THE TAXONOMY AND LIFE HISTORY OF THE BLUE STINGRAY *Dasyatis marmorata capensis* (BATOIDEA : DASYATIDAE) FROM SOUTHERN AFRICA.

THESIS

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Frontispiece : The blue stingray *Dasyatis marmorata capensis*.

TABLE OF CONTENTS

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ABSTRACT

The blue stingray, Dasyatis marmorata capensis is an important recreational shore angling species, especially amongst tournament anglers, in South Africa. The taxonomy and aspects of the biology of this species were investigated from specimens collected between March 1987 and May 1989, from various localities along the southern African coastline.

Morphological comparisons were made between Dasyatis pastinaca, Dasyatis marmorata and the local variety. The results indicated that the local variety is different to D. pastinaca in colouration, disc length size, and vertebral and radial counts. The proposed new sub-species Dasyatis marmorata capensis is closest to D. marmorata of the north-eastern Atlantic coast, but differs in snout angle, disc length and snout to vent length.

Analysis of catch per unit of effort data revealed that the blue stingray exhibits distinct seasonality. Adult and sub-adult fish undertake an annual onshore/offshore migration and invade the inshore region between spring and summer, while juveniles remain offshore and utilize this zone as a nursery area.

Length-at-age and growth rates for both sexes were estimated from bands formed seasonally in the vertebral centra. The derived von Bertalanffy growth parameters indicated that females reach a greater asymptotic size (913.8 mm DW) and have a slower growth rate (K = -0.07) than males (531.8 mm DW, K = -0.17). Growth rates of juvenile captive specimens compared favourably with back calculated values, at approximately 65 mm/year, for the first year of growth.

Dasyatis marmorata capensis is an aplacental viviparous elasmobranch with a well defined annual breeding cycle. Young are released, at a size of 170 - 200 mm DW, from October to December after a gestation period of approximately nine months. An average fecundity of 3.07 was calculated. Examination of gonadal development indicated that sexual maturity is first attained at a size of 408 and 500 mm DW in males and females, respectively, corresponding to ages 4.5 and 7 years.

Size-related food habits were determined independently from three depth zones. The major prey items for each size class were directly related to the abundance of the infauna of the different depth zones. Polychaeta, amphipoda and stomatopoda were the major prey items in the offshore zone. In the nearshore zone, the dominant prey species were *Balanoglossus capensis* and *Callianassa* spp.. The high incidence of empty stomachs and the presence of prey items which occur in greatest abundance beyond the surf zone indicated that this zone is not utilized for the purposes of feeding.

CHAPTER 1 INTRODUCTION

Elasmobranchs or sharks, rays and chimeras, are a diverse group of cartilaginous fishes. Eight major orders of sharks, five of rays and one of chimeras are currently recognized (Compagno 1973).

The seas around the southern African coastline contain a rich chondrichthyian fauna, with representatives of all the major orders (Compagno *et al.* 1989). There are at least 100 species of sharks, 64 rays and probably seven chimeras, which may collectively be divided into three major groups on the basis of spatial habitat. These habitats include the continental shelf, continental slope and the oceanic regions. The majority of all elasmobranch species occur on the continental shelf and slope (Compagno *et al.* op. cit.). Of the family Dasyatidae, the majority (ten species or 71.5%) form part of the inshore continental shelf fauna, while three species (21.5%) are shelf and slope dwelling. Only one species (7%) is oceanic. Five species of the stingray genus *Dasyatis* occur in the coastal waters of southern Africa - *D. thetidis*, *D. brevicaudata*, *D. kuhlii*, *D. violacea* and *D. pastinaca* (Smith & Heemstra 1986).

Although the ecological significance of certain batoid species has been outlined in several recent studies (Smith & Merriner 1985), there is a general paucity of biological information on this group of fishes. This can possibly be attributed to their low commercial value. However, knowledge of the ecological interactions between all marine organisms, and particularly of the pressure induced by man, are needed to ensure the conservation of different marine resources. Hence, the study of non-commercial organisms forms an integral part in the management of ocean ecosystems.

In South Africa elasmobranch research has generally been centred on the species potentially dangerous to man, although Bass et al. 1973; 1975a, b, c, d; 1976 included work on the less dangerous species. This research was motivated by the high incidence of shark attacks along the Natal coastline. Generally, research on the biology and ecology of the smaller species (especially batoids) has been neglected.

Research on South African batoid fishes has been largely taxonomic (Wallace 1967a, b, c; Hulley 1970, 1972; Heemstra & Smith 1980; Compagno & Heemstra 1984; Smith & Heemstra 1986). Despite their morphological diversity, wide distribution and abundance, the life history of most batoid fishes is poorly known. Previously, biological information on South African species was restricted to limited observations (Wallace 1967a, b, c; van der Elst 1981). However, Rossouw (1983) pioneered biological batoid research with a detailed account on the biology of the lesser sandshark Rhinobatos annulatus in Algoa Bay.

The blue stingray Dasyatis pastinaca (= D. marmorata capensis), with its conspicuous sea-blue and mottled golden-brown upper surface, is a coastal and inner continental shelf species which inhabits sandy beaches, river mouths, and sand and mud flats along the entire coastline from the north coast of Natal to northern Namibia. It is a popular sportfish, commonly caught by rock and surf anglers, and light tackle ski-boat anglers. Lasiak (1982) stated that in terms of biomass of the total catch of surf zone fishes in Algoa Bay (Eastern Cape), the lesser sandshark dominated with 22.5%, followed by the blue ray with 17.4%. Due to the abundance of the blue ray in the summer it was considered to be an important component of the predators in the surf zone. Rossouw (1983) suggested that a natural history study on this species would contribute to a better understanding of sandy beach ecology.

The blue stingray was originally assigned to D. pastinaca by Bleeker (1860) and subsequently reported by Norman (1922) in

Natal waters. Barnard (1925) stated, in his monograph on South African marine fishes, that its distribution extended from the Mediterranean Sea down the eastern Atlantic into local waters. Van der Elst (1981) first drew attention to distinct colouration and pattern differences between the local variety and the European common stingray *Dasyatis pastinaca*. This suggested that they were possibly different species, and that the southern African variety of *D. pastinaca* was a sub-species of a northern African species, *D. marmorata* described by Steindachner (1868).

The main aims of the present study were as follows :

1) To investigate the taxonomy and classification of the blue stingray.
2) To examine seasonal abundance and possible migratory patterns in this species.
3) To study various aspects of its natural history, including age and growth, reproduction, diet and feeding habits.

A taxonomic re-evaluation of this species is presented in Chapter 2. The study area and sampling methods related to biological studies are described in Chapter 3, and notes on the biological and physical features of the different sampling zones are reviewed. Data on the population structure, distribution and seasonal abundance are presented in Chapter 4. Followed by age and growth and reproduction in Chapters 5 and 6 respectively. In Chapter 7, the food habits of specimens collected from different sampling zones, the dietary changes with size, and feeding behaviour are described. Chapter 8 concludes with a general discussion and summary.

CHAPTER 2 TAXONOMIC STATUS

2.1 INTRODUCTION

The systematics of the family Dasyatidae worldwide is in a state of confusion, largely due to the vagueness of generic diagnosis and the virtual absence of information on intraspecific and ontogenetic variation (Last 1979).

Two major schools of thought exist regarding the family status of the Dasyatidae. Several authors *inter alia* Garman (1913), Fowler (1936, 1972), Irvine (1947) and Okada (1966) recognized a family group including the subfamilies Gymnurinae and Urolophinae, containing nine or 10 genera and approximately 90 species. The genus *Dasyatis* was subdivided into four subgenera (Flower 1941) : *Himantura*, *Pastinacus*, *Dasyatis* and *Amphotistius*. Smith & Heemstra (1986) used this system and check-listed seven genera with 16 species from the southern African subregion. Other authors, including Bigelow and Schroeder (1953), Cervigon (1966), Wallace (1967b), Nelson (1984), Compagno (1973), Stehmann (1981) have given *Urolophus* and *Gymnura* separate family status and elevated Fowler's subgenera to genera.

Clearly there was a need to clarify the taxonomic status of *Dasyatis ?pastinaca* from southern Africa prior to proceeding with a biological study. Bleeker (1860) first assigned the southern African species to *Dasyatis pastinaca*. This was subsequently verified by Norman (1922). Since then the range of distribution of this species was believed to extend from the North Sea and Mediterranean along the eastern Atlantic into South African waters up to the Natal coast. In 1981, van der Elst stated that disc colouration and patterns of the blue stingray, as it is known locally, differed to that of the European *D. pastinaca*.

The differences in colour patterns and meristic characters of Dasyatis pastinaca (Linnaeus 1758), Dasyatis marmorata (Steindachner 1868) and the local putative sub-species are outlined below. Evidence is presented that the local variety is different to Dasyatis marmorata and a description of the proposed new sub-species Dasyatis marmorata capensis is given.

2.2 MATERIALS AND METHODS

The study is based on material collected from March 1987 to May 1989 between Durban and Swakopmund (Figure 2.1). Data were collected from recreational fishing competitions and research sampling aboard the Sea Fisheries Research Institute's (S.F.R.I.) research ship R. V. Africana. A single specimen of D. marmorata collected in Senegal (14^0 34.5′ N : 17^0 27′ S) was donated by B. Seret (Museum national d'Histoire Naturelle, Paris). A single specimen of D. pastinaca was borrowed from the British Museum of Natural History (B.M.N.H. 1989.2.16.1). Data with radial and vertebral counts of two other D. pastinaca, collected in the Mediterranean Sea (Italy) were donated by L.J.V. Compagno. Additional data on snout angles, disc lengths and snout to vent lengths were collected from specimens caught in Algoa Bay in May 1989 aboard the R.V. Africana cruise 072.

Methods for measurements and counts follow Compagno & Roberts (1982, 1984). Disc width (DW) is the standard measurement of size, and proportional measurements are expressed as a percentage of disc width. Disc height (DH) is the greatest thickness of disc (at or near the scapulocoracoid). Disc length (DL) was taken from the tip of the snout to the fusion of the pelvic fins at the base of the tail, without projections. Other measurements and their abbreviations are as follows : pre-spine length (PSL), total length (TL), anterior pectoral length (APL), posterior pectoral length (PPL), inner pectoral length (IPL), pre-orbital length (POL), inter-orbital width (IOW), eye height (EH), eye length (EL), spiracle length (SPL), spiracle width (SPW), inter-spiracular width (ISPW), pre-narial length (PNL), pre-oral length (PROL), nasal flap length (NFL), inter-narial width (INW), mouth width (MW), first gill length (1GL), second gill length (2GL), third gill length (3GL), fourth gill length (4GL), fifth gill length (5GL), distance between first pair of gill slits (1GW), distance between fifth pair of gill slits (5GW), snout to vent length (SN-V), anterior pelvic length (APLL), posterior pelvic length (PPLL), inner pelvic length (IPLL), pelvic span (PLS), tail base width (TBW), tail base height (TBH), upper caudal fold length (UCF), lower caudal fold length (LCF), spine length (STL) and spine width (STW). A diagrammatic outline depicting these measurements is shown in Figure 2.2.

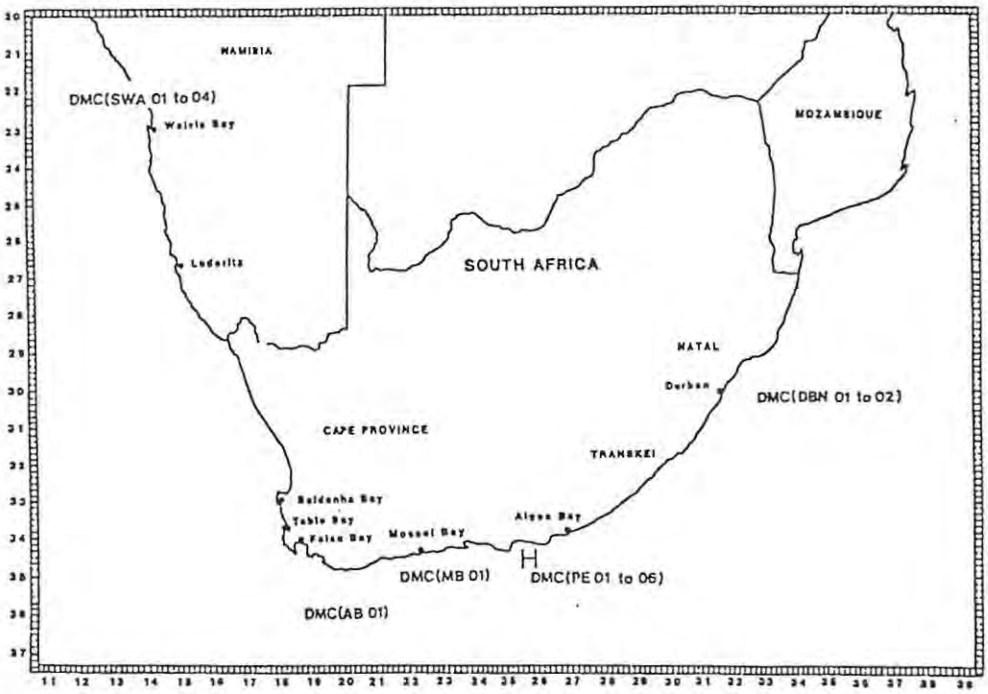


Figure 2.1. The catch localities of *Dasyatis marmorata capensis*, used for taxonomic studies, along the southern African coastline. DMC(SWA 01 to 04) caught in Swakopmund, DMC(AB 01) caught on the Agulhas bank, DMC(MB01) caught in Mossel Bay, DMC(PE 01 to 06) caught in Port Elizabeth, DMC(DBN 01 to 02) caught in Durban, H indicates the catch locality of the holotype.

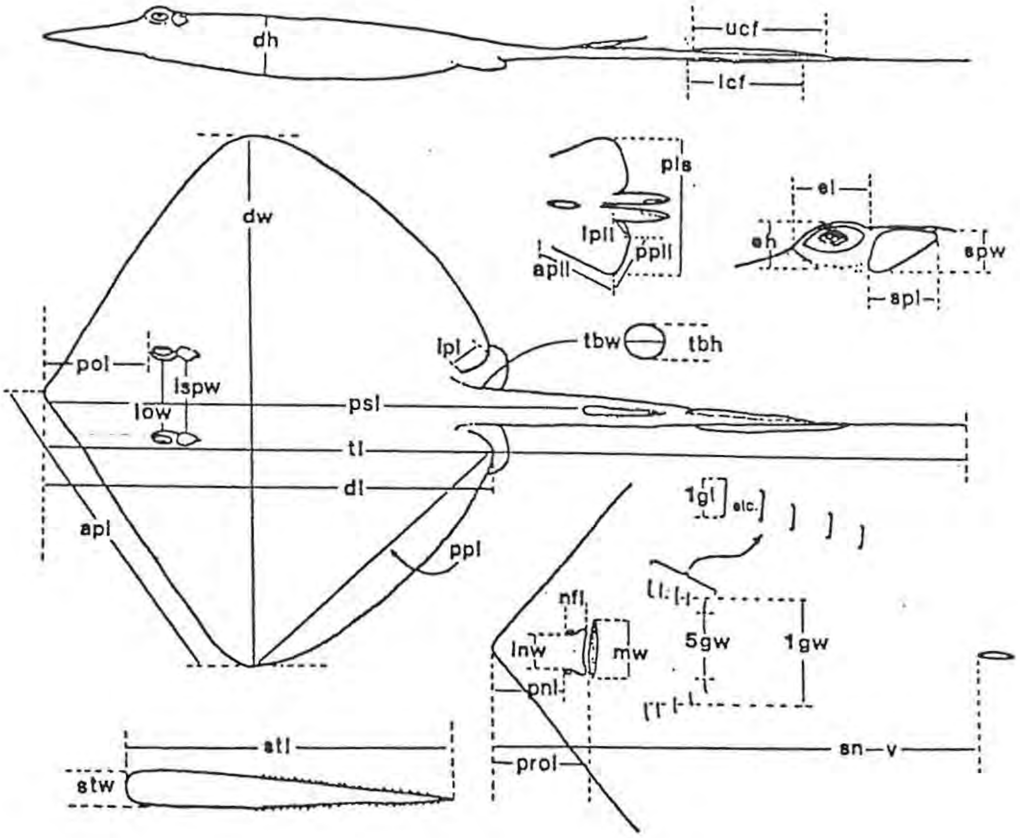


Figure 2.2. A diagrammatic outline of the proportional measurements used for meristic comparisons between *Dasyatis pastinaca*, *Dasyatis marmorata* and *Dasyatis marmorata capensis*.

Vertebrae and radial cartilage counts were made from either dissected material or radiographs. Radial counts include all radials with terminal branching. Pectoral radial counts include the radials in the anterior-most extension of the propterygium and the posterior-most extension of the metapterygium. Pelvic radial counts include the "fused" radials of the anterior-most large compound "radial". Vertebrae in the anterior-most part of the vertebral column in all Dasyatidae fuse to form two elongate synarcual complexes, the first or cervicothoracic synarcual and the second or thoracolumbar synarcual. The first synarcual incorporates a fixed number of the anterior-most centra, which are completely fused, but the number can be determined by counting spinal nerve foramina. The second synarcual is separated from the first by a small number of intersynarcual vertebrae. In the second synarcual the centra, although fused, retain their form and can be easily counted. Posteriorly the vertebral column ends in a long series of diplospondylous tail centra followed by a flexible rod consisting of the notochord and a calcified notochordal sheath (Figure 2.3).

Family : DASYATIDAE

According to Bigelow & Schroeder (1953) there are six genera in the family Dasyatidae : Dasyatis Rafinesque (1810); Himantura, Hypolophus, Taeniura, and Urogymnus Muller & Henle (1837); and Urolophoides Soldatov & Lindberg (1930). A seventh genus Amphotitius (Garman 1913) has been proposed as a valid grouping by some authors (Last 1979; Last & Dingerkus 1984).

DIAGNOSIS : Whiptail stingrays of varying size; disc width from about 30 cm to a maximum of 4 m. Circum-tropical distribution with most species occurring inshore, inhabiting the beach surf zone, river mouths and estuaries; some species also occur in freshwater.

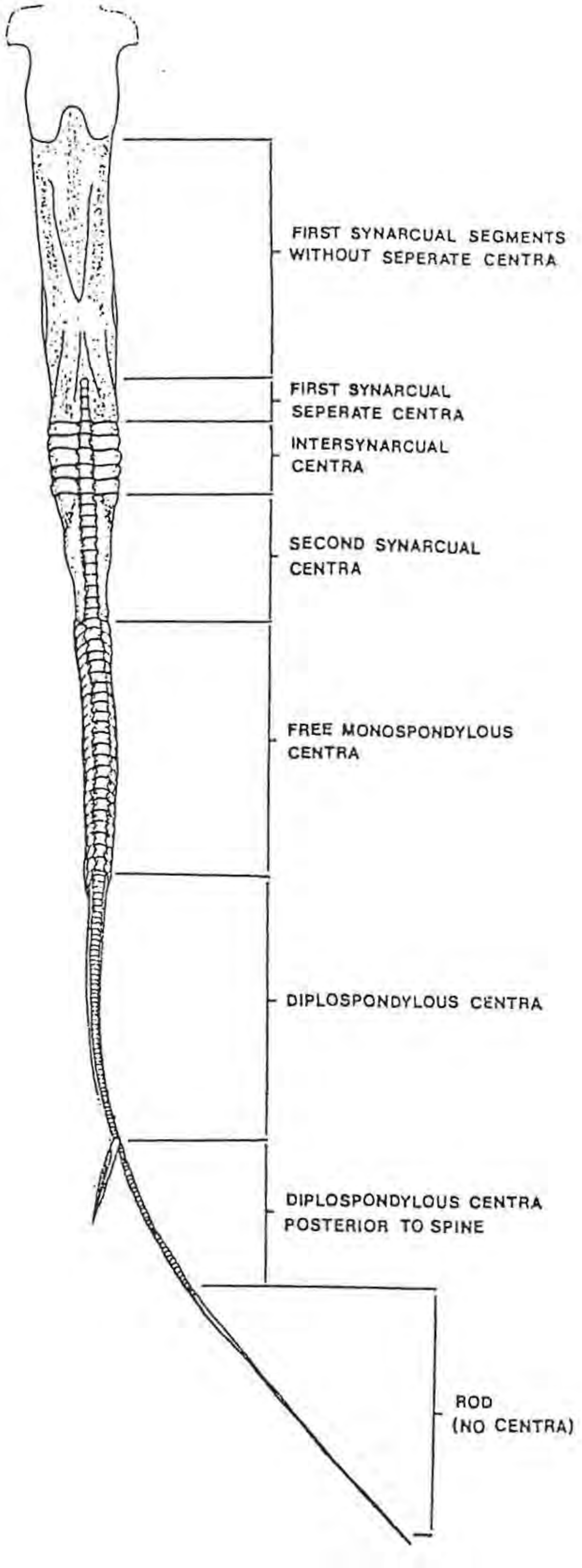


Figure 2.3. A diagrammatic representation of the vertebral column of a typical dasyatid ray, depicting the different zones referred to in the text.

Pectoral fins fused to the sides and front of head, and along the body to form a rounded or angular disc not more than 1.3 times as wide as long. Snout rounded to moderately pointed. Small blunt or cuspidate teeth in many series forming bands along the jaws. Several fleshy papillae on the floor of the mouth. Five pairs of gill openings on the underside of disc. Tail moderately slender to whiplike, varying from shorter than the disc to several times its length, and with one or more saw-edged spines on its basal part. Dorsal and ventral caudal fin-folds present or absent (after Bigelow & Schroeder 1953; Stehmann 1981; Compagno & Roberts 1982, 1984).

Genus : Dasyatis Rafinesque (1810).

Dasyatis Rafinesque 1810 : 16 [type species Dasyatis uyo Rafinesque (1810) (= Raja pastinaca Linnaeus 1758), by monotypy].

A full generic synonymy of the genus Dasyatis is given by Bigelow & Schroeder (1953).

DIAGNOSIS : Dasyatid rays with disc circular, oval, trapezoidal or diamond-shaped (Compagno & Roberts 1984). Dorsal surface smooth or variably covered with small, flat or prickle-like denticles. Snout angular or broadly rounded with projecting tip variably developed. Pectoral fins rounded or angular. Pelvic girdle moderately arched. Tail long and slender with ventral only, or dorsal and ventral folds. One or more tail spines usually present. Teeth small, rhomboidal, thin crowned ; sexual dimorphic differences in adults.

Dasyatis is a large, heterogeneous assemblage of approximately 33 species occurring worldwide. Five species occur in southern African waters - D. thetidis, D. violacea, D. brevicaudata, D. kuhlii and D. marmorata capensis (previously designated to D. pastinaca).

2.3 RESULTS AND DISCUSSION

Dasyatis marmorata (Steindachner 1868) (Figure 2.4).

A translation of Steindachner's original description of this species is as follows :

"The holotype, a well preserved male specimen was collected in the Bay of Gorde (Senegal) in October 1868. This variety is often caught and thus can be considered to be fairly abundant. It has been recorded from several localities but few dates of collection are known. Across the greater mid part of the disc the base colour is mainly violet blue. There are numerous oval shaped, unequal sized grey markings which become smaller at the tail and up the middle from the base of the tail. On the dorsal surface, anterior to the eyes and on the periphery of the disc the small marks come together to form large irregular marks. The ventral surface contains few to no marks and the ground colour is grey. Three cone shaped papillae occur on the lower lip of the mouth, but on the upper lip many small papillae occur. This specimen has a disc width of 28 cm. and a disc length (tip of snout to base of spine) of 22.5 cm".

Dasyatis marmorata capensis, a proposed new sub-species.

Proportional dimensions of the holotype as percentage disc width are given in Table 2.1. A full diagnosis and description, making use of additional specimens ranging between 270 mm and 719 mm DW, with proportional measurements and counts are provided in Tables 2.2, 2.3 and 2.4.

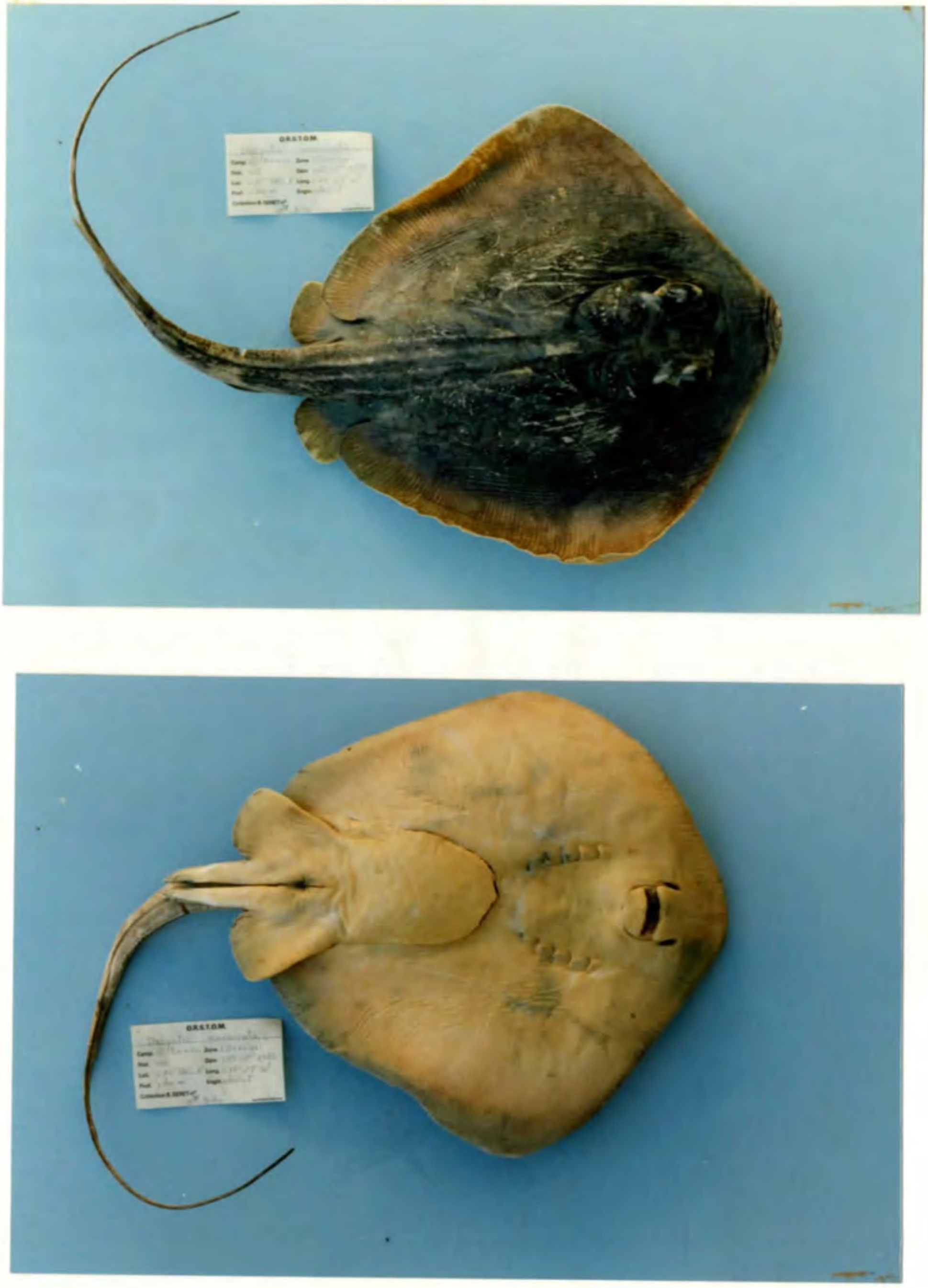


Figure 2.4. *Dasyatis marmorata* male, 313 mm disc width collected in Senegal (DM SEN 01).

Table 2.1. Proportional measurements expressed as percent disc width of <u>Dasyatis</u> <u>marmorata</u> <u>capensis</u>. HOLOTYPE S.A.M. 31697, 481 mm disc width, mature male. Gamtoos River, Eastern Cape.

Proportional Measurement	% DW	Proportional Measurment	% DW
DW	100.0		
DL	90.0	MW	10.7
PSL	114.5	IGL	3.3
TL	171.5	2GL	3.9
APL	64.5	3GL	3.9
PPL	58.0	4GL	3.5
1PL	10.2	5GL	2.5
DH	14.6	IGW	19.3
POL	18.7	2GW	12.9
IOL	18.1	SN-V	79.2
EH	4.2	APLL	16.2
EL	5.6	PPLL	14.9
SPL	6.2	IPLL	3.5
SPW	5.8	PLS	37.2
ISPW	15.6	TBW	7.1
PNL	13.9	TBH	4.2
PROL	19.1	UCF	23.1
NFL	5.8	LCF	37.8
INW	8.9		

Table 2.2. Proportional measurements, expressed as a percentage of disc width, for *Dasyatis pastinaca* (Thames River, England), *Dasyatis marmorata* (Senegal) and *Dasyatis marmorata capensis* (southern Africa).

Proportional	*D.pastinaca* (Thames R).		*D.marmorata* (Senegal)		*D. marmorata, capensis* collected from southern Africa			
Measurements		%DW		%DW	%DW RANGE	%DW MEAN	%DW SD	n
DW	232	100	313	100	——	——	——	—
DL	175	75.4	287	91.7	81.2 - 92.7	85.8	3.4	25
PSL	236	101.7	396	126.5	107.4 - 125.5	116.2	4.9	14
TL	385	165.9	665	212.5	154.6 - 219.7	178.1	15.4	14
APL	145	62.5	197	62.6	60.7 - 64.5	62.5	1.1	14
PPL	128	55.2	196	62.6	54.1 - 62.6	59.3	2.5	14
IPL	23	9.9	34	10.9	7.7 - 11.8	10.0	1.4	14
DH	35	15.1	50	16.0	11.9 - 16.8	14.3	1.3	14
POL	34	14.7	56	17.9	16.0 - 19.2	17.5	1.1	14
IOL	40	17.2	51	16.3	16.1 - 18.8	17.5	0.9	14
EH	11	4.7	9	2.9	1.8 - 4.1	3.1	0.6	13
EL	12	5.2	14.5	4.6	3.1 - 7.0	4.4	0.9	13
SPL	13	5.6	21	6.7	5.7 - 7.5	6.8	0.4	14
SPW	10	4.3	18	5.8	4.6 - 5.7	5.2	0.3	14
ISPW	36	15.5	51	16.3	14.2 - 16.4	15.2	0.6	14
PNL	25	10.8	47	15.0	12.5 - 14.3	13.4	0.6	14
PROL	38	16.4	68	21.7	17.8 - 20.3	18.8	0.7	14
NFL	12	5.2	17	5.4	4.2 - 6.2	5.0	0.5	14
INW	18	7.8	29	9.3	7.9 - 9.5	8.6	0.4	14
MW	20	8.6	29	9.3	7.5 - 9.3	8.4	0.5	14
1GL	7	3.0	9	2.9	2.3 - 3.8	3.1	0.4	14
2GL	8	3.4	9	2.9	3.2 - 4.2	3.6	0.3	14
3GL	7	3.0	11	3.5	3.2 - 4.2	3.6	0.3	14
4GL	7	3.0	9	2.9	3.1 - 4.0	3.5	0.2	14
5GL	5	2.2	6	1.9	2.0 - 2.9	2.3	0.2	14
1GW	45	19.4	57	18.2	17.8 - 21.8	20.1	1.0	14
5GW	29	12.5	40	12.8	10.8 - 14.2	12.6	0.9	14
SN-V	156	67.2	251	80.2	71.7 - 84.3	76.3	3.4	24
APLL	34	14.7	55	17.6	12.9 - 17.9	16.0	1.6	14
PPLL	31	13.4	36	11.5	14.6 - 25.4	17.5	3.1	14
IPLL	14	6.0	15	4.8	5.5 - 8.6	6.9	0.9	14
PLS	81	34.9	116	37.1	33.7 - 44.8	39.6	3.2	14
TBW	20	8.6	28	8.9	6.1 - 8.8	7.3	0.8	14
TBH	12	5.2	18	5.8	3.4 - 5.9	4.6	0.7	14
UCF	31	13.4	75	24.0	11.9 - 22.6	15.7	3.2	9
LCF	76	32.8	133	42.5	28.9 - 34.1	30,7	1.7	10
STL	55	23.7	86	27.5	13.2 - 17.9	15.7	1.7	4
STW	4	1.7	13	4.2	1.1 - 1.7	1.5	0.2	4

Table 2.3. Radial and spiral valve counts in Dasyatis pastinaca (DP 01 - Thames River, England; DP 02 and DP 03 - Venice, Italy), Dasyatis marmorata (Senegal) and Dasyatis marmorata capensis (southern Africa).

SPECIMEN NUMBER	PROPTERYGIAL RADIALS	MESOPTERYGIAL RADIALS	METAPTERYGIAL RADIALS	TOTAL PECTORAL RADIALS	PELVIC RADIALS	SPIRAL VALVE TURNS
DMC (PE 02)	46	15	48	109	27	22
DMC (PE 04)	42	13	48	109	18	21
DMC (PE 05)	45	15	48	108	27	22
DMC (PE 06)	47	16	46	109	—	22
DMC (AB 01)	48	15	50	113	27	23
DMC (DBN 01)	48	15	47	110	26	22
DMC (DBN 02)	44	17	47	108	25	22
DMC (SWA 01)	43	14	52	109	25	24
DMC (SWA 02)	46	15	49	110	25	22
DMC (SWA 03)	48	15	48	111	25	23
DMC (SWA 04)	49	13	50	112	26	22
DMC (PE 01)	45	16	48	109	25	22
DMC (MB 01)	49	11	50	110	27	22
DM (SEN 01)	48	13	50	109	19	21
DP (UK 01)	48	10	48	106	21	—
DP (IT 01)	44	12	47	102	20	—
DP (IT 02)	43	9	47	99	22	—

Table 2.4. Vertebral centra and segment counts in *Dasyatis pastinaca* (DP 01 - Thames River, England; DP 02 and DP 03 - Venice, Italy), *Dasyatis marmorata* (Senegal) and *Dasyatis marmorata capensis* (southern Africa).

Specimen Number	Total Vertebral Segments	Total Separate Centra	First Synarcual Segment without Separate Centra	First Synarcual Separate Centra	Inter-synarcual Centra	Second Synarcual Centra	Mono-spondylous Centra	Second Synarcual and free Mono-spondylous Centra	Diplo-spondylous Tail Centra	Centra Posterior to Sting
DMC (PE 02)	174	145	29	3	3	13	34	47	58	34
DMC (PE 04)	168	141	27	3	3	12	32	44	61	30
DMC (PE 05)	167	139	28	3	3	13	31	44	59	30
DMC (PE 06)	173	147	26	3	3	10	32	42	61	38
DMC (AB 01)	170	142	28	3	3	11	32	43	60	33
DMC (DBN 01)	169	138	31	3	5	10	31	41	61	28
DMC (DBN 02)	165	134	31	3	3	11	36	47	63	18
DMC (SWA 01)	171	141	30	3	3	12	31	43	62	30
DMC (SWA 02)	170	140	30	4	4	11	32	43	63	26
DMC (SWA 03)	165	135	30	3	4	11	31	42	63	23
DMC (SHA 04)	172	143	29	3	4	12	33	45	61	30
DMC (PE 01)	—	—	—	-	-	—	—	—	61	30
DMC (MB 01)	—	—	27	3	4	15	26	41	60	—
DM (SEN 01)	—	143	—	4	3	11	34	45	69	33
DP (UK 01)	173	144	29	3	4	9	22	31	63	43
DP (IT 02)	174	143	31	3	3	12	21	33	64	40
DP (IT 03)	169	144	25	5	5	—	—	30	64	40

HOLOTYPE : S.A.M. 31697, mature male, disc width 481 mm; total length 825 mm (tip of tail possibly incomplete); captured off the Gamtoos River surf at a depth of 53 m, Eastern Cape, South Africa (Figure 2.5).

ETYMOLOGY : capensis, from the Cape of Good Hope, South Africa.

DIAGNOSIS : A sub-species of Dasyatis marmorata with a moderately deep diamond shaped disc, snout broadly rounded with projecting tip ; disc depth 11.9 - 16.8% of disc width, disc width 0.81 - 0.93 times in disc length. Dorsal surface of disc usually smooth and devoid of rough denticles, but in some older individuals small circular flat denticles are present on disc and tail with small prickles; no enlarged thorns on disc or tail. Eyes moderately large, somewhat elevated, eyeball length 2.68 - 5.19 times in interorbital width; spiracles relatively large and obliquely oval. Floor of mouth with 5 elongated papillae, 3 positioned centrally ; total tooth rows 50-58/48-59. Pelvic fins moderately broad, pelvic span 33.7 - 44.8% disc width, their posterior margins not covered dorsally by disc, anterior margins 12.9 - 17.9% disc width. Pelvic radial counts highly variable (16 - 27), being sexually dimorphic, with higher counts in females. Tail gradually tapering to a narrow slender tip, tail base horizontally oval and depressed in section ; a single, but sometimes two, moderately large spines present on the tail, spine length 13.3 - 17.9% of disc width ; moderately depressed dorsal and ventral tail folds, ventral tail fold 28.9 - 34.1% of disc width. Total pectoral radials 108 - 113; total vertebral centra 134 - 147 and total vertebral segments 165 - 175 ; vertebral centra extending posteriorly beyond the spine. Total number of spiral valve turns 21 - 24.

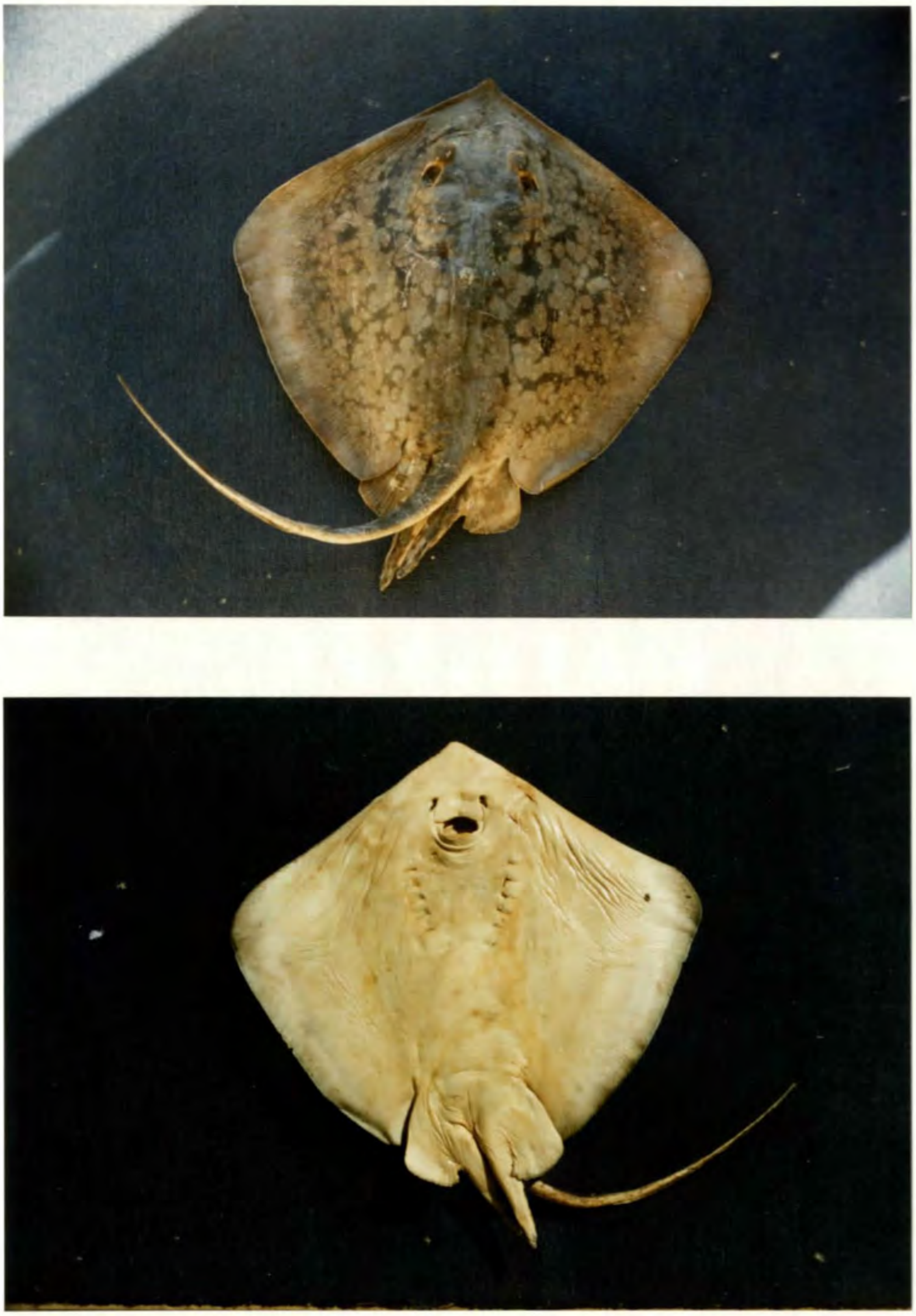


Figure 2.5. Dasyatis marmorata capensis, HOLOTYPE S.A.M. 31697, 418 mm disc width, mature male, Gamtoos River, Eastern Cape.

DESCRIPTION : Anterolateral margins of disc nearly straight, with a broadly rounded snout, posterior margins slightly rounded. Pre-orbital length 0.98 - 1.01 times in inter-orbital width ; pre-oral length 17.8 - 20.3% disc width, and 0.90 - 1.08 times in inter-orbital width and 1.11 - 1.14 times in width between first pair of gill slits. Snout angle in front of eyes 120 - 126^0. Spiracle length 0.54 - 0.93 times in eyeball length, 2.51 - 2.82 times in inter-orbital width, and 0.35 - 0.39 times in the distance between the fifth pair of gill slits. Mouth slightly arched, skin flap on upper jaw with 24 - 30 papillae, five oral papillae on the lower jaw. Teeth largest and most elongate at or near the symphysis and smallest and least elongate at mouth corners; teeth of mature males high crowned with angular cutting edges ; teeth of females and immature males with longer flat crowns and blunt cutting edges. Propterygial pectoral radials 42 - 49, mesopterygial pectoral radials 11 - 17, metapterygial pectoral radials 46 - 52. Neurocranium, pectoral and pelvic girdles and clasper morphology were not examined in detail.

COMPARISON BETWEEN Dasyatis pastinaca, D. marmorata and D. m. capensis.

Proportional Measurements

The proportional measurements expressed as percentage disc width for Dasyatis pastinaca, D. marmorata and D. m. capensis are given in Table 2.2. The three species are similar in proportional dimensions, possibly indicating that they are closely related. The most striking differences were in the proportional measurements of disc length and snout to vent length as a percentage of disc width (Figures 2.6 and 2.7). Values for both measurements in D. pastinaca were lower than the observed range for D. m. capensis. Values for D. marmorata were higher than those for D. m. capensis of the same size class, but still fell

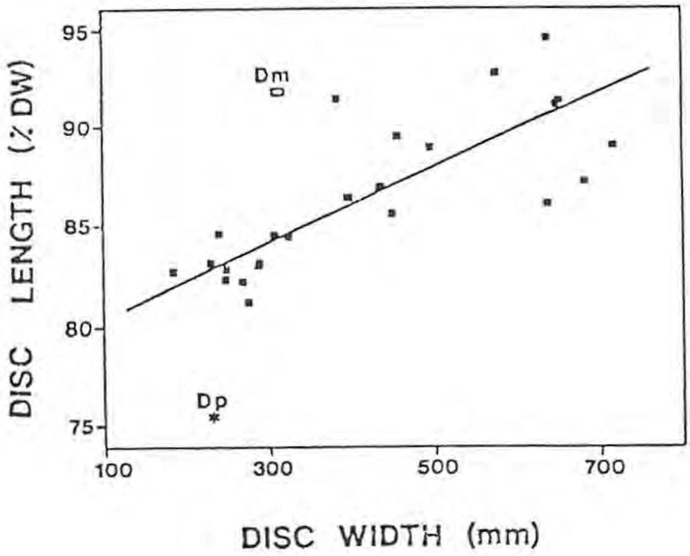


Figure 2.6 The relationship between the proportional measurement disc length (as a percent of disc width) and disc width in <u>Dasyatis</u> <u>pastinaca</u>, <u>Dasyatis</u> <u>marmorata</u> and <u>Dasyatis</u> <u>marmorata</u> <u>capensis</u>. Linear regression : y = 0.0179(x) + 78.77, r = 0.64.

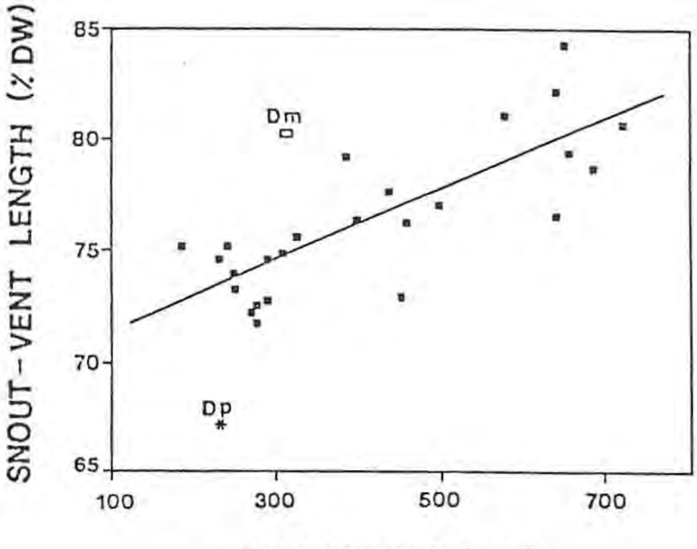


Figure 2.7. The relationship between the proportional measurement snout to vent length (as a percent of disc width) and disc width in <u>Dasyatis</u> <u>pastinaca</u>, <u>Dasyatis</u> <u>marmorata</u> and <u>Dasyatis</u> <u>marmorata</u> <u>capensis</u>. Linear regression : y = 0.0157(x) + 69.76, r = 0.64.

within the range of each measurement for larger individuals.

A clear difference in the snout angles of D. marmorata and D. m. capensis was observed. A mean snout angle of $122.4^{0} \pm 2.06$ (n = 11 ; 185 mm - 398 mm DW) was calculated for D. m. capensis, while the single specimen of D. marmorata (313 mm DW) had a snout angle of 113^{0}.

Proportional Counts

There were no observed differences in pectoral radial and spiral valve counts between D. marmorata and D. m. capensis. Mesopterygial radial counts and hence total pectoral radial counts were lower in D. pastinaca (Table 2.3). Vertebral centra and segment counts in D. marmorata and D. m. capensis overlapped. The monospondylous centra counts were lower in D. pastinaca, while the number of diplospondylous centra posterior to the sting in this species were higher in comparison to the other two species (Table 2.4).

Colour

Dorsal colouration of fresh D. m. capensis is best described as a sea-blue base with golden-brown mottled blotches, which coalesce at the periphery of the disc. These markings are comparable to those of D. marmorata as detailed by Steindachner (1868). Similarly, Stehmann (1981) described the colouration of D. marmorata as a broad brown outer margin, with a distinct pattern of sea-blue mottling on a golden-brown background. The dorsal colouration of D. pastinaca is uniformly greyish-green to olive-brown (Stehmann 1981) or brownish, varying to grey (Fowler 1936). Ventral colouration in both D. marmorata and D. m. capensis is uniformly pale-white, though occasionally with grey margins in immature D. m. capensis. The ventral colouration in D. pastinaca is whitish with disc margins grey to brown (Stehmann 1981).

Dorsal and ventral colouration of D. marmorata, D. m. capensis and D. pastinaca preserved in an alcohol medium can be observed in Figures 2.4, 2.5 and 2.8 respectively.

2.4 CONCLUSION

It has been suggested for some time that the South African variant was incorrectly assigned to Dasyatis pastinaca (van der Elst 1981). This study has outlined the differences in meristic features and colour patterns providing suitable evidence that the local variant is not D. pastinaca. Although apparently different to D. marmorata, in terms of snout angle, and disc length and snout to vent length as a percentage of disc width, it is suggested that the local variety constitutes a sub-species of D. marmorata. Further detailed studies may indicate that D. m. capensis is in fact a distinct species.

Figure 2.8. <u>Dasyatis pastinaca</u>, 232 mm disc width, immature female collected in the Thames River, England.

CHAPTER 3 STUDY AREA AND SAMPLING METHODS

3.1 INTRODUCTION

Problems associated with the collection of elasmobranch fishes for scientific studies are numerous. The relatively large size and potential dangers associated with numerous species pose difficulties while sampling. Furthermore, the collection of such species involves the use of expensive fishing gear and additional manpower. The scarcity of directed commercial fisheries for elasmobranchs, which are often good sampling sources, imposes a further problem to sampling in South Africa.

3.2 STUDY AREA

In the present study two principal techniques were used for the collection of samples. Specimens were collected from fishermen using rod and reel equipment at fishing competitions, and from trawls during research cruises on broad the R. V. Africana. Although the majority of the specimens were collected from the southern and eastern Cape regions, sampling was conducted along the entire southern African coastline from Swakopmund (Namibia) to Durban (Natal), from March 1987 to May 1989 (Figure 3.1).

3.3 SAMPLING REGIONS

A typical beach profile is divided into a surf zone, a nearshore zone and an offshore zone (McLachlan 1983a). The surf zone is characterized by the presence of a swash zone, a trough and a

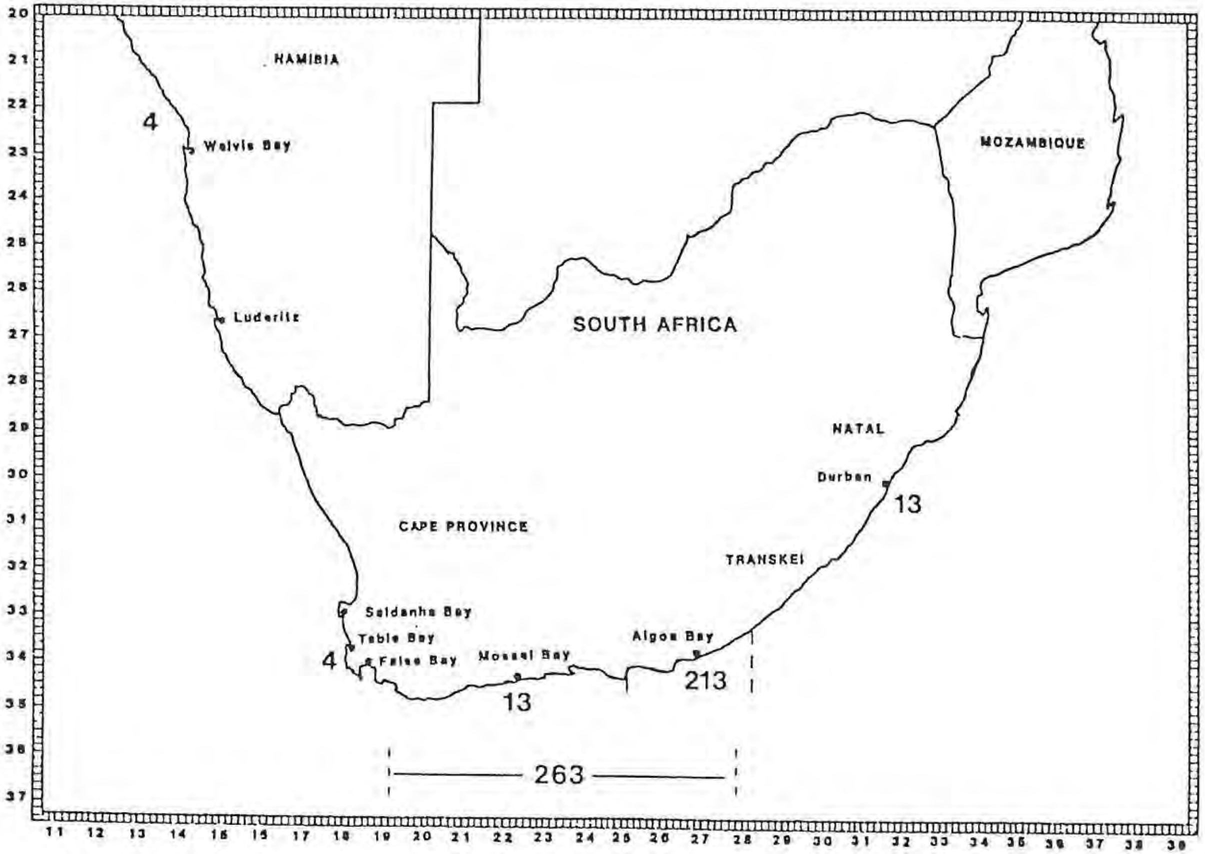


Figure 3.1. Capture localities of _Dasyatis marmorata capensis_, used for biological studies, along the southern African coastline. Numbers indicating the number of specimens examined.

bar. The latter, made of unconsolidated material, marks the breaker zone. The nearshore zone is defined as the area immediately seaward of the outer breaker zone to a depth which corresponds with the modal wave base (Short 1983). The modal wave base, or outer limit of surf circulation cells, is where wave orbital motions begin to interact with the bed sufficiently to initiate sand transport. The depth at which the modal wave base occurs depends on the beach type (see below). For intermediate beach types this depth can be between 10 and 30 metres (Short op. cit.). The indefinite zone extending seaward from the modal wave base is referred to as the offshore zone, which becomes the inner continental shelf with increasing distance from the shore (Figure 3.2, Horikawa 1988).

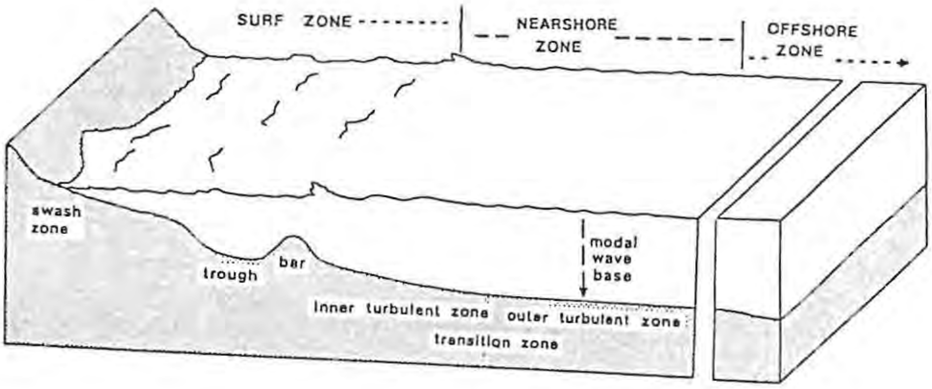


Figure 3.2. A profile of a typical sandy beach, showing the zones referred to in the text (adapted from McLachlan 1983a, Horikawa 1988).

Short & Wright (1983) identified different states that occur on natural beaches and classified a range of six beach types from dissipative to intermediate to reflective. According to this system of classification, blue rays were most commonly encountered on the intermediate beach types, specifically those associated with rhythmic bar and/or transverse bar and rip systems (see Short & Wright op. cit.).

SURF ZONE

The collection of samples from this zone was made possible by recreational rock and surf anglers. All the major rock and surf angling competitions from Swakopmund (Namibia) to Durban (Natal) were sampled between March 1987 and May 1989. These competitions included: the inter-provincial national championships (East London, March 1987; Swakopmund, March 1988; False Bay, March 1989), Natal Angling Unions' light tackle meet (Uvongo, 15 October 1988) and heavy tackle meet (Umhlanga Rocks, 13 November 1988) and several inter-provincial friendly competitions held in the Eastern Province region. Samples were also collected at monthly fixed venue league competitions (September to May 1987-88, 1988-89), organized by the Eastern Province Rock and Surf Angling Union, between Jeffreys Bay and Port Alfred. Monthly inter-club and club competitions of the Grahamstown and Districts Sea Angling Club, fished between Hamburg and Kenton-on-Sea, were also attended.

Angler effort on any given day is often influenced by prevailing weather and sea conditions, resulting in their targeting on certain species. This often resulted in the collection of no blue stingrays.

Physical and Biological Features of the Surf Zone

This extremely dynamic zone is affected by the combined action of waves, wave-induced currents and sediment movement (Horikawa 1988). It is a productive zone which relies on wave energy as the driving force responsible for surf circulation patterns, pumping water through the interstices of the sand body, transporting sediment and facilitating the transport and exchange of biological materials. Along the eastern Cape coastline, the surf zones are generally 150 - 400 metres wide, with well defined rip systems. The sand is fine to medium quartz with a high calcium carbonate content (McLachlan 1983b).

The surf zone is characterized by the regular occurrence of phytoplankton blooms (Lewin & Schaefer 1983), which supports a rich macrofauna consisting of molluscs, crustaceans and polychaetes (McLachlan & Hanekom 1979; Wooldridge 1983; McLachlan et al. 1984). This macrofauna in turn supports predators such as birds, fishes and swimming crabs (McLachlan 1983a). Among the benthic predators, elasmobranchs are the most important, particularly the batoid fishes (Rossouw 1983).

NEARSHORE ZONE

The collection of samples from this area was made possible by light tackle ski-boat anglers. Sample specimens were collected from the following major light tackle angling competitions : the South African national championships (Port Elizabeth, March 1987) and the all coastal inter-provincial tournament (Mossel Bay, October 1987).

Physical and Biological Features of the Nearshore Zone

This zone is less dynamic than the surf zone because of the diminishing effect of wave action with depth. Morphologically, it is more stable, allowing soft sediments seaward of the surf zone to remain relatively uniform. This zone is often associated with mega-ripples up to 5.0 metres long and 1.5 metres high, but these decrease in magnitude with depth (Short 1983). Although wave energy is still important, the decreasing disturbance by wave motions with depth increases the ability for benthic macrofaunal organisms to colonize this zone (McLachlan _et al._ 1984). This phenomenon explains the increased biomass of certain burrowing organisms such as _Callianassa_ spp. (Cockcroft & Tomalin 1987) in this zone.

OFFSHORE ZONE

Samples were collected while participating on research cruises on board the Sea Fisheries Research Institute's R.V. _Africana_. Stingrays were only encountered along the south east Cape coast from the Agulhas Bank to Port Alfred. Several trips on the south west Cape coast yielded no blue rays. Data were collected from the following cruises : 048 (12 September to 3 October 1986), 056 (7 September to 5 October 1987), 063 (10 May to 3 June 1988) and 072 (10 - 29 May 1989). Bottom trawling gear, comprising a 55 metre German Trawl fitted with a 27.5 mm mesh size bag, was used for the capture of samples.

Physical and Biological Features of the Offshore Zone

This zone offers a wide range of environmental conditions related to current circulation and wind systems. The offshore region between the Algulhas Bank and Port Alfred, from which all samples were collected, is strongly influenced by the Agulhas Current. In particular, the shallower area on the continental shelf is characterized by periodic current reversals, from southerly to northerly and back again over a period of four to six days. It is believed that these current reversals are closely linked with the atmospheric lows which move up the coast every few days, and that wind plays a role, but is probably not the primary forcing mechanism (Heydorn et al. 1978). Very strong thermoclines are common over the Agulhas bank, particularly in the summer. In winter, decreased solar heating and strong westerly gales cause substantial mixing and hence diminish the thermocline. Wind induced upwelling is also common along the coastal inshore region, causing sudden incursions of deeper cold water (Shannon 1989). In winter the inshore salinity may be slightly lower than that in the core of the main current, but in summer it can be appreciably reduced by run-off from the land (Heydorn et al. 1978). The sedimentology of most of the inner shelf is characterized by a blanket of sand and mud terrigenous sediments, with shells and shell fragments being subordinate except along the coast between Algoa Bay and Port Alfred (Flemming in Heydorn et al. 1978; Shannon 1989). Very little is known about the biological interactions and ecology of the benthic community in this zone.

3.4 GENERAL BIOLOGICAL SAMPLING METHODS

Sample specimens were either examined as soon as possible after capture, or were frozen and brought back to the laboratory. All specimens were sexed, measured and weighed. A section of the vertebral column was removed for age determination studies. Stomach contents were removed and preserved for subsequent analysis. The detailed methodologies used for each of these sections are described in their respective chapters.

CHAPTER 4 POPULATION STRUCTURE, SEASONALITY AND MIGRATORY PATTERNS

4.1 INTRODUCTION

Several important stingray fisheries exist worldwide. In countries such as Ghana, Senegal, Ivory coast (Stehmann 1981) and India (Devadoss 1978), stingrays are considered good marketable fishes and are consumed fresh or in a smoked or salted form. In southern Africa, there is no commercial exploitation of dasyatid rays, except as an unwanted bycatch of the inshore trawlers on the south east coast. There is, however a large shore-based recreational fishery, especially amongst tournament anglers, for certain batoid species along the entire southern African coastline. Although most of the captured specimens are returned to the water, it remains unknown what the survival rate is after being caught, handled and possibly seriously injured.

A data series of catch per unit of effort (CPUE) provides a suitable index of stock abundance (Cushing 1968, Royce 1984), and can, therefore, be used to monitor long term trends within a fishery. Furthermore, monthly changes in CPUE are useful in determining seasonal abundance, from which migratory patterns can be inferred. Various methods have been used to evaluate CPUE in recreational shore-angling fisheries in southern Africa (see Clarke 1988). In this study use was made of catch statistics compiled from angler catch returns (van der Elst & Adkin 1989) to investigate seasonal abundance of Dasyatis marmorata capensis.

Several authors (Lasiak 1982, Rossouw 1983, van der Elst 1981) have suggested that Dasyatis marmorata capensis exhibits a distinct seasonality, with peak abundance in the surf zone between spring and summer, thus suggesting an annual migration.

Royce (1984) stated that migratory patterns of fishes are related to either reproduction, climatic conditions or food availability. Rossouw (op. cit.) proposed that blue rays exhibit an annual onshore/offshore migration, similar to Rhinobatos annulatus, to liberate their young. The annual migration of D. m. capensis was investigated by analysing catch data based on angler effort and spatially related changes in size composition.

4.2 MATERIALS AND METHODS

Indices of CPUE expressed as numbers caught per 100 angling hours were used to determine monthly seasonal abundance of blue rays in the surf zone. Data on angler effort were collected from various sources :

1) **Catch Cards** - A single angler catch return card that is generally issued to non-affiliated anglers at resorts, coastal parks and other points of control.

2) **Monthly Competitions** - These forms are essentially similar for most regions and reflect the catches made by club anglers during competitions.

3) **Special Forms** - In addition to normal angling competitions, some angling unions have additional systems of recording catches of their members at times other than competitions. For example, the catch data collected from the St Croix Angling Club (Eastern Province Angling Union) (van der Elst & Adkin 1989).

The CPUE data series collected from the entire Natal coast and northern Transkei were analyzed from monthly competitions between 1956 and 1987. Independent CPUE analyses were made for the Natal north and south coasts between 1956 and 1976. The CPUE data for the Eastern Cape region were analyzed from Eastern Province Postal and the St Croix Angling Club competitions combined, by means of special forms between 1979 and 1983. In the Western Cape region, the CPUE data was analyzed from rock and surf angling competitions between 1981 and 1984. Most records pertain to catches made in Natal and the Transkei, because Cape anglers have been reluctant to fill in catch return cards (van der Elst & Adkin 1989).

Limited data on CPUE from the offshore zone were collected from three R.V. Africana cruises (056, 063, 072) and four R.V. Thomas B. Davie cruises (February, May, August, November 1980) (after Wallace et al. 1984). Unfortunately these data were not comparable because of differences in trawling gear used on the two vessels. The sampling gear aboard the R.V. Thomas B. Davie comprised a 20 m Otter trawl, while on the R.V. Africana a 55 m German trawl was used. The indices of CPUE data were expressed as numbers caught per 10 minutes trawl.

In an attempt to elucidate the migratory patterns and growth rates of marine fishes along the southern African coastline, 425 blue rays have been tagged in a national tag and release programme (SFW/ORI). This programme has yielded no catch returns for this species. Therefore, the proposed migratory pattern of D. m. capensis was based on seasonal changes in CPUE and spatially related changes in size composition. The size composition of samples collected from the surf, nearshore and offshore zones were investigated using length frequency analyses.

4.3 RESULTS

Population Structure

The population structure of all Dasyatis marmorata capensis sampled during this study (n = 510) revealed a bimodal disc width frequency distribution for both sexes (Figure 4.1). Females reached a larger maximum size than males. The largest female was

719 mm DW, while the largest male was 531 mm DW. The overall population sex ratio was 1 : 1.227 (229M : 281F), a ratio significantly different from unity ($x^2_{0.05} = 5.302$; d.f. = 1).

Significant trends were also observed when comparing the size frequency distribution and sex ratios of specimens collected from the surf, nearshore and offshore zones independently. The disc width frequency distribution of samples captured in the surf zone is shown in Figure 4.2. The results suggest size selective bias caused by the sampling technique (hook and line fishing), however competitive anglers make use of a variety of hook and bait sizes and types to maximize personal performances (personal observations). Therefore, it is assumed that the sample distribution is representative of the true size structure of specimens inhabiting the surf zone. This zone is frequented almost exclusively by mature and adolescent individuals (› 350 mm DW) of both sexes. Females significantly outnumbered males by a ratio of 1 : 2.265 (34M : 77F) ($x^2_{0.05} = 16.658$; d.f. = 1).

The disc width frequency distribution of specimens captured in the nearshore zone is shown in Figure 4.2. Mature and adolescent specimens of both sexes dominated numerically, but in contrast to the surf zone, smaller size classes of immature specimens (‹ 350 mm DW) were represented in the catches. The sex ratio was 1 : 1.566 (53M : 83 F), which is also significantly different from 1 : 1 ($x^2_{0.05} = 6.618$; d.f. = 1).

The disc width frequency distribution of blue rays collected from the offshore zone is shown in Figure 4.2. Samples from this zone were captured using trawling gear and therefore excludes the possible bias of size selective sampling. Immature specimens of both sexes numerically outnumbered adolescent and mature specimens. Males outnumbered females amongst the mature individuals. A sex ratio of 1.174 : 1 (142M : 121F) was calculated from all specimens captured in the offshore zone. However, this was not significantly different from unity ($x^2_{0.05} = 1.677$; d.f. = 1).

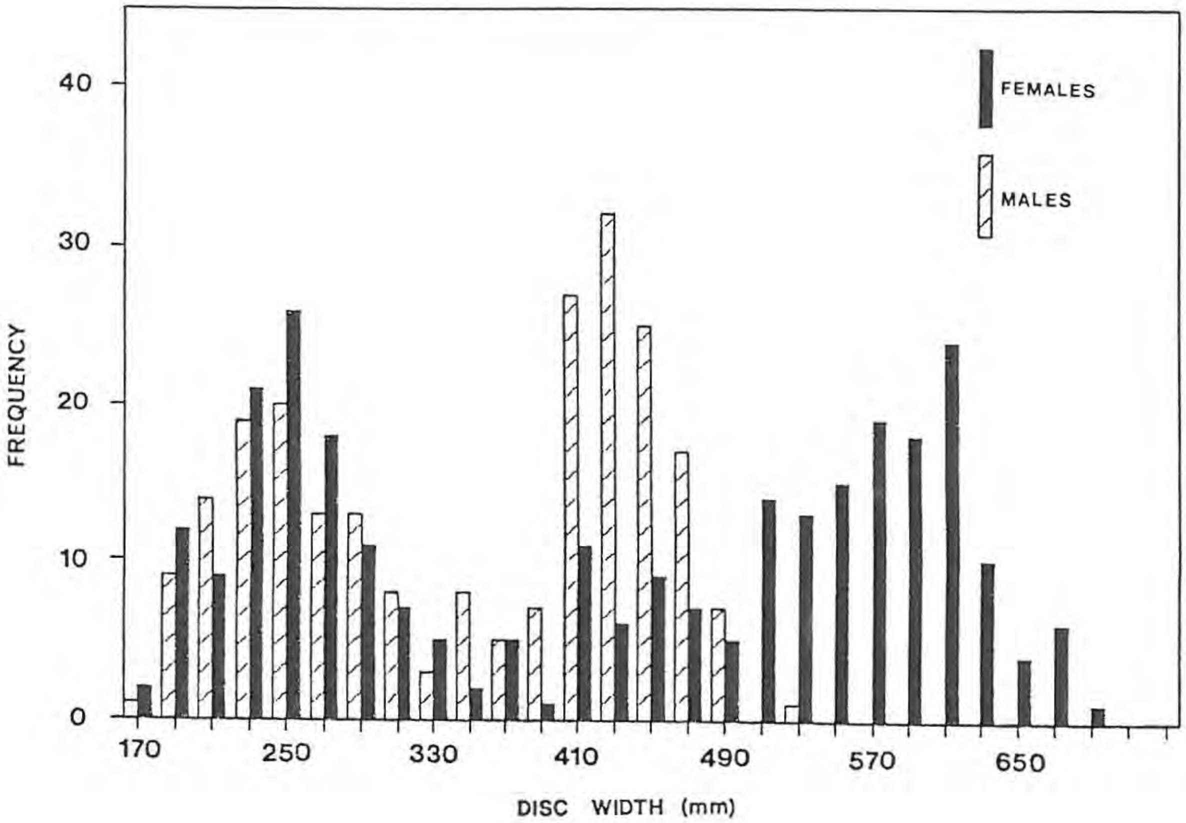


Figure 4.1. Disc width frequency distribution of all samples of <u>Dasyatis marmorata capensis</u> collected between March 1987 and May 1988 (n = 510).

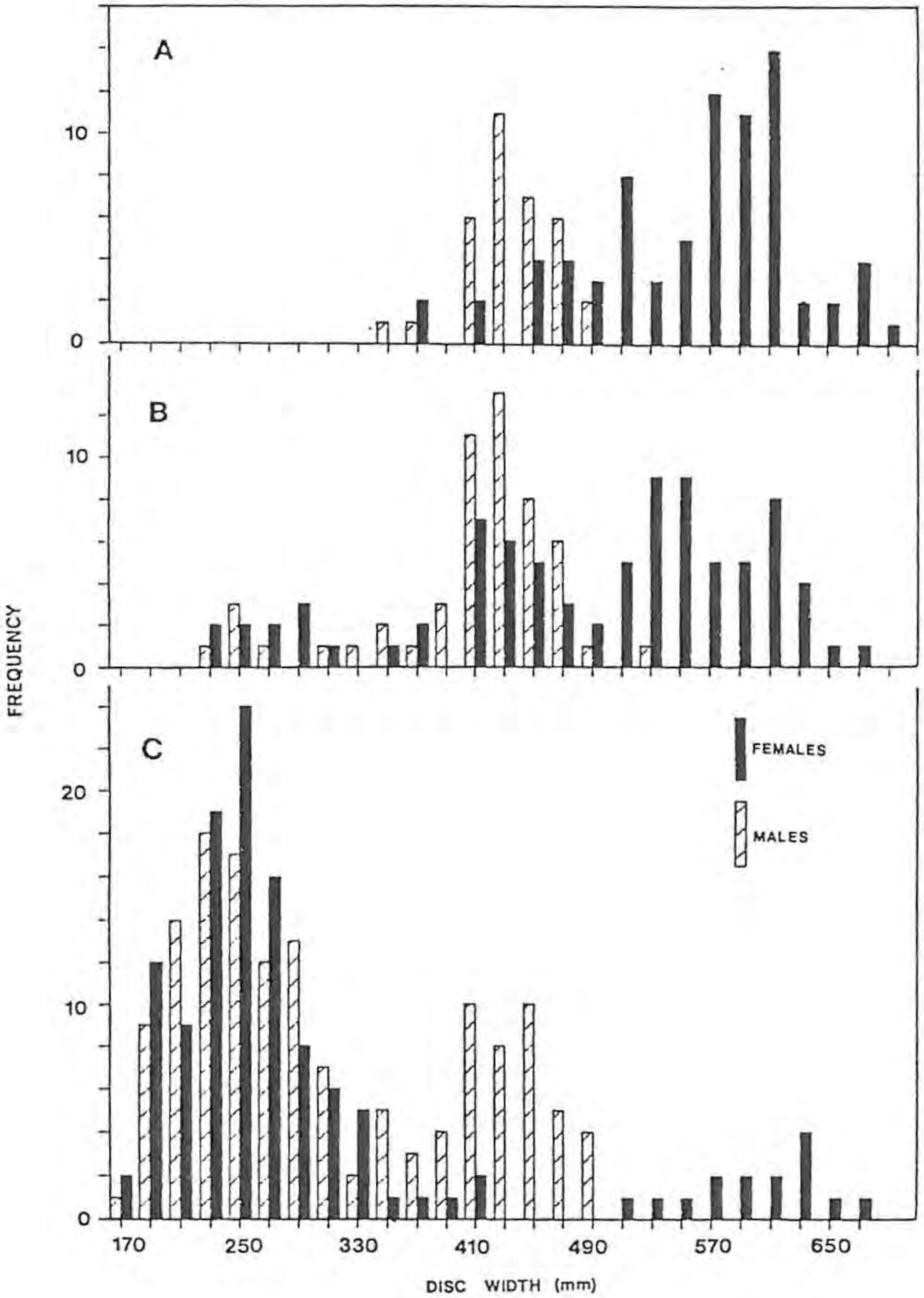


Figure 4.2. Disc width frequency distribution of Dasyatis marmorata capensis collected in (A) the surf zone (n = 111), (B) the nearshore zone (n = 136) and (C) the offshore zone (n = 263).

Seasonality

The monthly CPUE values, expressed as number caught per 100 angling hours, for Dasyatis marmorata capensis captured in the surf zone at different regions along the South African coastline are presented in Figures 4.3 to 4.5. Mean monthly CPUE values for specimens captured in Natal between 1956 and 1976 are shown in Figure 4.3. CPUE values remained consistently low between January and May, but peaked between August and September along both the Natal north coast and south coast. The same peak in CPUE was observed over the period 1977 to 1987 for the entire Natal coast (Figure 4.4), indicating that blue rays exhibit distinct seasonality. A similar trend in CPUE values was observed for the Eastern Cape region between 1979 and 1983 (Figure 4.5). CPUE values were low between April and August, but peaked between September and October. The monthly CPUE values for blue rays captured in the Western Cape region revealed a less distinct seasonality (Figure 4.6), probably due to the paucity of data collected from this region. However, no catches were made during the winter months of June, July and August between 1981 and 1984.

The CPUE values, expressed as numbers per 10 minutes trawl, for Dasyatis marmorata capensis collected from the offshore zone during trawling surveys are listed in Tables 4.1 and 4.2. These CPUE values do not show distinct seasonal patterns, possibly due to the lack of sufficient data. However, during the 1980 survey aboard the R.V. Thomas B. Davie (Table 4.1), highest CPUE values were recorded in February. CPUE values recorded from the R.V. Africana cruises (Table 4.2) were highest in the shallower waters (<40 m) during September 1987. During May 1988 fairly high CPUE values were also recorded in deeper waters (63 - 100 m). These data are in accordance with the seasonality observed in the surf zone.

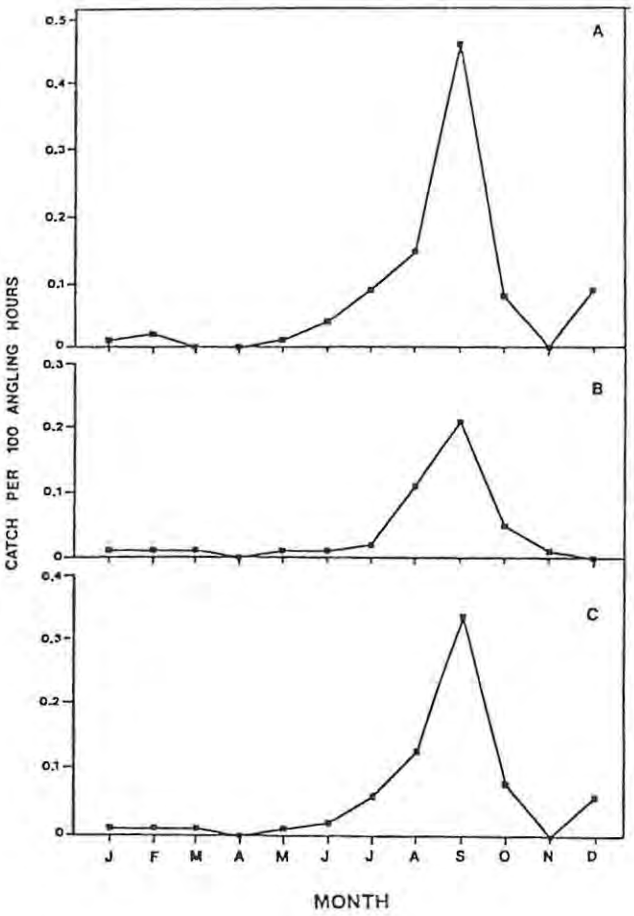


Figure 4.3. The mean monthly catch per unit of effort for Dasyatis marmorata capensis captured in the surf zone along (A) the Natal south coast, (B) the Natal north coast and (C) the entire Natal coast and northern Transkei between 1956 and 1976.

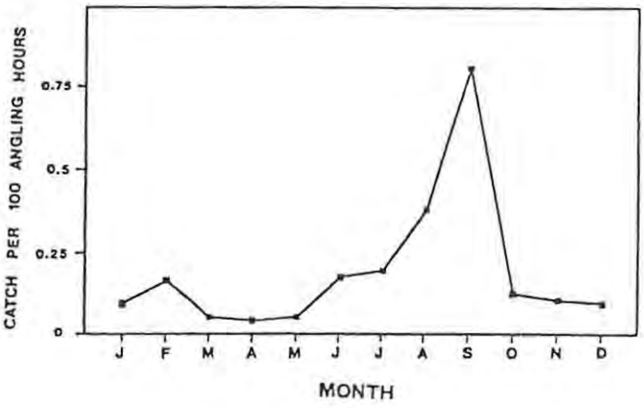


Figure 4.4. The mean monthly catch per unit of effort for Dasyatis marmorata capensis captured in the surf zone along the entire Natal coast between 1977 and 1987.

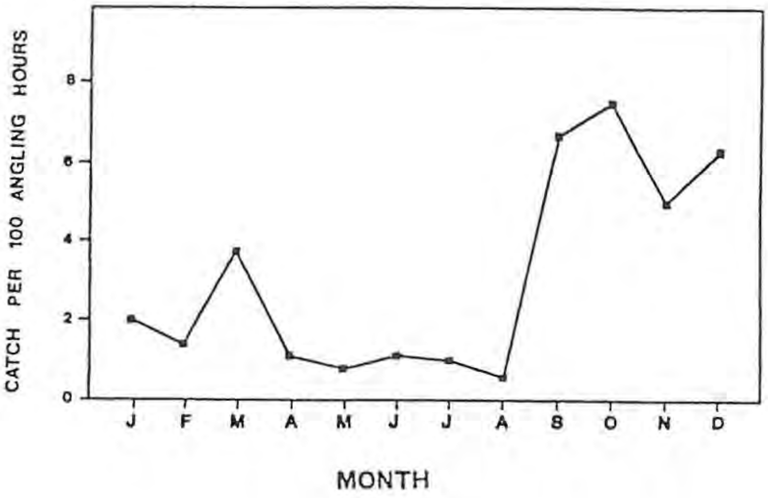


Figure 4.5. The mean monthly catch per unit of effort for Dasyatis marmorata capensis captured in the surf zone along the Eastern Cape coast between 1979 and 1983.

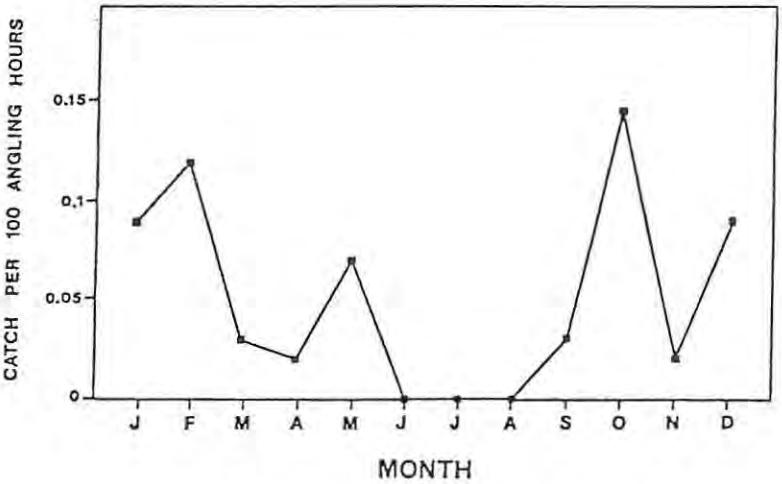


Figure 4.6. The mean monthly catch per unit of effort for Dasyatis marmorata capensis captured in the surf zone along the Western Cape coast between 1981 and 1984.

Table 4.1. The catch per unit of effort for *Dasyatis marmorata capensis* captured in the offshore zone aboard the R.V. *Thomas B. Davie* during 1980 (after Wallace *et al.* 1983).

FEBRUARY 1980

Tot. no. of trawls = 33
Trawl depth range 7-97 m
Tot. no. caught = 140

DEPTH (m)	CPUE n/10 min
7	68
9	5
27	6
28	19
31	3
32	10
32	1
33	3
35	3
41	1
41	17
41	2
49	2

MAY 1980

Tot. no. of trawls = 37
Trawl depth range 7-58 m
Tot. no. caught = 36

DEPTH (m)	CPUE n/10 min
7	1
10	1
10	5
13	1
24	6
27	2
27	2
32	2
33	3
36	10
39	2
42	1

AUGUST 1980

Tot. no. of trawls = 31
Trawl depth range 7-73 m
Tot. no. caught = 54

DEPTH (m)	CPUE n/10 min
9	7
12	2
13	6
13	15
16	18
20	1
22	3
23	9

NOVEMBER 1980

Tot. no. of trawls = 42
Trawl depth range 7-47 m
Tot. no. caught = 35

DEPTH (m)	CPUE n/10 min
7	3
9	3
11	1
12	2
13	2
15	1
17	1
18	1
19	3
19	8
22	1
24	2
25	1
27	4
28	1
40	2

Table 4.2 The catch per unit of effort for *Dasyatis marmorata capensis* captured in the offshore zone aboard the R.V. *Africana* during September 1987, May 1988 and May 1989.

SEPTEMBER 1987

Tot. no. of trawls = 88
Trawl depth range 17-395 m
Tot. no. caught = 90

DEPTH (m)	CPUE n/10 min
17	6.00
34	0.67
39	14.33
40	1.00
44	0.67
49	1.33
54	0.67
58	0.67
64	1.33
66	0.67
66	0.67
72	0.33
90	0.67
95	0.33
110	0.33
112	0.67
113	0.33

MAY 1988

Tot. no. of trawls = 93
Trawl depth range 30-383 m
Tot. no. caught = 89

DEPTH (m)	CPUE n/10 min
32	8.67
35	0.33
45	0.33
63	9.33
84	3.33
96	0.67
100	7.00

MAY 1989

Tot. no. of trawls = 93
Trawl depth range 30-383 m
Tot. no. caught = ? (120kg)

DEPTH (m)	CPUE n/10 min
32	-
36	15.33
42	1.33
48	2.33
53	-

Regional Abundance

Regional differences in CPUE values indicate that Dasyatis marmorata capensis are most abundant along the south eastern seaboard. Capture rates were highest in the Eastern Cape with an overall mean CPUE of 3.07 animals caught per 100 angling hours, followed by the Natal south coast, Western Cape and Natal north coast with 0.079, 0.051 and 0.038 respectively.

Migration

As already stated, analyses of monthly CPUE for Dasyatis marmorata capensis, captured in the surf zone, at different regions along the South African coast revealed a distinct seasonality (Figures 4.3 to 4.6). Highest CPUE values for all regions (Natal north coast, Natal south coast, Eastern Cape and Western Cape) were recorded during spring, between August and November. Therefore, these data indicate that no distinct annual longshore migration occurred. However, the low CPUE values recorded during the winter are indicative of an annual onshore/offshore migration. Furthermore, the size frequency distribution of specimens captured in the surf zone (Figure 4.2) suggest that the annual onshore/offshore migration occurs only amongst mature and adolescent specimens. The immature specimens, on the other hand, appear to utilize the offshore zone as a nursery ground (Figure 4.2).

4.4 DISCUSSION

Because the CPUE data series was collected from tournament anglers the possible bias related to species targeting is an important consideration. Van der Elst (1979) pointed out that the basic rules and regulations regarding fishing competitions have remained unchanged since their inception in 1914, and suggested that the anglers' incentives have always remained the same. However, Clarke (1988) and van der Elst (1989) stated that competition anglers specifically target for elasmobranchs because of their relatively large size, and hence weight contribution. It is virtually impossible to quantify the extent to which angling effort is species directed, therefore the nature of this potential source of error remains unknown.

The importance of Dasyatis marmorata capensis as a rock and surf recreational angling species, especially amongst competitive tournament anglers has been pointed out by van der Elst (1989) and van der Elst & Adkin (1989). Analyses of the monthly CPUE data has adequately shown the seasonal nature of this species. It is important to note that that the majority of the fish caught are adult females (Figure 4.2), and that maximum exploitation occurs just prior to the peak pupping season (see Chapter 6). Although a large proportion of the fish are returned to the water, it is uncertain what their survival rate is after capture. Furthermore, pregnant females have a tendency to drop their young or uterine eggs after capture. These results indicate that reproductively active females are particularly susceptible to exploitation in the recreational fishery.

Van der Elst (in prep.) has revealed a significant increase in the catch rate of Dasyatis marmorata capensis along the Natal coast from 1960 to 1987 (Figure 4.7). A similar trend was identified for other related batoid species, and was, in part, attributed to the reduced predation by sharks that have been eliminated by sharknets (van der Elst & Adkin 1989). Butterworth (1985) indicated that within a long term CPUE data series, a decline of more than 50% of the level at inception of the fishery is indicative of biological over-exploitation. These data, therefore, indicate that D. m. capensis along the Natal coast is presently not over-exploited.

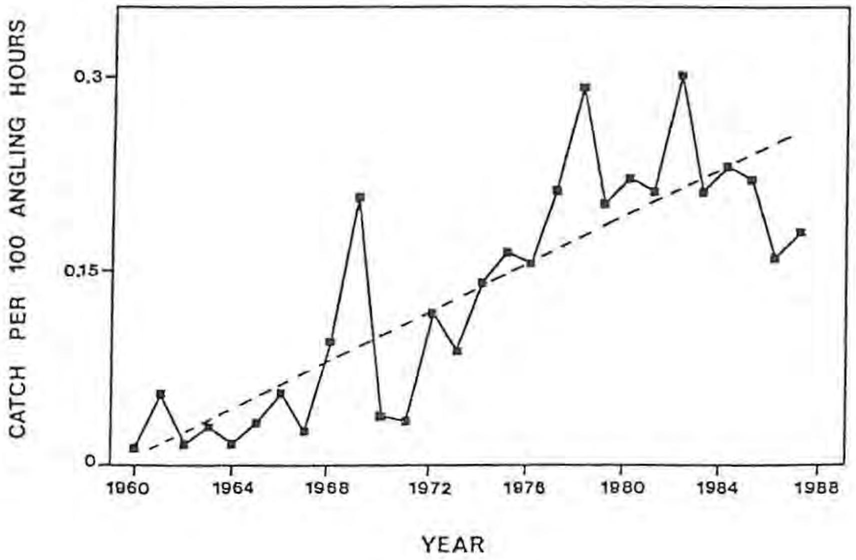


Figure 4.7. The trend in catch per unit of effort for Dasyatis marmorata capensis captured in the surf zone along the Natal coast between 1960 and 1987. Linear regression y = 0.0913(x) - 0.539, r = 0.69. (after van der Elst in prep.).

The results presented on regional changes in CPUE are possibly not conclusive because of the disproportionate amount of data collected from the different regions. This will only be confirmed once sufficient data is made available from the Cape regions. However, the abundance of Dasyatis marmorata capensis in the catches of rock and surf anglers in the Eastern Cape has been pointed out by Lasiak (1982), Rossouw (1984) and van der Elst (1989).

Analyses of monthly CPUE has confirmed an annual onshore/offshore migration, with peak abundance in the surf zone during spring, as proposed by Rossouw (1983). Similar offshore migrations during the winter have been reported in other rays of the order

Myliobatiformes, e.g. *Dasyatis centroura* (Struhsaker 1969), *Urolophus paucimaculatus* (Edwards 1980), *Rhinoptera bonasus* (Smith & Merriner 1986), *Myliobatis californica* (Martin & Cailliet 1988a) and *Dasyatis sabina* (Snelson *et al.* 1988). Most these studies have ascribed this migration to changes in water temperature. However, the findings of the present study are in agreement with Martin & Cailliet (op. cit.), and indicate that the surf zone is utilized as a pupping ground, hence the migration is related to reproductive seasonality. Furthermore, it is proposed that no distinct longshore migration occurs.

CHAPTER 5 AGE AND GROWTH

5.1 INTRODUCTION

Growth is commonly defined as an increase in size or mass of a living unit with time (Royce 1984). This phenomenon is of fundamental importance to an understanding of the life of an individual. More importantly, in conjunction with length and weight data, it provides the fisheries biologist with a tool for stock assessment and the ability to formulate models for the analysis of exploited populations. Such models are crucial for the development of management aimed at sustained utilization of the resource.

Several technique can be used for age determination in fishes. The most direct method involves artificial fertilization and rearing of offspring under controlled conditions. More indirect methods involve making use of length frequency distribution and tag-recapture data. However, these methods are generally used to confirm other procedures, particularly those involving the interpretation of age from calcified structures such as scales, spines, otoliths or vertebrae (Weatherley 1987). The absence of hard skeletal structures pose certain difficulties in the ageing of cartilaginous fishes. Several methods have been developed and applied to elasmobranchs, these were reviewed by Cailliet et al. (1986). The use of length frequency data to separate year classes has been commonly used with varying success (Olsen 1954; Pratt & Casey 1983; Natanson et al. 1984; Casey et al. 1985). Length frequency data coupled with tag-recapture analysis render results more interpretable (Babel 1967; Thorson & Lacy 1982; Casey et al. 1985). Other methods of age determination include the measurement of mercury accumulations in vertebrae (Forrester et al. 1972), and tooth replacement in sharks (Moss 1972). The use of fin spines has proved to be a reliable indicator of age in certain species, notably the spiny dogfish, Squalus acanthias (Holden & Meadows 1962) and the St. Joseph shark, Callorhinchus capensis (D. Freer, Zoology Department, University of Cape Town, pers. comm.). In recent years, vertebral centra have been used extensively and successfully as age indicators (Thorson & Lacy 1982; Casey et al. 1985; Pratt & Casey 1983; Branstetter 1987a; Branstetter & Stiles 1987; Smith & Merriner 1987; Martin & Cailliet 1988b; Davenport & Stevens 1988).

Most studies on age and growth in elasmobranchs using vertebrae have reported clear growth zones in their centra, from which age estimates have been made. However, few studies have validated the temporal periodicity of band deposition. Holden & Vince (1973), using tetracycline, were the first to validate elasmobranch ageing by establishing that opaque and translucent zones formed annually in Raja clavata. Since then, alternative methods have been used to verify the periodicity of band deposition. These include size frequency analyses, growth model parameters, centrum edge dimensions, histological characteristics, laboratory growth studies, tag-recapture results from the field, tetracycline marking in both laboratory and field studies, radiometric dating and electron microprobe analyses for calcium and phosphorus across sections of vertebral centra (Cailliet et al. 1986).

Once the sizes of individuals at various ages have been obtained from the skeletal elements, these data can be applied to a growth model such as the von Bertalanffy equation to obtain the parameters K and L_∞, which can be used to describe growth. These parameters allow comparisons with other species, or between the same species at different places and over different time periods (Ricker 1971; Weatherley 1987).

In South Africa, the recreational and commercial fishing pressure on many elasmobranch species has increased in recent years (van der Elst in prep.; Compagno et al. in prep.). For their sustained use it will be necessary to implement a management programme. However, population dynamics analyses, crucial to the development of such a programme, are not possible because little is known about the biology of most elasmobranch species.

In this chapter estimates of ages and growth rates for Dasyatis marmorata capensis are made using the vertebral centra.

5.2 MATERIALS AND METHODS

All the specimens (males n = 105 ; females n = 165) used in this study were collected along the Southern and Eastern Cape coastline between Mossel Bay and Port Alfred from March 1987 to May 1989. Samples collected elsewhere along the southern African coastline were excluded because of possible differences in growth rates due to different environmental conditions.

Vertebral Preparation and Reading

Vertebral centra were used for age determination. A section of seven to 10 of the largest monospondylous centra were removed from the vertebral column, labelled, and frozen. Three centra were removed from the defrosted vertebral segment, boiled for 3 - 5 minutes, and cleared of both connective tissue and the lateral portions of the neural arch. The centra were then immersed in 100% sodium hypochlorite bleach until all connective tissue had dissolved. Cleaned centra were rinsed in freshwater and stored in 70% propyl alcohol for subsequent analysis.

Initially, various techniques were assessed for their ability to enhance the bands on the cone surface of the vertebrae. Whole centra were stained with silver nitrate (Cailliet et al. 1983; Rossouw 1984), alizarin red (Gruber & Stout 1983) and xylene impregnated (Daiber 1960). None of these techniques resulted in the identification of distinct bands. Distinct bands were, however, visible in the corpus calcereum regions of sectioned centra. This method was therefore used for age determination. One vertebral centrum from each sample was embedded in clear casting resin and sectioned through the nucleus (< 0.5 mm) using a double bladed, diamond edged saw. The result, a thin "hour-glass" section was mounted on a glass slide, coated with D.P.X. mountant and viewed under transmitted light using a binocular dissecting microscope. Growth bands were fairly distinct in the corpus calcareum and occasionally observed in the intermedialia region. The term "band" in the present study includes a narrow dark band of opaque material and a broad translucent band including several "false rings". Bunching of one or more rings within the broad band, forming a false narrow band, often presented problems when interpreting distinct bands. Most consistent results were obtained from readings taken along the radius of the intermedialia region where the bunching effect of the rings appeared less prominent (Figure 5.1). To assess the accuracy of counts, the procedure was performed three times by one reader at least one week apart.

Growth Calculations

Growth parameters were calculated using age-length values and the computer program PC-YIELD (Hughes & Punt 1988). The results were computed using the absolute error model, which places emphasis on the larger size classes, and fitted to the equations proposed by Schnute (Schnute 1981). Back calculations of length-at-age for both sexes were performed on measurements of the diameters of all observed bands on the vertebral centra using the equation :

$$\mathbf{DWn = CDn / CD\ (DW - a) + a}$$

where : **CDn** and **CD** refer to the centrum diameter at age n and at time of capture respectively ; **DWn** and **DW** refer to disc width at age n and time of capture respectively ; a is the intercept of the regression of DW on CD, representing a correction factor (Bagenal & Tesch 1978). Average length-at-age values were calculated for each age class and used with back calculated values to check for Lee's phenomenon of apparent changes in growth rates for a particular age group (Bagenal & Tesch op. cit.; Weatherley 1987), and for consistency in reading vertebral bands in young and old specimens. Sections which did not pass through the centrum focus were discarded for back calculations, due to possible differences in centrum band measurements.

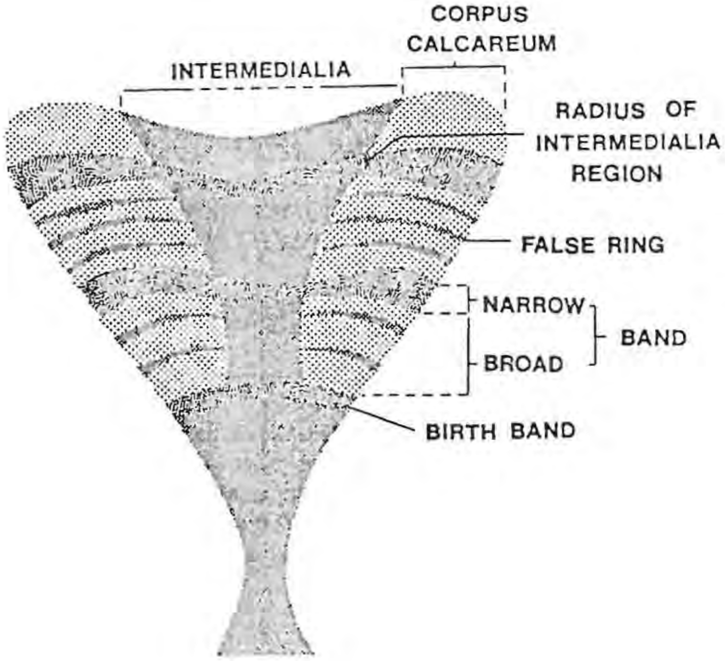


Figure 5.1. Diagrammatic representation of a sectioned vertebral centra showing the terminology referred to in the text.

Captive Specimens

Three specimens were captured in Algoa Bay on the 21 May 1988, using trawling gear. They were successfully transported to the Port Elizabeth Museum and housed in an indoor circular porta-pool with a capacity of 4000 litres natural sea water. All 3 specimens began feeding within 3 days of capture. The rays were fed to satiation once a day with a variety of foods, including pilchards *Sardinops ocellata*, sand prawns *Callianassa kraussi*, sand mussels *Donax serra* and squid *Loligo valgaris reynaudii*. After 3 months, the rays were measured and weighed at approximately monthly intervals to monitor growth. In November 1988 the rays were transferred to the Rhodes University laboratory at Port Alfred and housed in a semi-enclosed porta-pool (ca. 4000 litres) supplied with sea water via a biological filter. In Port Alfred, temperature and salinity readings were taken daily from the porta-pool and compared with ambient sea conditions.

5.3 RESULTS

Centrum Analysis

A series of regression analyses of disc width on centrum diameter for various age classes were calculated in both sexes to obtain the best fit linear relationship. Poor linear relationships were obtained for several age classes for both sexes, due to the low sample size represented in each age class. Therefore, all the age classes were combined for each sex. The result was a strongly correlated linear relationship for both sexes; males : $r = 0.921$, $n = 94$ (Figure 5.2) and females : $r = 0.935$, $n = 151$ (Figure 5.3).

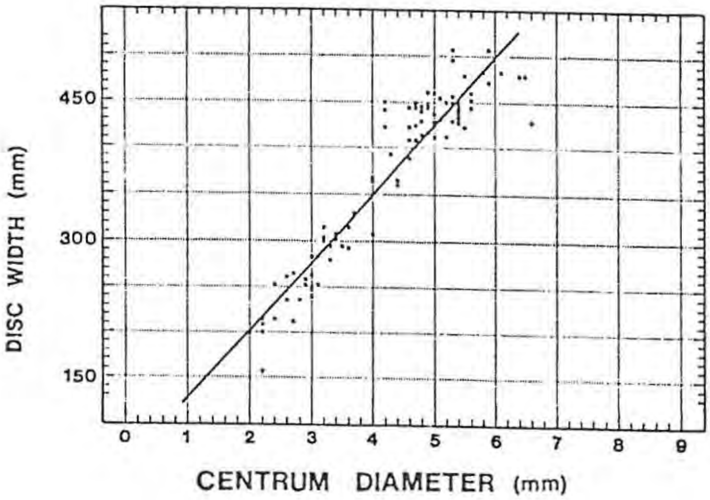


Figure 5.2. The disc width and centrum diameter relationship for male Dasyatis marmorata capensis (n = 94). Linear regression y = 0.887(x) + 4.626, r = 0.92.

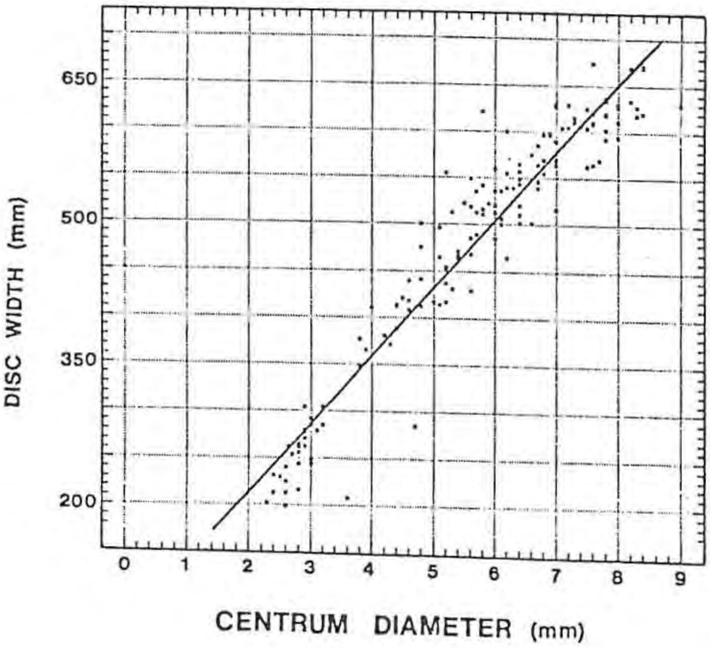


Figure 5.3. The disc width and centrum diameter relationship for female Dasyatis marmorata capensis (n = 151). Linear regression y = 0.887(x) + 4.64, r = 0.93.

The first narrow band, present in all sectioned vertebral centra at a diameter of 1.9 - 2.2 mm, was also present on the outer edge of a full term embryo prior to birth. This band is possibly formed in response to the changes in nutrient source during embryonic development (see Chapter 6). Other pre-birth marks were not visible because of the granular calcified nature of the sectioned centrum (Figures 5.4, 5.5 & 5.6).

The formation of narrow and broad bands correlated well with season in young individuals (< 4 years old). The narrow dark or optically dense bands form in the winter and the broad translucent bands in the summer. The first narrow band which forms just prior to birth (October - November) is proceeded by a broad band (December - April). These centrum characteristics were observed in several 0+ age class specimens collected in May 1988 (approximately six months old). The centra of specimens of the same age class collected in September 1987 (approximately 10 months old), contained a further narrow band which represents the winter period (May - September) (Figure 5.4).

Centra of older specimens were more variable in appearance and often presented problems in interpretation of age bands (Figures 5.5 & 5.6). Approximately 2 % of the 165 female centra and 5 % of the 105 male centra examined, were discarded because of obscure centrum edge characteristics, possibly due to bad sectioning.

Age and Growth Estimates

Length at age for male and female Dasyatis marmorata capensis are shown in Figure 5.7 and 5.8 respectively. The data were modeled using PC-YIELD (Hughes & Punt 1988), a programme specifically developed for desk top calculation. The data were best described using the absolute error model in which errors are randomly distributed with age. The derived von Bertalanffy growth

Figure 5.4. The sectioned vertebral centra of a 10 month old Dasyatis marmorata capensis, 253 mm disc width, captured on 18 September 1987. F = centrum focus, B = birth band, W = winter band.

Figure 5.5. The sectioned vertebral centra of a 10 year old female <u>Dasyatis</u> <u>marmorata</u> <u>capensis</u>, 583 mm disc width, captured on 14 October 1988.

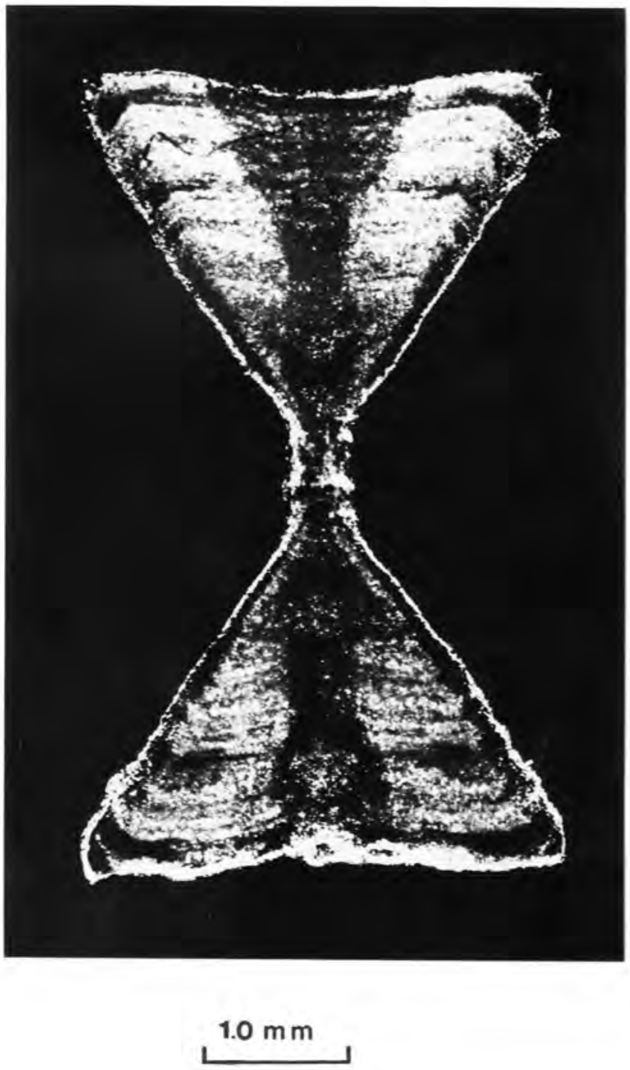


Figure 5.6. The sectioned vertebral centra of a five year old Dasyatis marmorata capensis, 442 mm disc width, captured on 16 March 1987.

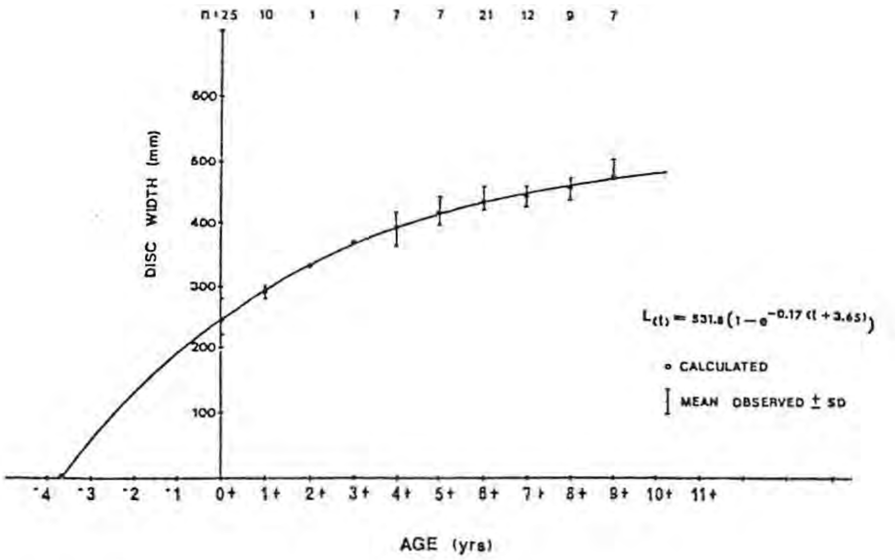


Figure 5.7. The von Bertalanffy growth curve for male *Dasyatis marmorata capensis*.

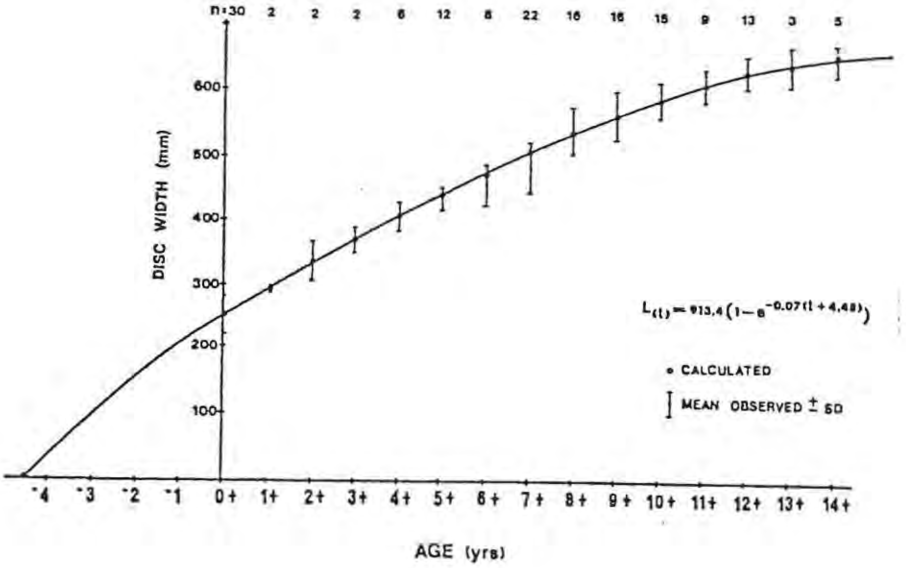


Figure 5.8. The von Bertalanffy growth curve for female *Dasyatis marmorata capensis*.

equations are :

$$L_{(t)} = 531.8(1-e^{-0.17(t+3.65)}) \quad \text{for males, and}$$

$$L_{(t)} = 913.4(1-e^{-0.07(t+4.48)}) \quad \text{for females.}$$

Size at birth and growth for the first three years are similar in both sexes. However, there is a distinct difference between the growth curves for males and females shown in Figures 5.7 and 5.8, respectively. The K values of 0.17 for males and 0.07 for females demonstrate a faster growth rate in males, in which the growth approaches an asymptote more quickly than it does for females. The L_∞ values of 531.8 mm for males and 913.4 mm for females are higher than the largest sizes aged in the present study (507 mm DW for males and 674 mm DW for females). These values are 95.3% and 73.8% of the asymptotic disc width of males and females, respectively. The largest recorded female in the present study, captured in Swakopmund (Namibia), was 719 mm. The largest male, from which no vertebrae were obtained, was captured in Algoa Bay and measured 531 mm. The observed minimum size at maturity for males at 408 mm DW and females at 500 mm DW, indicates a minimum age-at-maturity of five and seven years for males and females, respectively.

The back calculated disc widths at successive ages for males and females are presented in Tables 5.1 and 5.2 respectively. Noticeable variation in mean size for each age class indicates the presence of "Lee's phenomenon", when comparing mean observed and mean back calculated values (Table 5.3). The mean observed values of the 0+ age class are over estimated because specimens of this size class were collected in May and September exclusively, approximately six and 10 months old respectively. However, the mean back calculated value for this age class corresponds well with the actual size at birth (true age 0) between 170 and 200 mm disc width (see Chapter 6).

Table 5.1. Back calculated age-at-disc-width for male *Dasyatis marmorata capensis*.

		BACK CALCULATED DW (mm) AT SUCCESSIVE BANDS									
AGE	n	0	1	2	3	4	5	6	7	8	9
0	10	197.04									
1	3	168.49	243.15								
2	1	189.29	250.85	321.21							
3	0	-	-	-	-						
4	2	182.16	241.03	273.99	315.71	353.17					
5	5	181.88	248.20	226.24	323.93	356.89	403.33				
6	8	191.47	245.96	281.01	309.88	339.21	368.45	404.09			
7	6	181.04	231.53	260.79	292.88	326.26	255.31	386.03	421.14		
8	4	180.27	233.34	267.65	293.13	325.26	348.82	368.01	400.05	432.04	
9	3	186.95	248.55	290.36	306.58	332.81	361.77	387.58	422.55	454.67	472.25
MEAN DW		184.29	242.83	281.61	307.02	338.93	367.54	386.43	414.58	443.36	472.25

Table 5.2. Back calculated age-at-disc-width for female *Dasyatis marmorata capensis*.

		BACK CALCULATED DISC WIDTH (mm) AT SUCESSIVE BANDS														
AGE	n	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	18	173.71														
1	1	196.21	253.69													
2	0	-	-	-												
3	1	193.84	247.89	292.94	328.98											
4	2	193.34	268.39	301.27	343.24	390.11										
5	2	187.49	262.71	292.28	326.34	364.89	407.47									
6	5	207.35	273.69	304.94	336.36	369.47	402.14	437.54								
7	4	200.74	268.67	312.41	349.63	387.19	411.29	471.29	506.58							
8	2	198.76	255.86	293.01	320.88	362.44	408.90	446.05	486.77	523.93						
9	4	182.54	249.38	291.66	342.29	379.23	413.08	447.16	483.64	517.74	547.02					
10	5	188.52	257.37	293.55	333.06	369.25	398.84	426.64	457.67	490.60	525.03	552.87				
11	4	200.66	259.83	297.85	308.98	366.25	400.42	429.97	457.79	487.69	519.37	549.74	583.59			
12	5	178.63	230.83	262.93	304.72	343.59	361.25	401.09	430.29	458.83	489.80	521.23	558.89	600.86		
13	1	224.70	307.23	343.90	389.75	426.43	463.11	490.61	518.12	545.63	573.14	609.81	637.32	664.83	665.49	
14	2	179.19	223.26	250.51	286.24	317.96	341.82	369.66	397.45	421.25	449.04	472.85	496.64	528.38	560.07	
MEAN	DW	193.26	257.83	294.77	330.87	370.62	401.95	435.56	467.29	492.26	517.23	541.30	569.11	598.02	614.28	

Table 5.3. Calculated (A), mean observed (B) and mean back calculated (C) values of disc width at ages 0 - 9 and 0 - 14 in male and female *Dasyatis marmorata capensis* respectively.

	AGE(yrs)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	MAL	245.86	290.57	328.28	360.09	386.94	409.59	428.69	444.81	458.41	469.88	-	-	-	-	-
	FEM	245.87	291.01	333.08	372.32	408.89	443.00	474.81	504.46	532.10	557.88	570.59	604.33	625.22	644.71	662.87
B	MAL	249.12	301.30	330.00	368.00	384.86	417.14	437.52	441.25	454.44	485.14	-	-	-	-	-
	FEM	248.20	288.50	343.50	367.50	403.17	421.83	455.38	516.14	538.94	560.38	576.56	601.78	627.08	635.67	643.40
C	MAL	184.29	242.83	281.61	307.02	338.93	367.54	386.43	414.58	443.36	-	-	-	-	-	-
	FEM	193.26	257.83	294.73	330.87	370.62	401.95	435.56	467.29	492.26	517.23	541.30	569.11	598.02	614.28	-

Growth Under Captive Conditions

The observed growth of three specimens maintained under captive conditions is given in Figure 5.9. Considering that parturition occurs in November at a size of 170 - 200 mm disc width (Chapter 6), then extrapolation from observed growth rates indicates that all three specimens were approximately six months old when collected in May 1988. The mean annual growth for the first year after birth (1 November - 31 October) was calculated at 66.7 mm/year. Growth over the one year period from 1 September to 31 August was 69 mm/year. These growth rates are comparable to the value obtained from back calculations, for females, at 64.6 mm/year, but are higher than the calculated value at 45.1 mm/year. Branstetter (1987b) noted that seasonal fluctuations in temperature and light may be important controlling factors in growth and band formation. The mean monthly temperatures recorded in the porta-pool were comparable to the ambient surface sea temperatures, with the exception of slightly higher values during summer (Figure 5.10).

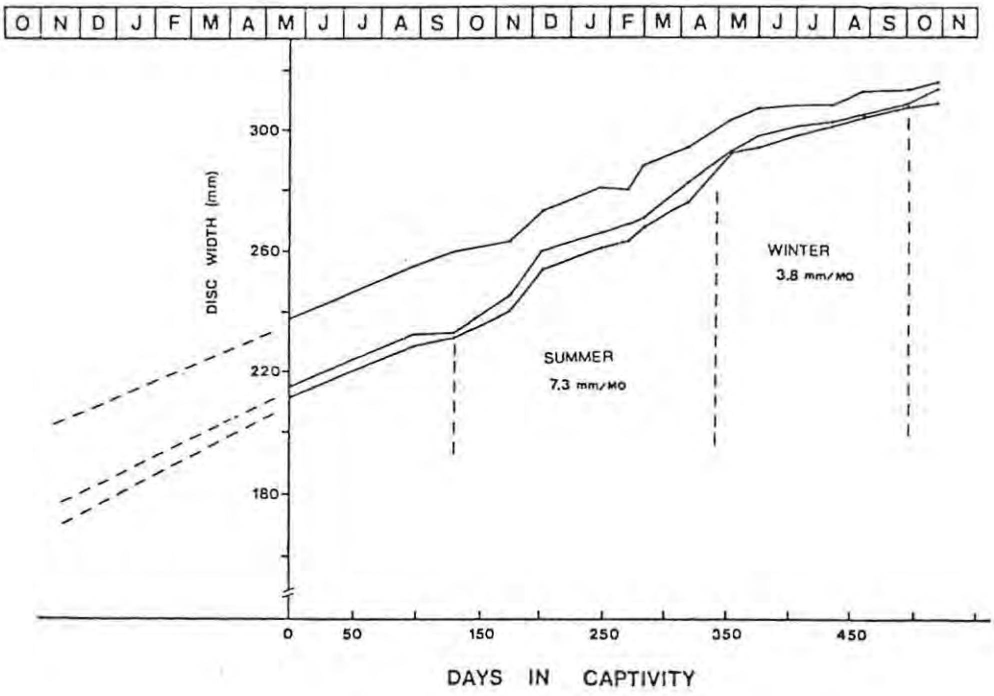


Figure 5.9 Observed growth increments of three Dasyatis marmorata capensis specimens kept in captivity between May 1988 and October 1989.

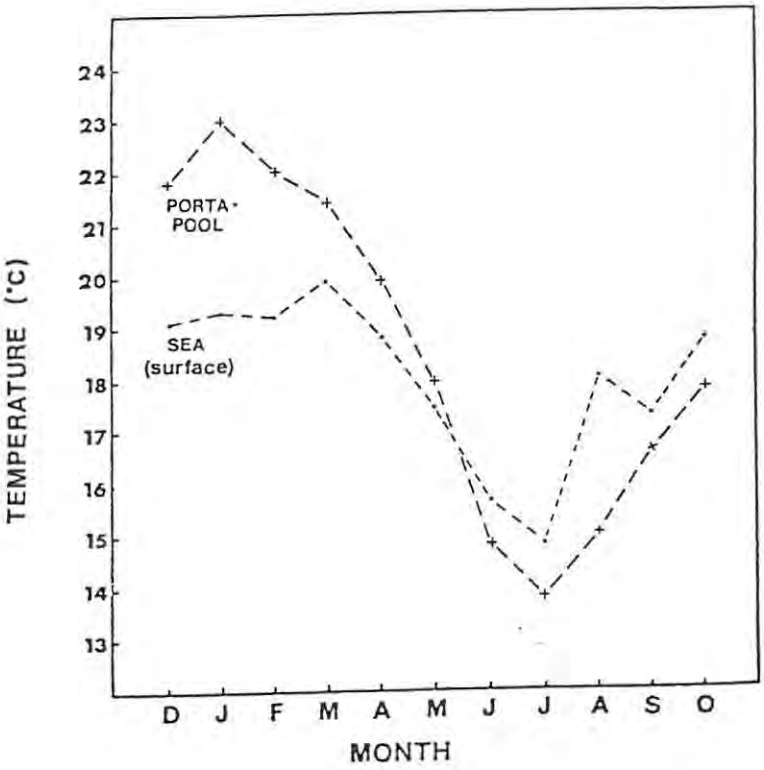


Figure 5.10 Mean surface sea and porta-pool temperatures in Port Alfred from December 1988 to October 1989.

Differences in seasonal growth were evident in the captive specimens. A mean monthly growth rate of 7.3 mm/month was calculated over the warmer period October to April, while a growth rate of 3.8 mm/month was calculated for the colder, May to September, period (Figure 5.9). These differential growth rates are supported by observations made on the captive specimens. During winter, feeding rates and general activity decreased considerably. The broad summer band and narrow winter band characteristics, clearly observed on the centra of the 0+ age class specimens, could be a direct result of this differential growth rate.

5.4 DISCUSSION

The use of vertebral centra band formation, as applied to ageing studies in elasmobranchs has been widely documented in the literature. In *Dasyatis marmorata capensis*, growth of the calcified centra provides a continuous record of body growth, as indicated by the direct relationship between disc width and centrum diameter. However, variation in band periodicity on the centra is the most important feature when attempting to age an animal. Results from most studies report the annual formation of one calcified opaque and one less calcified hyaline band in the centra, although Pratt & Casey (1983) showed that the shortfin mako *Isurus oxyrhinchus* produces two band pairs annually and Natanson *et al.* (1984) found no regular periodicity for band formation in *Squatina californica* (see Cailliet *et al.* 1986 for a review on age verification and validation).

The annual formation of one distinct opaque and one hyaline zone in the centra of *D. m. capensis* may be explained in the following way. Firstly, the observed differential growth rate of captive specimens between summer and winter suggests changes in the mineralization pattern in the centra due to varying environmental factors such as temperature or feeding activity. Secondly, free-swimming young-of-the-year captured in May (approximately six months of age) had both a birth band, formed *in utero*, and a clear broad band, but specimens collected in September (approximately 10 months old) contained an additional dark narrow band. Therefore, one clear broad band and one dark narrow band represent the annual band characteristics in *D. m. capensis*. These results indicate that the clear broad band is formed in summer from October to April and that the dark narrow band associated with slower growth is formed in the winter between May and September. The narrow false rings in the broad summer band are thought to result from changes in environmental conditions, such as spells of cold water upwelling, which have a marked effect on an animals' metabolism (see Chapter 3).

The growth parameters K and t_0, obtained from the von Bertalanffy equation, for several batoid species with an aplacental viviparous mode of reproduction are listed in Table 5.4. Holden (1974) stated that the calculated t_0 values should predict the gestation period, in years, for elasmobranchs. However, aplacental viviparity is an advanced reproductive mode (Wourms 1977), and t_0 values are over-exaggerated because of the much greater pre-parturition growth rate. Therefore, calculated t_0 values for species with this reproductive mode are meaningless and should be disregarded. Calculated t_0 values of -3.646 and -4.481 for male and female *D. m. capensis* respectively, were obtained in the present study. A known gestation period of approximately nine months, of which only five months is attributed to embryonic somatic growth, was observed for *D. m. capensis* (see Chapter 6).

Table 5.4. The von Bertalanffy parameters K and t_0 reported in six ageing studies conducted on batoid fishes with an aplacental viviparous mode of reproduction.

		MALES		FEMALES		SEXES COMBINED	
AUTHOR	SPECIES	K	to	K	to	K	to
Lessa (1982) in Martin & Cailliet (1988b)	*Rhinobatos horkelli*	-	-	-	-	0.194	-1.079
Rossouw (1983)	*Rhinobatos annulatus*	-	-	-	-	0.24	-
Edwards (1980)	*Urolophus paucimaculatus*	0.45	-0.57	0.21	-1.78	-	-
Martin & Cailliet (1988b)	*Mylidbatis californica*	0.229	-1.58	0.099	-1.935	-	-
Smith & Merriner (1987)	*Rhinoptera bonasus*	0.126	-3.699	0.119	-3.764	-	-
Present Study	*Dasyatis marmorata capensis*	0.175	-3.646	0.070	-4.481	-	-

Holden (1974) theorized that growth rates in the Batoidea typically have K values ranging between 0.2 - 0.3. These proposed values were based on growth data for rajoid skates which typically exhibit an oviparous reproductive mode. This fact could be attributed to the different growth rates obtained for the aplacental viviparous batoid fishes (Table 5.4).

Growth estimates for both sexes show a similar trend amongst batoid fishes. K values for Urolophus paucimaculatus (Edwards 1980), Myliobatis californica (Martin & Cailliet 1988b), Rhinoptera bonasus (Smith & Merriner 1987) and Dasyatis marmorata capensis (present study) are higher in males than in females. This illustrates a faster growth rate in males which attain their asymptotic length more quickly than females. It is hypotherized that this has important reproductive implications. As a result of the mating behaviour employed by viviparous batoids (Tricas 1980 ; McCourt & Kerstitch 1980), and the relatively large size of the offspring, it seems likely that females should attain a larger size (see Chapter 6).

CHAPTER 6 REPRODUCTION

6.1 INTRODUCTION

Elasmobranchs are phylogenetically amongst the oldest jawed vertebrates (Compagno 1973). In view of their long evolutionary history, which itself is a testimony to the continuing success of their reproductive strategies, they have received little attention in the context of reproductive biology.

The reproductive systems, structures and patterns amongst batoid fishes are poorly known. Wourms (1977) outlined the different modes of reproduction and presented brief notes on the reproductive systems, while Pratt (1988) described the gonad structure of a typical rajoid and commented on these structures in other batoids. Amongst the viviparous batoids, the most comprehensive study was conducted on *Urolophus halleri* (Babel 1967), while aspects of the reproductive biology, to varying degrees, are known for *Dasyatis centroura* (Struhsaker 1969), *D. americana* (Brockman 1975), *D. imbricatus* (Devadoss 1978), *D. pastinaca* (Capape 1976), *D. tortonesei* (Capape 1978), *D. sabina* (Snelson *et al.* 1988), *D. sayi* (Snelson *et al.* 1989), *Gymnura altavela* and *G. micrura* (Daiber & Booth 1960), *Urolophus concentricus* (McCourt & Kerstitch 1980), *Potomotrygon circularis* and *P. motoro* (Thorson *et al.* 1983), *Rhinobatos annulatus* (Rossouw 1983), *Rhinoptera bonasus* (Smith & Merriner 1986), *Myliobatis californica* (Martin & Cailliet 1988a), *Mobula thurstoni*, *M. japanica*, *M. munkiana* and *M. tarapacana* (Notarbartolo-di-Sciara 1988).

The reproductive biology of *Dasyatis marmorata capensis* is essentially unknown, with the exception of notes made by Wallace (1967b), van der Elst (1981) and Rossouw (1983). This chapter outlines the reproductive anatomy, size at sexual maturity, mode of reproduction, gestation period, embryonic development and reproductive seasonality in *Dasyatis marmorata capensis*.

6.2 MATERIALS AND METHODS

Reproductive information for both sexes of *Dasyatis marmorata capensis* was obtained from specimens collected along the entire southern African coastline between Durban (Natal) and Swakopmund (Namibia). Specimens were returned to the laboratory and examined immediately or frozen for later study. After being sexed, measured and weighed, the reproductive tracts and associated organs were examined. All specimens were assigned to one of four reproductive stages as follows : (1) embryo (2) immature (3) adolescent (4) mature. Specimens were considered immature if the gonads (ovaries or testes) were thin, flaccid and showed no signs of gonadal tissue differentiation. The onset of adolescence was determined by gonadal differentiation of ova in females and testicular lobes in males. The assessment of sexual maturity in males was based on the following criteria : (1) the presence of hard claspers, associated with the abrupt change in the relationship of clasper length and disc width, (2) the occurrence of coiling in the vasa deferentia and (3) the presence of sperm, as determined by applying pressure on the seminal vesicles. Maturity in females was determined by the presence of large yolked eggs in the ovaries, and well developed uteri with associated trophonemata. Female rays tended to abort uterine eggs or developing young after capture, so information on these was often lost (personal observations; Snelson *et al.* 1988). Furthermore, epigonal tissue tends to degenerate fairly rapidly and the fragile ova rupture. For these reasons a seasonal gonadosomatic index (GSI) for females could not be calculated. Whenever possible the diameter of the range of largest ova in the left ovary was measured with vernier calipers. The functional left uterus of all mature females was opened and its contents were recorded. In cases where developing young, were present the embryos were sexed and measured. A gonadosomatic index for males was calculated as :

GSI = (TESTES WEIGHT / BODY WEIGHT) X 100

6.3 RESULTS AND DISCUSSION

Description of Reproductive Apparatus

The reproductive anatomy of both sexes of Dasyatis marmorata capensis is similar to that previously described for other viviparous batoids (Babel 1967; Struhsaker 1969; Rossouw 1983; Thorson et al. 1983; Smith & Merriner 1986; Notarbartolo-di-Sciara 1988; Martin & Cailliet 1988; Snelson et al. 1988). Female reproductive anatomy consists of oviducts, nidamental glands, ovaries and uteri. As in other members of the genus Dasyatis, only the left ovary and uterus are functional (Bigelow & Schroeder 1953).

The ovaries are attached to the body wall by the mesovarian mesentary. Although only the left ovary is functional, both ovaries develop with the onset of maturity to produce ova of all sizes. Occasionally, no ova were observed in the right ovary. With increasing yolk deposition the ova coallesce and become bright yellow in colour. The smooth surfaced immature ovary is a pale white colour and contains no ova detectable to the naked eye. The functional mature ovary becomes vascularized and takes on a lumpy appearance on its ventral side. Detailed examination of 31 females showed that ovary length increased linearly with disc width (Figure 6.1). The left functional ovary was also consistently longer than the right ovary. Ovulated eggs are transported to the nidamental gland via the oviduct. Several functions have been ascribed to the nidamental gland, including albumin secretion, shell formation and sperm storage (Wourms 1977). It is assumed that eggs are fertilized in the nidamental gland, after which they are covered with a single thin walled capsule, and pass into the uterus. The functional left uterus is thick walled, highly vascularized and layered with trophonemata.

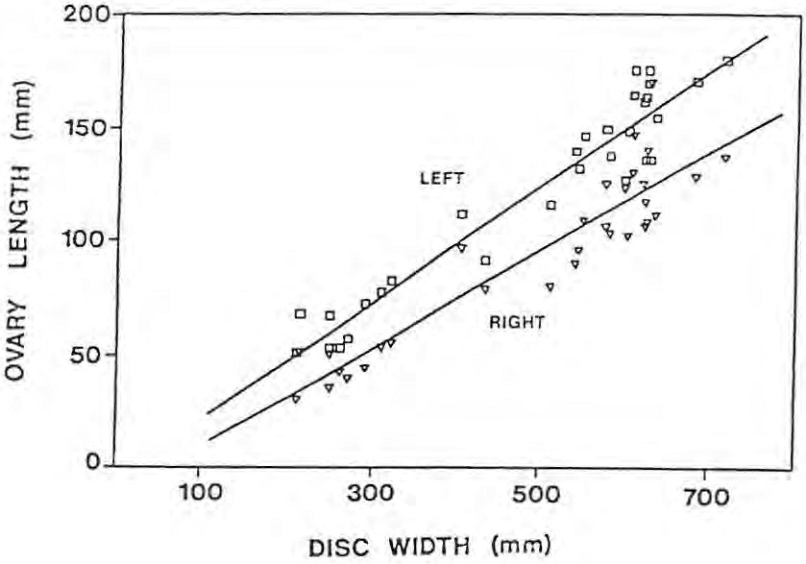


Figure 6.1. Left and right ovary lengths as a function of disc width for female Dasyatis marmorata capensis (n = 31). Linear regression : Left y = 0.254(x) - 2.30, r = 0.93 ; Right y = 0.212(x) - 10.33, r = 0.85.

The reproductive anatomy of male Dasyatis marmorata capensis consists of a pair of testes, efferent ducts, epididymi and seminal vesicles. The testes, containing approximately 14-22 testicular lobules, are attached to the body wall by the mesorchium. The posterior part of the testes forms the epigonal gland. Although both testes are functional, the left testis appeared to be slightly longer but less broad than the right testis. The mean length of the testes pair increased linearly with disc width (Figure 6.2). Variation in mean testes length in the larger (mature) males was due to individual differences in stages of development within a single reproductive season. Mature testes discharge spermatozoa via the efferent ducts, which in turn join the highly coiled epididymi, into the seminal vesicles where sperm maturation occurs. During copulation the claspers, each with an associated clasper gland and sac, release the sperm into the vagina of the female.

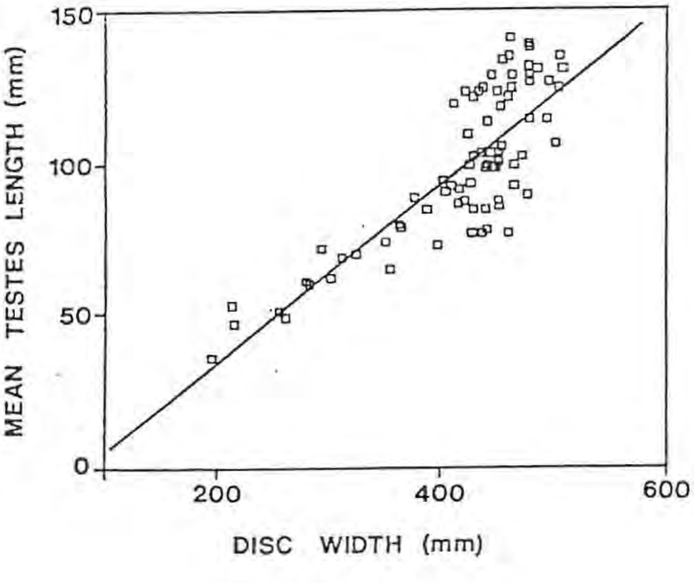


Figure 6.2. Mean testes length as a function of disc width in male Dasyatis marmorata capensis (n = 79). Linear regression : $y = 0.293(x) - 23.58$, $r = 0.68$.

Sexual Maturity

Indicators used to determine the different stages of maturity revealed that adolescence is attained at approximately the same size for both sexes. The smallest individual in which differentiation of ovarian tissue in females was first observed measured 379 mm disc width. In males, maturation of testicular tissue was first observed at 358 mm disc width (Figure 6.3). Values obtained for size at adolescence in both sexes correspond with an age of three years (Chapter 5). Sexual maturity is obtained earlier in males than in females, at a size of 408 mm disc width and at an age of five years. Changes in the relative size and hardness of claspers have been commonly used for determining sexual maturity in elasmobranchs. Several authors (Babel 1967; Struhsaker 1969; Devadoss 1978; Rossouw 1983; Smith & Merriner 1986; Martin & Cailliet 1988a; Snelson et al. 1988; Snelson et al. 1989) have shown that sexual maturity in male aplacental viviparous batoids is associated with an abrupt transition in the relationship of clasper length and disc width. This abrupt change in clasper length with the onset of maturity is associated with increased growth of additional cartilaginous elements in the claspers (Bigelow & Schroeder 1953). In D. m. capensis the change in clasper length to disc width relationship was observed at approximately 400 mm disc width, at an age of four to five years (Figure 6.4).

The occurrence of dense coiling in the vasa deferentia and enlarged seminal vesicles was also observed in all mature males (> 420 mm DW) (Figure 6.5).

Sexual maturity in females was determined by macroscopic examination of the ovaries and uteri. The left ovaries of all mature females were highly vascularized and contained large yellow ova with a maximum diameter of 5 to 13 mm. The presence of uterine eggs or developing embryos indicate that ovulation has

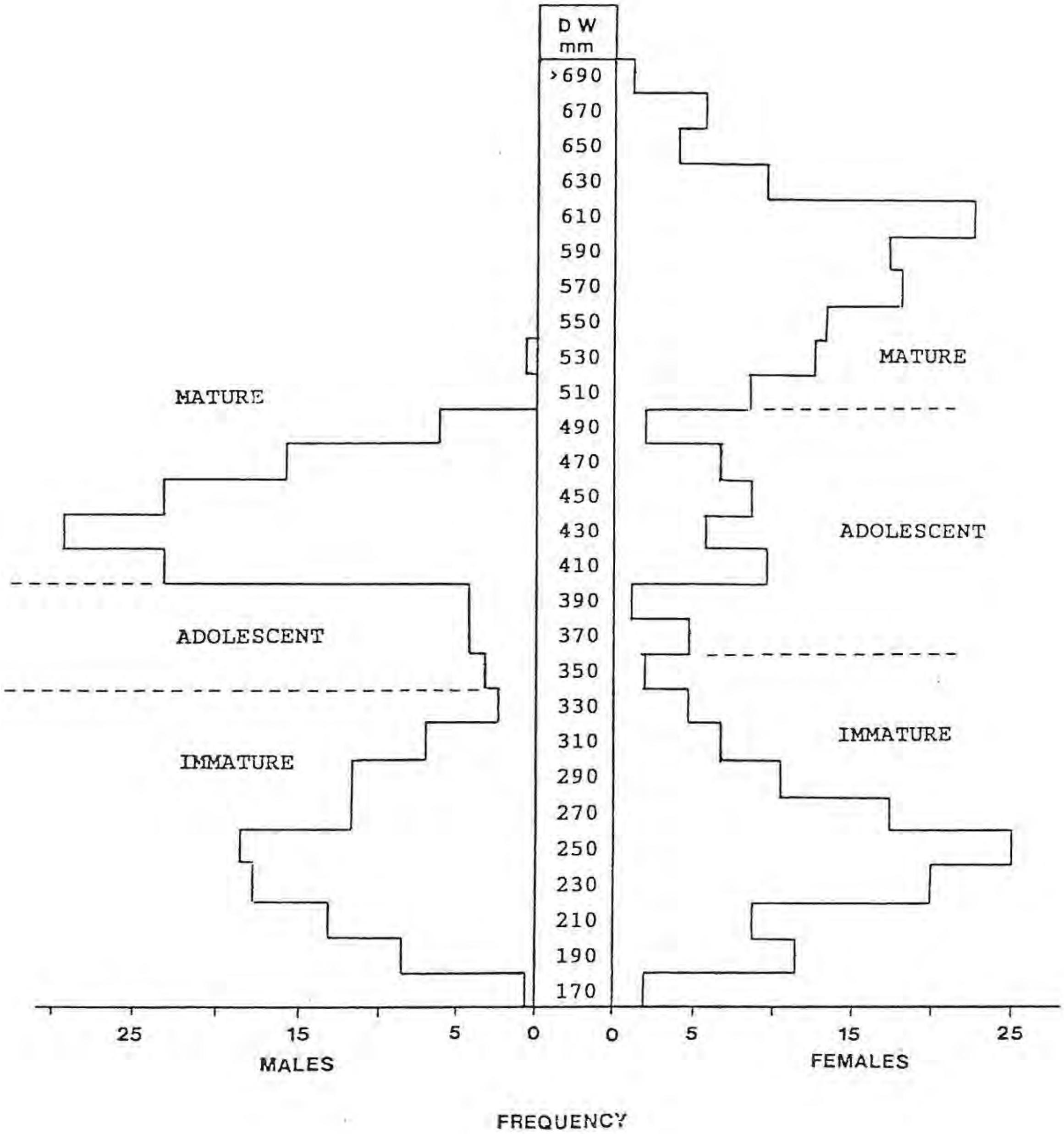


Figure 6.3. Disc width distribution frequency of immature, adolescent and mature male and female <u>Dasyatis marmorata capensis</u>.

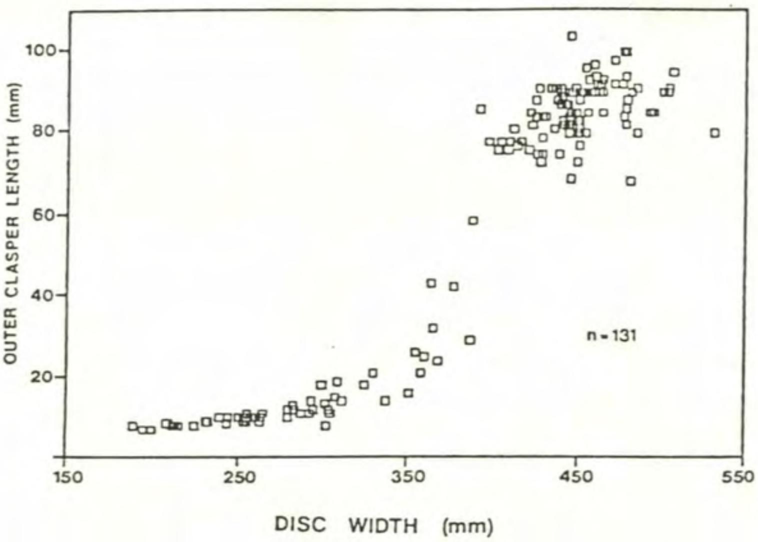


Figure 6.4. Outer clasper length as a function of disc width in male Dasyatis marmorata capensis.

Figure 6.5. The reproductive tracts of an adult male Dasyatis marmorata capensis. Note the densely coiled vasa deferentia and enlarged seminal vesicles.

occurred which in turn is indicative of sexual maturity. Size at first maturity was observed at 500 mm disc width (Figure 6.3), corresponding to an age of seven years (Chapter 5).

Mode of Reproduction

Dasyatis marmorata capensis typically exhibits an aplacental viviparous mode of reproduction, with placental analogues. These analogues occur in the form of villi-like extensions (trophonemata) of the uterine wall which secrete "uterine milk". The developing young obtain this histotroph via the mouth, spiracles or gill slits. This mode of reproduction appears to be common in the batoid fishes of the suborder Myliobatoidei and has been observed in *Urolophus halleri* (Babel 1967); *Dasyatis centroura* (Struhsaker 1969); *D. imbricatus* (Devadoss 1978), *Potamotrygon circularis* and *P. motoro* (Thorson *et al.* 1983); *Rhinoptera bonasus* (Smith & Merriner 1986) and *Myliobatis aquila*, *Pteromyleus bovinus* and *Gymnura natalensis* (personal observations). Wourms (1977) stated that the efficiency of this mode of reproduction surpasses that of the yolk sac placenta, in terms of increased organic material being made available to developing young, and may be regarded as evolutionarily more advanced.

Reproductive Seasonality

Wourms (1977) postulated that elasmobranchs exhibit one of three basic types of reproductive cycles : (1) being reproductively active throughout the year, (2) having a partially defined annual cycle with one or two peaks, or (3) having a well defined annual or biennial cycle. Most aplacental viviparous batoids exhibit a well defined annual breeding cycle (Babel 1967; Struhsaker 1969; Devadoss 1979; Rossouw 1983; Smith & Merriner 1986; Martin &

Cailliet 1988a; Snelson et al. 1988; Snelson et al. 1989). In most cases annual reproductive seasonality is associated with some form of migration. Peak abundance of sexually active individuals occurs in the warmer months, between spring and autumn, in the shallow coastal waters. While an offshore migration to deeper waters occurs in the winter (see Chapter 4).

Although no specimens of Dasyatis marmorata capensis were collected in the winter months (June, July and August), due to their offshore migration, sufficient evidence is presented that this species exhibits an annual breeding cycle. The correlated events in the breeding cycles of male and female D. m. capensis are outlined in Figure 6.6.

A mean monthly GSI for adult males is given in Figure 6.7. Maximum GSI values, associated with enlarged testicular lobules (14 to 25 mm diameter), were observed between September and October. With decreasing GSI values between November and December the spermatozoa are discharged from the testes and stored in the seminal vesicles, where sperm maturation occurs. During this period the seminal vesicles become enlarged as sperm accumulates in them. (Figure 6.5). Ripe running males were encountered between January and April, and during this period lowest GSI values were recorded. None of the 18 mature males captured in May 1988 contained sperm in their seminal vesicles, indicating that copulation occurred before May and hence prior to their winter offshore migration.

According to Holden (1974), it is often difficult to determine the reproductive cycle of elasmobranchs because of their migratory and schooling behaviour. This is pertinent to females, since the winter period in which no samples were collected represents an important stage in the reproductive cycle. For this reason, the precise length of the gestation period could not be determined. Furthermore, given that ovarian tissue and ova degenerate after capture, a monthly GSI for females could not be calculated. Similar problems have been

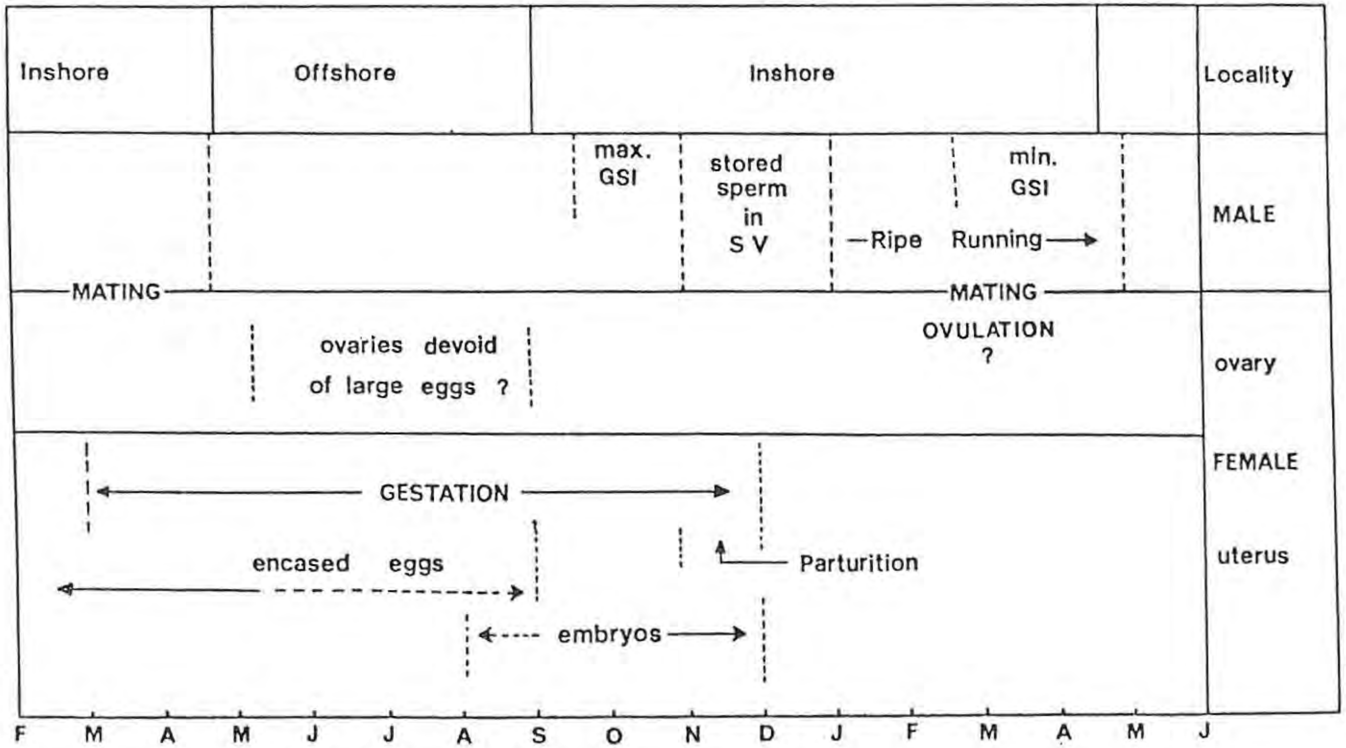


Figure 6.6. The correlated events in the breeding cycle of male and female Dasyatis marmorata capensis.

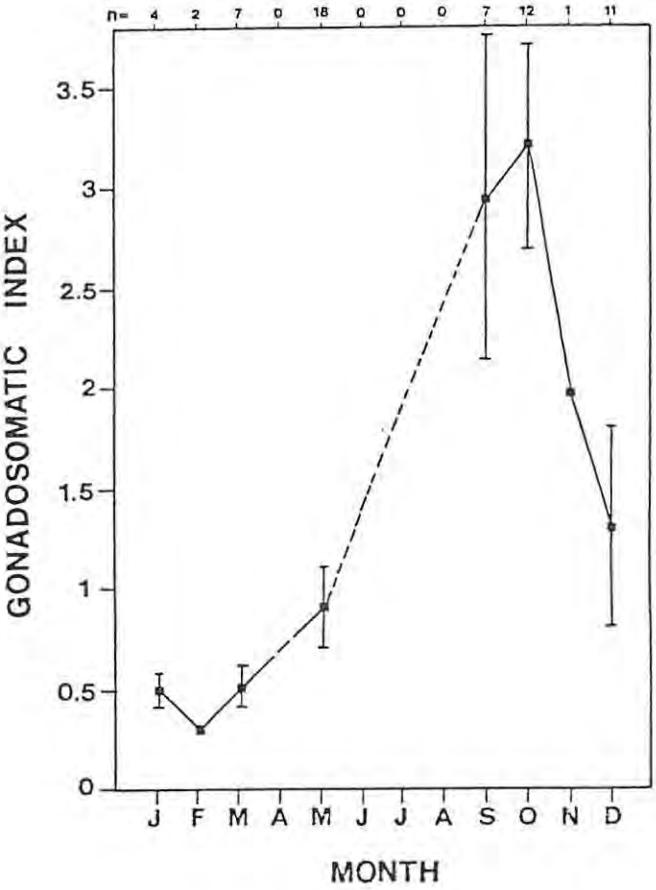


Figure 6.7. Mean monthly gonadosomatic indices for male Dasyatis marmorata capensis. Vertical bars = standard deviation.

encountered in studies on other aplacental viviparous batoid species (Smith & Merriner 1986; Martin & Cailliet 1988a).

Encased uterine eggs, without recognizable foetal development, were first observed in a specimen (640 mm DW) caught on 14 January 1989, indicating that ovulation starts soon after parturition. However, encased eggs were also observed in specimens caught between February and May, and also in September, suggesting a prolonged ovulation period. Prolonged ovulation has also been reported in *Dasyatis sayi* (Snelson *et al.* 1989). Mature females with large ovarian eggs, ranging between 8 and 14 mm diameter, were encountered between November and January. Furthermore, considering that no ripe running males were collected after April, it is felt that ovulation and hence fertilization occurs between January and April. Within this context, it is proposed that a reduction or cessation of embryonic growth occurs in the winter months because of high energy demands during the winter offshore migration. Rapid embryonic growth, on the other hand, occurs between September and the time of parturition. Parturition has been correlated with maximum uterus length and width, expressed as percentage of disc width, which occurs between November and December (Figure 6.8). Therefore, a gestation period of 9 months (February / March to November / December) seems most probable.

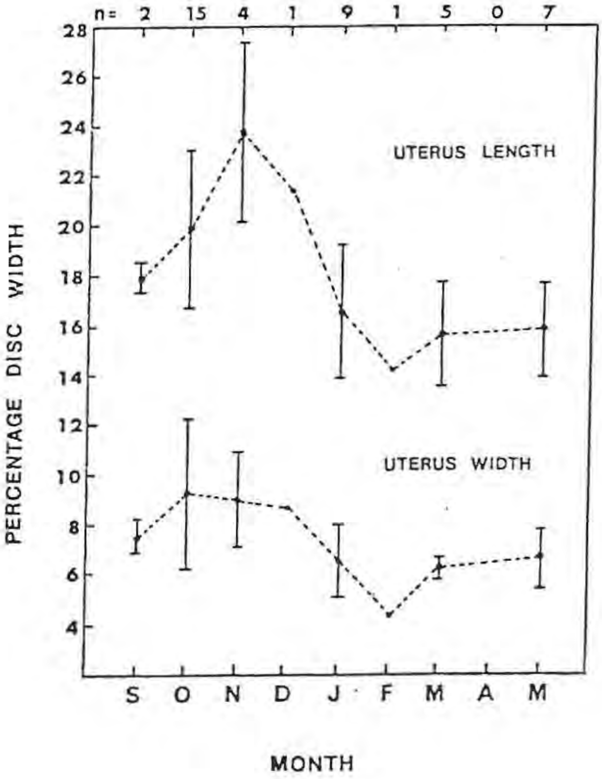


Figure 6.8. Mean uterus length and width, expressed as a percentage function of disc width in female *Dasyatis marmorata capensis*.

Fecundity

A direct relationship between size (age) of female and the number of young has been reported for several elasmobranchs (Olsen 1954; Babel 1967; Pratt 1979; Rossouw 1983; Parsons 1983). Martin & Cailliet (1988a) proposed that in Myliobatis californica litter size is ultimately limited by space, which is in turn determined by the size of the female, and suggested that fecundity might increase with the size of the parent in Myliobatis californica. No correlation (r = 0.208) between uterine fecundity and parent size was observed in Dasyatis marmorata capensis (Figure 6.9). An average fecundity of 3.07 (range 1 - 5) was calculated from 41 individuals carrying either uterine eggs or embryos. Compared to other dasyatid rays of similar size, fecundity of D. m. capensis is lower than that observed for Dasyatis pastinaca at 6.2 (Capape 1976) and D. tortonesei at 4.0 (Capape 1978), and similar to D. sayi at 3.5 (Snelson et al. 1989), but higher than that obtained for the smaller species D. sabina at 2.6 (Snelson et. al. 1988).

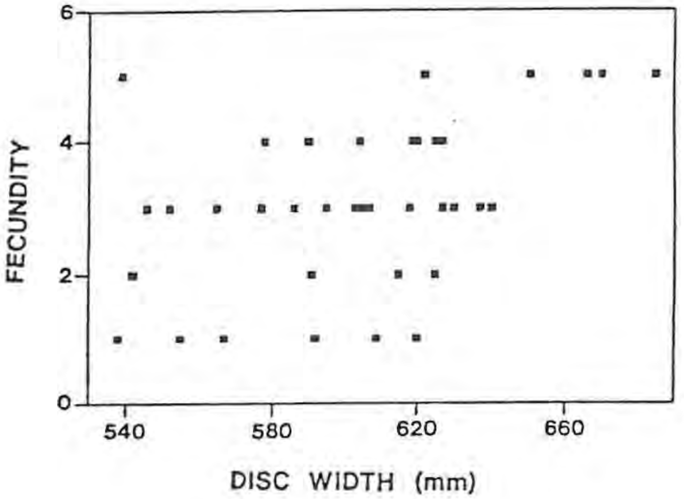


Figure 6.9. The relationship between uterine fecundity and disc width in female Dasyatis marmorata capensis.

The regular occurrence of infertile or non-developing eggs, resulting in a decreased fecundity of up to 7.7%, has been reported in Mustelus lenticulatus (Francis & Mace 1980). This observation has not been confirmed for any viviparous batoid, with the exception of a report of deformed embryos in Rhinobatos annulatus (Rossouw 1983). The reproductive success of D. m. capensis can thus be considered as high. Based on average fecundity, a single female produces 21.5 young in its lifetime, with an active reproductive lifespan of seven years (see Chapter 5).

Sex Ratio

A total number of 15 foetal young were collected from pregnant D. m. capensis during the sampling period. Of the 13 whose sex could be determined, eight (61.5%) were males and five (39.5%) were females. Although embryo numbers were low, the sex ratio is similar to the trend reported for other viviparous batoids. The following ratios, in favour of males, have been reported in the literature : 56% in Dasyatis sabina, 55.5% in D. americana (Breder & Krumholtz 1941 in Thorson et al. 1983), 61.5% in Urolophus halleri (Babel 1967), 56% in Potomotrygon circularis, 55.6% in P. motoro (Thorson et al. 1983) and 52.3% in D. sabina (Snelson et al. 1988) and 54.8% in D. sayi (Snelson et al. 1989).

A sex ratio of 1 : 1.03 ($x^2_{0.05}$ = 0.045 ; d.f. = 1) for all immature specimens of D. m. capensis captured in the offshore zone revealed a slight numerical superiority in favour of females (males = 98; females = 101). A ratio of 2.32 : 1 ($x^2_{0.05}$ = 9.921 ; d.f. = 1) in favour of males was obtained from all adolescent and mature specimens collected from the offshore zone. In contrast, adolescent and mature females outnumbered males (M29 : F62) in the surf zone, by a ratio of 1 : 2.14 ($x^2_{0.05}$ = 11.967 ; d.f. = 1). This supports the theory that mature females utilize sheltered bays in the inshore region as pupping grounds, and soon after birth the young move off into deeper waters (see Chapter 4).

Several studies have reported a sex ratio in favour of males _in utero_, but the ratio changes in favour of females when calculated for the entire population (e.g. Babel 1967). Two alternative suggestions are proposed to explain these changes in sex ratio. Firstly, because of the higher longevity in females (see Chapter 5), the age specific sex ratio should favour males until the age at which females outlive them. Therefore, by having a foetal sex ratio in favour of males implies an evolutionary means of attaining unity in the population sex ratio. Secondly, the higher sex ratio in favour of females amongst the larger fish can be attributed to sampling bias because of sexual segregation or size selection.

Mating Related Behaviour

Until fairly recently, the courtship and mating behaviour of viviparous batoids was essentially unknown (Tricas 1980; McCourt & Kerstitch 1980). Copulation in the wild was not observed in _Dasyatis marmorata capensis_. However, courtship or premating behaviour similar to that described for _Aetobatis narinari_ (Tricas 1980), was observed while diving beyond the breaker zone off Kenton-on-Sea (Eastern Cape) in March 1986. A large specimen (female ?) was observed lying on the bottom with four to five smaller rays (males ?) biting it on its pectoral and pelvic fins. After being prodded all the smaller rays swam off, and distinct biting scars were observed on the larger specimen (M. Griffiths, Department of Ichthyology and Fisheries Science, Rhodes University, pers. comm.). Biting scars were observed on only one other specimen (619 mm DW), captured on 14 January 1989 in the Kabeljous River surf (Eastern Cape) (Figure 6.10).

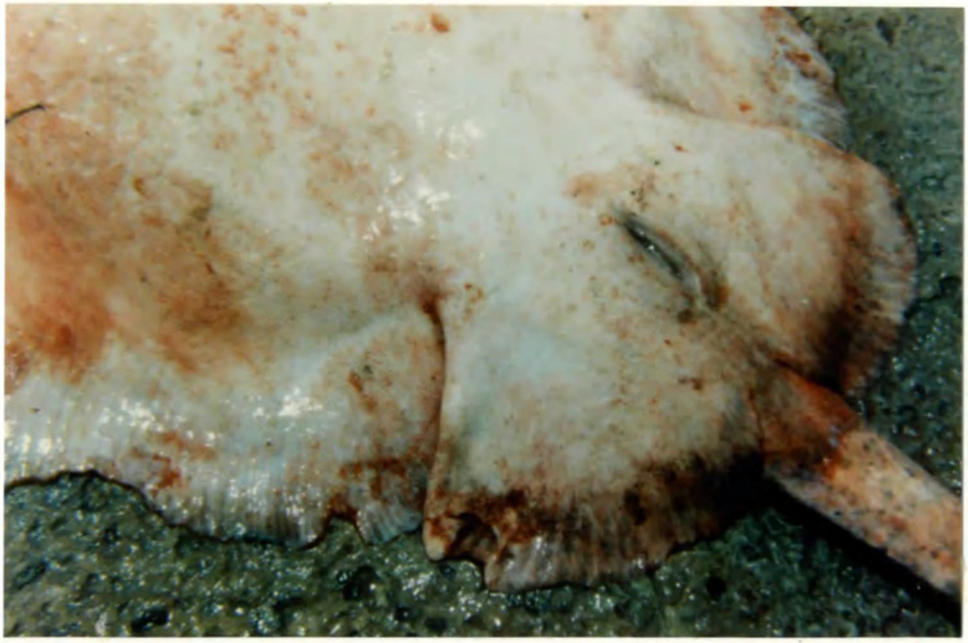


Figure 6.10. Mating scars on a female Dasyatis marmorata capensis, 619 mm disc width, captured on 14 January 1989.

Embryonic Development and Nutrition

Egg capsules containing between one and five ova were collected from 33 mature Dasyatis marmorata capensis females. The thin walled, brownish amber egg capsule is oval shaped, approximately 25-40 mm long and 20-30 mm wide with a mean weight (without ova) of 0.69 ± 0.22 grams (n=9). The yellow ova are extremely flaccid, about 12-18 mm in diameter with a mean weight, after preservation in 10 % formalin, of 1.70 ± 0.28 grams (n=30). At the early stages of gestation the uterus of the mother is fairly thick walled with the trophonemata poorly developed. However, just prior to parturition the uterus wall is thin and extended with its trophonemata highly vascularized and enlarged.

Embryos at seven different developmental stages, ranging from 13 mm to 172 mm disc width were collected, of which five are shown in Figure 6.11. The description of individual developmental morphology is as follows :

1) Embryo (13 mm DW) - This specimen was collected from a female (591 mm DW) with a uterus length of 121 mm and width of 66 mm, caught at Kasouga (Eastern Cape) on 21 October 1988. At this stage of development, the unencapsulated embryo was slightly more elongate than wide, was yellowish white in colour, with transparent poorly formed pectoral fins. Numerous highly vascularized external gill filaments protruded from the gill arches. Nutrition was from the yolk sac, which had an approximate diameter of 9 mm.

2) Embryo (43.5 mm DW, 39 mm DL) Figure 6.12 - This specimen, sex undetermined, was collected from a 620 mm DW female with a uterus length of 195 mm and width of 76 mm, caught at Hamburg (Ciskei) on 18 October 1987. The pale yellow embryo had no apparent pigment markings. The branchial region was highly vascularized with gill filaments still present. Nutrition was dependent on the yolk sac, which together with the yolk stalk had

Figure 6.11. A series of Dasyatis marmorata capensis embryos ranging between 43,5 mm and 172 mm disc width.

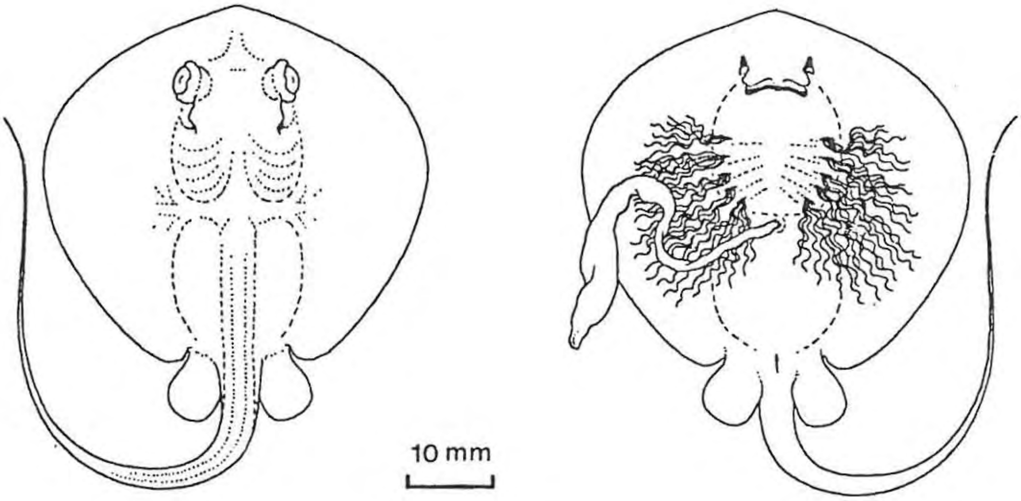


Figure 6.12. A diagrammatic representation of the dorsal and ventral views of a 43.5 mm disc width Dasyatis marmorata capensis embryo.

a length of 40 mm and maximum diameter of 4.5 mm.

3) Embryo (49 mm DW, 45 mm DL) Figure 6.13 - This specimen was one of two collected from a 625 mm DW female, with a uterus length of 121 mm and width of 60 mm, caught at Kasouga on 22 October 1988. The posterior region of the tail was darkly pigmented. Small gill openings were present on the outer margins of the gill arches, while the branchial filaments were absent. The yolk stalk and sac had a length of 48 mm and a maximum diameter of 5mm.

4) Embryo (male 72 mm DW, 67 mm DL) Figure 6.14 - This specimen was one of three collected from a 630 mm DW female with a uterus length of 188 mm and width of 76 mm, caught at Paradise Beach (eastern Cape) on 7 November 1987. Claspers in an early stage of development were observed. Upper and lower caudal folds were present on the dark pigmented tail. A small soft caudal spine, still well sheathed was present. Teeth were present on both the upper and lower jaws. Nutrition was by yolk supply ; the yolk stalk and sac had a length of 27 mm and a maximum diameter of 4.5 mm.

5) Embryo (female 76 mm DW, 70 mm DL) - This specimen was one of two collected from a 626 mm DW female with a uterus length of 112 mm and width of 60 mm, caught at Kasouga on 22 October 1988. The morphological characteristics were similar to the previous specimen, with the exception of a smaller yolk sac. The yolk stalk and sac had a length of 22 mm and a maximum diameter of 3 mm. Although nutrition was still by yolk supply, the decreased size of the yolk sac is indicative that histotroph (uterine milk) becomes the nutritional supplement soon after this development stage.

6) Embryo (male 133.5 mm DW, 119.5 mm DL) Figure 6.15 - This specimen was taken from a 538 mm DW female with a uterus length of 115 mm and a width of 70 mm, caught at Kasouga on 22 October 1988. The dorsal surface of the disc was well pigmented with a

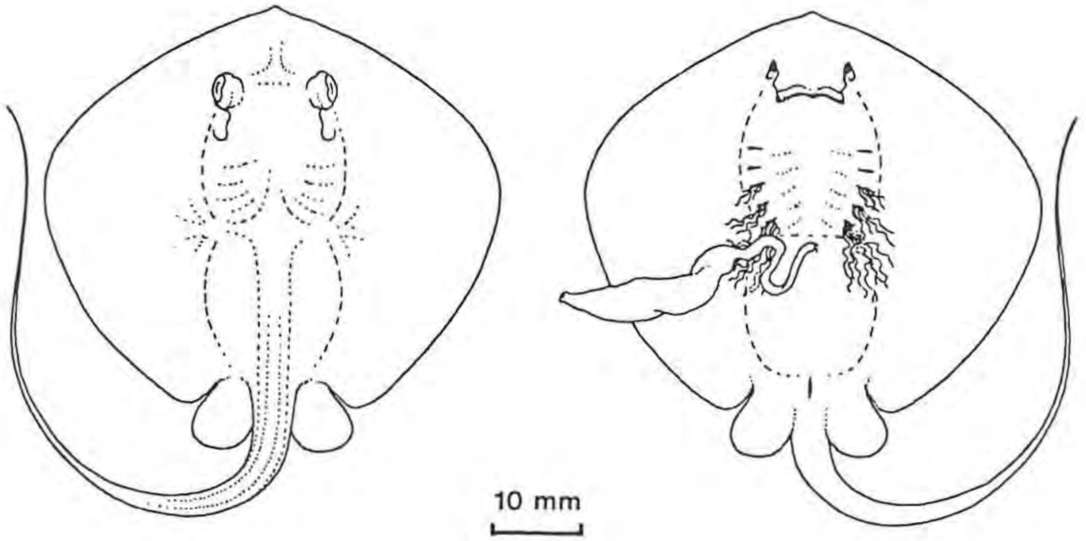


Figure 6.13. A diagrammatic representation of the dorsal and ventral views of a 49 mm disc width *Dasyatis marmorata capensis* embryo.

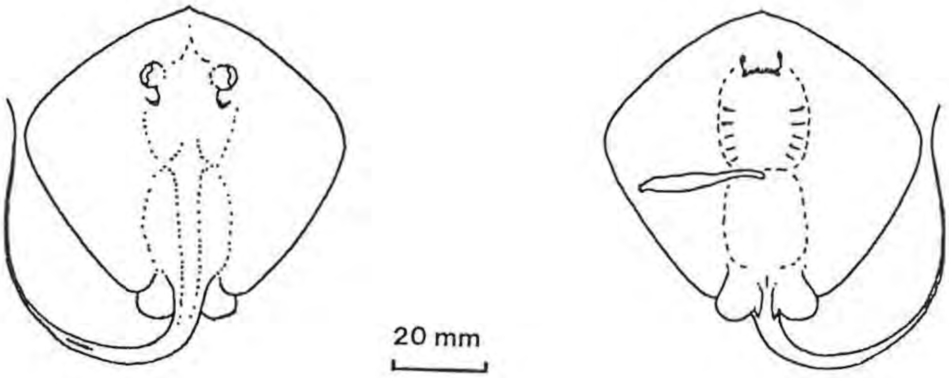


Figure 6.14. A diagrammatic representation of the dorsal and ventral views of a 72 mm disc width *Dasyatis marmorata capensis* embryo.

pattern resembling that of an adult. The dorsal colouration was light brown and grey with the characteristic sea blue base colour absent. The ventral pectoral margins were dark. The caudal spine was clearly visible but still sheathed and the upper and lower caudal folds were well formed. The yolk stalk and sac were absorbed, with only a 1 mm umbilicus protruding from the abdomen. Nutrition by this stage was solely dependent on histotroph secreted by the well developed trophonemata.

7) Embryo (female 172 mm DW, 144 mm DL) Figure 6.16 - This specimen was taken from a 567 mm DW female with a uterus length of 148 mm and width of 68 mm, caught at Uvongo (Natal) on 15 October 1988. The dorsal colouration resembled that of an adult. The caudal spine with serrations was no longer sheathed. The yolk stalk and sac were completely absorbed, leaving only a small umbilical scar that is evident on free swimming young. The uterus of the mother was filled with soup-like yellow histotroph, in which the embryos are bathed for nutrition. This embryo represents a full-term fetus and compares favourably with the size of young-of-the-year specimens collected in May 1988. The size range of specimens collected in May 1988 (approximately six months old) was 174 - 251 mm disc width.

6.4 CONCLUSION

This chapter has outlined aspects of the reproductive biology of Dasyatis marmorata capensis. However, the reproductive seasonality in females remains somewhat unclear. Snelson et al. (1989) suggested two alternative explanations regarding the prolonged period of Dasyatis sayi females carrying encased uterine eggs : (1) that fertilization of uterine eggs occurs sometime after mating from sperm stored by the female; or (2) that fertilization occurs shortly after ovulation but zygote development is arrested for a lengthy period of time. Because

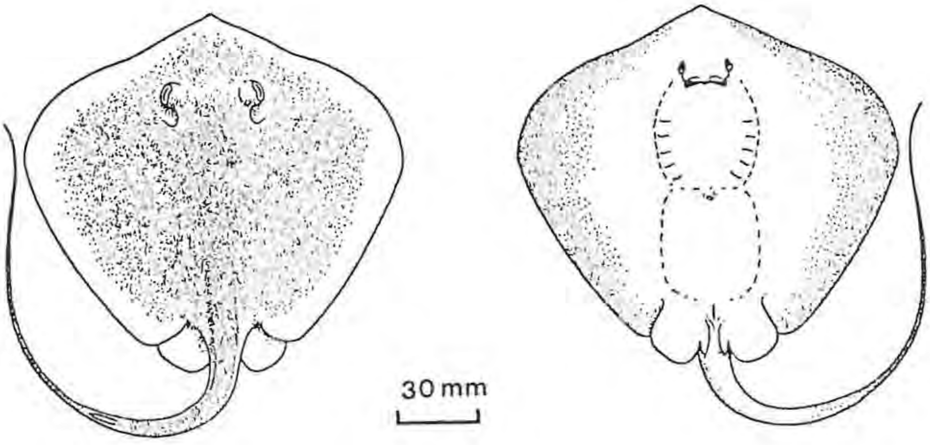


Figure 6.15. A diagrammatic representation of the dorsal and ventral views of a 133.5 mm disc width Dasyatis marmorata capensis embryo.

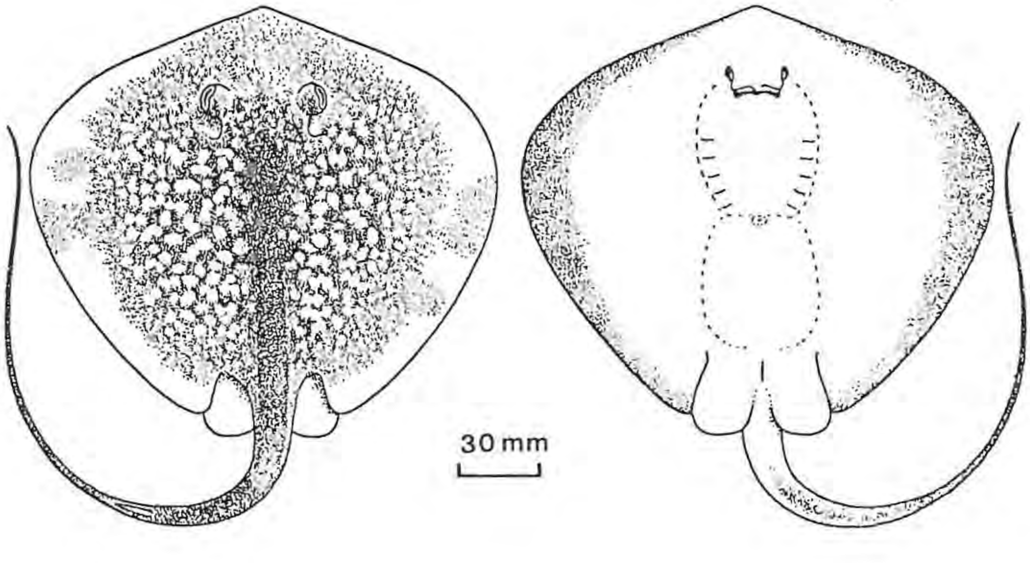


Figure 6.16. A diagrammatic representation of the dorsal and ventral views of a 172 mm disc width Dasyatis marmorata capensis embryo.

the uterine eggs of viviparous batoids are encased at least until the early stages of foetal development, the first alternative seems unlikely. It is proposed that the arrested zygote development in D. m. capensis is a result of the winter offshore migration, during which time the female has a high energy demand. Examination of mature females from the winter months, along with histological studies, should confirm the reproductive seasonality by determining the time of ovulation and hence the precise gestation period.

CHAPTER 7 FOOD AND FEEDING HABITS

7.1 INTRODUCTION

Studies on the food and feeding habits of fishes not only reveal what prey items are taken, but are also helpful in gaining an understanding of trophic interrelationships in an ecosystem (Hacunda 1981). Furthermore, biological interactions such as predation and competition by co-occurring species are essential for understanding community organization within an ecosystem.

The ecological importance of batoid fishes has been outlined in several recent studies. Smith & Merriner (1985) noted that feeding schools of *Rhinoptera bonasus* inflict serious damage to commercial oyster beds and natural eelgrass beds in Chesapeake Bay on the east coast of the United States. In the Eastern Cape, Rossouw (1983) studied elasmobranchs with particular emphasis on the ecology of *Rhinobatos annulatus* and stated these and other batoids form an important component as predators in the surf zone. Due to the abundance of *Dasyatis marmorata capensis* during the summer (Lasiak 1982; see Chapter 4), it was suggested that an investigation of its feeding biology would contribute to the better understanding of sandy beach ecology (Rossouw 1983). No quantitative data on the food habits of *Dasyatis marmorata capensis* have been published. However, notes given by Wallace (1967b), van der Elst (1981), Rossouw (1983) and Compagno *et al.* (1989) indicate that blue rays feed on a variety of benthic invertebrates and small fishes.

The objectives of the present investigation were three-fold. The first was to establish the spatial and size-related diet of *Dasyatis marmorata capensis*. Secondly, to examine its importance as a predator in the surf zone as suggested by Rossouw (1983), and thirdly, to determine its feeding behaviour.

7.2 MATERIALS AND METHODS

Stomach samples were obtained from specimens caught by rock and surf anglers (surf zone), light tackle ski-boat anglers (nearshore zone) and trawling aboard the R.V. Africana (offshore zone). Stomachs were cut open as soon as possible after capture and the contents preserved in 10% formalin for subsequent analysis. Spiral valve contents were in an advanced state of digestion and therefore ignored.

On reviewing the literature on stomach content analyses, Hyslop (1980) stated that no single method would give a complete picture of dietary importance. He suggested that at least one method for measuring the amount and one method for measuring the bulk of food should be used. The reason for this is that numerical methods overestimate the importance of small prey items, while weight measurements favour large items which take longer to digest completely.

The following methods were used for the analyses of D. m. capensis stomachs (after Hynes 1950; Hyslop 1980) :

i) Frequency of occurrence (%F) : The number of stomachs which contained one or more individuals of each food category was recorded and expressed as a percentage of all the stomachs which contained food.

ii) Numerical method (%N) : The number of individuals in each food category were counted and totalled for all stomachs, and expressed as a percentage of all individuals in all food categories.

iii) Weight method (%M) : Each food item was weighed and the weights of individuals in each category were totalled and expressed as a percentage of the total weight of all prey items.

The results from all three methods were combined to obtain an index of relative importance (IRI). In the present study a modification of the IRI used by Pinkas et al. (1971) was used, by replacing percentage volume with percentage weight :

$$IRI = \%F\ (\%N + \%M)$$

The analyses of stomach contents were then compared on the basis of spatial and size-related differences. The dietary importance of the major prey species or group are expressed as a percentage of total IRI.

The feeding behaviour of three rays kept in captivity in a porta-pool at the Rhodes University laboratory in Port Alfred was observed. Live sand prawns, Callianassa kraussi were introduced to the porta-pool and allowed to settle in the sand substrate, to simulate the natural environment. The food searching and prey seizing behaviour was then observed and noted.

7.3 RESULTS

Food Composition

A total of 369 stomachs were examined, of which 315 (85.6%) contained prey items. Results of the quantitative stomach content analyses of all Dasyatis marmorata capensis captured during the study period are listed in Table 7.1.

The phylum of prey items appearing in most stomachs (%F) were arthropods, chordates, annelids, molluscs and nemertea in order of importance. In terms of highest numbers and total prey weight, arthropods dominated (41.7 %N, 43.8 %M), followed by annelids and

Table 7.1. The incidence of various species or groups of organisms represented in the food of all *Dasyatis marmorata capensis* collected between March 1987 and May 1989.

PREY ITEM	F	%F	N	%N	M	%M
NEMERTEA Unidentified	47	14,9	255	6,2	34,83	1,7
SIPUNCULIDA Unidentified	3	1,0	17	0,4	26,4	1,3
ECHIURIDA						
Unidentified spp.	13	4,1	57	1,4	34,27	1,6
Ochoetostoma sp.	2	0,6	16	0,4	23,59	1,1
ANNELIDA						
POLYCHAETA Unidentified	193	61,3	1115	27,2	465,44	22,4
ARTHROPODA						
CRUSTACEA Unidentified	26	8,3	118	2,9	34,38	1,7
STOMATOPODA						
Pterygosquilla armata capensis	20	6,3	144	3,5	267,07	12,9
ANOMURA						
Callianassa spp.	61	19,4	327	8,0	384,53	18,5
AMPHIPODA Unidentified	105	33,3	567	13,8	21,78	1,0
ISOPODA Unidentified	17	5,4	27	0,7	8,12	0,4
COPEPODA Unidentified	4	1,3	4	0,1	1,29	0,1
MYSIDACEA Unidentified	40	12,7	71	1,7	5,07	0,2
Gastrosaccus psammodytes	4	1,3	4	0,1	0,4	0,0
MACRURA						
PENAEIDEA (?*Funchalia* spp.)	35	11,1	100	2,4	29,71	1,4
Macropetasma africana	1	0,3	2	0,0	0,8	0,0
CARIDEA (?*Processa* spp.)	50	15,9	145	3,5	22,27	1,1
BRACHYURA Unid. Larvae	11	3,5	68	1,7	8,89	0,4
BRACHYURA Unidentified	17	5,4	35	0,9	27,4	1,3
Ovalipes punctatus	6	1,9	7	0,2	15,18	0,7
Thaumastoplax spiralis	18	5,7	33	0,8	21,7	1,0
Mursia cristimanus	13	4,1	41	1,0	25,08	1,2
Neopilumnoplax sp.	5	1,6	9	0,2	14	0,7
Goneplax rhomboides	2	0,6	9	0,2	24,71	1,2
MOLLUSCA						
PELECYPODA Unidentified	36	11,4	71	1,7	29,17	1,4
Donax spp.	13	4,1	125	3,0	106,17	5,1
GASTROPODA						
Bullia sp.	1	0,3	1	0,0	3,4	0,2
CHORDATA						
HEMICHORDATA						
Balanoglossus capensis	53	16,8	520	12,7	325,88	15,7
PISCES Unidentified	31	9,8	59	1,4	32,28	1,6
Bregmaceros sp.	30	9,5	110	2,7	19,57	0,9
Gobius sp.	4	1,3	24	0,6	31,17	1,5
Gonorhynchus gonorhynchus	3	1,0	5	0,1	13,39	0,6
Cynoglossus spp.	3	1,0	5	0,1	10	0,5
Gnathophis sp.	2	0,6	2	0,0	2,74	0,1
Engraulis capensis	5	1,6	7	0,2	6,51	0,3
TOTALS			4100	100	2077,2	100

chordates.

The prey groups or species which contributed to the highest frequency of occurrence were polychaetes, amphipods, Callianassa spp., Balanoglossus capensis and caridae. The most numerous prey species or groups were polychaeta, amphipoda, Balanoglossus capensis and Callianassa spp., and those which contributed to the greatest portion of total prey weight were polychaeta, Callianassa spp., Balanoglossus capensis, Pterygosquilla armata capensis and Donax spp. (Table 7.1).

Food Preference by Habitat and Size

Surf Zone

Results of stomach contents analyses in D. m. capensis of three size classes (300 - 450 mm ; 450 - 600 mm ; › 600 mm), captured in the surf zone are listed in Table 7.2. The dietary importance of the major groups or species are shown in Figure 7.1. Of the 100 stomachs examined from this zone, only 39 contained prey items.

The major prey organisms of both the 300 - 450 mm and 450 - 600 mm size classes were pelecypods (Donax spp.), which contributed 63.2% and 64.9% towards the IRI, respectively (Figure 7.1). In the 300 - 450 mm size class, the other major prey items in order of importance included echiurida, brachyura, polychaeta and Callianassa spp., which collectively contributed 35.6% towards the IRI. In the 450 - 600 mm size class the other major prey items were polychaeta (23.9% of the IRI) and to a lesser extent echiurida, brachyura and Callianassa spp. A marked change in the food composition was observed in the › 600 mm size class. The major prey item was Callianassa spp. which contributed 83.1% towards the IRI, while brachyura, echiurida and polychaeta

Table 7.2. The food composition of three size classes of *Dasyatis marmorata capensis* collected in the surf zone.

	300-450 mm				450-600 mm				›600 mm			
PREY ITEM	%F	%N	%M	IRI	%F	%N	%M	IRI	%F	%N	%M	IRI
SIPUNCULIDA Unidentified					4,3	5,33	2,33	11,96				
ECHIURIDA												
Unidentified spp.	44,4	8,3	6,6	661,56	8,7	3,34	5,7	78,65	14,3	12	9,1	301,73
Ochoetostoma sp.	11,1	1,3	8,3	106,56	4,3	9,34	11,2	88,32				
ANNELIDA												
POLYCHAETA Unidentified	22,2	10,9	6,7	390,72	26,1	17,33	23,2	1057,83	28,6	4	4,1	231,66
ARTHROPODA												
STOMATOPODA	11,1	1,9	0,7	28,86								
ANOMURA												
Callianassa spp.	11,1	3,8	251,7	283,05	13	6,66	4,5	145,08	42,9	62,7	66,4	5538,39
AMPHIPODA Unidentified	11,1	0,65	0,2	9,44								
ISOPODA Unidentified	11,1	0,65	0,2	9,44								
MYSIDACEA												
Gastrosaccus psammodytes	11,1	0,65	0,2	9,44	13	2	0,2	28,6				
PENAEIDEA												
Macropetasma africana									14,3	2,7	1	52,91
BRACHYURA Unid. Larvae	11,1	34,6	11,5	511,71								
BRACHYURA Unidentified	11,1	0,65	0,3	10,55	13	3,34	0,93	55,51	14,3	14,7	13,8	407,55
Ovalipes punctatus					8,7	2	5	60,9	14,3	1,3	0,7	28,6
Thaumastoplax spiralis					8,7	2,66	0,54	27,84				
MOLLUSCA												
PELECYPODA Unidentified	33,3	3,9	4	263,07					14,3	1,3	0,8	30,3
Donax spp.	44,4	32,7	39,6	3210,12	30,4	48	46,4	2869,76				
GASTROPODA												
Bullia sp.									14,3	1,3	4,1	77,2

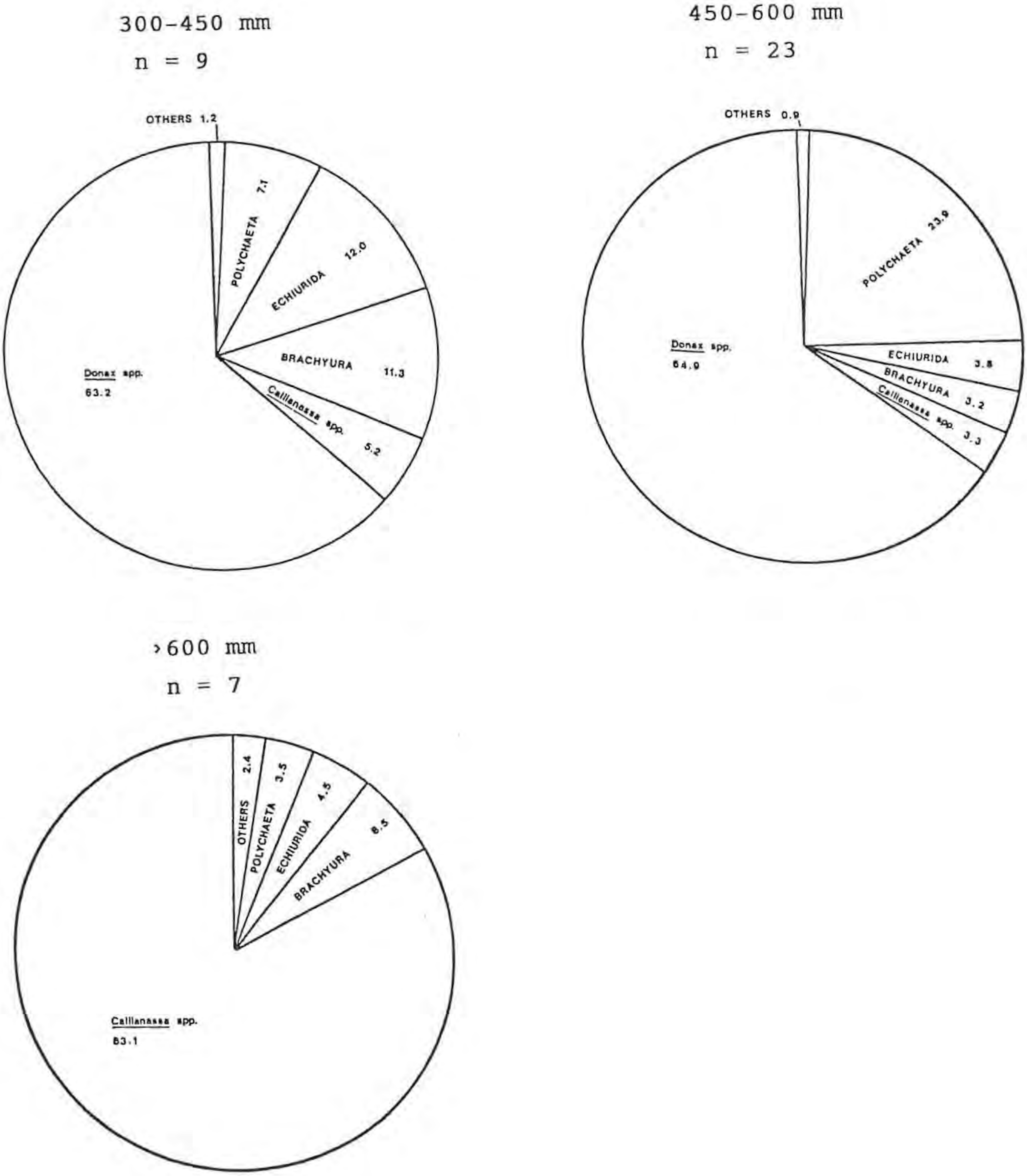


Figure 7.1. A comparison of the major prey species or groups in the stomachs of three size classes of Dasyatis marmorata capensis captured in the surf zone.

collectively only contributed 14.5% (Figure 7.1). In contrast to the smaller size classes pelecypods were absent in the › 600 mm size class.

Nearshore Zone

All prey items found in the stomachs of *D. m. capensis* captured in the nearshore zone are listed in Table 7.3. The major dietary categories, expressed as a percentage of the total IRI are given in Figure 7.2. Prey organisms were present in 77 of the 95 stomachs examined from this zone.

The major prey species were *Balanoglossus capensis* and *Callianassa* spp., which collectively contributed 97.9, 94.4 and 99.3% towards the IRI in the 300 - 450 mm, 450 - 600 mm and › 600 mm size classes, respectively. A decrease in the importance of *B. capensis* was observed with an increase in predator size, while the inverse was true for *Callianassa* spp. The contribution of all other dietary items for each size class were relatively insignificant (Table 7.3, Figure 7.2).

Offshore Zone

The food composition for *D. m. capensis* captured in the offshore zone are listed in Table 7.4, and the major prey groups or species, expressed as a percentage of the IRI are given in Figure 7.3. This zone was well represented by the presence of small individuals, hence includes the food habits of an additional size class (those ‹ 300 mm). The stomachs of 206 specimens were examined, of which 199 contained prey items.

Polychaeta constituted the major prey group in the ‹ 300 mm, 300 - 450 mm and 450 - 600 mm size classes, and contributed to 61.1,

Table 7.3. The food composition of three size classes of *Dasyatis marmorata capensis* captured in the nearshore zone.

	300-450 mm				450-600 mm				›600 mm			
PREY ITEM	%F	%N	%M	IRI	%F	%N	%M	IRI	%F	%N	%M	IRI
ANNELIDA												
POLYCHAETA Unidentified	9,1	3,2	2,4	50,96	21,4	11,1	5	344,5	15,4	3,1	0,9	61,6
ARTHROPODA												
Callianassa spp.	59,1	22,1	30,6	3114,57	59,5	25,8	35,9	3671,2	69,2	35,2	41,9	5335,32
MYSIDACEA Unidentified	13,6	1,2	0,2	19,04	4,8	0,7	0,1	3,8				
PENAEIDEA Unidentified	4,5	0,8	0,5	5,85								
BRACHYURA Unidentified					7,1	0,7	0,3	7,1				
Ovalipes punctatus					4,8	0,5	1	7,2	7,7	0,5	2,4	22,33
Thaumastoplax spiralis	27,2	3,6	3,3	187,68	23,8	4,9	5,1	238				
MOLLUSCA												
PELECYPODA												
Donax spp.	4,5	0,4	1,4	8,1	2,4	0,25	1	3				
CHORDATA												
HEMICHORDATA												
Balanoglossus capensis	81,8	68,3	58,8	10396,78	61,9	55,8	50,2	6561,4	69,2	61,2	54,8	8096,4
PISCES Unidentified	4,5	0,4	2,8	14,4	2,4	0,25	1,4	4				

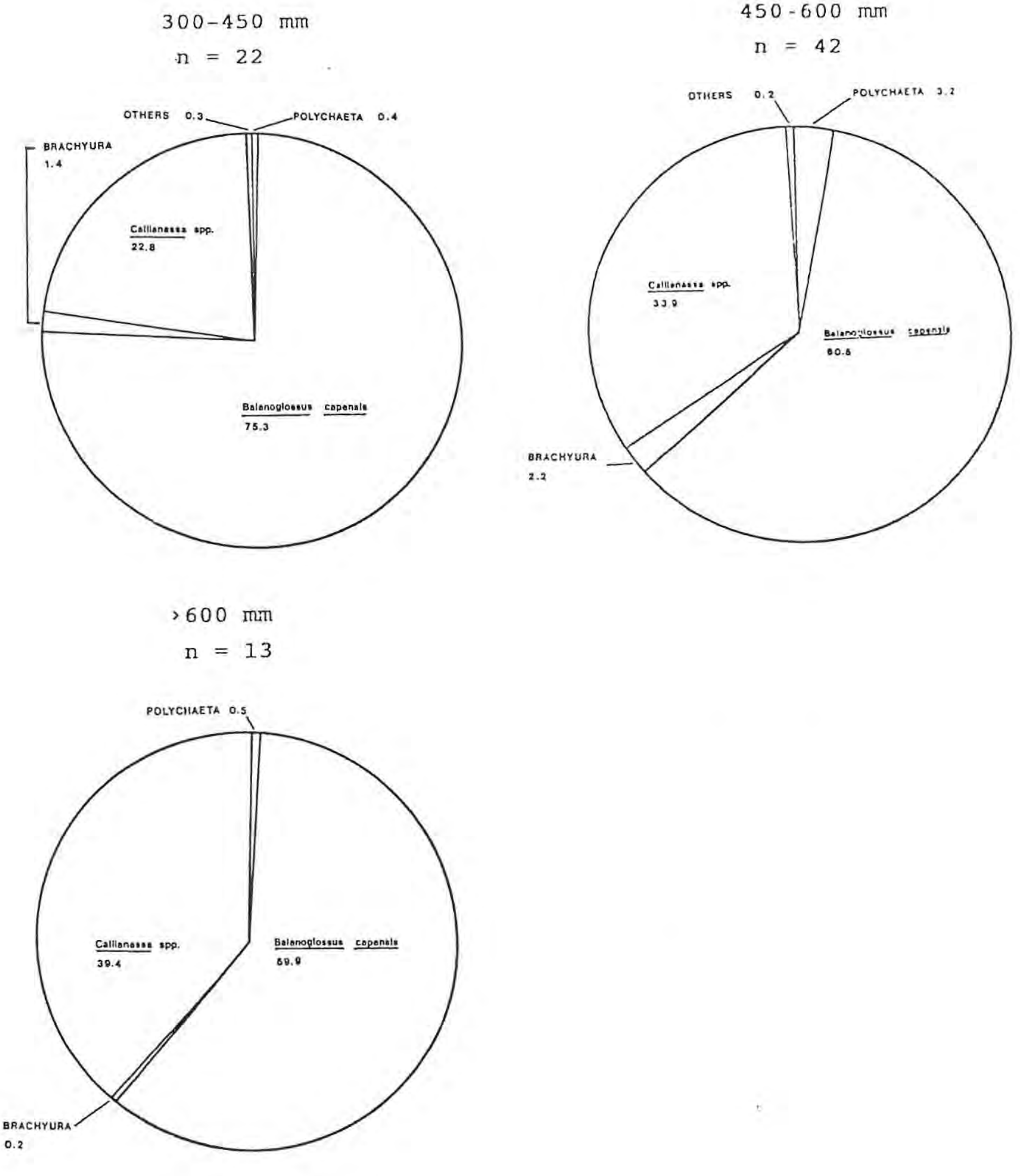


Figure 7.2. A comparison of the major prey species or groups in the stomachs of three size classes of *Dasyatis marmorata capensis* captured in the nearshore zone.

Table 7.4. The food composition of four size classes of *Dasyatis marmorata capensis* captured in the offshore zone.

	<300 mm				300-450 mm				450-600 mm				>600 mm			
PREY ITEM	%F	%N	%M	IRI	%F	%N	%M	IRI	%F	%N	%M	IRI	%F	%N	%M	IRI
NEMERTEA Unidentified	26,1	6,1	7,8	362,79	27,4	18,8	8,2	739,8	5,9	0,4	0,4	4,72				
SIPUNCULIDA Unidentified					1,6	0,1	0,6	1,12					11,1	3,6	4,7	92,13
ECHIURIDA Unidentified	4,5	1,7	4,1	26,1	1,6	0,5	2,6	4,96								
ANNELIDA																
POLYCHAETA Unidentified	86,5	34,8	42	6643,2	87,1	38,8	53,3	8021,91	76,5	39,8	33,4	5599,8	77,8	19,7	21,1	3174,24
ARTHROPODA																
CRUSTACEA Unidentified	13,5	6,1	3,1	124,2	14,5	2,2	3,6	84,1					22,2	3,2	4,5	175,38
STOMATOPODA																
Pterygosquilla armata capensis	2,7	0,3	0,2	0,72	9,7	0,9	5	57,23	23,5	15,5	26,4	984,65	66,7	40,3	39,1	5295,98
ANOMURA																
Callianassa spp.					1,6	0,1	1,3	2,24	17,6	1,5	3	61,6	33,3	13,2	17,5	1022,31
AMPHIPODA Unidentified	70,3	30,8	9,6	2840,12	32,3	9,7	1,6	364,99	29,4	4,9	0,9	170,52	11,1	0,4	0,1	5,55
ISOPODA Unidentified	7,2	0,6	0,1	5,04	9,7	1,3	0,9	21,34	11,8	2,3	1,8	48,38				
COPEPODA Unidentified	2,7	0,2	0,2	1,08	1,6	0,1	0,3	0,64								
MYSIDACEA Unidentified	16,2	2,4	1,8	68,04	30,6	2,7	0,5	97,92	11,8	1,9	0,1	23,6				
PENAEIDEA Unidentified	15,3	3,4	7,3	163,71	17,7	3,4	2,4	102,66	17,6	1,9	0,5	42,24	33,3	5,5	2,2	256,41
CARIDEA (?*Processa* spp.)	27,3	6,3	7,7	390,6	30,6	4,5	3	229,5	23,5	3,8	0,7	105,75				
BRACHYURA Unid. Larvae	9	0,9	1	17,1												
BRACHYURA Unidentified					9,7	1,4	1,9	32,01	5,9	0,4	1,5	11,21	22,2	0,9	1,4	28,86
Neopilumnoplax sp.									29,4	3,4	4,7	238,14				
Mursia cristimanus	0,9	0,1	0,1	0,18	14,5	3,3	4,6	114,5	17,6	4,5	4,2	153,12				
Goneplax rhomboides													22,2	4,1	5,6	215,34
MOLLUSCA																
PELECYPODA Unidentified	16,2	2	5,3	84,51	19,4	2,2	2,2	85,36	5,9	0,4	0,1	2,95	11,1	5,5	2,7	91,02
CHORDATA																
PISCES Unidentified	11,7	1,5	3,3	56,16	14,5	2,1	1,2	47,85	35,3	4,6	4,4	317,7	11,1	1,8	0,4	24,42
Bregmaceros sp.	13,5	2,6	4,3	93,15	19,4	6,9	3,2	195,94	11,8	3,4	0,8	49,56	11,1	0,9	0,5	15,54
Gobius sp.	0,9	0,1	0,1	0,18	1,6	0,1	0,7	1,28	5,9	7,6	9,4	100,3	11,1	0,9	0,2	12,21
Gonorhynchus sp.	0,9	0,1	2	1,89	1,6	0,1	0,3	0,64	5,9	1,1	3,2	25,37				
Cynoglossus spp.					3,2	0,2	1,5	5,44	5,9	1,1	2	12,39				
Gnathophis sp.					1,6	0,1	0,1	0,32	5,9	0,4	0,8	7,08				
Engraulis capensis					4,8	0,5	0,5	4,8	11,8	1,1	1,7	33,04				

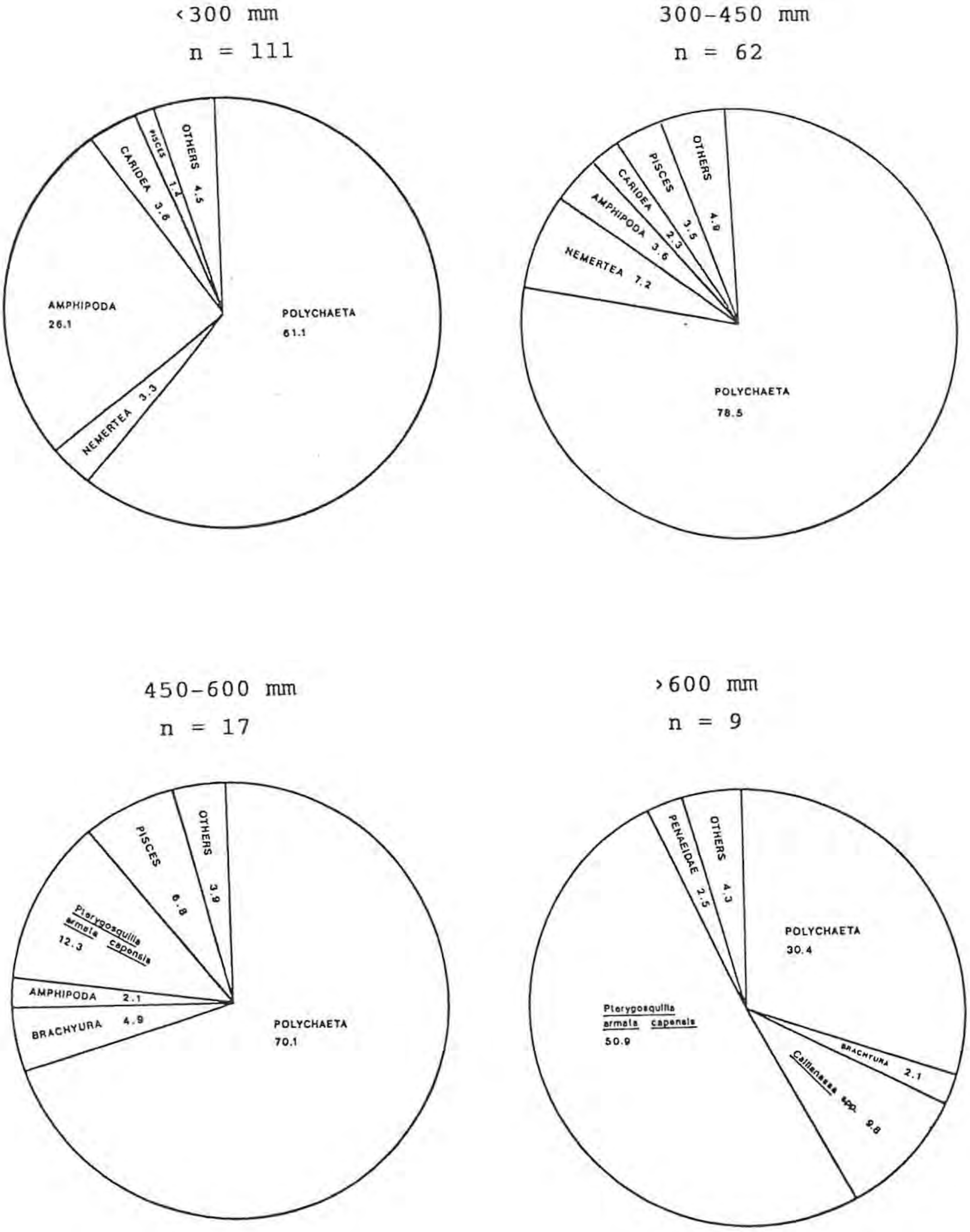


Figure 7.3. A comparison of the major prey species or groups in the stomachs of four size classes of *Dasyatis marmorata capensis* captured in the offshore zone.

78.5 and 70.1% towards the total IRI, respectively. In the largest size class (› 600 mm) the importance of polychaeta (30.4% IRI) decreased and the major prey item was Pterygosquilla armata capensis (50.9% of the IRI). Amphipoda (26.1% of the IRI) were an important prey item in the smallest size class (‹300 mm), but decreased in importance with increasing predator size (Figure 7.3).

Figure 7.4 summarizes the size related dietary preferences of the major prey organisms for each habitat. As stated previously, Donax spp. was the major prey item for the two smaller size classes in the surf zone, but was absent in the › 600 mm size class. In this size class, Callianassa spp. contributed the bulk of the diet. In the nearshore zone, Balanoglossus capensis and Callianassa spp. were the dominant prey items in all size classes. The importance of Balanoglossus capensis decreased with increasing predator size, while the inverse was true for Callianassa spp.. In the offshore zone, polychaeta was an important prey component in all size classes. Amphipoda were of secondary importance in the 300 - 450 mm size class, but decreased in importance with increasing predator size. Similarly, Pterygosquilla armata capensis increased in importance with predator size, and was the major prey item in the › 600 mm size class.

Prey Diversity

The diversity of prey organisms was highest in the stomachs of specimens captured in the offshore zone, with a total number of 26 prey groups or species being represented, followed by 17 in the surf zone and 10 for the nearshore zone (Tables 7.2, 7.3, 7.4).

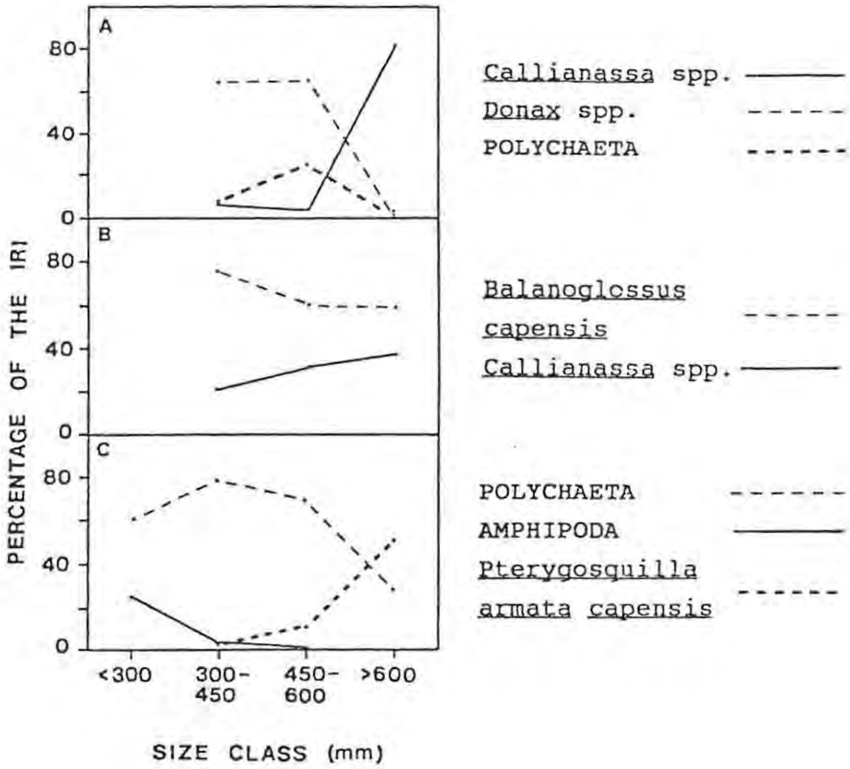
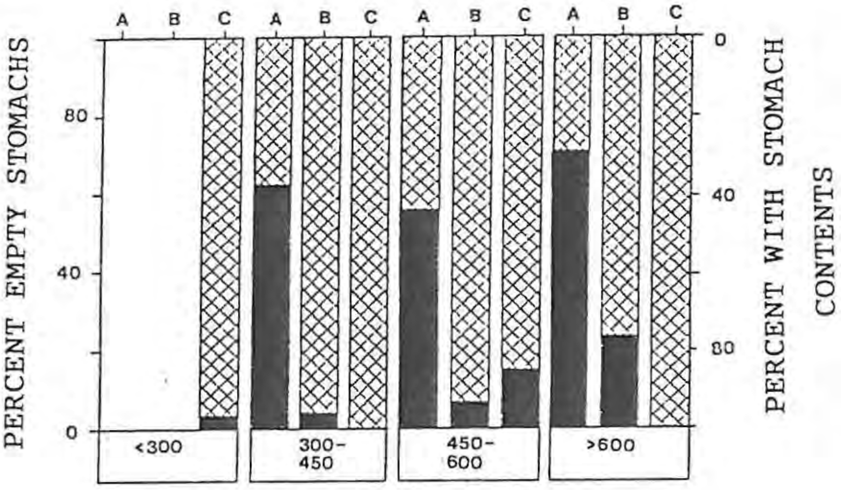


Figure 7.4. Size related dietary preferences of the major prey items in _Dasyatis marmorata capensis_ captured from three depth zones. A = surf zone, B = nearshore zone, C = offshore zone.

Empty Stomachs

Figure 7.5 summarizes the percentage of empty stomachs and those with contents by size class and habitat. The highest percentage of empty stomach were those obtained from the surf zone. In their respective size classes (300 - 450 mm ; 450 - 600 mm ; › 600 mm), 62.5%, 55.8% and 70.8% of the examined stomach were empty. In the nearshore zone an increase in percentage empty stomach was observed with increasing size ; 4.3% in the 300 - 450 mm size class, 6.7% in the 450 - 600 mm size and 23.5% in the › 600 mm size class. The majority of stomachs examined from the offshore zone contained prey organisms, with the exception of 3.5% in the ‹ 300 mm size class and 15% in the 450 - 600 mm size class.



SIZE CLASS (mm)

Figure 7.5. The percent empty stomachs and those with contents for different size classes and depth zones in Dasyatis marmorata capensis. (A = surf zone, B = nearshore zone, C = offshore zone).

Feeding Behaviour

The behaviour related to prey detection and capture in D. m. capensis was observed from specimens kept in captivity. The following sequence of events, describes the feeding behaviour in D. m. capensis.

1) **Prey searching** : A feeding bout was initiated by slow swimming (almost "motionless gliding") along the bottom, approximately 5 cm above the substratum (Figure 7.6). Occasionally a "sniffing" motion of the snout was observed, possibly in response to an olfactory stimulus. In captivity, the searching behaviour appeared to be very social, as the three rays moved together in a triangular formation. It remains uncertain whether blue rays feed in schools in the wild, however, fishing activities usually resulted in the capture of several individuals over a short period of time, inferring that they feed in schools.

Dense foraging schools have been observed in other batoid species, such as Rhinoptera bonasus (Smith & Merriner 1985) and Myliobatis californica (D. Ebert, Department of Ichthyology and Fisheries Science, Rhodes University, pers. comm.).

2) **Prey detection** : Upon detection, either by electroception or olfaction, swimming activity became more intense, intermixed with abrupt sideways and sometimes backward movements. Once the precise location of prey was determined the ray stopped suddenly and settled on the substratum.

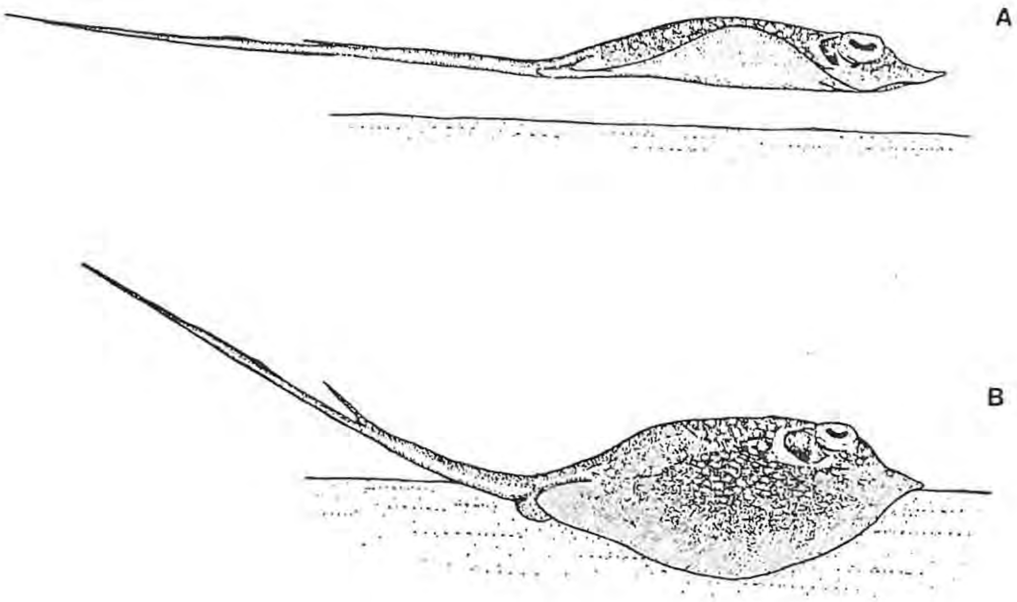


Figure 7.6. The foraging behaviour of Dasyatis marmorata capensis : (A) prey searching, initiated by slow swimming near the substratum (B) the body assumes a convex shape over the prey location, followed by expansions and contractions of the orobranchial chamber to draw the prey from its burrow.

3) **Prey capture** : The body then assumes a convex shape over the location of the prey (Figure 7.6). Continuous rapid expansion and contraction of the orobranchial chamber occurred while water and sediments were taken in via the mouth and expelled from the gill slits and occasionally via the spiracles. This caused a hydraulic action, pushing water towards the posterior margin of the disc. The raised pelvic fins act as an outlet region for water and sand sediments from the evacuated depression. Once the prey is drawn from its burrow it is seized by the highly protruberant jaw and drawn into the mouth. In the event of a prey organisms escaping, the ray rapidly pounces on it again, but this time the body does not assume the convexed shape. It should be noted that prior to the rays becoming placid after continual handling, during a feeding bout the tail with its serrated spine was positioned dorsally at an angle of $40 - 60^0$ (Figure 7.6).

7.4 DISCUSSION

The dorso-ventrally flattened bodies and ventrally positioned mouth of all rays are clear indicators of a sedentary lifestyle. Stomach content analyses indicate that Dasyatis marmorata capensis is a benthic carnivore, preying on a wide variety of slow moving epifauna and infauna. This is amply shown by the presence of burrowing polychaete and hemichordate worms, crustaceans and bivalves in the diet.

Food Preference by Habitat and Size

Dill (1983) stated that the diet of an animal ultimately depends on the local food availability. Therefore, analyses of stomach contents were examined independently from three habitats. Dietary variations in terms of prey size, which generally increase in accordance with that of the predator, are common amongst fishes (Marcotte & Browman 1986), and have been reported for several batoid species (McEachran et al. 1976; Rossouw 1983; Smith & Merriner 1985). Changes in dietary preference attributed to prey size were observed in blue rays collected from the offshore zone. The importance of small amphipoda decreased with increasing predator size, while the importance of the large stomatopod, Pterygosquilla armata capensis, increased in accordance with predator size. In the nearshore zone, the changes in importance of Balanoglossus capensis and Callianassa spp. were small and could not be attributed to prey size, because varying sizes of both prey species were present in all the predator size classes. The observed changes in importance of the major prey organisms with predator size, captured in the surf zone, is attributed to reasons other than prey size, and are discussed below.

Although a large number of prey items contribute to the overall food composition of Dasyatis marmorata capensis, a fairly stenophagic preference was observed for each size class within each habitat. These data suggest they feed opportunistically on the dominant macrofaunal organisms in each zone. McLachlan et al. (1984) studied the abundance and biomass of macrofaunal organisms along three beaches in Algoa Bay (Eastern Cape), and showed that Donax sordidus had the highest biomass in the shallow intertidal region on all 3 beaches, and Callianassa spp. had the highest overall biomass in the nearshore zone on one of these beaches.

The distribution and abundance of macrofaunal organisms has been related to many physical and biological factors (McLachlan 1983a). However, McLachlan et al. (1984) showed that species diversity and abundance increased inshore and offshore of the outer breaker zone on three beaches in Algoa Bay. Considering that the nearshore zone in the present study was defined as the area directly offshore of the outer breaker zone, the diversity of prey organisms in the stomach contents of blue rays conform with the findings of McLachlan et al. (1984). Prey diversity was lowest in the nearshore zone with 10 prey groups or species, followed by the surf zone with 17 and the offshore zone with 26.

Aspects of the ecology of many macrofaunal surf zone organisms are known, but much less is known about those occurring below the intertidal region (McLachlan 1983b). The major prey items of the 300 - 450 mm and 450 - 600 mm size classes from the surf zone were small Donax spp. (< 20 mm shell length). Donax spp. of the smaller size classes occur throughout the intertidal region but highest concentrations occur around the extreme low water level in the surf zone (McLachlan & Hanekom 1979; McLachlan et al. 1984). The other surf zone dwelling prey organisms found in the stomachs of blue rays caught in this zone include : 1) Gastrosaccus psammodytes, which burrows into the sand surface during the day but becomes planktonic at night. It is also a tidal migrant moving up and down the beach as tides rise and fall (Wooldridge 1983); 2) Macropetasma africana juveniles and post-larvae which utilize the surf zone as a nursery area and occur in greatest abundance around the outer breaker zone in the summer (Cockcroft & McLachlan 1986); 3) larger size classes of Ovalipes punctatus, which are common residents of the surf zone, and invade the intertidal region on the high tide to prey on Donax spp. and Bullia spp. (Du Preez 1981) and 4) Bullia spp., which are important scavengers in the mid-littoral zone (McLachlan 1983a). Because the polychaete worms in the diet of D. m. capensis were not identified to a lower taxonomic level, a comparison with those resident to the surf zone was precluded. With the exception of Donax spp., the other true surf zone dwelling organisms were of minor importance in the diet of blue rays captured in this zone.

Contrary to the hypothesis proposed by Lasiak (1982) and Rossouw (1983), that Dasyatis marmorata capensis is an important surf zone predator, this study has revealed that this is in fact not so, for the following reasons : Firstly, many of the prey organisms of the surf zone caught specimens occur in greatest abundance beyond the outer breaker zone (nearshore zone). For example sipunculids, echiurids, stomatopods, Callianassa spp., isopods, and Thaumastoplax spiralis (McLachlan et al. 1984; Day 1969). The distribution of these macrofaunal organisms, particularly the infauna, is strongly affected by the diminishing effect of wave action beyond the outer breaker zone, where the number of bioturbations increases with depth (McLachlan et al. op. cit.). The major prey item of the › 600 mm size class, from the surf zone, was Callianassa spp., which does not occur in the surf zone and in fact only reaches peak abundance beyond the outer breaker zone (McLachlan et al. 1984; Cockcroft & Tomalin 1987). Secondly, the high incidence (61%) of empty stomachs from the surf zone greatly exceeded those from the nearshore (8.4%) and the offshore (3.4%) zones. It is possible that the high percentage of empty stomachs from the surf zone could be attributed to sampling bias, where angling efforts result in the capture of hungry individuals (i.e. those with empty stomachs). This however is unlikely because the same method of capture was employed in the nearshore zone. Furthermore, the importance of Rhinobatos annulatus as a surf zone predator was recognized using the same methods of collection (Rossouw 1983). In the same study, Rossouw (op. cit.) examined the stomach contents of 42 blue rays of which 95.2% were empty, while only 13.8% empty stomachs were reported for R. annulatus.

Feeding Behaviour

Because of the benthic food habits and dorsally situated eyes of rays, the prey searching and detection behaviour must be initiated by means other than a visual stimulus. Kalmijn (1971) proposed that sharks and rays make use of a set of elecroreceptors, the Ampullae of Lorenzini, to detect electrical fields emitted by prey organisms. More recently, Blonder & Alevizon (1988) showed that Dasyatis sabina, using a well developed electrosensory system could detect the precise location of concealed prey. The prey searching and detecting behaviour, aided by electroreception, in D. sabina (Blonder & Alevizon op. cit.) was comparable to that observed in D. m. capensis.

Various behavioural patterns have been described as to how rays extract the benthic infauna, on which they feed. Bigelow & Schroeder (1953) stated that rhythmic flappings of the pectoral fins serve to erode bottom sediments, while Coles (1910) (in Smith & Merriner 1985) suggested that the snout is used to dig the substrate for shellfish. The use of hydraulic action, by pumping water from the spiracles to the mouth and gills, to evacuate sediments has also been documented (Babel 1967; Gregory et al. 1979). Furthermore, Moss (1977) suggested that most batoids are capable of suction feeding, because of their expansive orobranchial chambers.

Smith & Merriner (1985) described the feeding behaviour in Rhinoptera bonasus, and indicated that initially movements of the pectoral fins are used to make a feeding depression, followed by hydraulic venting of water and sediments. The former was not observed in D. m. capensis, but the method of pumping water under pressure, formed in the orobranchial chamber, are comparable to that described by Babel (1967), Gregory et al. (1979) and Smith & Merriner (1985), and is proposed to be true for all rays of the order Myliobatiformes.

Stingrays are popular prey items of large predatory sharks (Compagno 1984). Tail spines, lodged in the mouth, have been observed in Notorhynchus cepedianus, Carcharias taurus, Carcharodon carcharias, Galeocerdo curvier, Carcharhinus brachyurus, C. obscurus, C. leucas, C. limbatus and Sphryna zygaena (personal observations; D. Ebert, Department of Ichthyology and Fisheries Science, Rhodes University and B. Wilson, formerly of the Natal Shark Board, pers. comm.). For this reason, it is believed that the dorsally positioned tail, observed in D. m. capensis (and possibly true for other batoids), during feeding is a predator deterrent tactic. This is further supported by the collection of several blue rays with their tails missing, presumed to have been bitten off by predatory sharks.

CHAPTER 8 GENERAL DISCUSSION

A taxonomic revision of the blue stingray from southern Africa showed that the species was incorrectly assigned to Dasyatis pastinaca by Bleeker (1860) and Norman (1922). The results of this study relegated it to a sub-species of Dasyatis marmorata (Steindachner 1868), D. m. capensis on the basis of distinct colour patterns, differences in snout angle, snout to vent length and disc length. The known distributional range of the proposed new sub-species extends from St Lucia (northern Natal) on the east coast to Henties Bay on the west coast of southern Africa. It is possible that D. m. capensis extends further up the west coast, but due to the paucity of distributional records of fishes along the south-eastern Atlantic the exact range of this species remains uncertain.

In a study of the surf zone ichthyofauna in the Eastern Cape, Lasiak (1982) suggested that surf zone fish communities are highly dynamic assemblages with few resident species. The community showed a high degree of short term variability with no overall seasonal trends. It was concluded that the structure and dynamics of this community was largely influenced by abiotic factors, particularly wind induced effects, while biological interactions were of secondary importance. In the same study, Lasiak (op. cit.) showed that Dasyatis marmorata capensis represented an important component, in terms of biomass, of the surf zone ichthyofauna in the Eastern Cape. Rossouw (1983) suggested that due to its abundance in the surf zone, a natural history study of this species would contribute to a better understanding of sandy beach ecology. Contrary to the belief that D. m. marmorata is an important predator in the surf zone, this study showed that this species is relatively unimportant in the food chain dynamics of this zone. The presence of several prey items such as sipunculids, echiurids, stomatopods, prawns

(Callianassa spp.) and crabs (Thaumastoplax spiralis), which occur in greatest abundance beyond the surf zone, indicate that they utilize this zone for purposes other than feeding. This was particularly evident in the largest size class (>600 mm DW), in which the major prey item, Callianassa spp., contributed 83.1% (IRI) towards the total diet. The high incidence of empty stomachs (61%) recorded in the surf zone greatly exceeded those from the nearshore (8.4%) and the offshore (3.4%) zones.

Rossouw (1983) suggested that the dorso-ventrally flattened bodies of batoid fishes are morphologically suited for a successful existence in the surf zone. This was shown by the abundance of Rhinobatos annulatus, which uses this zone as a nursery area. However, this is not true for Dasyatis marmorata capensis, as indicated by the absence of juveniles in the catches from this zone. The abundance of Myliobatis aquila juveniles in the offshore zone (personal observations) is indicative of a similar trend. Differences in body form and general morphology between R. annulatus and the myliobatiform rays are apparent. Furthermore, R. annulatus exhibits a selachian type swimming mode, as opposed to a typical batoidean swimming mode in the myliobatiform rays. This in turn poses difficulties for juvenile rays to feed successfully under the physically harsh conditions in the surf zone. Clearly the results of this study show that the distribution of adult D. m. capensis in the surf zone is related only to reproductive activity and that the rays spend a large proportion of their lives in the nearshore and offshore zones where they have a significant contribution to the trophic dynamics.

Quantitative analyses of stomach contents revealed that Dasyatis marmorata capensis feeds on a wide variety of benthic epifauna and infauna. However, the relative importance of certain dominant macrofaunal organisms in the diet from each zone suggests an opportunistic feeding strategy. For example, McLachlan et al. (1984) showed that Callianassa spp. contributed to the highest overall biomass of macrofaunal organisms in the nearshore zone on three beaches in the Eastern Cape. This crustacean contributed 32% towards the IRI of all specimens collected in this zone. The most important prey item, Balanoglossus capensis, which contributed 65.2% towards the IRI is also a dominant macrofaunal organism in Algoa Bay (P. Sieben, Zoology Department, University of Port Elizabeth, pers. comm.), where the majority of the samples from the nearshore zone were collected. Although not much is known about the distributional abundance of macrofaunal organisms in the offshore zone, the importance of polychaetes and Pterygosquilla armata capensis in the diets of other demersal species (Ebert et al. in prep.; Payne et al. 1987) is indicative of the abundance of these prey organisms. Collectively these two prey organisms contributed 75.8% towards the total IRI in the diet of D. m. capensis collected from the offshore zone.

The life history of Dasyatis marmorata capensis is summarized in Figure 8.1. Changes in the monthly catch per unit of effort data series, collected from the shore-based recreational fishery, revealed a distinct seasonal trend, thereby, confirming an annual onshore/offshore migration, with peak abundance in the surf zone during spring.

Analysis of length frequency distributions indicated that D. m. capensis exhibits a marked vertical zonation with size (age). Juvenile fish (0 - 3 years old) of both sexes were abundant in the offshore zone, which indicated that this zone is utilized as a nursery area. Once adolescence is reached, some fish join the adult migration to the surf zone. During the period of peak abundance in the surf zone adult females, most carrying either uterine eggs or embryos, were numerically abundant. It was, therefore, proposed that this zone is utilized as a pupping ground. The reasons why adults undergo a migration from a stable environment to an unstable, physically harsh region to liberate their young is not clear. It is possible that the higher temperatures in the shallow water are a requisite for the observed rapid embryonic growth prior to birth. Probably most

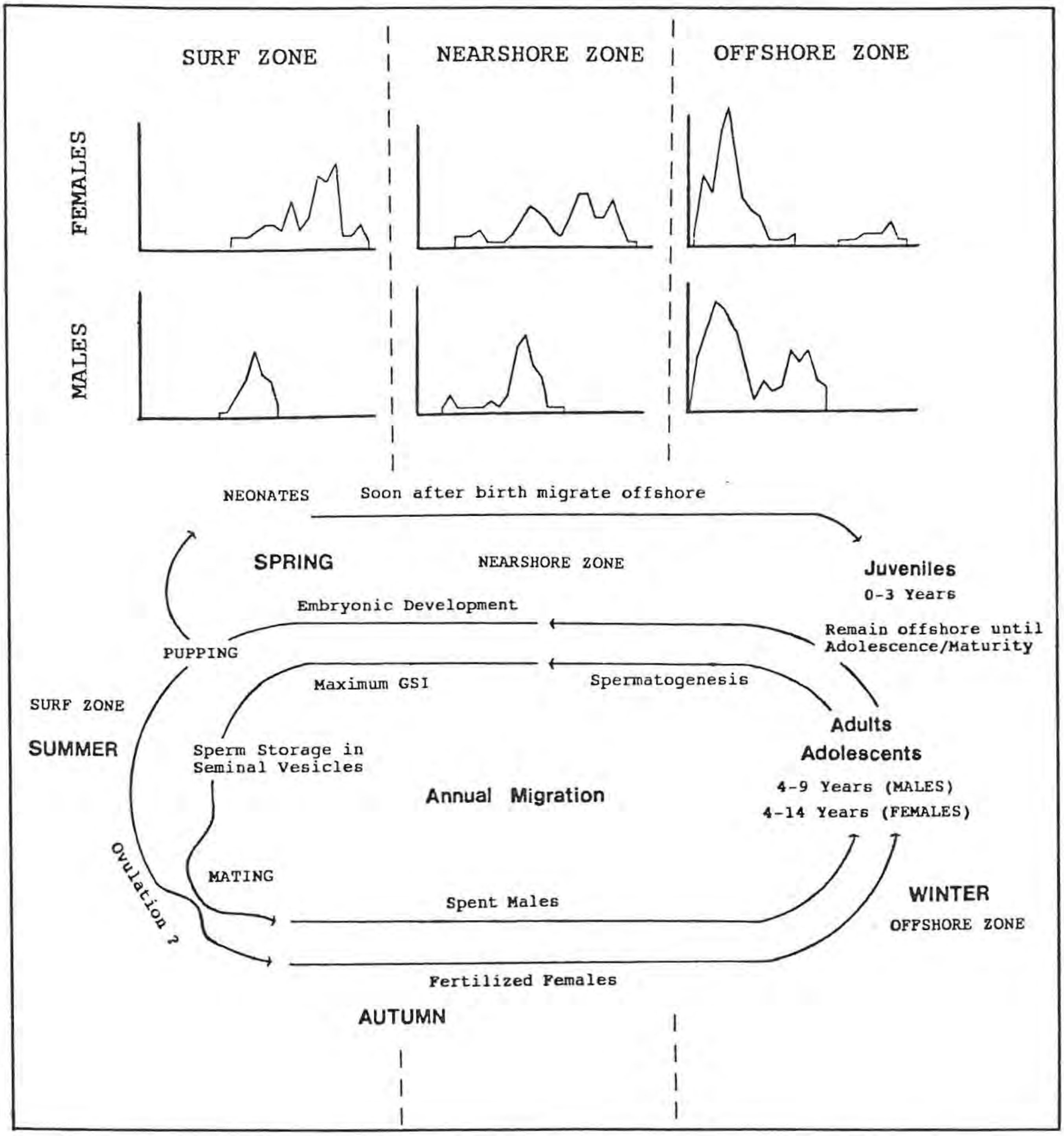


Figure 8.1. A diagrammatic outline of the life history of *Dasyatis marmorata capensis*.

likely however, is that the surf zone provides a predator-free environment for both the young and the mother at the time of birth. The occurrence of adults and the absence of immature males in the surf zone suggests that mating occurs in this zone as well, prior to the offshore migration in winter.

Elasmobranch fisheries have in general been incapable of sustaining long-term yields (Ripley 1946; Olsen 1959; Holden 1974). Holden (op. cit.) stated that elasmobranchs are long lived, mature at a late age and have a low fecundity, which render them highly susceptible to over-exploitation. These life history characteristics are typical of K-selected (Holden 1974; Branstetter 1987a) or precocial (Balon 1981) species. Conversely most of the important commercial fisheries target on r-selected or altricial species which typically have a shorter life span, higher fecundity and a low parental investment per individual young (Buxton 1987). The reason for the collapse of most shark fisheries may be attributed to incorrect management. Most are managed in a manner which might be appropriate for certain teleost fisheries but are inapplicable to K-selected elasmobranch fishes (Bedford 1987).

The following life history characteristics of _Dasyatis marmorata capensis_ are relevant to the management and conservation of elasmobranchs in general. Firstly, _D. m. capensis_ and all viviparous elasmobranchs have a high parental investment per individual, and give birth to a few, large, precocial young. The average fecundity calculated for _D. m. capensis_ was 3.07 young per year. These characteristics offer their offspring a competitive advantage over fishes which produce many small eggs or larvae. However, when subjected to exploitation, elasmobranchs have a competitive disadvantage to the highly fecund teleosts. Secondly, Holden (1977) estimated that elasmobranchs attain sexual maturity at approximately 60% to 90% of their asymptotic length. Results of this study revealed that _D. m. capensis_ attains sexual maturity at 76.7% and 54.7% of their asymptotic length in males and females, respectively, corresponding to ages 4.5 and 7 years. Combined, the factors of low fecundity and late maturation suggest that a strong relationship must exist between stock size and recruitment. Therefore, to ensure correct management the annual sustainable harvest must be set at a level significantly smaller than the existing stock.

A further life history characteristic relevant to management is longevity. Dasyatis marmorata capensis attains a maximum age of at least nine and 14 years in males and females, respectively. These values are lower in comparison with many teleost species which attain ages in excess of 40 years (Buxton & Clarke 1989). However, certain elasmobranch species are also believed to attain 30 years of age (Casey et al. 1985). Slow growth and longevity have important consequences in terms of a fishery's potential, these include an older age at maturity, a lower yield per unit stock and a slower recovery rate after heavy exploitation (Buxton 1987).

The importance of Dasyatis marmorata capensis as a recreational shore angling species has been outlined by van der Elst (1989) and van der Elst & Adkin (1989). Van der Elst (op. cit.) revealed that the blue stingray is the fifth most important species, in terms of percentage frequency, in the catches of competition anglers in the Eastern Cape. In the recreational fishery, maximum exploitation occurs just prior to the peak pupping season in November. Considering the current expansion of this fishery (van der Elst op. cit.) and the increase in the catch rate (see Figure 4.7), the blue stingray and possibly other related species might be exposed to over exploitation in the near future. Although a large proportion of the captured specimens are returned to the water alive there is evidence, though inconclusive, to suggest that survival after capture is low. During angling competitions many of the larger fish are gaffed, particularly by the anglers using light tackle (i.e. line with a breaking strain of 10 kg. or less). After capture the fish are often dragged over the sand and weighed by means of a large hook, attached to the scale, which is placed into either the spiracles, gill slits or mouth (see frontispiece). These event induce severe stress, which in turn make stingrays extremely vulnerable to predation by sharks once they get beyond the outer breaker zone. It is well known that stingrays make up a significant proportion of the diet of several predatory sharks (Compagno 1984). Furthermore, more than 400 blue stingrays have been tagged in the national SFW/ORI tagging programme, but has yielded no catch returns. This provides supportive evidence that the survival rate, after capture, is low. However, other factors such as tag shedding should not be disregarded.

Considering the increasing popularity of rock and surf angling and the expansion of the fishery, this thesis would be incomplete without considering possible management strategies for the future survival of Dasyatis marmorata capensis. Because this species forms part of the linefish assemblage, measures for its conservation should be derived firstly in terms of the present management options :

1) **Bag limits and size limits.** The imposition of a bag limit would be irrelevant because this species is, in most cases returned to the water and not considered as an edible catch by anglers. Similarly, a size limit would be inapplicable because the majority of the fish landed in the shore-based recreational fishery are large sexually mature individuals.

2) **Closed season and closed area.** Assuming the cause of over-exploitation is a result of a low survival rate after capture, the imposition of a closed season would be inappropriate. Therefore, total protection in the form of a closed area would be most effective for the conservation of this species. However, this would be impractical because of the multi-species nature of the recreational fishery (Wallace & van der Elst 1983).

Clearly, therefore, not one of the present options would be suitable. The only option relies on the importance of the angler to act as conservator of this species. It is, therefore, proposed that the management and conservation of Dasyatis marmorata capensis and other related species can be successfully achieved in the form of angler education. For example, anglers should be encouraged not to use gaffs to land their catches. If assistance is required, a landing net should be used. Injury related stress can be further reduced if the landed catch of the competition angler is weighed using a bag-net, instead of a hook, attached to the scale. Furthermore, to prevent loss of the body mucous coating, efforts should be made not to drag a landed stingray over the dry beach sand.

The education of anglers can be realized via several media avenues such as magazines, radio and television programmes or the distribution of posters. Conservation, in the form of angler education, of Dasyatis marmorata capensis and many other recreational angling species provides management with a unique opportunity to introduce pro-active measures.

Finally, considering the increasing levels of exploitation by both recreational and commercial fishermen, together with the susceptibility to over-exploitation emphasizes the need for continued research into this and other elasmobranch species. The important areas requiring research include stock assessment, reproductive potential and migratory patterns.

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