of juvenile sharks.

Juveniles are found throughout the lower river and the channels connected with it. They are concentrated in some of the side channels where presumably they are safer from predation by adults, but they are not restricted to these "nursery grounds." They are numerous, especially below the rapids, at El Castillo and occur, in small numbers, in Lake Nicaragua.

Tagging showed that most of the recoveries of juvenile sharks were made in the same general area where tagging occurred. However, they move freely locally, for instance among the channels and sites included within the designation "Barra del Colorado", and between the various coastal tagging sites (Table 5, Figures 4 and 5). One tagged at Barra del Colorado was recovered 420 days later at Rio Maiz, the greatest distance north of the tagging sites of any recovery, including adult and juvenile sharks and sawfish.

At the upstream sites, recoveries were mostly local (as at El Castillo) or showed downstream movements, including the single juvenile tagged at San Carlos, which was recovered 493 days later at Barra del Colorado.

Most of the juvenile recoveries were made within a month or two of tagging, largely during the time when we were still present in the study area. Apparently most of the young leave the area after their first few months of life and probably return after an undetermined length of time. To date I have only two recoveries between one and two years after tagging, and one approaching three years (965 days). However I have accurate total length measurements for none of them, so I cannot as yet determine the growth rate, nor the length of time the young are absent.

Sawfish Tagging

A summary of the tagging of 345 sawfish and the recovery of 153 is provided in Table 3. The high recovery rate (44.3% until Jan. 1, 1973) is in part a reflection of a commercial sawfish fishery operating in Lake Nicaragua since 1970 and the efforts of personnel of Instituto de Fomento Nacional (INFONAC) in handling tag recoveries.

Of the 17 sawfish tagged at Barra del Colorado, seven were recovered at least once, all at Barra del Colorado. Two of them were recovered a second time, also at Barra del Colorado. Time at liberty ranged from one day to 629 days (Table 6).

Two sawfish were tagged at El Castillo, one of which was recovered at Barra del Colorado 85 days later (Figure 6).

Of the 326 sawfish tagged at San Carlos, 64 were also recovered there, from two hours to 752 days later. Only four were re-captured downstream,

one at El Castillo 450 days later, two at Barra del Colorado 577 and 743 days later, and one that passed out one of the mouths of the river and made its way down the coast to Parismina (1398 days), the greatest distance south of the tagging sites of any shark or sawfish tagged in the program.

By far the greatest number of sawfish recoveries were of those tagged in San Carlos and later taken in Lake Nicaragua. These were taken in relatively shallow water along the coasts of the lake and various islands in the lake in from 34 to 1334 days after tagging.

Some of the sawfish may remain in one locality for extended periods, as in the case of a 362 cm. female taken at San Carlos June 28, 1970, and recaptured four times at intervals of 3, 21, 368 and 143 days, every time within a few hundred yards of the same place in San Carlos. On the other hand, they are clearly very mobile, having been recovered in the sea and all over Lake Nicaragua.

That they move between the lake and the sea was clearly demonstrated by three individuals that moved from San Carlos the full distance down the river. Unfortunately, relatively few sawfish are taken at the river mouths, and only 17 were tagged in five tagging seasons there and none were proven to make the complete trip upstream. There can be little doubt, however, that they do so, as there is a pre-reproductive size range virtually missing from the population either in the lake or at the river mouths, which must occur in the sea.

Ultrasonic Tracking

Table 7 summarizes the electronic tagging activities carried out from 1967 through 1970.

In 1967, when portable tracking equipment was used, 11 sharks were tagged. One at San Carlos was lost almost at once, but ten were tracked in the channels near Barra del Colorado and Samay Lagoon for from five minutes to nine hours and 20 minutes, and for distances of from less than a kilometer to about seven km. Most of them tended to move downstream. Three of four tagged in the river mouth headed directly out to sea; the fourth circled about and moved back and forth within a radius of about 1/2 km for two or three hours on two different days. Four of the eleven were caught by fishermen 29, 30, 35, and 39 days after the original marking, and one was taken about a year later, all of them in the river mouth.

In 1968, 1969 and 1970, movements were monitored by recording receivers installed along the river banks. Numerous movements were demonstrated between various pairs of points, but the most noteworthy movements were the following ones.

Two sharks tagged at El Castillo each passed out the river mouth at Barra del Colorado about 36 hours later, having traveled a distance of about 125 km.

Three sharks tagged at San Carlos were recorded in the Barra del Colorado area about 175 km downstream, one in five to seven days, one in 11+ days and one in 12 days. A fourth shark tagged at San Carlos passed the Delta monitor (below all of the rapids) in four days and 17 hours.

A single shark tagged at the river mouth passed the full length of the river upstream, in 25 days or less. It was one of 38 sharks tagged at Barra del Colorado and Samay Lagoon from two to 25 days before its arrival at San Carlos.

Table 1. Summary of tagging and recoveries of Carcharhinus leucas adults.

	Barra del Colorado			Samay Lagoon			San Juan del Norte			Tortuguero		
	Tagged	Recovered	Pct	Tagged	Recovered	Pct	Tagged	Recovered	Pct	Tagged	Recovered	Pct
1966	215	10	4.7	38	6	15.8	0	0	0.0	0	0	0.0
1967	328	47	14.3	10	1	10.0	0	0	0.0	1	1	100.0
Total Petersen	543	57	10.5	48	7	14.6	0	0	0.0	1	1	100.0
1968	337	39	11.6	8	2	25.0	0	0	0.0	0	0	0.0
1969	300	39	13.0	22	4	18.2	6	4	66.7	0	0	0.0
1970	183	28	15.3	0	0	0.0	3	1	33.3	0	0	0.0
1971	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
1972	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
Total Rototag	820	106	12.9	30	6	20.0	9	5	55.6	0	0	0.0
Grand Total	1363	163	12.0	78	13	16.7	9	5	55.6	1	1	100.0

Table 1 continued.

	Cano Negro			El Castillo			San Carlos			Total		
	Tagged	Recovered	Pct	Tagged	Recovered	Pct	Tagged	Recovered	Pct	Tagged	Recovered	Pct
1966	0	0	0.0	0	0	0.0	6	3	50.0	259	19	7.3
1967	1	1	100.0	0	0	0.0	3	0	0.0	343	50	14.6
Total Petersen	1	1	100.0	0	0	0.0	9	3	33.3	602	69	11.5
1968	0	0	0.0	30	8	26.7	39	14	35.9	414	63	15.2
1969	0	0	0.0	7	2	28.6	51	11	21.6	386	60	15.5
1970	0	0	0.0	0	0	0.0	34	4	11.8	220	33	15.0
1971	0	0	0.0	0	0	0.0	1	0	0.0	1	0	0.0
1972	0	0	0.0	0	0	0.0	11	0	0.0	11	0	0.0
Total Mototag	0	0	0.0	37	10	27.0	136	29	21.3	1032	157	15.2
Grand Total	1	1	100.0	37	10	27.0	145	32	22.1	1634	225	13.8

Table 2. Summary of tagging and recoveries of Sarcocheirus leucas juveniles.

	Barra del Colorado			Barra Lagoon			San Juan del Norte		
	Tagged	Recovered	Pct.	Tagged	Recovered	Pct.	Tagged	Recovered	Pct.
1966	5	0	0.0	0	0	0.0	0	0	0.0
1967	201	17	8.5	43	5	11.6	0	0	0.0
Total Petersen	206	17	8.3	43	5	11.6	0	0	0.0
1968	186	20	10.8	2	0	0.0	0	0	0.0
1969	131	38	21.0	8	5	62.5	0	0	0.0
1970	427	87	20.4	1	0	0.0	3	2	66.7
1971	0	0	0.0	0	0	0.0	0	0	0.0
1972	0	0	0.0	0	0	0.0	0	0	0.0
Total Rototag	794	145	18.3	11	5	45.5	3	2	66.7
Grand Total	1000	162	16.2	54	10	18.5	3	2	66.7

Table 2 continued

	El Castillo			San Carlos			Total		
	Tagged	Recovered	Pct.	Tagged	Recovered	Pct.	Tagged	Recovered	Pct.
1966	0	0	0.0	0	0	0.0	5	0	0.0
1967	0	0	0.0	0	0	0.0	244	22	9.0
Total Petersen	0	0	0.0	0	0	0.0	249	22	8.8
1968	61	16	26.2	0	0	0.0	249	36	14.5
1969	35	9	20.0	1	1	100.0	235	53	22.6
1970	39	6	15.4	0	0	0.0	470	95	20.2
1971	0	0	0.0	0	0	0.0	0	0	0.0
1972	0	0	0.0	0	0	0.0	0	0	0.0
Total Rototag	145	31	21.4	1	1	100.0	954	184	19.3
Grand Total	145	31	21.4	1	1	100.0	1203	206	17.1

Table 3. Summary of tagging and recoveries of Fristis perotteti.

	Barra del Colorado			El Castillo			San Carlos			Total		
	Tagged	Recovered	Pct.	Tagged	Recovered	Pct.	Tagged	Recovered	Pct.	Tagged	Recovered	Pct.
1966	2	0	0.0	0	0	0.0	2	1	50.0	4	1	25.0
1967	1	0	0.0	0	0	0.0	2	0	0.0	3	0	0.0
Total Petersen	3	0	0.0	0	0	0.0	4	1	25.0	7	1	14.3
1968	5	4	80.0	1	0	0.0	22	14	63.6	28	18	64.3
1969	5	2	40.0	1	1	100.0	37	21	56.8	43	24	55.8
1970	4	1	25.0	0	0	0.0	233	102	43.8	237	103	43.5
1971	0	0	0.0	0	0	0.0	22	6	27.3	22	6	27.3
1972	0	0	0.0	0	0	0.0	8	1	16.7	8	1	16.7
Total Rototag	14	7	50.0	2	1	50.0	322	144	44.7	338	152	45.0
Grand Total	17	7	41.2	2	1	50.0	326	145	44.5	345	153	44.3

Table 4. Movements demonstrated for Carcharhinus leucas adults.

Tagging site: Barra del Colorado (1363 tagged)

Recovery site	No. of recoveries	Days at liberty
Barra del Colorado	101	2 hrs. - 1402 days
Samay Lagoon	22	1 - 1479
San Juan del Norte	20	18 - 841
Tortuguero	1	118
Caño Bravo	1	642
Caño Madre	2	225 - 349
Delta	2	7 - 29
El Castillo	8	17 - 258
San Carlos	4	123 - 741
Ometepe	1	1141
Nancital	1	?

Tagging site: Samay Lagoon (78 tagged)

Samay Lagoon	3	31 - 39
Barra del Colorado	4	3 - 289
San Juan del Norte	3	58 - 1135
Tortuguero	1	64
Rio Bartola	1	98
El Castillo	1	?

Tagging site: San Juan del Norte (9 tagged)

San Juan del Norte	3	22 - 79
Barra del Colorado	2	35 - 46

Tagging site: Tortuguero (1 tagged)

Barra del Colorado	1	286

Tagging site: Caño Negro (1 tagged)

Barra del Colorado	1	30

Tagging site: El Castillo (37 tagged)

Rio San Carlos	1	200
Barra del Colorado	9	16 - 1399

Tagging site: San Carlos (145 tagged)

San Carlos	4	2 - 56
Los Cocos	1	?
Rio Tipitapa	1	38
El Castillo	2	96 - 553
Delta	2	? - 352
Caño Madre	2	41 - 1375
Barra del Colorado	13	32 - 1108
Samay Lagoon	4	78 - 1524
San Juan del Norte	3	1 - 810

Table 5. Movements demonstrated for Carcharhinus leucas juveniles.

Tagging site: Barra del Colorado (1000 tagged)

Recovery site	No. of recoveries	Days at liberty
Barra del Colorado	154	2 hrs. - 346 days
Rio Maiz	1	420
Samay Lagoon	3	5 - 32
Caño Madre	2	48 - 80
Delta	2	25 - 35

Tagging site: Samay Lagoon (54 tagged)

Samay Lagoon	6	2 - 23
Barra del Colorado	2	3 - 13
Tortuguero	1	965
El Castillo	1	217

Tagging site: San Juan del Norte (3 tagged)

San Juan del Norte	2	34 - 34

Tagging site: El Castillo (145 tagged)

El Castillo	20	1 - 2 hrs. - 132 days
Rio Isla Chica	1	115
Rio Bartola	1	33
Rio San Carlos	1	3
Rio Sarapiqui	1	307
Barra del Colorado	4	4 - 25

Tagging site: San Carlos (1 tagged)

Barra del Colorado	1	493

Table 6. Movements demonstrated for Pristis perotteti.

Recovery site	No. of recoveries	Days at liberty
Tagging site: Barra del Colorado (17 tagged)		
Barra del Colorado	7	1 - 629
Tagging site: El Castillo (2 tagged)		
Barra del Colorado	1	85
Tagging site: San Carlos (326 tagged)		
San Carlos	64	2 hrs. - 752 days
El Castillo	1	450
Barra del Colorado	2	577 - 743
Parismina	1	1398
Lake Nicaragua:		
Rio Zapote	1	1267
Rio Boca Ancha	5	506 - 874
Islas Balsillas	1	188
Archipielago Solentiname	3	312 - 1279
Morillo	4	46 - 1300
Punta El Tule	3	559 - 589
San Miguelito	5	183 - 1239
El Pedernal	3	171 - 510
Punta El Copelito	4	160 - 795
Isla San Bernardo	6	128 - 594
Islas del Mancital	5	179 - 725
San Ubaldo	2	272 - 601
Puerto Diaz	6	29 - 817
Punta Santa Clara	2	185 - 244
Rio Malacatoya	3	222 - 461
Los Cocos	7	336 - 1334
Las Isletas	13	19 - 808
Isla El Armado	1	736
San Jorge	2	803 - 815
Isla Ometepe	8	60 - 738
Unknown	2	663 - 720

Table 7. Ultrasonic tagging.

Year	Site	Number of tags
1967	Barra del Colorado	6
	Samay Lagoon	2
	Cano Negro	1
	San Carlos	1
1968	Barra del Colorado	16
	Samay Lagoon	2
	El Castillo	2
	San Carlos	3
1969	Barra del Colorado	22
	Samay Lagoon	15
	San Juan del Norte	4
	San Carlos	4
1970	Barra del Colorado	15
	San Carlos	5

Table 8. Sites referred to in text and maps.

1. Barra del Colorado
2. Sanay Lagoon
3. San Juan del Norte
4. Tortuguero
5. Parismina
6. Rio Maiz
7. Caño Bravo
8. Caño Madre
9. Caño Negro
10. Delta
11. Rio Sarapiqui
12. Rio San Carlos
13. Rio Bartola
14. El Castillo
15. Rio Isla Chica
16. San Carlos
17. Rio Zapote
18. Rio Boca Ancha
19. Islas Balsillas
20. Archipielago Solentiname (with Isla Mancarron)
21. Morillo (with Rio Ansuelo and Rio Consuelo)
22. Punta El Tule (with El Corosal and Rio El Congo)
23. San Miguelito (with El Morro and Isla El Boquete)
24. El Pedernal (with Rio Camastro)
25. El Copelito (with Guabo)
26. Isla San Bernardo (with Isla San Bernardito)
27. Islas del Mancital (with Isla Grande)
28. San Ubaldo
29. Puerto Diaz (with Arrayan)
30. Punta Santa Clara (with Punta El Recreo)
31. Rio Malacatoya (with El Guayabo)
32. Los Cocos (with Punta San Pedro and Rio Tipitapa)
33. Las Isletas (with Granada)
34. Isla El Armado
35. San Jorge
36. Isla Ometepe (Moyogalpa, Punta Jesus Maria, Ensenada el Istian)

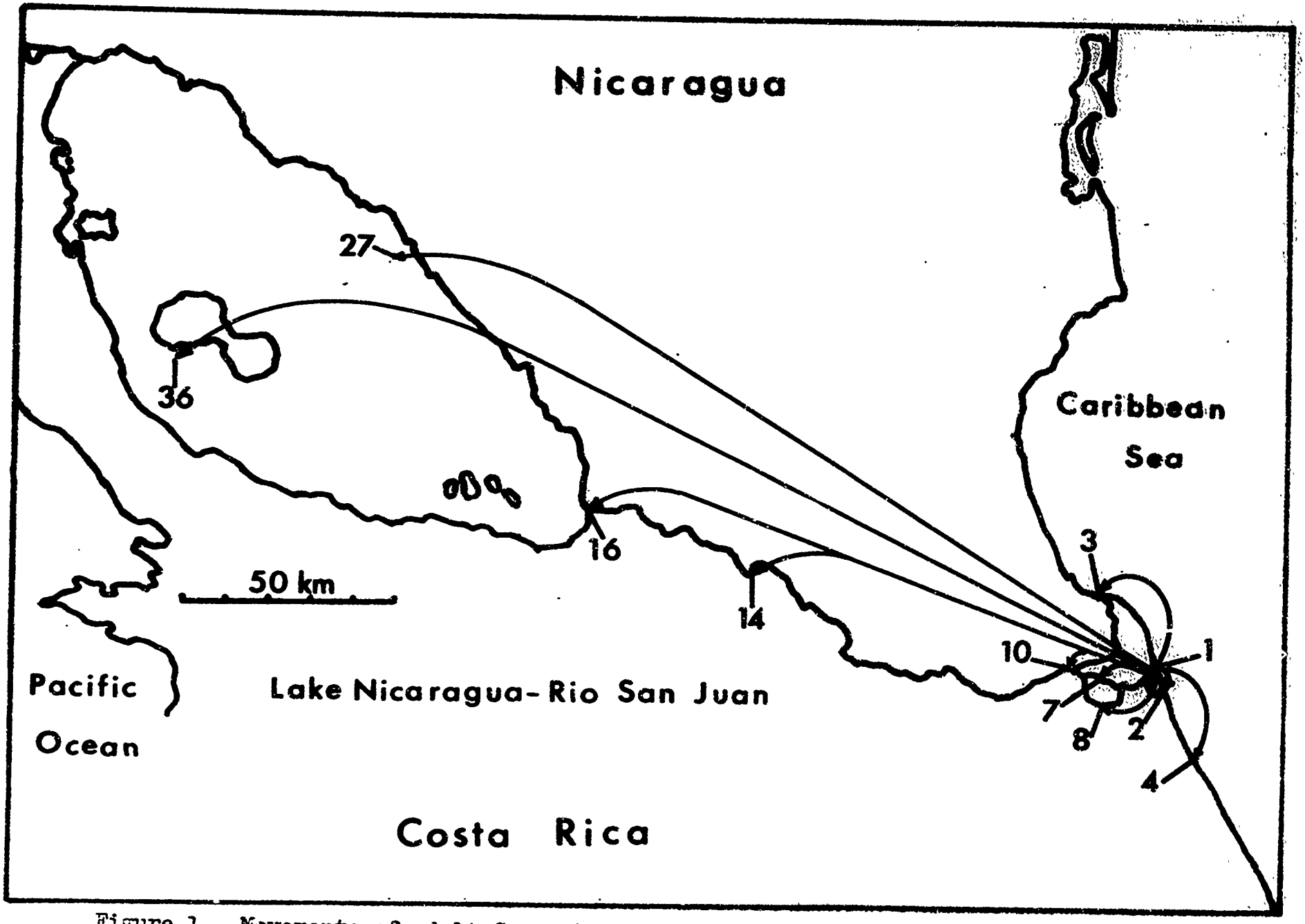

Figure 1. Movements of adult Carcharhimus leucas tagged at Barra del Colorado (1).

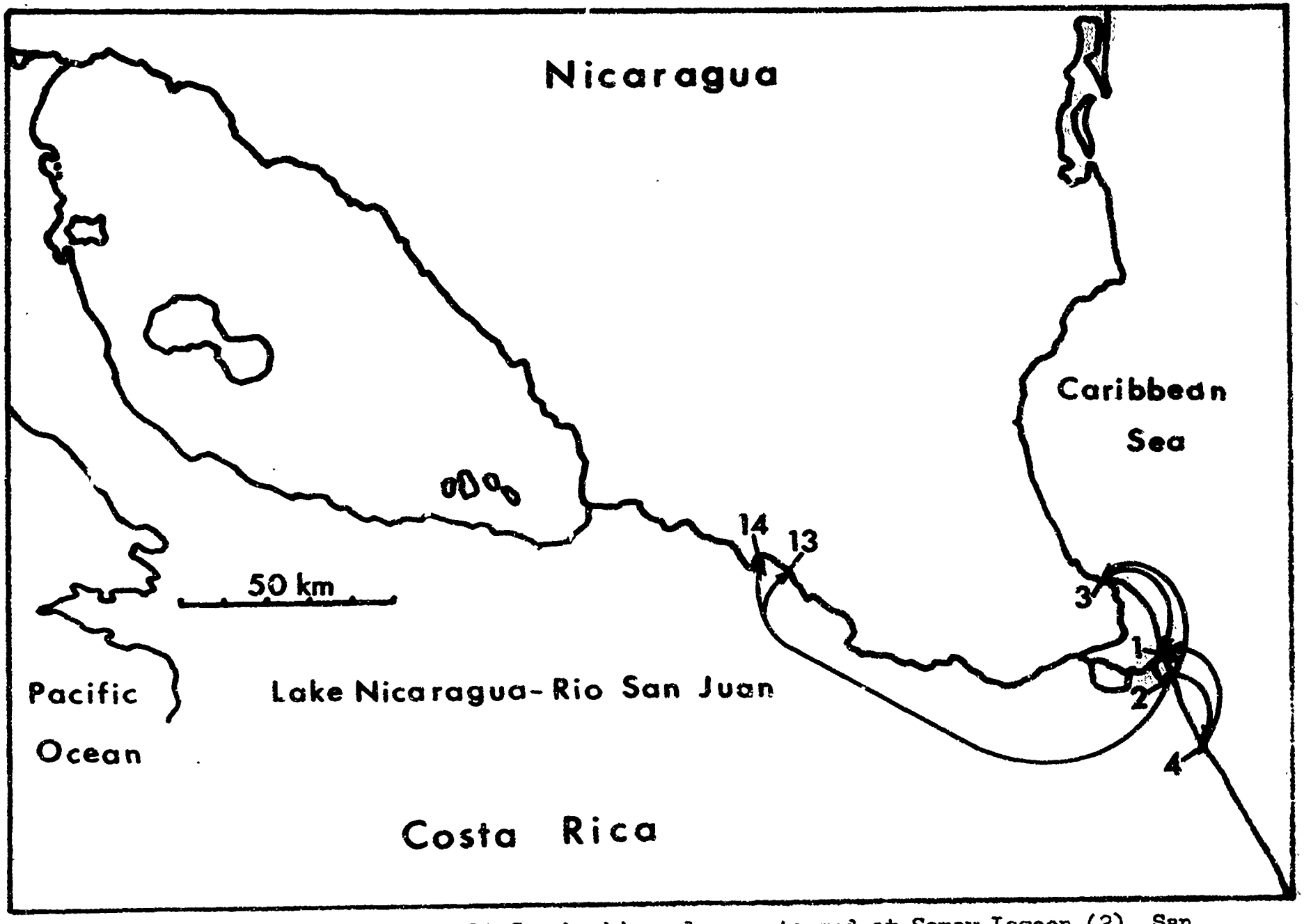

Figure 2. Movements of adult Carcharhinus leucas tagged at Samay Lagoon (2), San Juan del Norte (3) and Tortuguero (4).

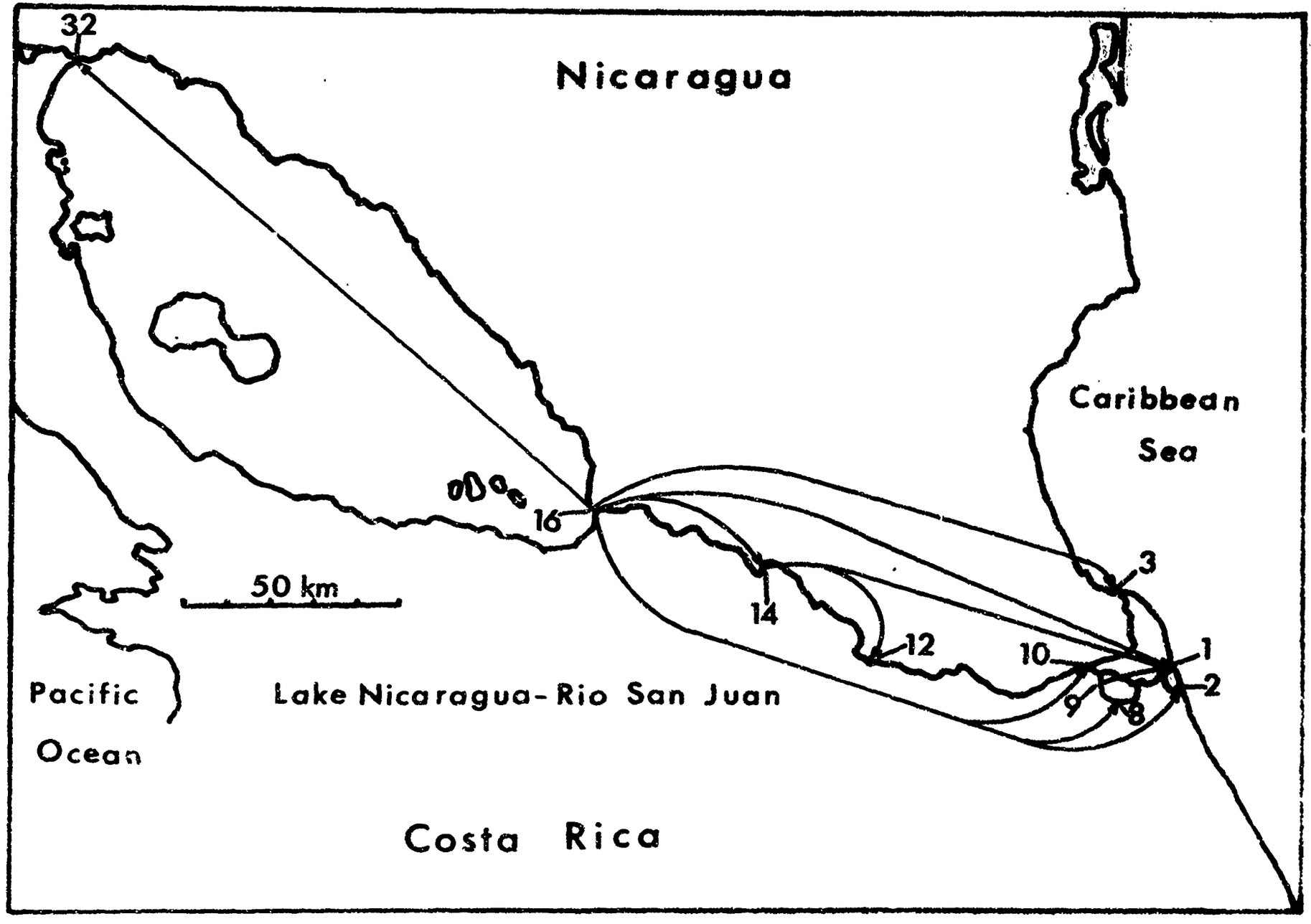

Figure 3. Movements of adult Carcharhinus leucas tagged at San Carlos (16), El Castillo (14) and Cano Negro (9).

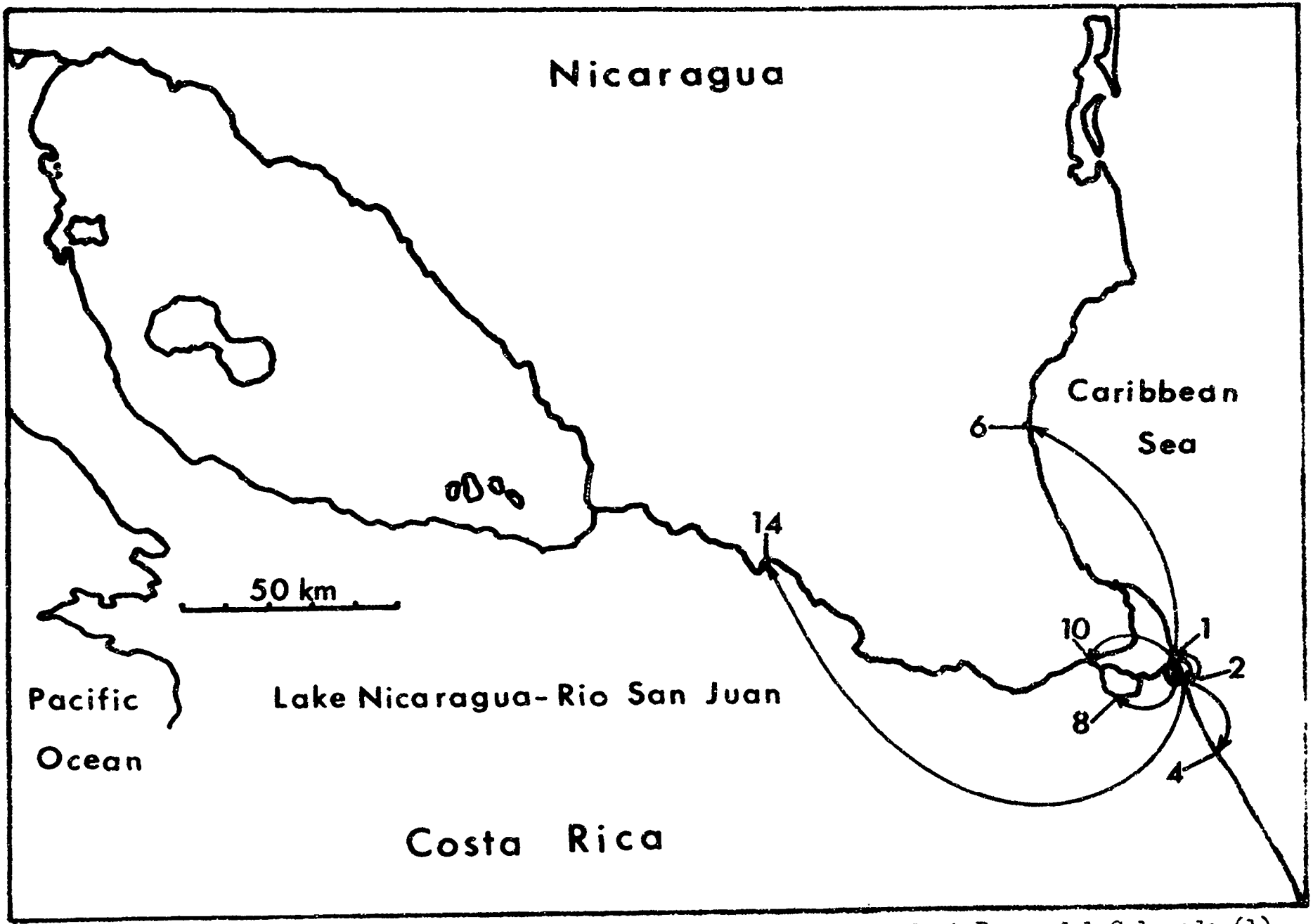

Figure 4. Movements of juvenile Carcharhinus leucas tagged at Barra del Colorado (1) and Sonay Lagoon (2).

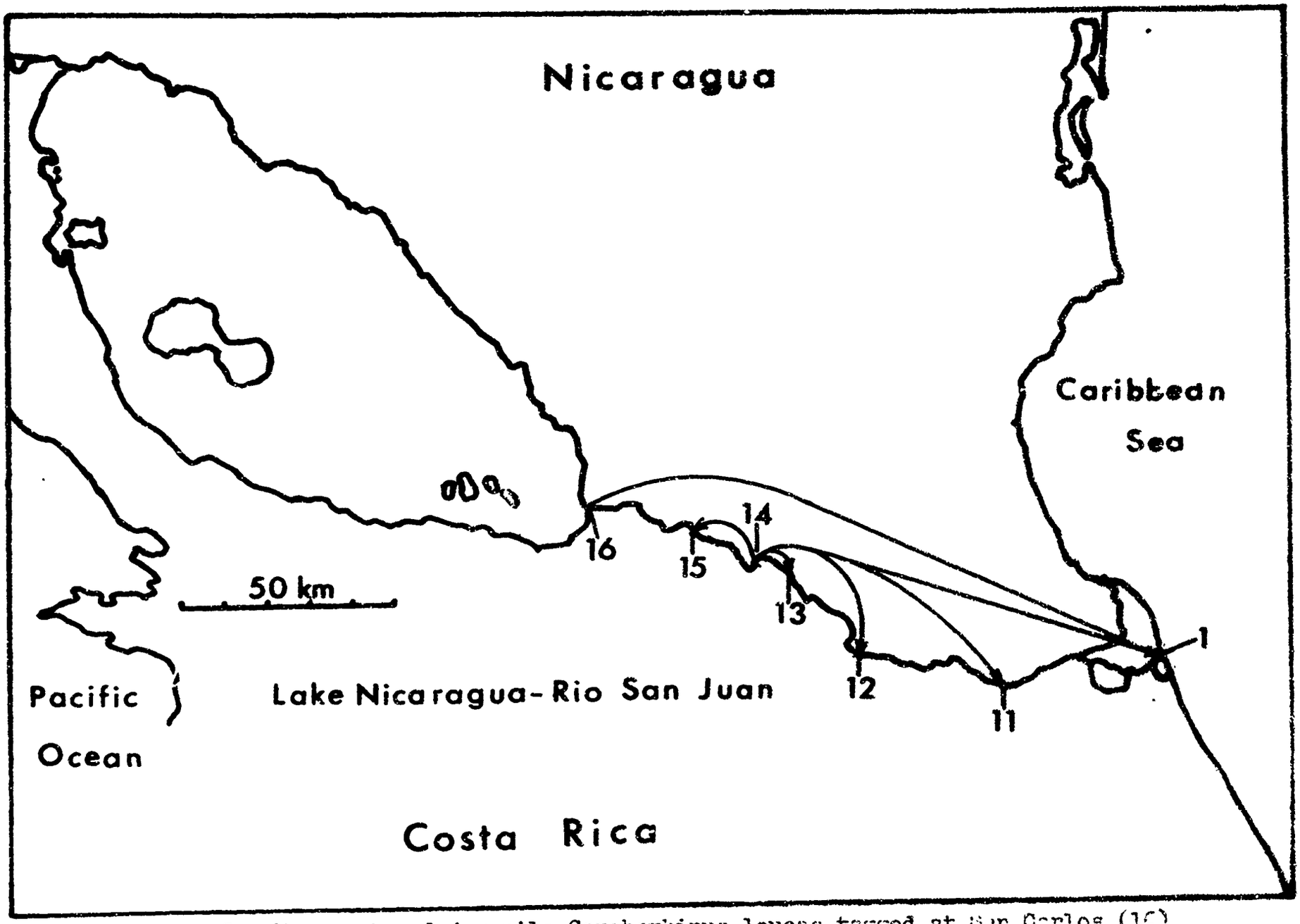

Figure 5. [illegible] of juvenile Carcharhinus leucas tagged at San Carlos (16) and El Castillo (14).

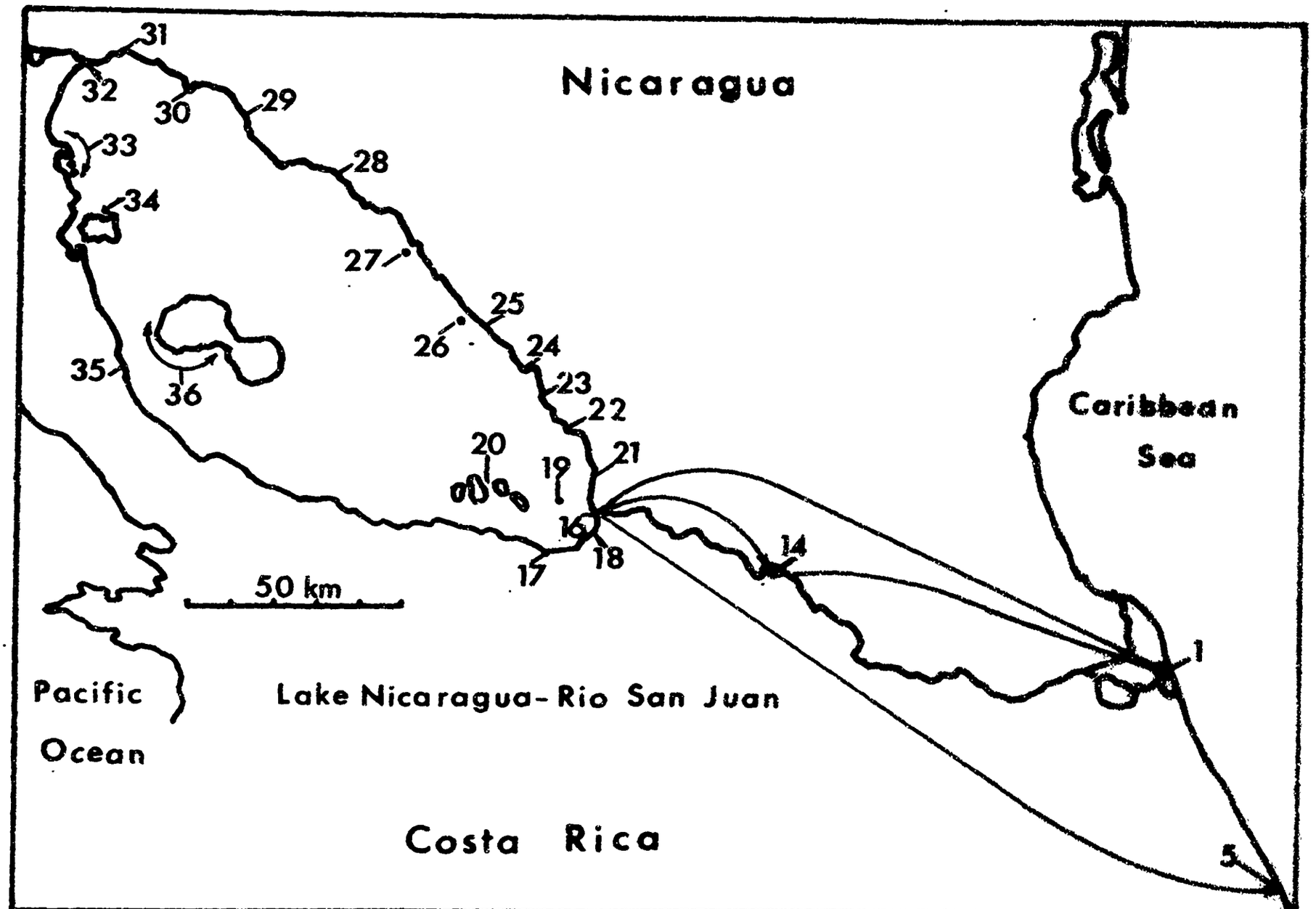

Figure 6. Movements of Pristis perotteti tagged at San Carlos (16) and El Castillo (14). All sawfish recovered in Lake Nicaragua were tagged at San Carlos and sites are indicated by number only.

PUBLISHED AND UNPUBLISHED PAPERS, THESES AND REPORTS

Thorson, T.B., G.F. Esterberg, and J.H. Johnson. 1969. Ultrasonic shark tag monitoring system. Technical Report to Office of Naval Research. Department of Zoology, University of Nebraska, 2 June 1969.

Thorson, T.B. 1970. Proof from tagging that sharks of Lake Nicaragua are not land-locked. Proc. Nebr. Acad. Sci., 80:14. (abstract)

Thorson, T.B. 1971. Movement of bull sharks, Carcharhinus leucas, between Caribbean Sea and Lake Nicaragua demonstrated by tagging. Copeia 1971(2):336-338.

Thorson, T.B. 1972. The sharks of Lake Nicaragua: Visitors from the Caribbean Sea. Historia Natural y Pro Natura 4(3):34-36.

Thorson, T.B. 1973. Sexual dimorphism in number of rostral teeth of the sawfish, Pristis perottati Müller and Henle, 1841. Trans. Amer. Fish. Soc. 102(3): In press.

Jensen, N.H. The reproduction and development of the bull shark, Carcharhinus leucas, in the Lake Nicaragua-Rio San Juan System. Department of Zoology, University of Nebraska, July 1972. (PhD thesis)

Tuma, Robert E. An investigation of the feeding habits of the bull shark, Carcharhinus leucas, in the Lake Nicaragua-Rio San Juan System of Nicaragua and Costa Rica. Department of Zoology, University of Nebraska, December, 1972. (MS thesis).

To be published:

A tagging study of the movements of the bull shark, Carcharhinus leucas, in the Lake Nicaragua-Rio San Juan System.

Tagging of the sawfish, Pristis perotteti, in the Lake Nicaragua-Rio San Juan System.

Some aspects of reproduction and life history of the sawfish, Pristis perotteti.

Notes on the development of the sawfish, Pristis perotteti.

Three papers based on the thesis of Norman H. Jensen (above).

A paper based on the thesis of Robert E. Tuma (above).

Several other papers based on data recorded for sharks and sawfish in the tagging program.

A monograph on the bull shark, *Carcharhinus leucas*.

A monograph on the sawfish, *Pristis perotteti*.

GRADUATE STUDENTS EMPLOYED

The ONR-sponsored tagging program was conducted in conjunction with an NIH-supported study of osmoregulation in freshwater elasmobranchs. Personnel and equipment were shared and the lines between the projects were not always distinct. The following students took part, but only as indicated did they conduct their thesis work with ONR support.

Cowan, C. Michael, Nov., 1967 (other periods with other sources of support), PhD 1968. Thesis: The blood proteins of the bull shark, Carcharhinus leucas. (not ONR)

Gerst, Jeffery W., summer 1969, 1970 (other periods with other sources of support), PhD 1973. Thesis: Osmoregulation and nitrogen metabolism of Potamotrygon, freshwater stingrays of South America. (not ONR)

Greiner, Ellis C., summer, 1967, PhD 1971. Thesis not related to this project.

Jensen, Norman H., summer, 1968 (other periods with other sources of support), PhD 1972. Thesis: The reproduction and development of the bull shark, Carcharhinus leucas, in the Lake Nicaragua-Rio San Juan System (supported largely with ONR funds). This will be published in three papers.

Olander, Charles P., summer 1968, 1969 (other periods with other sources of support), PhD nearing completion. Thesis not related to this project.

Tuma, Robert E., June, 1967, MS 1972. Thesis: An investigation of the feeding habits of the bull shark, Carcharhinus leucas, in the Lake Nicaragua-Rio San Juan System of Nicaragua and Costa Rica (supported largely with ONR funds). This will be published as one paper.

Watson, Donald E., summer 1967 (other periods with other sources of support), PhD 1966. Thesis: Some helminth parasites of fishes in fresh waters of Nicaragua. (not ONR)