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Catch Distribution, Stomach Contents and Size at Maturity of Two Squaloid Sharks, *Deania calceus* and *D. crepidalbus*, from the Southeast Atlantic off Namibia

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Abstract

The catch distribution, stomach contents and size at maturity of two squaloid sharks, *Deania calceus* and *D. crepidalbus*, are discussed. The two species were caught with bottom otter trawls from the Southeast Atlantic off Namibia. Most specimens of *D. calceus* were caught at depths between 620 and 644m, and most *D. crepidalbus* were taken between 402 and 408m. Stomach contents indicated that both species fed on squids and fishes. Size at maturity for both sexes of *D. calceus* was larger than that for *D. crepidalbus*. Size at maturity of male *D. calceus* was about 800mm TL and that of *D. crepidalbus* was about 530mm TL. Only one near-adult female (965mm TL) of *D. calceus* was collected. Size at maturity of female *D. crepidalbus* was about 690mm TL.

1. Introduction

Several squaloid sharks including those of the genus *Deania* have world-wide distributions in continental slope regions (COMPAGNO, 1984). Although *D. calceus* and *D. crepidalbus* [=*D. profundorum* after YANO (1989)] have been recorded from Namibia and adjacent regions (PENRITH, 1969; BASS *et al.*, 1976; CADENAT and BLACHE, 1981; MACPHERSON, 1983; LLORIS, 1986; ROEL, 1987; MACPHERSON and ROEL, 1987; MACPHERSON, 1989), there is little information on their biology in the regions (COMPAGNO, 1984). Knowledge of their biology is fragmentary and based on a few specimens only, because they are rare and are not fished commercially in Namibia waters. This paper presents catch distribution, stomach contents and size at maturity of the two *Deania* species from the Southeast Atlantic off Namibia.

2. Materials and Methods

During a biological survey off Namibia from 9 May to 29 June, 1987 the R/V Shinkai Maru (3395.12t, 94.93m in length) of the Japan Marine Fishery Resource Research Center completed 25 bottom otter trawls (110mm mesh-size in cod-end) at depths of 255–644m (Fig. 1), and 107 midwater otter trawls (60mm mesh-size in cod-end) at depths of 27–290m over bottom depths ranging from 187m to 787m. Depth was measured using a sonar fish finder. Water temperature and salinity were measured with a Memory STD (STD-1000, Union Engineering Ltd.). Vertical opening of the net was measured with a net recorder (FNR-80, Furuno Co., Ltd.), and width between otter boards was measured with an otter graph (KOG-10L, Kaijo Denki Co., Ltd.). Horizonal opening of the net was estimated after the methods of KOYAMA (1974).

Total lengths (TL, mm) are used throughout this report. Specimens for size frequency analysis were grouped into 10mm intervals for *D. crepidalbus* and 20mm intervals for *D. calceus*. Length-weight equations were calculated by the least squares method. Curves for both sexes of both species were fitted to the data by the following formula: $W=aL^b$ where W is weight in grams, L is total length in millimeters, and a and b are fitted constants (RICKER, 1973). Hepatosomatic index (%) was calculated by following formula: liver weight (g)/body weight (g)$\times$100.

Stomach contents were identified to the lowest possible taxon and enumerated. Analy-

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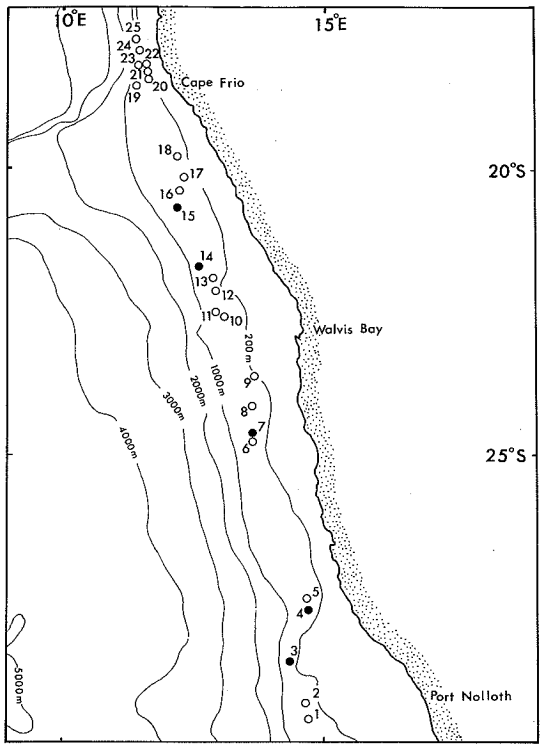

Fig. 1. Fishing stations and numbers of 25 bottom otter trawls off Namibia. Solid circles indicate stations that collected *Deania* spp. (107 midwater otter trawls were mainly fisehd between 17° S−23° S and 11° E−13° E, and are omitted from figure).

ses of stomach data were summarized by the index of relative importance *(IRI)* modified from PINKAS *et al.* (1971): $IRI=PO(PN+PW)$ where *PO* is percent frequency occurrence of prey items, *PN* is percent of total prey number, and *PW* is percent of total stomach content weight (wet weight) calculated for each prey category. Gonads were visually inspected. Left clasper length was measured from the anterior end of the cloaca to the tip of the clasper.

3. Results

3−1. Catch distribution

Catch conditions were similar for all 25 bottom trawls. Speed of tow varied from 3.1-4.1 knots (3.4-4.1 knots for *Deania* collected nets), vertical opening of net from 6.5-10.0m (7.0-8.8m); and horizontal opening of net from 55.3-68.1m (59.6-62.0m). Water temperature and salinity for the fishing localities and depths that collected *D. calceus* were 5.3-8.1℃ and 34.5-34.8‰, and for *D. crepidalbus* were 6.5-8.9℃ and 34.4-34.8‰.

Specimens of *Deania* were caught in only 5 of the 25 bottom trawls, the other 20 bottom trawls operated between 239m and 431m and all midwater trawls had no specimens (Fig. 1, Table 1). Most specimens (364 of 366) of *D. calceus* were caught in one trawl (net 14, Fig. 1) between 620m and 644m. Most specimens (36 of 40) of *D. crepidalbus* were caught in one trawl (net 15) between 402m and 408m. These were adjacent fishing localities (Fig. 1).

Total catch of net 14 (set time 23:00-hauled time 01:45) was 2344kg and species composition consisted of 73.70% *Merluccius* spp., 1.32% *Lophius* sp., 1.66% *Todarodes sagittatus* and 23.29% sharks (*D. calceus* occupied 91.69% of total shark catch). Total catch of net 15 (07:50-10:30) was 1249kg, and species composition consisted of 73.02% *Merluccius* spp., 20.18% *Helicolenus* sp., 4.96% *Lophius* sp. and 1.84% sharks (*D. crepidalbus* occupied 87.80% of total shark catch).

3−2. Size composition

The specimens of *D. calceus* ranged from 470mm to 919mm TL for males and from 452mm to 980mm TL for females (Fig. 2), and the specimens of *D. crepidalbus* ranged from 523mm to 604mm TL for males, and from 507mm to 694mm TL for females (Fig. 3). The length frequency analysis showed that there were seven size

Table 1. Water depth and number of specimens of *D. calceus* and *D. crepidalbus* collected from Namibia waters.

Water depth (m)	Net No.	Number of specimens			
		D. calceus		*D. crepidalbus*	
		Male	Female	Male	Female
359-386	7	0	0	1	1
400-442	3	0	0	0	1
404-408	15	1	1	28	8
414-543	4	0	0	0	1
620-644	14	217	147	0	0

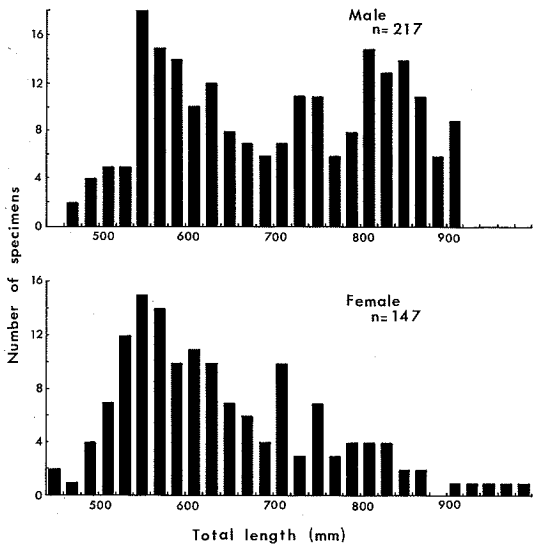

Fig. 2. Length-frequency distribution of *D. calceus*. Specimens are grouped into 20mm size classes.

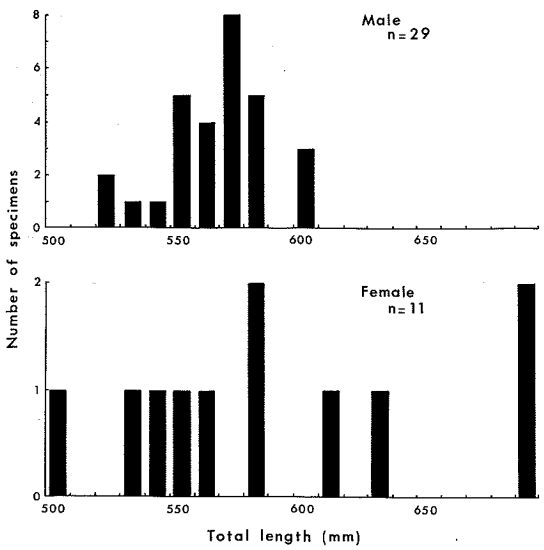

Fig. 3. Length-frequency distribution of *D. crepidalbus*. Specimens are grouped into 10mm size classes.

peaks, 500-519mm, 540-559mm, 620-639mm, 720-739mm (or 740-759mm), 800-819mm, 840-859mm and 900-919mm for male *D. calceus* (Fig. 2). The length of female *D. calceus* peaked at 440-459mm, 540-559mm, 600-619mm, 700-719mm, 740-759mm, and 800-819mm, with a possible peak between 900 and 999mm (Fig. 2). Fewer female *D. calceus* were over 800mm TL (11.6%) than males (31.3%). Male *D. crepidalbus* had a mode at 570-579mm TL (27.6%) (Fig. 3). The females of *D. crepidalbus* had no clear mode because there were few specimens (Fig. 3).

3—3. Length-weight relationship

There were significant curvilinear relationships between body weight and total length for *D. calceus* (Fig. 4) and *D. crepidalbus* (Fig. 5). The weight range for male *D. calceus* was from 305g (474mm TL) to 2200g (865mm TL), and 266g (458mm TL) to 3800g (968mm TL) for females. The weight range *D. crepidalbus* was from 366g (524mm TL) to 590g (574mm TL) for male, and

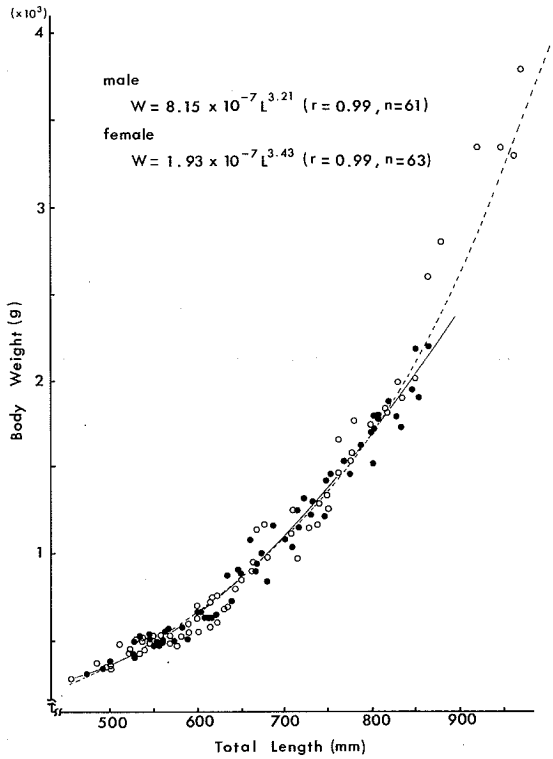

Fig. 4. Length-weight relationship, by sex, for *D. calceus*. Solid circles and solid line represent males. Open circles and dotted line represent females.

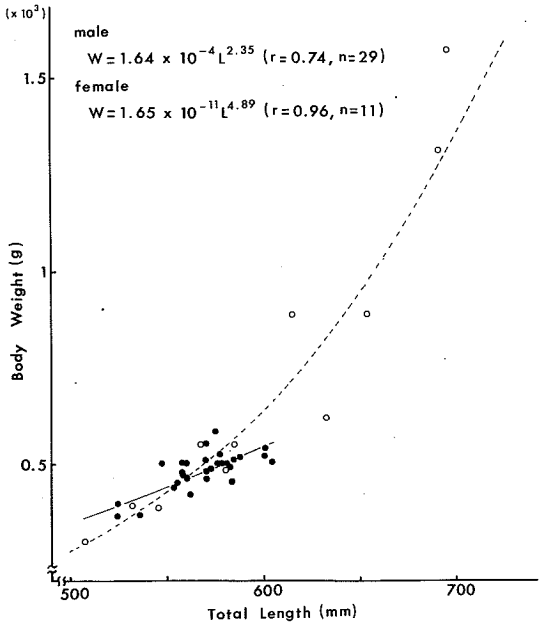

Fig. 5. Length-weight relationship, by sex, for *D. crepidalbus*. Solid circles and solid line represent males. Open circles and dotted line represent females.

300g (507mm TL) to 1580g (694mm TL) for females.

3—4. Hepatosomatic index

Hepatosomatic index of *D. calceus* ranged from 7.10% to 21.18% (average $\bar{x}$=15.52%, SD=3.36, n=59) for male and from 8.08% to 27.94% ($\bar{x}$=14.93%, SD=3.38, n=58) for female, and that of *D. crepidalbus* ranged from 6.27% to 20.33% ($\bar{x}$=11.98%, SD=3.86, n=23) for male and 8.25% to 21.97% ($\bar{x}$=13.76%, SD=5.20, n=11) for female. In addition there were variations in the hepatosomatic indexes of both species, and they did not display any tendency by size.

3—5. Stomach contents

Stomachs from 130 *D. calceus* and from 40 *D. crepidalbus* were examined. A large percentage of stomachs of *D. calceus* (53.0%) and *D. crepidalbus* (62.5%) were empty. Both species fed on squids and fishes (Table 2). In *D. calceus*, teleostei (56.6% of total *IRI*), especially family Myctophidae (10.2%), and cephalopoda (42.5%) dominated the contents. In *D. crepidalbus*, teleostei (73.9%), especially family Myctophidae (26.2%) and cephalopoda (18.0%) dominated the contents. The proportion of the weight of stomach contents to body weight averaged 2.3% (range of 0.1–9.9%) for *D. calceus*, and 1.7% (0.1–7.8%) for *D. crepidalbus*.

3—6. Size at maturity

Mature males of *D. calceus*, 802–865mm TL (n=11), had hard claspers, 93–107mm in length, and immature males 474–820mm TL (n=52) had soft claspers, 23–83mm in length (Fig. 6). Mature males of *D. crepidalbus*, 536–604mm TL (n=27), had hard claspers, 46–60mm in length, and their testes weighed 1.8–5.2g. Two immature males, 523 and 524mm TL, had soft claspers, 45 and 47mm in length, and their testes weighed 1.9 and 2.8g.

One female of *D. calceus*, 965mm TL, had 19 ovarian ova measuring 10mm in diameter with developing uteri measuring 9mm in width, representing a near-adult condition. Sixty-six immature females, 458mm to 968mm TL, had small ovarian ova measuring 1–8mm in diameter and

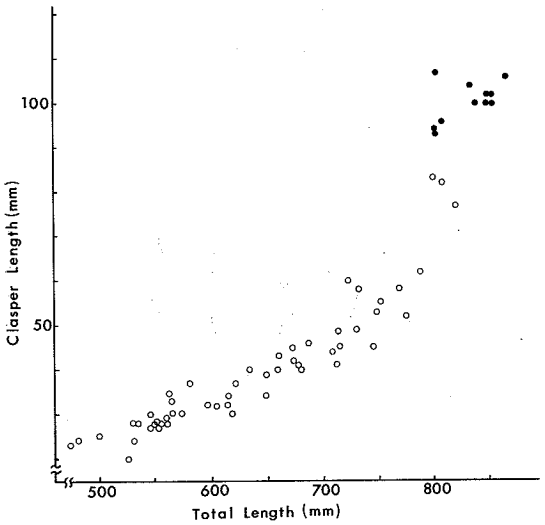

Fig. 6. Relationship between clasper length and total length in *D. calceus*. Open circles indicate soft claspers. Solid circles indicate hard claspers.

Table 2. Stomach contents of 61 *D. calceus* (average size $\bar{x}$=694.6mm TL, SD=114.58, min= 500mm TL, max= 968mm TL), and 15 *D. crepidalbus* ($\bar{x}$=576.7mm TL, SD= 43.45, min= 507mm TL, max= 690mm TL). *PO*= percent occurrence, *PN*= percent number, *PW*= percent weight, *IRI*= index of relative importance. Parentheses indicate total of each prey category.

Prey item	*D. calceus*				*D. crepidalbus*			
	PO	*PN*	*PW*	*IRI*	*PO*	*PN*	*PW*	*IRI*
Cephalopoda	(40.99)	(33.78)	(73.78)	(4408.88)	(26.67)	(21.05)	(47.01)	(1815.16)
Ommastrephidae spp.	8.20	6.76	29.31	295.77	—	—	—	—
Todarodes sagittatus	3.28	2.70	14.61	56.77	6.67	5.26	31.55	245.52
Unidentified	29.51	24.32	29.86	1598.85	20.00	15.79	15.46	625.00
Teleostei	(70.50)	(58.11)	(25.09)	(5864.60)	(73.33)	(57.90)	(43.54)	(7438.59)
Myctophidae spp.	29.51	24.33	11.54	1058.52	40.00	31.58	34.31	2635.60
Electrona sp.	3.28	2.70	1.90	15.09	—	—	—	—
Diaphus spp.	3.28	2.70	0.95	11.97	—	—	—	—
Unidentified	34.43	28.38	10.70	1345.52	33.33	26.32	9.23	1184.88
Unidentified organic material	(9.84)	(8.11)	(1.13)	(91.02)	(26.67)	(21.05)	(9.45)	(813.44)

undeveloped uteri measuring 1–5mm in width. Two females of *D. crepidalbus* were considered mature. One, 690mm TL, had eight large ovarian ova measuring 20mm in diameter and developing uteri measuring 7mm in width. The second, 694mm TL, had nine large ovarian ova measuring 25mm in diameter and developing uteri measuring 8mm in diameter. Their ovary weights were 33.9g and 62.0g, respectively. Nine females of *D. crepidalbus*, 507–653mm TL, had small ovarian ova measuring 1–6mm in diameter and undeveloped uteri measuring 1–4mm in width. Their ovary weight was 0.9–4.2g.

4. Discussion

In this study, most specimens of *D. calceus* were caught deeper than *D. crepidalbus*. In the waters off Namibia and adjacent regions, *D. calceus* has been recorded from depths of 457m (PENRITH, 1969), 398–500m (CADENAT and BLACHE, 1981), 398–500m (LLORIS, 1986), 400–826m (BASS *et al.*, 1986), and 400–650m (MACPHERSON and ROEL, 1987), while *D. crepidalbus* has been recorded from depths of 275m (BASS *et al.*, 1976), down to at least 350m (CADENAT, 1960), 400–600m (WILLIAMS, 1968), and 275–716m (BASS *et al.*, 1986). *D. calceus* was usually captured in deeper water than *D. crepidalbus* in these studies as well. Similarly, YANO and TANAKA (1983) and YANO (1985) reported that the vertical distribution of Japanese *D. calceus* extended to deeper water than that of the smaller Japanese species *D. rostratus*. In deep sea squaloid sharks, the close related species in the same locality show habitat segregation by vertical, e.g. *Centroscymnus* spp., *Centrophorus* spp. and *Etmopterus* spp. in Suruga Bay (YANO and TANAKA, 1983; 1984; 1986), and *Centrophorus* spp. and *Etmopterus* spp. in Kumano-nada (KOBAYASHI, 1986). Thus, it is possible that there is a vertical segregation between the two species of *Deania* in this region.

In this study, the length-frequency peaks for both sexes of *D. calceus* may distinguish age classes or may be due to sample variation. Further studies are needed to determine conclusively whether these peaks accurately represent age and growth. If *D. calceus* has several age classes, the species appears to live together with many age classes (at least many sizes) in the about same area because most specimens of it was caught with one operated net.

The hepatosomatic index of *D. calceus* in this study is lower than that found by HIGASHI *et al.* (1953) (13.4–24.2%, *Deania* spp.), CADENAT and BLACHE (1981) (14.9–22.3% for *D. calceus* 15.3–

20.3% for *D. mauli* = *D. calceus*), YANO (1985) (16.1-20.4%) and KOBAYASHI (1986) (about 20.0%). The hepatosomatic index was slightly different between the present study and other reports, and those differences may be at the population and/or season. The large livers in both species appear to be useful in regulating buoyancy as already reported by CORNER *et al.* (1969) for deep sea sharks. HIGASHI *et al.* (1953) reported that hydrocarbon contents (mainly consisting of squalene) in liver oil of Japanese *Deania* spp. ranged from 22.53% to 77.07% ($\bar{x}$=37.51%, SD=10.32, n=37). New Zealand specimens of *D. calceus* contained about 44% squalene in their liver oil (UEKI, per. comm.). The sharks are fished commercially in the regions. Thus, both species in Namibia waters may have commercial value.

MACPHERSON (1983), MACPHERSON and ROEL (1987), and MACPHERSON (1989) reported that *D. calceus* collected from Namibia ate mainly cephalopoda and fish, especially family Myctophidae. In *D. calceus* of this study, fish, especially family Myctophidae, and cephalopoda dominated the contents. CADENAT and BLACHE (1981) reported that *D. calceus* fed on shrimps and mainly Stomiatidae and Sternoptychidae. MAUCHLINE and GORDON (1983) reported that northeastern Atlantic *D. calceus* mainly ate fish and cephalopoda. YANO (1985) reported that Japanese *D. calceus* ate fish and crustaceans. KOBAYASHI (1986) reported that 6 specimens of *D. calceus* collected from Kumano-nada, Japan ate fishes, squids and crustaceans. CADENAT (1960) examined the stomachs of 12 specimens of *D. cremouxi* (= *D. crepidalbus*); eight were empty, the other four contained teleosts (chiefly myctophids) and crustaceans. BASS *et al.* (1976) reported one specimen of *D. crepidalbus* had a teleost fish and small squid in its stomach. Thus, both species of *Deania* in Namibia waters fed on squids and fishes, but in other areas crustaceans also dominated the stomach contents.

In hook and line fishing, YANO (1985) reported a high incidence of empty stomach (90%) of *D. calceus*. CLARK and MERRETT (1972) reported that the high incidence of empty stomachs (90%) of deep sea fishes may be due to the frequent loss of food during their ascent from great depths. YANO and TANAKA (1984) and YANO (1985) fishing with bottom longlines and bottom drop lines observed water in the stomachs of the squaloid sharks, *D. calceus*, *Centroscymnus owstonii* and *C. coelolepis*, and postulated that food was washed out of the stomach while the sharks were being hauled to the surface. In the bottom trawls of this study, empty stomachs were not as frequent (53.0% of *D. calceus* and 62.5% of *D. crepidalbus*). MAUCHLINE and GORDON (1983) reported that empty stomachs of *D. calceus* collected by trawls were 58.7% (79-98cm TL) and 69.2% (99-111cm TL), and these values were about equal to the present study. It suggests that food was not washed out of the stomachs or that the sharks preyed on food in the net. However, fresh stomach contents included only one *Electrona* sp. and two *Diaphus* sp. Specimens of the above species were not observed in the net. Thus, it appears that the sharks did not actively feed while in the net, but that sharks collected by nets probably do not have food washed out of their stomachs as readily as do those collected with hook and line fishing.

The data in this study suggested that size at maturity for male *D. calceus* is about 800mm TL and about 530mm TL for *D. crepidalbus*. BASS *et al.* (1976) reported that a male *D. calceus* of 840mm was mature and male *D. crepidalbus* in the waters off Namibia matured 500mm to 550mm TL. CADENAT (1960) reported that size at maturity of male *D. cremouxi* (= *D. crepidalbus*) off the coast of Senegal was also 500mm to 550mm TL.

Size at maturity for female *D. calceus* appeared to be greater than 970mm TL, and size at maturity for female *D. crepidalbus* was about 690mm TL. The size at maturity of female *D. calceus* is about 1050mm TL in Japanese waters (YANO, 1985), and female *D. crepidalbus* matured at about 700mm TL in Senegal waters (CADENAT, 1960). These lengths at maturity were about equal to the lengths found in this study. Males were smaller than females in both species. YANO and TANAKA (1983) reported that most other squaloid sharks also had smaller males than females. In the length frequency

distributions, number of the specimens greater than the length of 800mm TL for female *D. calceus* was fewer than that for male. Size at maturity for male *D. calceus* was about 800mm TL, while that for female was greater than 970mm TL.

Segregation by size, sex and reproductive stage is reported in deep sea sharks (BULLIS, 1967; MUÑOZ-CHÁPULI, 1984; KOBAYASHI, 1986; BABA *et al.*, 1987; YANO and TANAKA, 1988; TANAKA *et al.*, 1990). YANO and TANAKA (1988) reported that deep sea squaloid sharks of the genus *Centroscymnus* undergo a depth segregation related to breeding. In this study, mature females of *D. calceus* were not caught. Thus, mature females probably occur elsewhere.

COMPAGNO (1984) reported that the number of fertilized ova in uteri of *D. calceus* ranged from 6 to 12. YANO (1985) reported that Japanese *D. calceus* carried 13-19 fertilized ova in the uteri and 12-23 embryos per litter. The number of ova found during this study (19) is within the range noted for Japanese *D. calceus*. CADENAT (1960) observed that five specimens of *D. cremouxi* (= *D. crepidalbus*) had 5-7 fertilized ova (35-40mm in diameter) in the uteri, the number of the fertilized ova was about equal to that of the large ova in the ovaries examined in this study. Therefore, the fecundity of *D. calceus* is probably higher than that of *D. crepidalbus*. In contrast to the differences in fecundity and maximum size, the size at birth for the two species is similar. The smallest free swimming specimen of *D. calceus* was a 312mm TL (YANO and TANAKA, 1983), and for *D. crepidalbus* was a 310mm TL (CADENAT, 1960).

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南東大西洋ナミビア沖で漁獲されたヘラツノザメ属2種 *Deania calceus* と *D. crepidalbus* の分布，食性および生殖

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南東大西洋ナミビア沖でオッタートロール漁法により漁獲されたヘラツノザメ属2種の漁獲状態，体長組成，体長体重関係，胃内容物，成熟に関する研究を行った。*D. calceus* は水深620mから640mの間で，*D. crepidalbus* は402mから408mの間で多く漁獲され，両種の漁獲水深に違いがみられた。両種の胃内容物は主にイカ類と魚類であった。成熟体長は，*D. calceus* の雄では全長800mm，雌では少なくとも全長965mm以上であり，*D. crepidalbus* の雄では全長530mm，雌では全長690mmであった。

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