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Aspects of the biology of the jonah crab, *Cancer borealis* Stimpson, 1859 in the mid-Atlantic Bight*

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Introduction

Two species of cancrid crab commonly inhabit the coastal waters of eastern North America (MacKay, 1943). The rock crab, *Cancer irroratus* Say, ranges from Labrador to South Carolina while the jonah crab, *Cancer borealis* Stimpson, has been found from Newfoundland to Florida and in the Bermudas (Rathbun, 1930; Squires, 1966). Both species are known to occur in the shore zone in more northern latitudes, but *C. borealis* has been reported from deeper water (to 750 m) than *C. irroratus* (to 550 m) (Squires, 1966).

While the Dungeness crab, *Cancer magister*, of the Pacific coast of North America supports a valuable fishery and has been well studied (Butler, 1967), the Atlantic coast species have received little attention (Saila & Pratt, 1973; Haefner, 1976). This is particularly true of the larger species, *C. borealis*. Information on the jonah crab is limited to a few cruise reports, e.g. National Marine Fisheries Service *Delaware II* Report 70–8, 1971, miscellaneous papers on distribution (Smith, 1879; Rathbun, 1930; Squires, 1965, 1966; Musick & McEachran, 1972) and physiological aspects (Redfield, Coolidge & Hurd, 1926; Jeffries, 1964, 1966; Stewart & Dingle, 1968; Telford, 1968).

This paper provides information on distribution, relative abundance, reproductive biology and intermoult cycle of jonah crabs captured on the continental shelf. The major portion of this report is based on collections from the Norfolk Canyon and adjacent slope area of the Chesapeake Bight in June, 1973 (R/V *Columbus Iselin* cruise CI–73–10). Other data included in this report were obtained from the following cruises: M/V *Blesk* 71–4, R/V *Albatross IV* 74–4 and R/V *Eastward* 74–2. I am grateful to James E. Weaver, Charles A. Wenner, Elizabeth G. Lewis and Alyce O. Thomson for collecting crab data during these cruises.

Methods

R/V *Columbus Iselin*

From 4–16 June 1973, a trawl survey of the Norfolk Canyon and adjacent continental shelf and slope was made aboard the University of Miami research vessel *Columbus Iselin* (Cruise CI–73–10). Trawls were made within Norfolk Canyon (37° 00′–37° 10′ N; 74° 10′–74° 45′ W), on nearby slope area (36° 32′–36° 48′ N; 74° 25′–74° 46′ W) and on the shelf between the mouth of Chesapeake Bay and the Canyon (36° 56′–37° 09′ N; 74° 50′–75° 51′ W).

Forty-nine half-hour tows were made in depths ranging from 15 m to 2000 m. The fishing effort was distributed according to depth strata as

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follows: 3, 3, and 2 trawls in 10–20 m, 20–40 m and 40–60 m, respectively; 6, 7, 5 and 4 trawls in the canyon at 75–150 m, 150–400 m, 400–1000 m, and 1000–2000 m, respectively, and 6, 6, 5 and 2 tows in the slope at the same respective depths. The nets used were 15 m semi-balloon, four-seam shrimp trawls constructed of nylon netting of the following stretch mesh: 44 mm body, 37 mm intermediate, 36 mm cod-end with 12 mm inner liner.

Water samples for salinity and dissolved oxygen (DO) analyses were collected with Niskin bottles before each trawl. Salinity was determined with an RS–7 conductivity meter; DO by Winkler titration. Temperature readings were obtained from reversing thermometers, bathy-thermographs or expendable bathy-thermographs.

All jonah crabs larger than 50 mm carapace width were processed on board; smaller specimens were preserved in 10% sea-water formalin for later examination. The following observations were made on as many individuals as possible: maximum carapace width to the nearest millimetre, sex, moult stage, gonad development (table 1) and fouling organisms. The catch was subsampled when numerical abundance or condition of the specimens prevented detailed examination of each crab. In each catch except one, every crab was at least sexed, measured and assigned to a moult stage. In the exception, only the subsample was processed.

Table 1

Stages in gonadal development of *C. borealis*

Stage of development	Description: Male	Description: Female
Undeveloped	Organs not observed even under 40 × magnification	
Very slight	Vasa deferentia thread-like, detectable with scope. Colourless	Ovary thread-like, detectable with scope. Colourless
Slight	Thickened strands of vasa deferentia evident without scope. Colourless	Thickened ovary evident with naked eye. Colourless to white
Moderate	Testes and vasa deferentia equal approximately one-fourth the volume of the hepatopancreas. White	Ovary about one-half the volume of the hepatopancreas. White, tan, to light orange
Well developed	Volume of male organs subequal to that of hepatopancreas. White	Volume of ovary subequal to that of hepatopancreas. Light orange to orange
Very well developed	Testis the dominant internal organ. White	Ovary the dominant internal organ; eggs are obvious. Orange

M/V *Blesk*

Information on size, sex and abundance of jonah crabs and hydrographic data were collected during the M/V *Blesk* cruise 71–4, 30 September–12 October 1971. A 27·1 m Soviet otter trawl with 32–40 mm stretch mesh cod-end was towed for 30 min at each of 48 stations on the continental shelf from Cape Cod, Massachusetts (41° 09′ N) to south of Oregon Inlet, North Carolina (35° 37′ N). Sampling was confined to 20–260 m.

R/V *Albatross IV*

During the R/V *Albatross IV* cruise 74–4 (12–21 March 1974) a 24 m high opening otter trawl was towed for 30 min at each of 54 stations on the continental shelf from Long Island, New York (41° 04·5′ N) to north of Oregon Inlet, North Carolina (35° 58·5′ N). The net was made entirely of 127 mm mesh, with a cod-end liner of 12·5 mm stretch mesh. Sampling was confined to 22–338 m. Crabs were sexed and measured. The presence of soft crabs was noted, but hard crabs were not examined for signs of incipient ecdysis. Bottom temperature was measured by bathy-thermograph.

R/V *Eastward*

From 15 to 20 April 1974, 20 trawls were made during the R/V *Eastward* cruise 74–2 which included stations along the North Carolina shelf and slope (34° 29′ N; 76° 18′ W), Norfolk Canyon area, and adjacent slope area of Virginia. Half-hour and hour trawls were made with a 9 m semi-balloon otter trawl fitted with a 12 mm stretch mesh liner. Bottom temperature was recorded prior to each tow. Sex, size and moult stage were observed for each crab.

Results

Jonah crabs were contagiously distributed in March, June and October (fig. 1) within a 20–400 m depth range. An index of transformed mean abundance (Y = natural log $(x+1)$, where x is abundance in number of crabs per tow) was calculated for each depth stratum within the sampling zones.

Crabs were most abundant in the 150–400 m depth stratum from late winter to early summer (fig. 2). In the fall they were slightly more abundant at depths of 61–160 m within the New York Bight (Cape Cod to Cape Henlopen), and at depths greater than 160 m in the Chesapeake Bight (Cape Henlopen to Cape Hatteras) (fig. 3). Comparison of relative abundance between months was not attempted because of the difference in gear and effort.

Most *C. borealis* were distributed within a range of 6·0–15·9°C in March, 4·0–13·9°C in June and 6·0–13·9°C in October (figs. 4 and 5). A seemingly unusual catch was made at 22·2°C in the New York Bight in October. Maximum abundance occurred at 8·0–11·9°C in March and June and at 10·0–13·9°C in October. Crabs were scarce in June at $<$ 8·0°C. In April, 45 crabs were taken within the 9·4–13·9°C range.

In June, temperatures above 10·0°C were recorded within the 75–150 mm depth stratum; 8·0–9·9°C recordings were about equally distributed between the 150–400 m and 20–60 m ranges; while temperatures $<$ 8°C were confined to depths $>$ 400 m (Haefner, 1976).

In June 1973, male jonah crabs ranged from 13–175 mm in carapace width; females from 13–141 mm. Width frequency data from all areas and strata were pooled into 5 mm size groups (fig. 6). All plots represent total number of individuals caught. Three modal groups for males and females are recognizable: 13–40 mm, 41–80 mm and 81–110 mm. A fourth group is evident for male crabs over 110 mm carapace width. The few female crabs $>$ 110 mm do not constitute a well-defined modal group.

On the basis of these modal groups, transformed indices of abundance were calculated by modal group for each sex in each area and stratum (fig. 7).

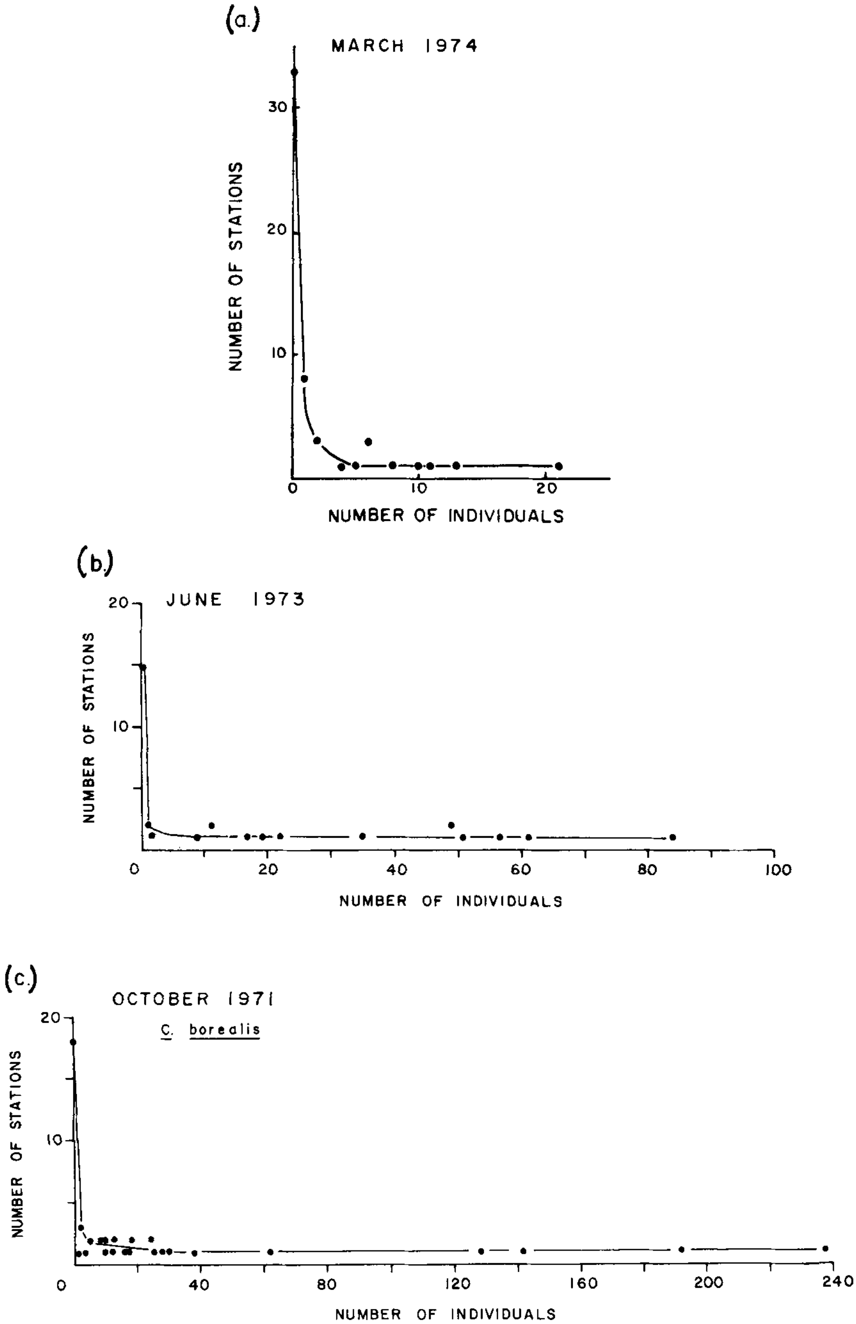

Fig. 1. Distribution of the number of individuals of *C. borealis* captured per station withi the 15–400 m depth range in March 1974, June 1973 and October 1971.

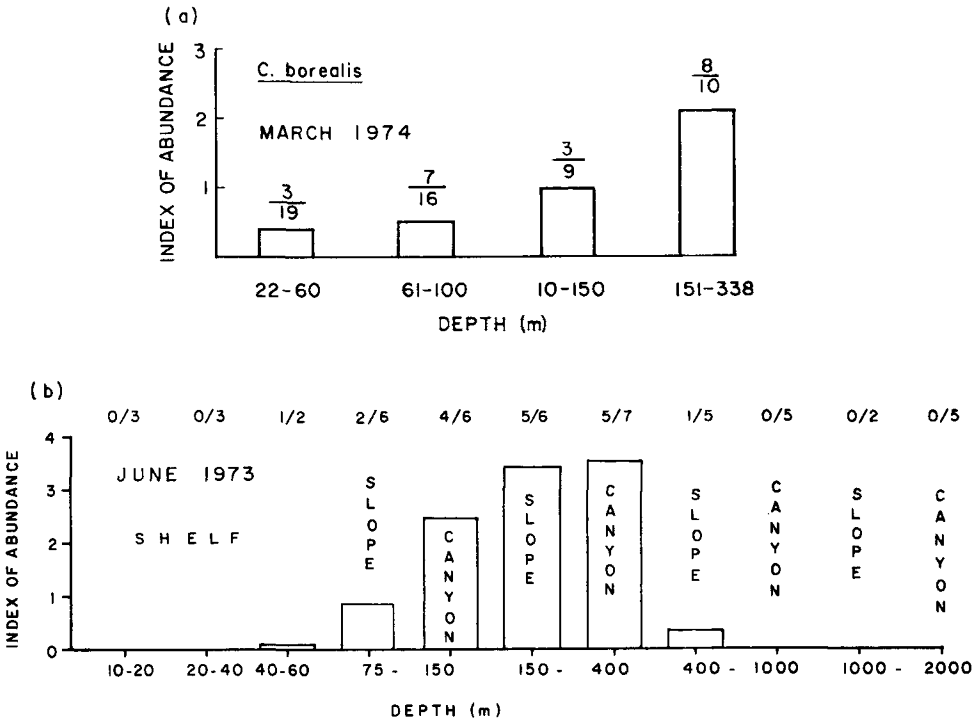

FIG. 2. Index of transformed mean abundance of *C. borealis* captured in March 1974 and June 1973 within each depth stratum. The fraction over each bar is the ratio of the number of stations at which the species was captured to the total number of stations in each depth stratum.

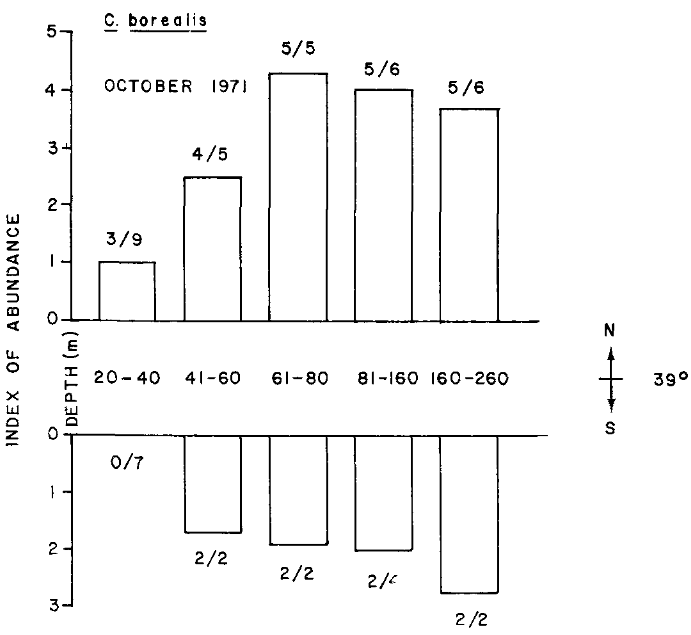

FIG. 3. Index of transformed mean abundance of *C. borealis* captured in October 1971 within each depth stratum north and south of 39° latitude. Fractions as in fig. 2.

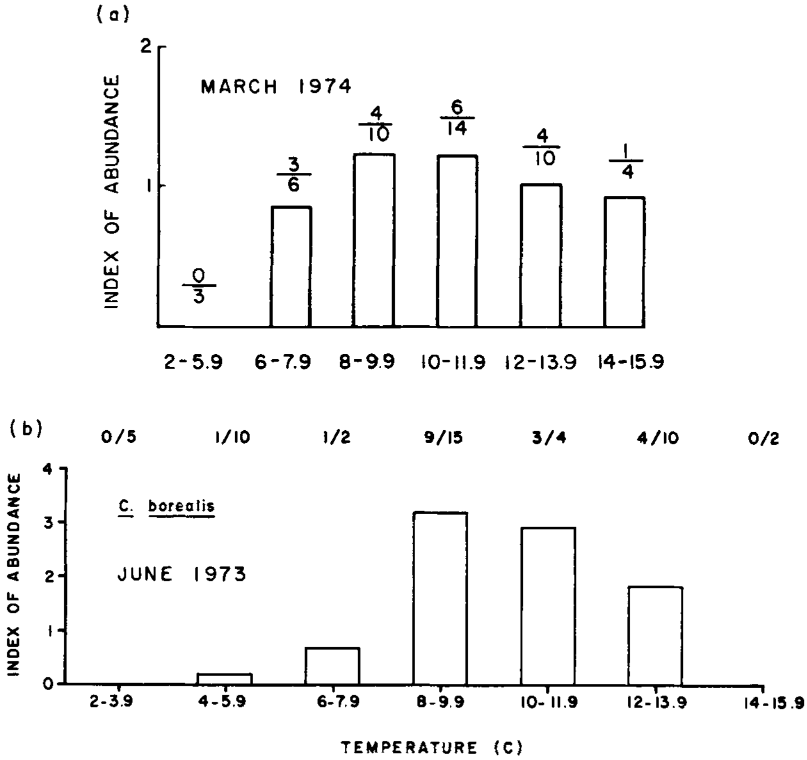

Fig. 4. Index of transformed mean abundance of *C. borealis* captured during March 1974 and June 1973 within each temperature stratum. Fractions as in fig. 2.

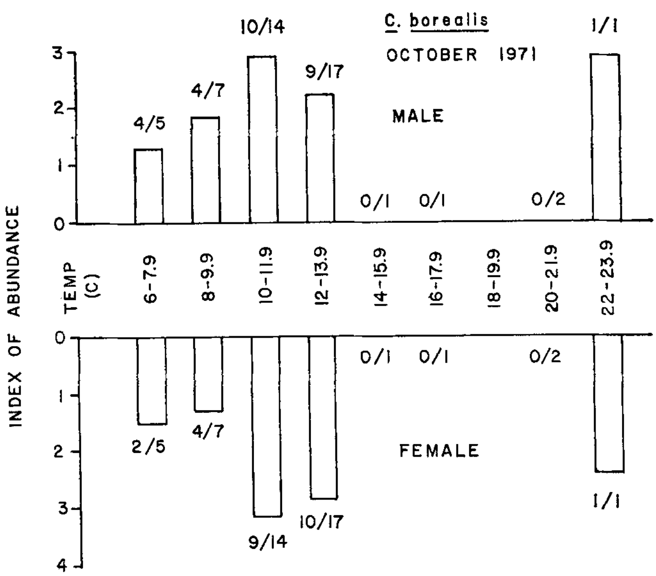

Fig. 5. Index of transformed mean abundance of jonah crabs in relation to temperature strata for October 1971. Fractions as in fig. 2.

Crabs $\leqslant 40$ mm in width ranged from 75 to 400 m and were most abundant at 75–150 m in the canyon. Crabs 41–80 mm in width were not captured at depths < 150 m, but they comprised the dominant modal group in strata > 150 m in the slope and canyon. Crabs 81–110 mm occurred from 40 to 400 m, maximally at 150–400 m. Male crabs $\geqslant 111$ mm, were found only in the 150–400 m depth stratum. A single female was the only crab > 111 mm captured in the 75–150 m stratum.

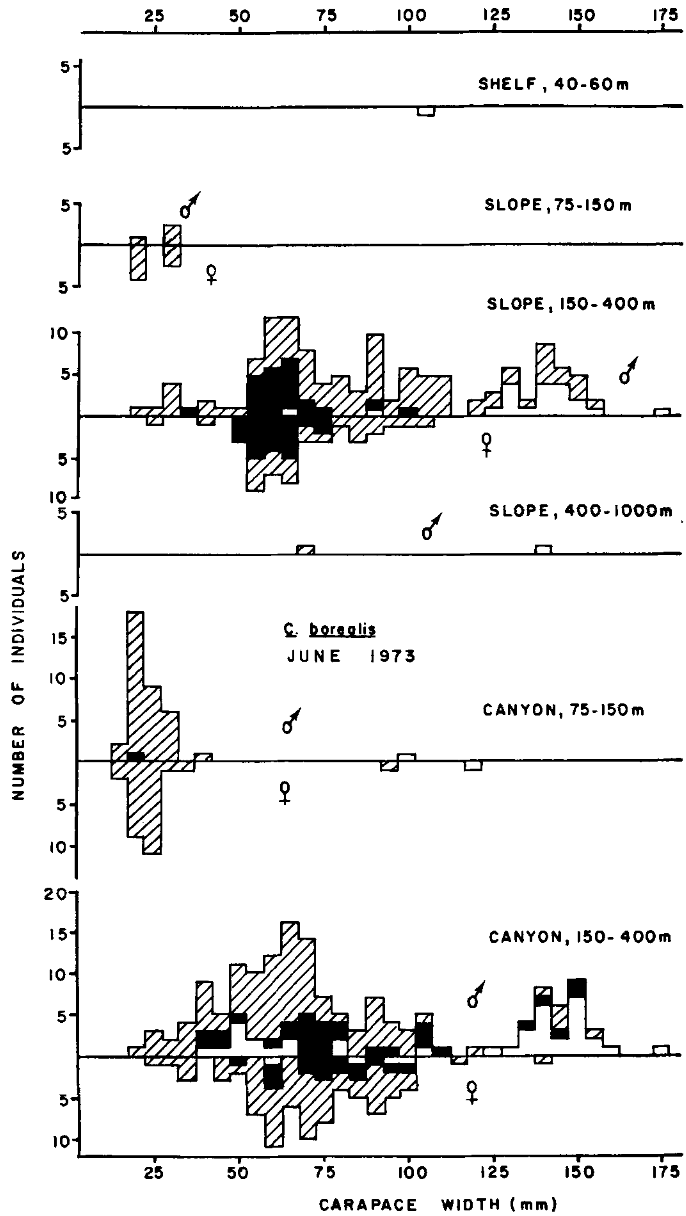

FIG. 6. Width frequency distribution for *C. borealis* captured during June 1973. Intermoult stage C_1–C_4 is shown as blank area; peeler (D_1–D_4) by the solid and soft or paper-shell (A_1–B_2) by the crosshatched areas. Males are plotted above the line; females below.

A plot of the indices of abundance of the modal groups in relation to temperature (fig. 8) is similar to the pattern shown in fig. 4, but it does indicate that female jonah crabs were not taken in areas where the bottom water temperature was $< 8°C$. The smallest crabs (< 40 mm) were captured over the broadest range of temperature, intermediate sizes (41–110 mm) over the narrowest range.

The width frequency distribution in October 1971, based on subsample data, does not clearly show the modal groups indicated by the June 1973 data. For the sake of consistency, however, the data were treated in the same manner as those of the June Samples. All modal groups were present in depths > 40 m, although in different relative numbers (fig. 9). Crabs < 40 mm were nearly equally distributed, but absent in depths < 40 m. Larger crabs (> 41 mm) were not consistently captured in shallow (< 40 m) water but were relatively abundant at depths > 60 m.

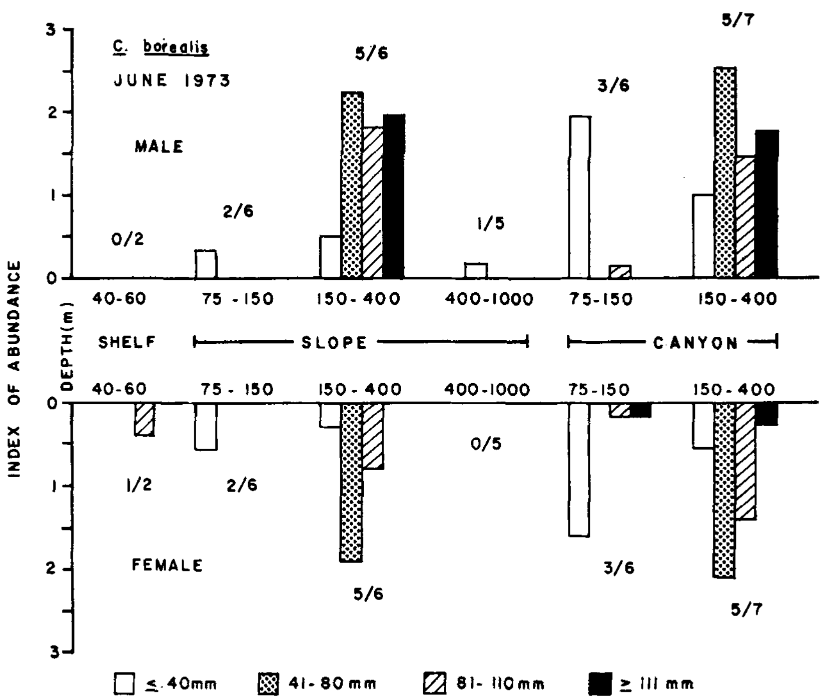

FIG. 7. Index of transformed mean abundance of four size groups of male and female *C. borealis* captured in June 1973, within each depth stratum. Fractions as in fig. 2.

The width frequency distribution (fig. 10 *a*) of the March 1974 collections reflects the selectivity of the trawl for larger individuals and illustrates the preponderance of male crabs. The sex ratio (2·9 : 1, M : F) was significantly different from the expected 1 : 1. Although the modal groups observed in June 1973 are suggested by the distribution in fig. 10 *a*, further analysis of these data was not made because of the small number of crabs.

Modal groups could not be detected in the small sample of April 1974 (fig. 10 *b*). The male dominated sex ratio (1·9 : 1) differed significantly from the expected 1 : 1.

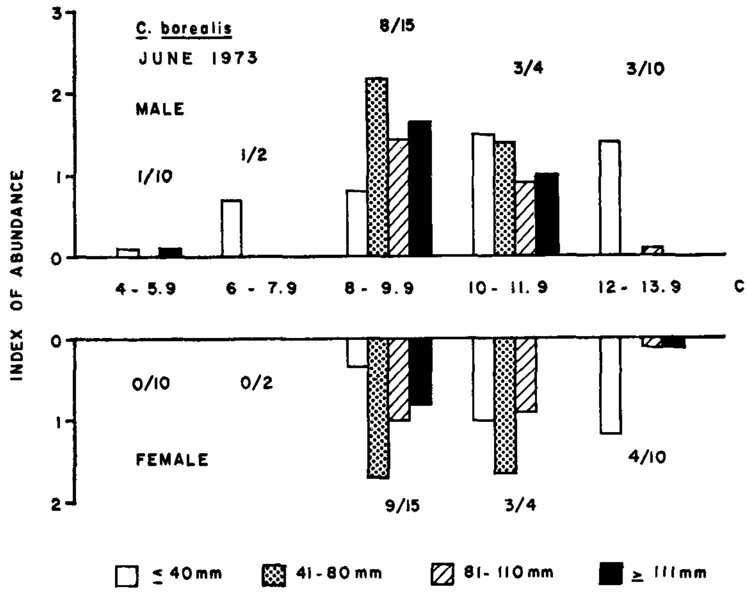

FIG. 8. Index of transformed mean abundance of four size groups of male and female *C. borealis* in relation to temperature of capture in June 1973. Fractions as in fig. 2.

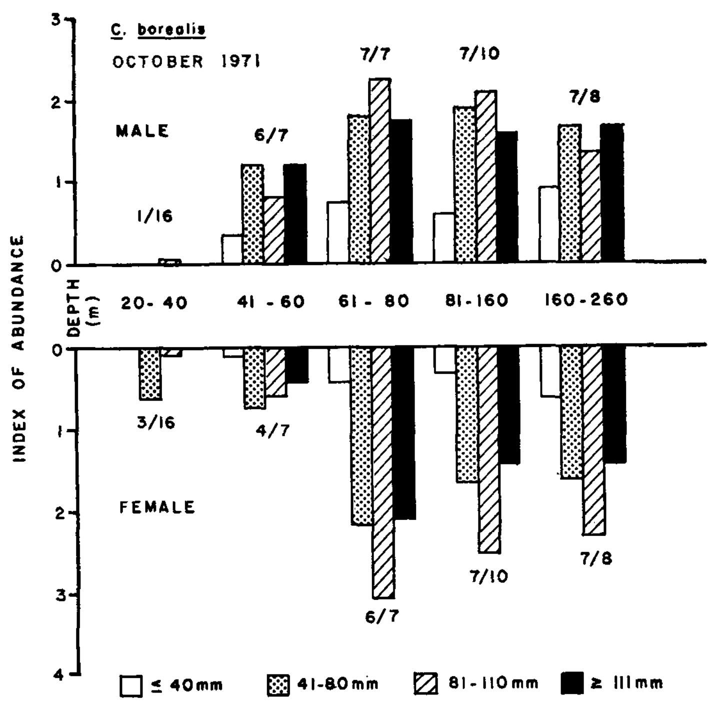

FIG. 9. Index of transformed mean abundance from size groups of jonah crabs captured during October 1971 within each depth stratum. Fractions as in fig. 2.

Sex ratios (M : F) were calculated for each modal group in each stratum in which at least ten crabs were captured in June 1973 (table 2). Males predominated in every case.

Sex ratios for jonah crabs taken in October 1971 ranged from 1 : 16 to 2·4 : 1 and in all but one stratum (61–80 m) the ratios were significantly different from 1 : 1 (table 3). The ratio was in favour of males at only one stratum, 41–60 m. In the various modal size groups males were dominant among crabs < 40 mm in width, while females dominated the 81–110 mm group. The ratios for crabs 41–80 mm and > 111 mm were essentially 1 : 1.

The incidence of intermolt stages of the crabs collected in June are shown in table 4 and fig. 6. The majority (68%) of all jonah crabs were in soft or papershell condition (A_1–B_2); 19% were 'peelers' (D_2–D_4); only 13% were in the

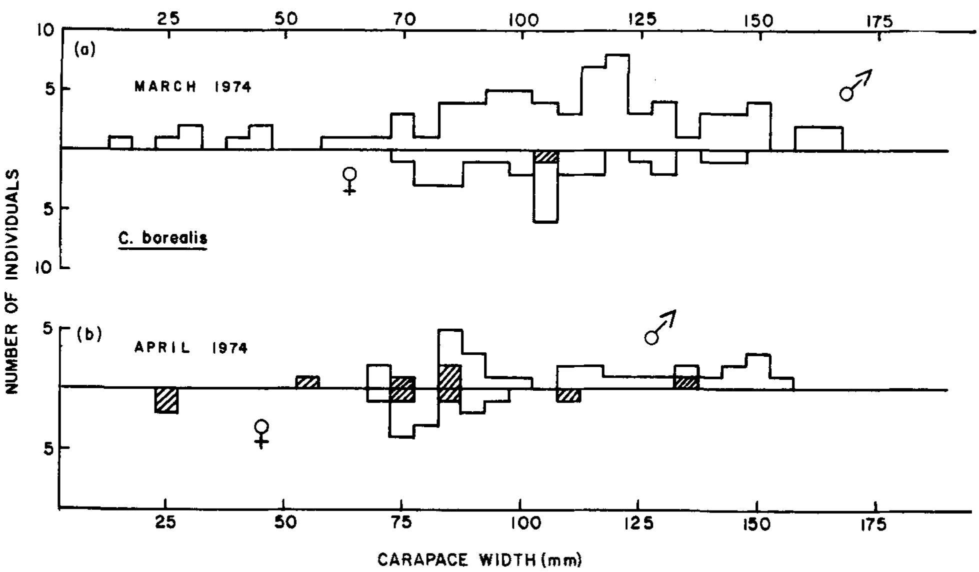

Fig. 10. Width frequency distribution of *C. borealis* captured during March and April 1974. The cross-hatched area indicates soft or papershell crabs (A_1–B_2); intermoult stage (C_1–C_4) is shown by the blank area.

Table 2

Sex ratios, by area and depth, for *C. borealis* captured during June 1973. Significant deviations from the expected 1 : 1 ratio are indicated by asterisks

Area	Depth (m)	Male	Female	Ratio
		⩽40 mm width		
Slope	150–400	9	2	4·5 : 1*
Canyon	75–150	36	24	1·5 : 1
Canyon	150–400	19	5	3·8 : 1*
		41–80 mm width		
Slope	150–400	50	35	1·4 : 1
Canyon	150–400	81	50	1·6 : 1
		81–100 mm width		
Slope	150–400	31	7	4·4 : 1*
Canyon	150–400	23	21	1·1 : 1
		⩾111 mm width		
Slope	150–400	36	0	36 : 0*
Canyon	150–400	34	2	17 : 1*

Table 3

Sex ratios, by depth, for *C. borealis* captured in Chesapeake Bight in October 1971. Significant deviations from the expected 1 : 1 ratio are indicated by asterisks

Depth	≤40 mm width			41–80 mm width			81–110 mm width			≥111 mm width			All crabs		
(m)	M	F	Ratio	M	F	Ratio	M	F	Ratio	M	F	Ratio	M	F	Ratio
20–40	0	0		0	14		1	2	1 : 2	0	0		1	16	1 : 16*
41–60	3	1	3 : 1	16	8	2 : 1	9	6	1·5 : 1	17	4	4·3 : 1*	45	19	2·4 : 1*
61–80	8	1	8 : 1*	35	55	1 : 1·6*	59	144	1 : 2·4*	33	51	1 : 1·6*	135	251	1 : 1·9*
81–160	8	4	2 : 1	58	43	1·4 : 1	70	115	1 : 1·6*	38	32	1·2 : 1	174	194	1 : 1·1
161–260	12	7	1·7 : 1	35	33	1·1 : 1	23	74	1 : 3·2*	35	48	1 : 1·4	105	162	1 : 1·5*
Total	31	13	2·4 : 1	144	153	1 : 1·1	162	341	1 : 2·1*	123	135	1 : 1·1	460	642	1 : 1·4*

Table 4

Percentage occurrence of brachyuran intermoult stages among various size male and female jonah crabs captured in June 1973

Area	Depth (m)	≤40 mm width				41–80 mm width				81–110 mm width				≥111 mm width				Total crabs			
		No.	C_1–C_4	D_2–D_4	A_1–B_2	No.	C_1–C_4	D_2–D_4	A_1–B_2	No.	C_1–C_4	D_2–D_4	A_1–B_2	No.	C_1–C_4	D_2–D_4	A_1–B_2	No.	C_1–C_4	D_2–D_4	A_1–B_2
Male																					
Slope	75–150	3	0	0	100·0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	100·0
	150–400	9	0	11·1	88·9	49	2·0	40·8	57·1	31	3·2	6·5	90·3	36	50·0	0	50·0	125	16·0	18·4	65·6
Canyon	75–150	36	0	0	100·0	0	0	0	0	1	100·0	0	0	0	0	0	0	37	2·7	0	97·3
	150–400	19	5·2	10·5	84·2	80	15·0	22·5	62·5	23	4·3	26·0	69·6	33	66·7	15·2	18·2	155	23·2	20·0	56·8
Total		67	1·5	4·5	94·0	129	10·1	29·5	60·5	55	5·5	14·5	80·0	69	57·9	7·2	34·8	320	17·8	16·9	65·3
Female																					
Slope	75–150	6	0	0	100·0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	100·0
	150–400	2	0	0	100·0	35	0	57·1	42·9	8	0	0	100·0	0	0	0	0	45	0	44·4	55·6
Canyon	75–150	24	0	0	100·0	0	0	0	0	1	0	0	100·0	1	100·0	0	0	26	3·8	0	96·2
	150–400	5	0	0	100·0	50	4·0	18·0	78·0	21	14·3	23·8	61·9	2	0	0	100·0	78	6·4	17·9	75·6
Total		37	0	0	100·0	85	2·4	34·1	63·5	30	10·0	16·7	73·3	3	33·3	0	66·7	155	3·9	21·9	74·2
Total crabs		104	0·9	2·9	96·2	214	7·0	31·3	61·7	85	7·1	15·3	77·6	72	56·9	6·9	36·1	475	13·2	18·5	68·2

true hard-shell stage (C_1–C_4). Of all crabs $\leqslant 40$ mm, 96% had recently moulted; only 1% were hard. The larger modal groups contained progressively more hard-shell crabs and fewer peelers and paper-shells. Very few (7%) peelers were observed among crabs > 111 mm width; the majority (57%) of these were hard-shell. A higher incidence of moulting was observed for crabs captured in 75–150 m than in the 150–400 m stratum because the catch from the shallower depth was comprised almost entirely of crabs $\leqslant 40$ mm width, the most actively moulting group. These trends were similar for males and females and were fairly consistent for all the areas in which jonah crabs were captured.

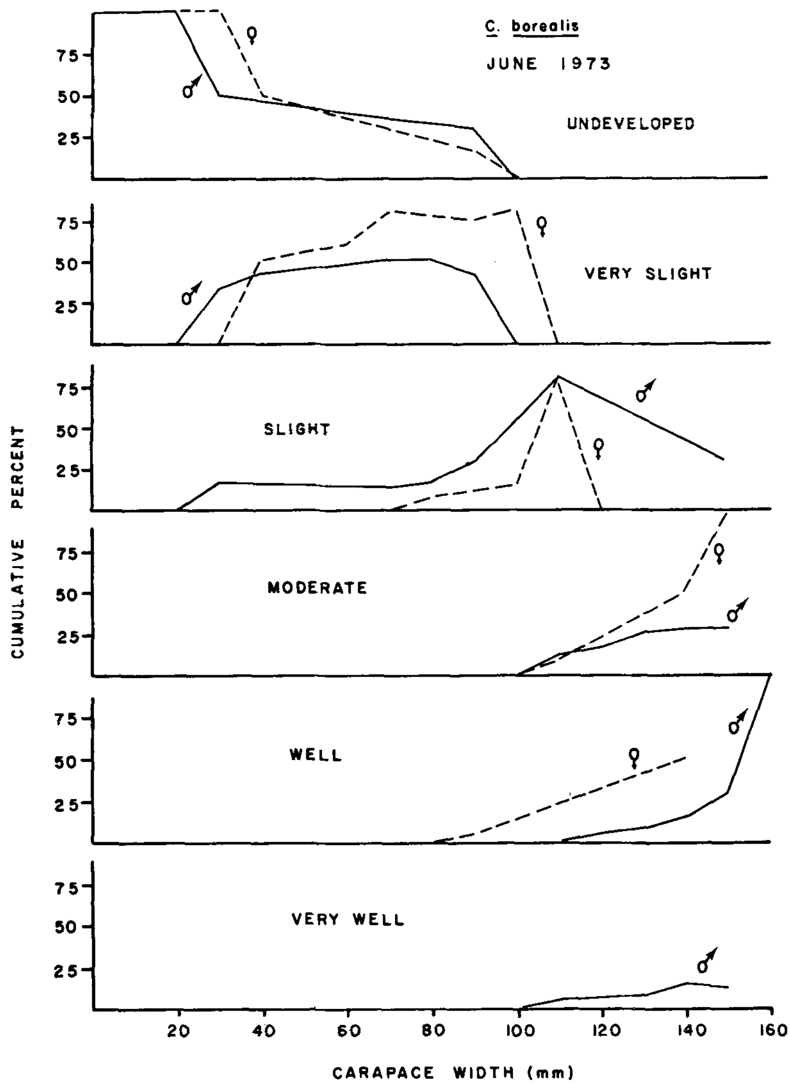

FIG. 11. Cumulative percentage occurrences of various stages of gonad development in relation to size of 65 male and 31 female jonah crabs captured in June 1973.

Gonad development of 65 male and 31 female jonah crabs collected in June was related to size (fig. 11). The gonads of most crabs < 80 mm width were undeveloped or only slightly developed. Moderate to well-developed gonads were generally observed only in crabs > 100 mm width. Most males > 150 mm possessed well-developed testes and vasa deferentia. No females had ripe ovaries. This was not unexpected considering that no ovigerous individuals were captured during this cruise.

Table 5

Relationship of intermoult stage to gonad development in 96 jonah crabs captured during June 1973

Gonad development	Male N	Male Per cent N	Male C_1–C_4	Male D_2–D_4 (%N)	Male A_1–B_2	Female N	Female Per cent N	Female C_1–C_4	Female D_2–D_4	Female A_1–B_2
Undeveloped	7	10·8	0	0	100·0	3	9·7	0	0	100·0
Very slight	10	15·4	0	20·0	80·0	16	51·6	0	25·0	75·0
Slight	14	21·5	7·1	7·1	85·7	7	22·6	0	29·6	71·4
Moderate	12	18·5	25·0	0	75·0	3	9·7	33·3	0	66·7
Well	16	24·6	56·3	6·3	37·5	2	6·5	50·0	0	50·0
Very well	6	9·2	33·3	66·7	0	0	0	0	0	0
Total	65		23·1		64·6	31		6·5	19·4	74·2

Table 6

Condition of the seminal receptacle in relation to width of 19 female *Cancer borealis* captured during June 1973

Range (mm)	Total	Number of crabs: Undeveloped	Developed not distended	Swollen (with sperm plugs)	Swollen (without sperm plugs)
21–40	2	2			
41–60	2	1	1		
61–80	8	3	5		
81–100	6		2	2	2
101–120	1			1	

Most crabs (67–100%) in early stages of gonad development were soft or papershell, reflecting some relationship to the intermoult cycle (table 5). The majority of crabs in advanced gonadal development were hardshell or peeler.

Spermathecae may be undeveloped in crabs as large as 80 mm (table 6). They were present, but not distended, in crabs as small as 41 mm. In this sample, most of the 81–120 mm crabs had swollen spermathecae, and three of seven had sperm plugs inserted in the vulvae, which indicated they had mated.

One ovigerous individual and one soft crab were observed in March. Most crabs collected in April were hardshell intermoult (C_1–C_4); 26% were paper-shell. None of the crabs were peelers (D_2–D_3). Twelve females collected in April, ranging in width from 60–180 mm, were examined for the presence of sperm plugs in the external vulvae. Only one paper-shell crab contained plugs; plugs were absent in two other paper-shell and nine hard crabs.

The possibility of association of *C. borealis* with other major decapods in the March, 1974, collections was explored. Cole's (1949) coefficient of association (C_7) was calculated to determine whether a given pair of species co-occurred more or less frequently than could be expected by chance. Comparisons were made with the C_7 values of Musick & McEachran (1972) and Haefner (1976). The C_7 value ($-0{\cdot}571$) computed for *C. borealis* and *C. irroratus* indicated significant negative association ($P=0{\cdot}025$, $t=2{\cdot}38$). *Homarus americanus* and *C. borealis* were positively associated ($C_7=0{\cdot}488$, $P=0{\cdot}005$, $t=2{\cdot}92$) (table 7).

Table 7

Contingency tables used in computing Cole's coefficient of association (C_7) for March 1974 collections

		C. borealis	
		Present	Absent
	Present	3	15
C. irroratus	Absent	18	18
		C. borealis	
		Present	Absent
	Present	11	5
H. americanus	Absent	10	28

The branchial chambers and external surface of 48 crabs from the June collections were examined for the presence of epizoites. The incidence of infestation reflected the moulting history of the crabs. Twelve of 19 (63·2%) hard or peeler crabs, and 4 of 29 (13·8%) paper-shell crabs were fouled. Three of the four fouled paper-shell crabs were in an advanced state of shell hardening. The predominant organism was the lepadid barnacle, *Poecilasma inaequilaterale* Pilsbry which was found attached to the gills in the branchial chamber. An unidentified polychaete was also found in the branchial chamber on two occasions, but its presence was most likely accidental, occurring during collection. No external fouling was observed.

Thirty-eight crabs (26 male, 12 female) from the April Norfolk Canyon collections were examined for epizoites. Two were infested with *Poecilasma inaequilaterale*.

Discussion

Although jonah crabs are contagiously distributed on the continental shelf of the mid-Atlantic Bight, maximum abundance appears to be dependent on depth and temperature. Fall and winter 1967–1968 collections by Musick and McEachran (1972) (36° 05′ N–38° 43′ N; 73° 28′ W–74° 50′ W) revealed two major zones of abundance: 166–274 m along the shelf edge throughout their collecting area and 74–110 m only at stations north of 37° N latitude. *Cancer borealis* was collected over a temperature range of 3–14°C, but maximum abundance occurred within 9–11°C. Crabs collected in the fall of 1971 had a similar distribution. In the entire north–south collecting area, crabs were generally equally abundant from 61–260 m. North of 39° N latitude, however, crabs were most abundant at 61–80 m. South of 39° N latitude the zone of maximum abundance was 160–260 m. Although collected over an extensive temperature range (6–23·9°C), maximum abundance was associated with the 10–13·9°C strata. In June, March and April, jonah crabs were most abundant at 150–400 m depth and 8–11·9°C.

The temperature range (8–13·9°C) associated with maximum abundance falls within the 6–14°C range which Jeffries (1966) observed as experimental 'optimum' walking temperature for *C. borealis*. It also complements the distribution of jonah crabs in relation to water temperature, observed by Rathbun (1930).

Jeffries (1966) noted that *C. borealis* and *C. irroratus* seldom co-occur in Narragansett Bay, Rhode Island and attributed this to differential preference for substrate by these congeneric species. The former species prefers rocky substrates; the latter sandy bottoms.

Musick & McEachran (1972) found these species to be distributed randomly with respect to one another in Chesapeake Bight, based on computed coefficients of association. They ruled out the segregation of these species in the Chesapeake Bight by substrate preference because rock substrates are few. Shelf sediments are mostly sand with a few patches of gravel. Slope sediments are mostly silt and clay.

Apparently the degree of association varies seasonally. The coefficient of association computed for *C. borealis* and *C. irroratus* for October was not significant, i.e. they were randomly distributed relative to each other (Haefner, 1976), but that for March denoted negative association. However, that of June indicated very close association between these species (Haefner, 1976). *Cancer borealis* was significantly associated with the American lobster, *Homarus americanus* in June (Haefner, 1976) and in March. These species were also closely associated in fall and winter (Musick & McEachran, 1972).

The apparent lack of association of *C. borealis* and *C. irroratus* in fall, winter and early spring and their close association in June suggest population movements, particularly for *C. irroratus*. *C. irroratus* seems to migrate inshore in the fall and offshore in the spring (Shotton, 1973; Terretta, 1973; Haefner, 1976). The consistency of maximum abundance of *C. borealis* in relation to depth and temperature and the association between *C. borealis* and *H. americanus* for fall, winter and spring collections suggest limited population movements of jonah crabs.

Cancer borealis and *C. irroratus* of the Chesapeake Bight exhibit differences in distribution by sex and size and in certain aspects of reproductive and moulting biology. The normal sex ratio of small rock crabs taken in June was 1 : 1 with some preference of intermediate size males for depths greater than 60 m and of females for shallower water (Haefner, 1976). Although male jonah crabs were generally more numerous than females, there was insufficient data to indicate depth preference by sex or size group. Only very large males appeared to prefer deeper water. It is difficult to compare sex ratios and depth distribution of these two species from the collections because most jonah crabs were collected north of 39° N latitude, whereas most rock crabs were collected south of that parallel (Haefner, 1976).

Very little is known about the spawning period of *C. borealis*. Smith (1879) recorded 'many' ovigerous females in August and September from Casco Bay, Maine, and Sastry & McCarthy (1973) reported finding ovigerous crabs in mid-July in Narragansett Bay. They related their finding to the high density of *Cancer* spp. larvae in July (Hillman, 1964). Within the mid-Atlantic region, no ovigerous females were reported by Musick & McEachran (1972) in winter. One sponge female was observed in March. None were recorded during the October cruise and no evidence of sponge or egged-off females was seen in June or April. The lack of females with ripened ovaries in June suggests that spawning is not imminent in late spring or early summer. The few large females taken in June and April with swollen spermathecae and sperm plugs in the vulvae is some evidence that spawning may occur by mid-summer. On this evidence, it appears that the spawning season of *C. irroratus* differs from that of *C. borealis*. Female rock crabs are known to carry eggs from September to June in Chesapeake Bight (Haefner, 1976), and larvae are present from May through October in the vicinity of the mouth of Chesapeake Bay (Sandifer, 1972).

Moulting data for *C. borealis* is insufficient to define the seasonal pattern. This species was actively moulting in June, but evidence of recent or incipient ecdysis was not observed in October or in the winter collections of Musick & McEachran (1972). One soft crab was noted in the March 1974 collection and one in an August 1881 collection from Nantucket Shoals (Rathbun, 1930). Paper-shell crabs noted in April 1974 suggest earlier moulting, perhaps in March. It is conceivable that some component of the population is moulting throughout the year as is the case of *C. irroratus* along the coast of Maine (Krouse, 1972). Moulting of *C. irroratus* in the Chesapeake Bight is known to occur from December through February (Terretta, 1973; Shotton, 1973) and in June (Haefner, 1976).

Summary

Jonah crabs, *Cancer borealis*, were collected in October 1971, June 1973, and March and April 1974 during trawl surveys of the continental shelf of the mid-Atlantic Bight and the shelf and slope east of Beaufort, North Carolina. In 171 trawls made from the M/V *Blesk*, R/V *Columbus Iselin*, R/V *Albatross IV* and R/V *Eastward*, 1626 jonah crabs were captured. Crabs were contagiously distributed within a depth range of 20–400 m. Maximum abundance occurred within 150–400 m and 8–13·9°C.

Male crabs ranged from 12 to 175 mm in carapace width; females from 13 to 152 mm. Three modal size groups for males and females were recognized: 13–40 mm, 41–80 mm and 81–110 mm. There was a fourth group of male crabs over 110 mm width. Crabs $\leqslant 40$ mm were most abundant at depths of 75–150 m; crabs 41–80 mm were not captured in depths < 150 m, but were the dominant group in strata > 150 m. Larger crabs (81–110 mm) occurred from 40 to 400 m and reached maximum numbers at 150–400 m. Male crabs $\geqslant 111$ mm were found only in 150–400 m.

Male crabs predominated in June. Sex ratios (M : F) ranged from 1·1 : 1 to 17 : 1. In October the ratios ranged from 1 : 16 to 2·4 : 1. In March and April the ratios were 2·9 : 1 and 1·9 : 1, respectively. In most cases the ratios were significantly different from 1 : 1.

The species was actively moulting in June, but recent or incipient ecdysis was not observed in October. Only one recently moulted crab was noted in March.

Gonad development in June was related to size. Most crabs $\leqslant 80$ mm width were undeveloped or only slightly developed. Mature gonads were seen only in crabs $\geqslant 100$ mm width. Testes and vasa deferentia of most males $\geqslant$ 150 mm were well to very well developed. No ripe ovaries were seen and no ovigerous individuals were taken in June. One berried female was observed in March.

The incidence of fouling organisms on crabs reflected the moulting history of the crabs. Sixty per cent of crabs in anecdysis and 14% of those in postecdysis were fouled. The predominant organism was the lepadid barnacle, *Poecilasma inaequilaterale* Pilsbry, which was attached to the gills in the branchial chamber.

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