

XXXIX.—*Remarks on the Age of some Arctic and North-Atlantic Starfishes.* By JAMES A. GRIEG, Curator of the Bergen Museum, Bergen, Norway.

DR. MORTENSEN has shown, in "Smaa faunistiske og biologiske Meddelelser" *, that ophiurids of various ages are found simultaneously in shallow water at the same locality within the boreal region; transformed young were collected recently, together with one-year old, fully developed two-year old, and older individuals. At Sallingsund Dr. Mortensen obtained young of *Ophiura ciliaris* with a disc-diameter of $\frac{1}{4}$ – $\frac{1}{2}$ mm., one-year old individuals with a disc-diameter of 3–4 mm., two-year old ones with a disc-diameter of 7–11 mm., and several whose disc-diameter was more than 12 mm. and whose age was probably three years.

The circumstances are the same on the Norwegian southern and western coasts; on the other hand, Dr. Mortensen in "Echinoderms from East Greenland" † mentions that a large number of *Ophiura sarsi* obtained off Jan Mayen were all of about the same size (disc-diameter 15–20 mm.). As numerous specimens of *Ophiura robusta*, a very small species, were taken in the same haul, the small *Ophiura sarsi* could not have been overlooked. At Jan Mayen there could only have lived a single year-class of *Ophiura sarsi*, whose age Dr. Mortensen estimates at one year, though I am most inclined to estimate it at three years.

An examination of the ophiurids collected by the 'Michael Sars' in the Norwegian Sea shows that very often a single year-class occurs at a locality, exactly as stated by Dr. Mortensen in regard to Jan Mayen; but several year-classes may also be found—in this case, one of them is generally more numerously represented than the others ‡.

In this paper I shall confine my remarks to a haul which the 'Michael Sars' made in the summer of 1914 off the mouth of the Varanger Fjord. From this haul 157 *Ophiura sarsi* were obtained with a disc-diameter of 16–27 mm., and one specimen measuring 11 mm.; of these no fewer than 99 (or 63 per cent.) have a disc-diameter of 22–24 mm.—this large group represents a year-class whose age must be put at four years. There were also several individuals—not very

* Vidensk. Meddel. 1897, p. 321.

† Meddel. om Grönland, xxix. 1903, p. 82.

‡ 'Bergens Museums Aarbok,' 1903, no. 13, p. 23.

distinct, however—with a disc-diameter of 16–19 mm., which must correspond to Dr. Mortensen's of 15–20 mm. from Jan Mayen; the majority in this group cannot be more than three years old. Finally, there is the specimen of 11 mm., the age of which must be estimated at two years.

The ophiurids from the great depths of the North Atlantic collected by the 'Michael Sars' in 1910 show that the same conditions exist as in the Norwegian Sea. A species of ophiurids may be represented at a locality by several year-classes, but only one of them numerous.

During the examination of the echinoderms collected by the 'Michael Sars' in 1910, I also commenced work on the starfishes to see whether the conditions were the same as in the ophiurids. In order to have material as abundant as possible I did not confine my attention to that taken in 1910, but added some from other cruises of the 'Michael Sars' and similar expeditions. Altogether I examined 14 species, which were collected in Arctic waters, off the Norwegian coasts, and in the North Atlantic. I had abundant material of some species: thus of about 500 specimens of *Pontaster tenuispinus* 155 were from one locality, and of about 800 specimens of *Ctenodiscus crispatus* 355 were from one locality; of the remaining species the material was somewhat scanty—it is, however, of importance for the purpose of comparison. The result of these investigations is more fully discussed in "Nogen asteriders alder og aarsklasser"*; as this paper is written in Norwegian, I here give an abstract from it.

The diameter of the disc served to determine the annual classes of the ophiurids, but in the starfishes it was more convenient to use the radius of the disc.

The measuring method requires many examples, and even then the age of a specimen can only be determined with certainty if its size comes within the measurements of the majority of the individuals of a year-class. Another drawback to this method is that the conditions of life and, consequently, growth may differ at different localities; the results from one locality can therefore not be applied unconditionally to another. Following the usual practice when studying fishes, I have examined the marginal plates of the starfishes and other parts of their skeleton in order to arrive at the age of each individual, but I have not definitely succeeded in finding annual rings. I have therefore been obliged to fall back upon the measuring method.

* 'Bergens Museums Aarbok,' 1916–17, Naturvidensk Række, no. 1.

| Radius of disc in millimetres. | <i>Pontaster tenuispinus.</i> | | | | | <i>Ctenodiscus crispatus.</i> | | | <i>Hymenaster pellucidus.</i> | <i>Bathypaster robustus.</i> | <i>Plutonaster bifrons.</i> | <i>Benthopecten spinosus.</i> | <i>Dytaster agassizi.</i> |
|-----------------------------------|-------------------------------|----------------------|-------------|-----------|-----|-------------------------------|-----|-----|-----------------------------------|----------------------------------|---------------------------------|-----------------------------------|-------------------------------|
| | Mouth of Sogne Fjord. | Coast of Romsdal. | Fro Island. | Kara Sea. | | Barent's Sea. | | | E. off Iceland. | S.W. off Ireland. | W. off Hebrides. | W. off Hebrides. | N. off Azores. |
| 1 | ... | ... | 1 | 1 | 1 | 1 | ... | ... | 1 | ... | ... | 1 | 2 |
| 2 | ... | ... | 6 | 11 | 19 | 1 | ... | ... | ... | ... | ... | 2 | 3 |
| 3 | 1 | ... | 13 | 6 | 20 | 1 | ... | ... | ... | ... | ... | 2 | 4 |
| 4 | ... | ... | 9 | 5 | 10 | 4 | ... | ... | ... | ... | ... | 2 | 8 |
| 5 | ... | ... | 4 | 3 | ... | 11 | ... | ... | ... | ... | ... | 2 | 10 |
| 6 | 4 | 4 | ... | 3 | ... | 23 | ... | ... | ... | ... | ... | 3 | 4 |
| 7 | 16 | 18 | ... | ... | ... | 34 | ... | ... | ... | ... | ... | 2 | 3 |
| 8 | 38 | 15 | ... | 1 | ... | 38 | ... | ... | ... | ... | ... | 2 | 3 |
| 9 | 48 | 12 | 1 | 3 | ... | 33 | ... | ... | ... | ... | ... | 2 | 3 |
| 10 | 33 | 2 | ... | ... | 3 | 15 | ... | ... | ... | ... | ... | 2 | 3 |
| 11 | 8 | 1 | ... | 2 | ... | 8 | ... | ... | ... | ... | ... | ... | 3 |
| 12 | 4 | ... | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | 3 |
| 13 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 14 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 15 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 16 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 17 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 18 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 19 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 20 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 21 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 22 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 23 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 24 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| 25 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 3 |
| | 153 | 52 | 34 | 55 | 37 | 169 | 149 | 335 | 26 | 25 | 87 | 12 | 34 |

Originally my intention was only to settle whether one or several year-classes of a species of starfishes occur at a locality, and, if several, whether one of these is more numerous represented than the others. In the course of my investigations it appeared that a similar number of annual classes is gathered at the same locality of more than one species. In *Pontaster tenuispinus* we find an annual class with a disc-radius of 3-4 mm., another of 8-10 mm. We find the same number of *Ctenodiscus crispatus*, *Psilaster andromeda*, etc., or else the numbers are very close to those mentioned for *Pontaster tenuispinus*. Therefore, if we could determine the age of a year-class for one species, that of the others would also be known. Among some echinoderms from Utne, Hardanger, I was fortunate enough to find some very small *Psilaster andromeda*, which had apparently been recently transformed to the bottom stage. This was consequently group 0, other material belonged to group I., etc.

The measurements mentioned in this paper are given in the table on p. 402, the remainder appear in "Nogen asteriders alder og aarsklasser."

I shall first endeavour to show that starfishes occurring at a locality are, as a rule, represented by several year-classes, but only one of them numerous. The 'Voeringen' took 153 *Pontaster tenuispinus* off the mouth of the Sogne Fjord: of these one specimen had a disc-radius of 3 mm., the rest measured 5-12 mm., with a maximum of 119 specimens (or 76.8 per cent. of the total number) at 8-10 mm. A year-class is evidently gathered about these measurements. The 3 mm. specimen belongs to another year-class, as is clearly shown by 34 specimens taken by the 'Voeringen' off the Fro Islands; of these one specimen had a disc-radius of 9 mm., the rest 1-5 mm., including 12 specimens at 3 mm. The conditions in the two localities were therefore quite different: off the Fro Islands there was a maximum of 12 specimens at 3 mm. and one only at 9 mm.; the Sogne Fjord locality had, on the contrary, a maximum of 48 specimens at 9 mm., but one only at 3 mm. Common to both localities is the circumstance that two year-classes were represented, only one of them numerous.

At a station off the coast of Romsdal the 'Voeringen' took 52 *Pontaster tenuispinus*, which had a disc-radius of 6-11 mm., with a maximum of 45 specimens at 7-9 mm. Evidently only one annual class was represented here, and that one must have been of the same age as the large group from the station off the Sogne Fjord. As stated above, there was at

this locality a maximum at 8–10 mm., while at the station off the coast of Romsdal it was at 7–9 mm. The difference must be attributed to the fact that there were better conditions of life at the one locality than at the other.

Quite the same result that the Fro Islands material gives is exhibited by 55 specimens from a locality in the Kara Sea. As the table shows there is a marked maximum of 49 specimens at 3–5 mm., while only 5 specimens have a disc-radius of 7–10 mm. From another locality in the Kara Sea there are 37 specimens, which show that three year-classes may be represented at a locality, but only one of them numerous. We have first a large group of 29 specimens which have a disc-radius of 2–7 mm., with a maximum of 22 specimens at 3–5 mm. Then, a group of 7 specimens with a disc-radius of 9–13 mm., and, finally, one specimen of 23 mm. Each of these groups must represent an annual class, the youngest of which only was numerous.

The material of *Pontaster tenuispinus* examined by me shows that this species has a year-class at 3–4 mm., another at 8–10 mm., and I have had some specimens with a disc-radius of more than 13 mm. The material of this last group is unfortunately so sparing that it has not been possible to determine where its maximum is to be found; I should be inclined to think that it must be looked for at about a radius of 15 mm. With a disc-radius of 23 mm. *Pontaster tenuispinus* has attained its maximum of growth. Whether it is possible to find one or two year-classes between 13 mm. and 23 mm. cannot at present be definitely determined, but I am most inclined to think that representatives of two year-classes are to be found between these two sizes.

From three localities in the Barent's Sea I have measured 169, 149, and 335 specimens respectively of *Ctenodiscus crispatus*. The specimens from the first locality measured 3–13 mm. and had a maximum of 128 specimens (or 77·7 per cent. of the total number) at 7–10 mm.; at the second locality there was a maximum of 132 specimens (or 88·6 per cent.) at 8–11 mm.—these specimens measured 6–13 mm.; at the third locality the specimens measured 6–16 mm.—at 9–12 mm. there was a maximum of 267 specimens (or 79·7 per cent. of the total number). If we compare the material, we find that the majority of the specimens at all three localities are of the same size and represent the same annual class. It is very probable, however, that at two of the localities, at least, there were specimens of still another year-class, for material from other localities indicates that the smallest specimens from the

first locality and the largest from the last-named one must be of an age other than the rest.

I stated above that the examples of *Pontaster tenuispinus* examined represent three or possibly four annual classes. The material of *Ctenodiscus crispatus* is only composed of three year-classes: the maximum of the youngest class is at 4-5 mm., that of the second at about 10 mm., and that of the third at 15-16 mm. A fourth year-class seems to be out of the question in the case of this species, as it has already attained its maximum growth at 18-19 mm.

It has been mentioned already that the food-conditions and therefore the conditions of growth may be different in different localities. The maximum of a year-class will be gathered about a measurement which varies somewhat for different localities. In speaking of *Pontaster tenuispinus* I have called attention to this fact, which is still more striking when we compare the material of *Ctenodiscus crispatus* mentioned above. As will be shown below, the two-year old annual class has its maximum at a disc-radius of 7-10 mm. at one locality, at 8-11 mm. at another, and at 9-12 mm. at a third, which has evidently offered the best conditions of life. I ought to mention that the material from all localities was collected in June, though in different years.

As it is with these two species, so it is with others that live at shallower depths in Arctic and boreal waters. The conditions are the same at the great depths in the Norwegian Sea and the North Atlantic. The 'Michael Sars' took 26 *Hymenaster pellucidus* in 1900 in the cold area off the east coast of Iceland with a disc-radius of 4-25 mm. This material affords a maximum of 9 specimens at 8-9 mm., fewer at 14-15 mm., and still fewer at 22 mm.; there were thus three year-classes from this locality. Other material indicates that the 4 mm. specimens represented a fourth annual class.

Another species characteristic of the cold area of the Norwegian Sea is *Bathybiaster vexillifer*, which may also be represented by several year-classes at a locality. It may be mentioned that the juvenile specimens of *Bathybiaster vexillifer*, described by Danielssen and Koren under the name *Ilyaster mirabilis*, was taken together with two full-grown ones. The 'Michael Sars' found in 1902 at a locality in the cold area north of the Faroe Islands a very young specimen whose disc-radius measured 4 mm., another of 7 mm., and still others of as much as 22 mm.; some of these were thus among the largest known in this species. In other words,

there have been living at least three year-classes at the same locality. In the cold area off "Tampen" the 'Armauer Hansen' in 1914 took three *Bathybiaster vexillifer* whose disc-radius measured 2.7, 3.5, and 25 mm. respectively; here were therefore two quite young individuals which must represent one annual class and a full-grown individual belonging to quite another.

In the North Atlantic the genus *Bathybiaster* is represented by *Bathybiaster robustus*, a species which shows so much likeness to *Bathybiaster vexillifer* that Verrill* considered it as probably identical. A closer examination, however, shows that they are two different species, each living within its own territory—the one within the cold area of the Norwegian Sea, the other in the warm area of the North Atlantic. They also differ from one another in the structure of the skeleton. There is the same difference between them that there is between *Pecten frigidus* of the Norwegian Sea and *Pecten biskayensis* of the North Atlantic. S.W. of Ireland the 'Michael Sars' obtained 25 specimens of *Bathybiaster robustus*, which are grouped as follows: two specimens measured 11–12 mm., the rest 15–21 mm., with a maximum of 11 specimens at 19–20 mm. That the maximum is found among the largest specimens seems to indicate that the smallest (11–12 mm.) specimens must belong to another annual class.

In the eastern part of the North Atlantic *Plutonaster bifrons* is the most commonly distributed starfish. It is known from numerous localities between Faroe-Shetland Channel and the Cape Verde Islands. In 1910 the 'Michael Sars' collected this species at no fewer than seven localities, at some of them in great numbers—thus at a station W. of the Hebrides as many as 87 specimens were found. This material has a disc-radius of 8–21 mm., besides which there is a specimen of 24 mm. There are two marked maxima, one at 10–11 mm. comprising 28 specimens (or 32.2 per cent. of the total number) and another at 17–18 mm. with 17 specimens (or 19.5 per cent. of the total number). Both these maxima must represent annual classes. Judging from material from another locality the 24 mm. specimen must belong to yet another year-class.

The examples given must suffice. It appears from all the material examined that starfishes living at a given locality may belong to one year-class; but most frequently they

* Proc. U.S. Nat. Museum, xvii. 1894, p. 256.

represent two or more, only one of them being numerous. The material also shows that each year-class is grouped about certain definite sizes, and that these as a whole are common to all species examined. *Pontaster tenuispinus* has a year-class whose maximum is gathered about a disc-radius of 3-4 mm.; *Ctenodiscus crispatus*, *Leptychaster arcticus*, *Bathybiaster vexillifer*, *Solaster papposus*, *Hymenaster pellucidus*, *Henricia sanguinolenta*, etc., have likewise a year-class of this size; *Pontaster tenuispinus* has the next year-class at 8-10 mm. In like manner we find that *Plutonaster bifrons*, *Dytaster agassizi*, *Ctenodiscus crispatus*, *Hymenaster pellucidus*, etc., have a year-class at the same size. It should be noted that the figures are not absolutely exact; with respect to some species and localities they may be found a little above or a little below those given, as I have already stated. Speaking generally, these are agreements which cannot be due to accidental circumstances. Each of these year-classes must have a fixed age, and if the year-class 3-4 mm. of *Pontaster tenuispinus* is one year old, then that year-class of the other species which is of the same size must also be one year old. It was therefore important to fix the age of a year-class in a species, as thereby the age was given for the other species.

I was fortunate to determine the age of some of the specimens of *Psilaster andromeda*, collected by Dr. D. C. Danielssen at Utne, Hardanger. The smallest specimens from Utne have a disc-radius of 0.5 mm. They were young which had recently been transformed to the bottom stage, and thus belong to group 0. Of the rest two specimens measured 3 mm., three 7-8 mm., four 10-12 mm., and two 14-15 mm. By comparing this material with some from other localities it appeared that the next year-class, which is one year old (group I.), is gathered about a disc-radius of 3-4 mm. Two-year old individuals (group II.) have a disc-radius of 7-8 mm., three-year old ones (group III.) 12-15 mm., and four-year old ones (group IV.) 18-20 mm. *Psilaster andromeda* has attained its maximum of growth at a disc-radius of 20-22 mm. It should not therefore attain a greater age than four years. The same also holds good for *Pontaster tenuispinus*, *Plutonaster bifrons*, *Bathybiaster vexillifer*, and probably most of the Northern starfishes.

Among the species whose age I have determined, *Ctenodiscus crispatus* and *Hymenaster pellucidus* differ from the above; the former seems only to attain three years and the latter five or possibly six years.

Several species, among them our most common starfish (*Asterias rubens*), I have been unable to examine. The material of some of the species was rather scanty and was from a single locality only. This was the case with *Benthopecten spinosus* and *Dytaster agassizi*. The specimens examined of these two species (see the table, p. 402) have a disc-radius of 5-10 mm. and 6-12 mm. respectively*, and seem to belong to the same year-class (group II.). The question regarding the age of the starfishes therefore needs further investigation.

XL.—Synopsis of the American Species of *Rana*.

By G. A. BOULENGER, F.R.S.

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I. Toes pointed or with slightly swollen tips.

A. Glandular dorso-lateral fold absent or flat and ill-defined, or, if narrow and prominent, not extending to the hip; tympanum at least $\frac{2}{3}$ diameter of eye, usually much larger, especially in males; tibia $2\frac{1}{2}$ to 4 times as long as broad; toes $\frac{3}{4}$ to entirely webbed; outer metatarsals separated by web nearly to the base; nasal bones in contact with each other or narrowly separated.

1. Male with internal vocal sacs; dorso-lateral fold absent or flat and very indistinct.

Vomerine teeth between the choanæ (rarely just behind them); first finger as long as or a little longer than second; tibio-tarsal articulation reaching tympanum or eye; heels meeting or slightly overlapping when the hind limbs are folded at right angles to the body; tibia $2\frac{1}{10}$ to $2\frac{1}{2}$ times in length from snout to vent; tip of fourth toe free; no dorso-lateral fold

R. catesbiana, Shaw.

Vomerine teeth between the choanæ; first finger a little shorter than second; tibio-tarsal articulation reaching tympanum

* The material of *Benthopecten spinosus* has not a maximum; of *Dytaster agassizi*, on the other hand, there is a marked maximum at 9-10 mm. comprising 18 individuals (or 52.9 per cent. of the total number).



Grieg, James A. 1919. "XXXIX.—Remarks on the age of some Arctic and North-Atlantic starfishes." *The Annals and magazine of natural history; zoology, botany, and geology* 3, 400–408. <https://doi.org/10.1080/00222931908673836>.

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DOI: <https://doi.org/10.1080/00222931908673836>

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