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EVIDENCE FOR SPAWNING BY *GONATUS* SP. (CEPHALOPODA: TEUTHOIDEA) IN THE HIGH ARCTIC OCEAN

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ABSTRACT

A specimen of the squid, Gonatus *sp., was captured through an ice hole at 79° 58' N. lat., 170° 23' E. long. (about 500 miles north of Wrangel Island, Siberia) whose condition suggests it had spawned just before its capture on March 30, 1962. The emaciated condition is described in specimens of other Californian female* Gonatus *that presumably had spawned just before capture, and a brief review is given of the records of the degeneration and fatal effects from spawning by females in other genera of squid and octopods.*

The cephalopod fauna of the high Arctic Ocean is poorly known; pelagic cephalopods have been reported only on a few occasions. Berry (1925) described from seal stomachs a small collection of cephalopod beaks, one of which taken at 70°13'N, 140°50'W, probably belongs to a squid. MacGinity (1955) recorded a juvenile and adult *Cirroteuthis* sp. (finned octopods) that were dip-netted near shore and 3 specimens of *Gonatus "fabricii"* (72, 63, 59 mm mantle length) that had washed ashore at Pt. Barrow, Alaska. Voss (1967), in a footnote, mentioned the capture of *Cirrothauma* (finned octopod) in the high Arctic. The locality of this capture is 86°N, 173°E (Roper and Brundage, 1972). Nesis (1971a) found 2 specimens of *Gonatus "fabricii"* (175 and 87 mm Mantle Length) in an ice hole at 87°24.2'N, 132°01.5'E and one specimen of *G. "fabricii"* (130 mm ML) in an ice hole at 80°13.3'N and 143°01'E. He further reports that *Gonatus* is abundant at the border of the Arctic Basin and the Greenland Sea, particularly young specimens ranging from 30-71 mm ML. The only pelagic cephalopods known from the high Arctic Ocean, therefore, are members of the squid family Gonatidae and two species of finned octopods.

The squid reported here was captured from ice island Arlis II (Arctic Research Laboratory Ice Station No. 2) in the high Arctic Ocean on March 30, 1962. The squid, alive at the time of capture, was found floating head downward in a hole cut through the ice for hydrographic and plankton studies.

DESCRIPTION

Since the identity of this specimen is of considerable importance but impossible to determine to species at present due to the condition of the animal, a brief description is presented (Fig. 1 & 2). The pen is 210 mm in length. The mantle and fins are gelatinous and flaccid. A well-developed conical "tail" is present posterior to the conus of the pen. In preservation in 70% ethanol the fins measure 102 mm in total length and 145 mm in total width. The fins extend posteriorly along the "tail."

The funnel is large and reaches to the level of the midpoint of the eyes. The funnel locking-cartilages bear simple straight grooves (Fig. 2, F). The dorsal pad of the funnel organ has an inverted V-shape, the anterior half of each limb has low ridges along the lateral margin (Fig. 2, G). A small anterior papilla is present. The ventral pads are small and nearly teardrop-shaped with the blunt end anterior. A large funnel valve is present.

The head is short and bears large eyes with a distinct sinus on the anterior margin of each eyelid. A nuchal crest with three indistinct pairs of nuchal folds occurs on the head. "Olfactory" lobes lie on the second pair from the funnel on each side. The nuchal cartilage, which is long and slightly rounded at either end, bears a median ridge containing a central groove.

The arms are gelatinous and relatively short (Arm I = 73 mm, III - 97 mm, IV = 98 mm). A weakly developed aboral keel is present on each arm III and large lateral keels are present on each arm IV. All arms bear very broad, thick, gelatinous trabeculae that are joined by thick, poorly defined protective membranes which converge and conceal the hooks in the distal portion of the arms. The arm tips are not attenuate. The armature of arms I-III consists of two alternating rows of small hooks (Arm I = 42

hooks, II = 41 hooks, III = 44 hooks). The marginal and terminal rows of suckers are absent and only small grooves indicate their former presence. Suckers are absent from arms IV (Fig. 2, B). The tenta - cles have been lost except for rounded stubs.

The specimen is a female. Oviducal and nidamental glands are slightly swollen (lengths: 28 mm and 14 mm respectively). The ovary is rather small but still contains many elongate immature ova and a few scattered, larger sperical ova of various sizes, the largest of which measures about 1.5 mm in diameter.

The radula (Fig. 2, C) contains only five teeth in a transverse series. The rachidian tooth has a short central cusp and two small lateral cusps. The first lateral teeth are absent. The second laterals have broad bases each with a rather blunt medial cusp. Marginal plates are absent. The beaks (Fig. 2, D) are heavily pigmented. The lower mandible shows a faint ridge on the lamella. Many sperm reservoirs are attached to the inner wall of the buccal membrane.

Although the generic boundaries in the family Gonatidae appear to be somewhat indistinct (Okiyama, 1969; Fields & Gauley, 1971; Nesis, 1971b), this specimen clearly belongs within the genus *Gonatus sensu stricto* as indicated by the presence of a tail extending beyond the gladius, tentacle stubs and a radula with only five teeth.

DISCUSSION

The following evidence suggests that the specimen has recently spawned:

1. The specimen had mated as indicated by the presence of sperm reservoirs (discharged spermatophores) embedded in the buccal membrane.
2. The nidamental and oviducal glands are of intermediate size (i. e. these glands are larger than would be expected in immature specimen but much smaller than would be expected in a gravid specimen.
3. The ovary is almost totally depleted of mature ova.
4. The specimen has undergone degeneration as indicated by the gelatinous nature of the muscular tissues and the loss of suckers from all arms, as well as the loss of the tentacles.

The features which typify spent females are not well-known. In order to confirm the above list as characteristic of spent females of the family Gonatidae, I have examined the extensive collections of cephalopods at the University of Southern California for females that appear to have recently spawned. Four species of *Gonatus* are found in the waters off southern California; females of three species were found which appear to have spawned.

Gonatus pyros Young, 1972. Two specimens, 135 mm pen length (P. L.) and 130 mm pen length, easily identified by the presence of a large oval photophore on the ventral surface of each eye, showed extreme signs of degeneration. In consistency they are flaccid and gelatinous which contrast strongly with the muscular condition of immature specimens. Tentacles are absent except for small stubs. All arm suckers are absent; small pockets or slight puckerings of the skin on the gelatinous trabeculae mark the spots where the suckers had once been. The nidamental glands in both specimens are considerably larger (30 and 25 mm) than one would expect to find in a large immature specimen. The oviducal glands are fairly large (22 and 16 mm). In both cases the ovary is small and filled with small, deteriorated eggs. In one specimen a mature egg which was presumably dislodged from the oviducal gland during dissection was found in the mantle cavity. No other eggs were found in the oviducal glands or oviducts. The mature egg, oval in shape, measures 3 mm long by 1.7 mm at the widest point. The deteriorating eggs are slightly more than .5 mm in length. A number of sperm reservoirs were found attached to the buccal membrane. Clusters of small oval vesicles also were found in the buccal membrane; broad funnel-shaped ducts connected the clusters to the oral surface of the buccal membrane (one funnel per cluster). Presumably these are organs for storing sperm. All of the vesicles examined appear to be empty.

Gonatus berryi Naef, 1923. A single female (185 mm P. L.), tentatively identified as this species on the basis of the massive size of the arms, showed evidence of having spawned. In most respects the features of this specimen are the same as in *G. pyros.* The consistency is gelatinous; suckers are absent; the ventral arms are completely bare and the tentacles are absent. The buccal membrane lacks sperm reservoirs but most of the membrane is

missing. Nidamental and oviducal glands are somewhat enlarged (35 mm and 25 mm respectively). (For comparison, nidamental and oviducal glands of an immature specimen (103 mm P. L.) measured 5 and 4 mm respectively). The ovary is small but has a large number of small, elongate immature ova. Interspersed among these cells are a number of spherical, pale orange ova in various stages of maturity, the largest of which is about 3.5 mm in diameter.

Gonatus onyx Young, 1972. One presumably spent female has tentatively been identified to this species, primarily on the basis of body proportions. This specimen is somewhat different than the others; the tissues are much firmer and more muscular but still not as muscular as in an immature specimen of this species. Both tentacles are missing and suckers are absent from the dorsal three pairs of arms. The ventral arms are bare except for a few suckers at the arm bases. The nidamental and

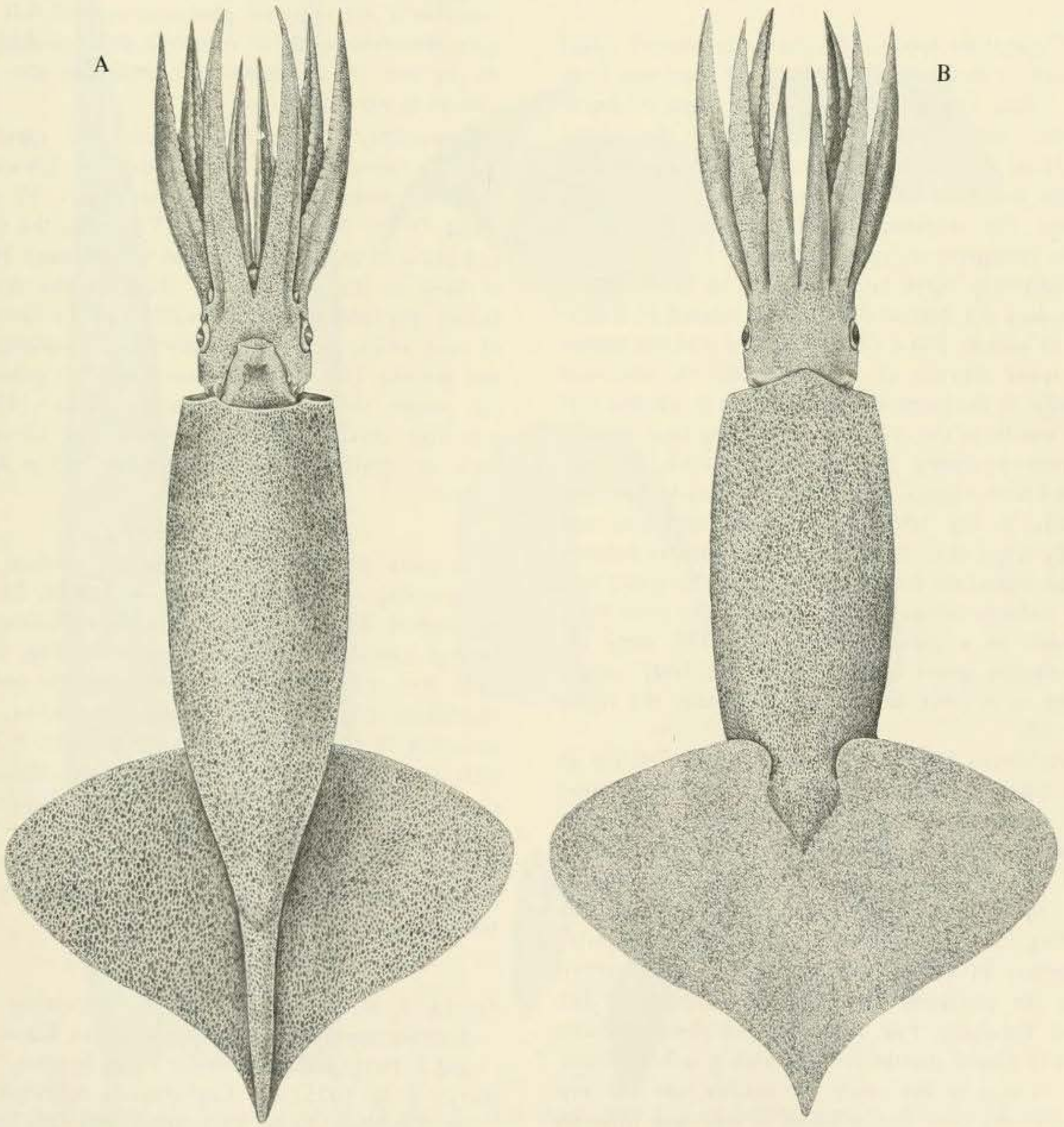

FIG. 1. Gonatus *sp. from the Arctic Ocean. A, Ventral view; B, Dorsal view.*

oviducal glands are somewhat enlarged (34 mm and 22 mm respectively). A small portion of the buccal membrane is missing; the remaining portion is strewn with sperm reservoirs and some of these are attached to the bases of the arms. The ovary is somewhat larger than in the other species and is packed with long (about 1 mm in length), slender immature eggs with a few larger orange, sperical, partically mature eggs (1 mm diam.) interspersed. Apparently a larger percentage of the eggs of this specimen failed to mature completely before spawning.

These three species of *Gonatus* correspond rather closely in their appearance with the specimen from the Arctic Ocean. All show similar signs of degeneration, and comparable conditions of the ovary, oviducal and nidamental glands; and several have sperm reservoirs still attached to the buccal membrane. The evidence strongly suggests that all of these specimens are spent females.

Relatively little information is in the literature regarding the degeneration effects related to spawning in squids. Fields (1965) showed that the mantle of spent females of *Loligo opalescens* decreased greatly in thickness and girth and he concluded that the mantle is the chief site for storing food reserves consumed during the spawning period. He also noted that oviducal and nidamental glands decreased greatly in size after spawning but were still relatively larger than these glands in immature females. In an immature female (ML 87 mm) he found that the nidamental gland was 0.6% of the total body weight. In a mature female (ML 151 mm) the nidamental gland was 22.8% of the body weight while in a spent female (ML 151 mm) the figure was 5%.

McGowan (1954) observed a mass mortality of the squid *Loligo opalescens* following copulation and spawning. He noted that in the dead and dying squid that the mantles were thin and limp. Sasaki, 1913 (according to Hamabe, 1963) found that in the squid, *Watasenia scintillans*, males die after mating in off-shore waters while females die after spawning in coastal waters. Hamabe (1963) noted that the cuttlefish *Sepia esculenta* apparently dies after spawning. For *Todarodes pacificus*, Hamabe (1963) found that in females with a reduced number of eggs in the ovary the mantle was thin and flabby, the liver was reduced in size and firmness and the stomach walls were thin and flabby. These animals had large numbers of eggs in the oviducts and Hamabe assumed that they had not yet spawned but were about to do so.

It has been thought for many years that *Octopus* dies after brooding its eggs (Nixon, 1969). Recently W. Van Heukelem (in press) has noted rather rapid degenerative changes occurring in the muscles of female octopods in aquaria upon completion of the brooding period and just prior to death.

The evidence suggests that degeneration and death following spawning by female squid is a common if not universal phenomenon, and that the same situation occurs in octopods although delayed to the end of the brooding period (See also discussion in Arnold, in press).

Presumably the Arctic specimen had spawned and was about to die when captured. Spawning therefore probably occurred near March 30 and about 79°58' N lat. and 170°23'E long., the time and place of capture. This point is over water 2655 m deep in the Hyperborean Basin of the Arctic Ocean. No information is available on the amount of time which passes from spawning to hatching in any gonatid. It is also not known whether gonatids lay pelagic or benthic egg masses. Nesis (1971a) estimates that the young specimens of *Gonatus* from the northern Norwegian Sea hatched in April or May.

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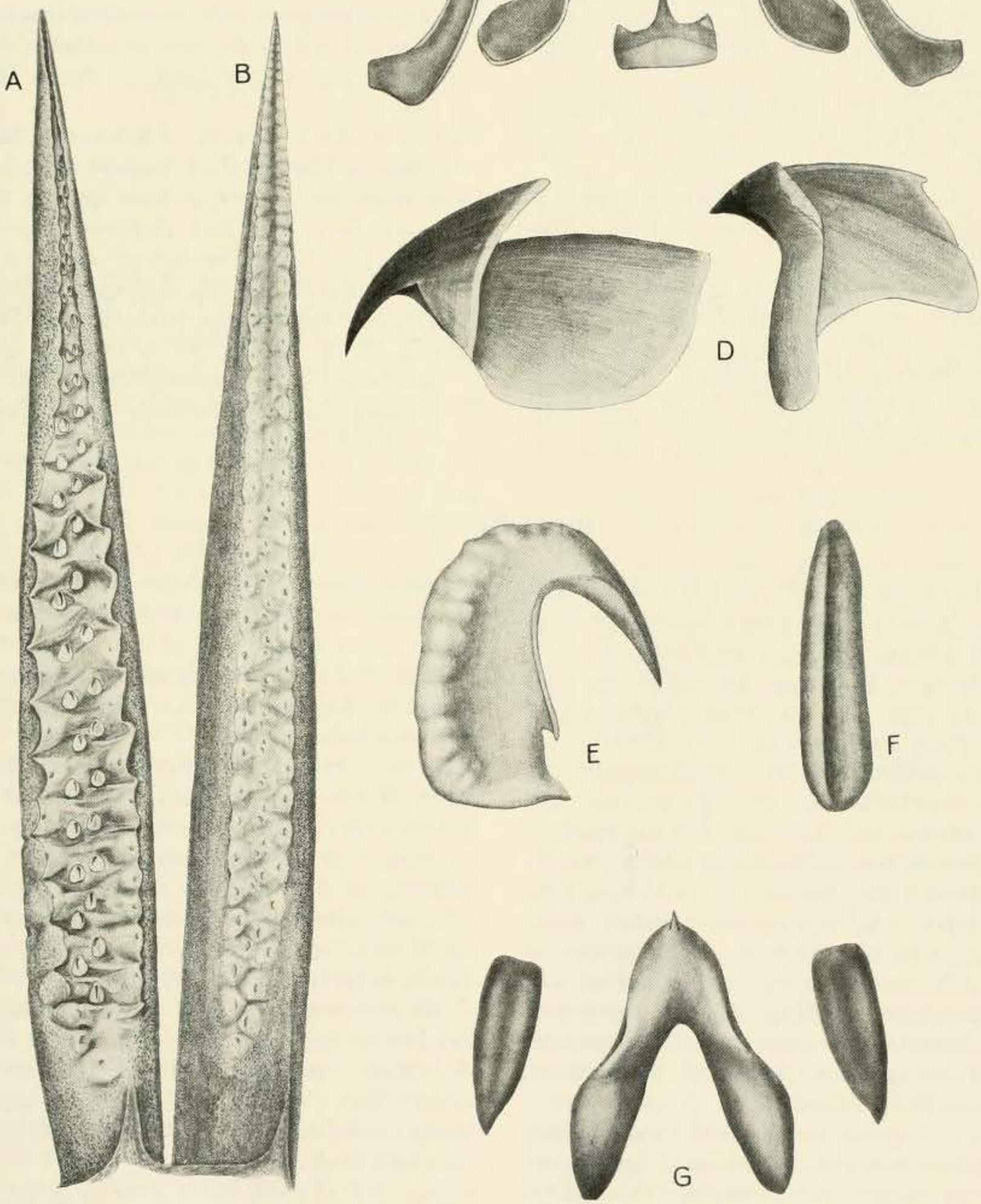

FIG. 2. Gonatus *sp. from the Arctic Ocean. A, Left third arm; B, Left ventral arm; C, Radula; D, Beaks; E, Large arm hook; F, Funnel-locking cartilage; G, Funnel organ.*

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BOOK REVIEW

SEA SHELLS OF TROPICAL WEST AMERICA. Marine Mollusks from Baja California to Peru. Second Edition. By A. Myra Keen; with assistance by James H. McLean. xvi + 1064 pp., 4000 illus., 22 pages in color. Index. Stanford University Press, Stanford, Calif. 1971. $29.50.

It seems almost superfluous to recommend this classic compendium to both professional and amateur students of the tropical West American marine mollusk fauna. The second and greatly enlarged edition is the labor of love of A. Myra Keen and a number of her able associates, such as James H. McLean who undertook the herculean task of organizing the section on the Turridae and most of the Archaeogastropoda. Twila Bratcher and Robert Burch contributed the revision of the Terebridae; Eugene Coan and Barry Roth, the Marginellidae; and Spencer Thorpe, the chitons.

Over 3,325 species are included, most of which are well-illustrated and accompanied by succinct descriptions, ranges, and synonyms. The updated bibliography is one of the most complete ever assembled for the mollusks of a major marine province. The index, a measure of the magnitude of the book, contains over 7,000 scientific entries. A bonus comes to the users of the book in the form of a good glossary, a geographical guide to and a series of maps of the area, and tables for fathom-meter-feet conversion.

A very welcome addition is a fairly full treatment of the known nudibranchs, thanks to the efforts of Jame Lance. This rapidly growing subfield of malacology has been greatly stimulated by the inclusion of these shell-less orphans of conchology.

Twelve new plates of stunning color photographs of 72 living mollusks add to the beauty and usefulness of this remarkable faunal guide.

In the face of such a huge, meticulous and detailed documentation, one cannot resist repeating Dr. Keen's quote from another woman writer, George Eliot: "Why, you might take up some light study - conchology now; I always thought that must be a light study."

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