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Observations on the Tubicolous Amphipod, *Corophium acherusicum* COSTA, in Fukuyama Harbor Area

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(Text-figs. 1-7; Tables 1-3; Plate 1)

Gregariousness of tubicolous amphipods on the surfaces of various structures in sea water in and around Fukuyama Harbor* attracted the author's attention in the winter of 1955. Since the biological knowledge on these animals seemed very poor, some observations were made on *Corophium acherusicum* COSTA, which was the most abundant species of the tubicolons amphipods in the area.

In the studies of the bionomics of *C. volutator*, which inhabits intertidal mud-flats in Europe, HART[1] described the characteristics of the habitat and the feeding habit, with a note on the life cycle. SEGERSTRÅLE[2] studied on the seasonal fluctuation in abundance of the species. CRAWFORD[3] gave some ecological accounts on several species of *Corophium* in the review of the genus. Concerning other ecological information on *Corophium*, many fragmentary records are found in the studies of benthic fauna and fouling organisms done by many workers.[4)~13)]

In this paper, the ecology of *C. acherusicum* observed around Fukuyama Harbor is mainly described.

MATERIALS AND METHODS

The materials used in length measurements and other biological observations were obtained from a mooring buoy located near Fukuyama Harbor from November, 1955 to October, 1956. The buoy was situated at about 30m off from the shoreline with a depth of about 5 m at high tide. The bottom sediment was composed of soft, silty mud, and a luxuriant growth of *Zostera marina* was found all over the neighboring shallower regions. The submerged surface of the buoy was thickly covered with layers of mud-tubes built almost exclusively by the tubicolous amphipod, *C. acherusicum*.

Collections of the amphipod were made by scraping off small quantities of mud-tubes, which were immediately preserved in 4% neutral formalin. Several trials had been made to sort the amphipod from the sample, and the following technique was found the most effective and convenient one. First, whole samples are placed in a

* Located at about the central part of the Inland Sea of Japan. Recently, most part of the area have been reclaimed.

beaker; the fixative is decanted off and replaced with the saturated solution of sodium chloride. By gentle stirring, small animals including amphipods float up to be caught in surface film; then they are filtered off and bottled for later uses. Almost complete recovery of amphipods is expected by repeating the procedure several times.

Precipitating mud, which was derived mainly from the tubes of *C. acherusicum*, was dried at room temperature and weighed after thorough washing with tap water. On length measurement, the animal was laid flat on glass slide and covered. The length from rostrum to tip of telson was taken as standard[1]. Sex and the number of eggs and embryos in brood pouch were recorded. As other tubicolous species were very few in number, no record was taken.

The distribution of *C. acherusicum* was investigated in and around the area at every opportunity. In 1961, availability of the amphipod as food for some littoral fishes was examined.

RESULTS AND DISCUSSION

1) Sexual Dimorphism

According to CRAWFORD[3], the genus *Corophium* can be divided into three sections based on the difference in the shape of urosome. *C. acherusicum* belongs to the "Section B," in which "segments of urosome fused; uropods 1 and 2 inserted in notches in the lateral margins of the urosome". This species can be distinguished from the other species of the section by the following combination of characters: adult male has short rostrum, is scarcely setose in antennae and is armed with a small process near the base and a large blunt terminal process in antenna 2, segment 5; adult female bears usually 7 spines on the lower margin of antenna 2, segment 4, arranged 2, 2, 2, 1 (Text-fig. 1; Pl. 1, Figs. 1—4). The number of spines on antenna 2, segment 4, of females increases with growth. Larger specimens of this collection had usually 8—9 spines, the largest number of spines being 11 (arranged, 1, 2, 2, 2, 3, 1).

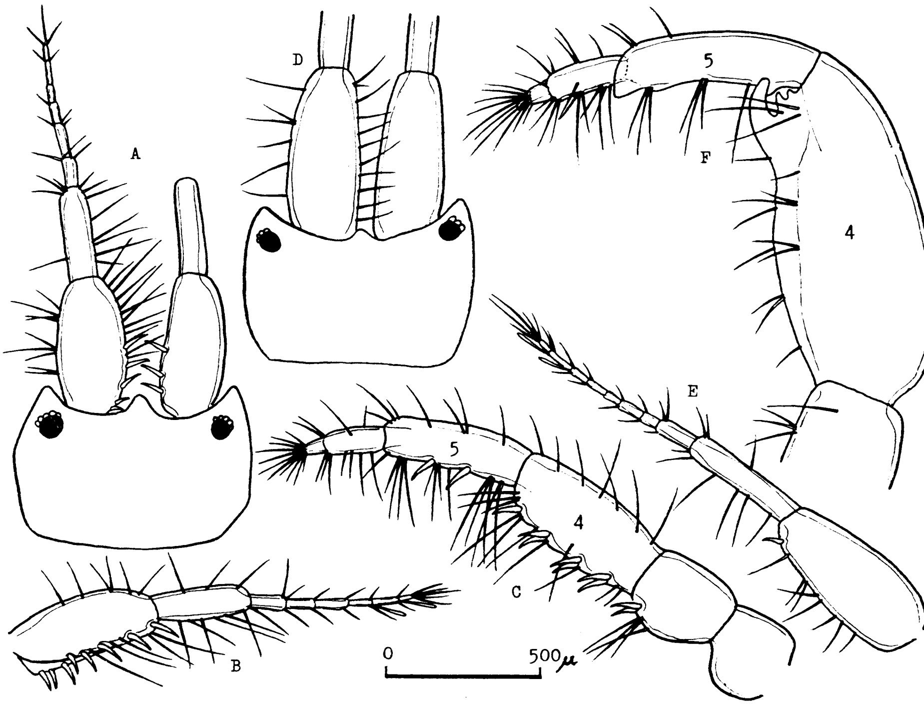
The greatest differences between male and female are those in the shape and size of antennae. In Text-fig. 2, the length of antenna 2, segment 4, is plotted against the standard length. It is clear in the figure that the increase in the length of antenna 2, segment 4, with increasing standard length is far greater in males than in females. Similar result was obtained in the case of the length of antenna 1.

Ovigerous females have four pairs of incubatory lamellae at the bases of gnathopod 2 and pereiopods 1—3. These lamellae overlap together to form a brood pouch on the ventral side of the body.

By these secondary sexual characters, the sexes can be distinguished at about 1.3mm in standard length.

2) Distribution and Habitats

It is known that *C. acherusicum* is distributed almost all over the world[3]. In Japan, it has been found in Ariake Sea[6][14], Amakusa area[15], and the various parts



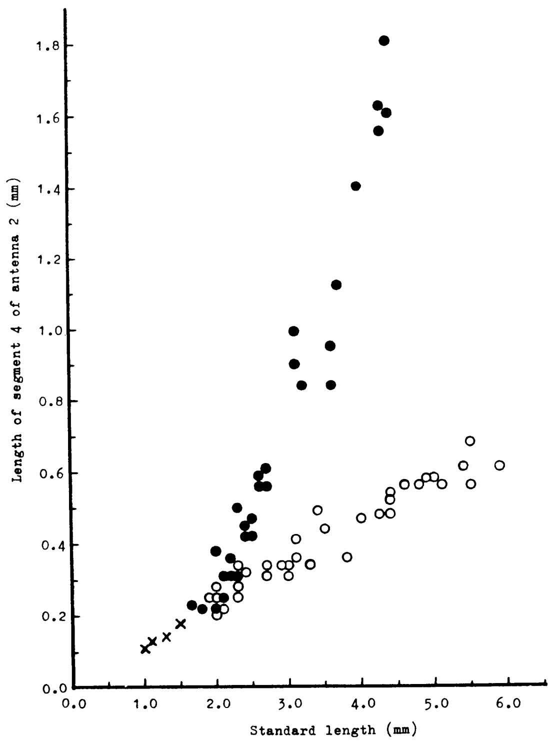
Text-fig. 1. *Corophiun acherusicum* COSTA, showing cephalons and antennae 1 and 2.
A—C: Ovigerous female (5.2mm); D—F: Male (4.0mm).
A and D: Cepalons with antennae 1.
B and E: Left antennae 1 from right and left sides, respectively.
C and F: Left antennae 2 from left side.
The figures indicate segment numbers.

of the Inland Sea[16)17)]. In the observations in and around Fukuyama Harbor, it was commonly found at any submerged structures such as piles, pontoons, buoys, ropes of set-nets, ships' bottoms and shells of cultivating oysters or pearl-oysters. It was once obtained from sandy bottom about 20m in depth.

C. acherusicum builds a "sticky parchment tube to which silt grains and detritus particles adhere"[7)]. Part of a fouling mat of the tubes built by *C. acherusicum* is shown in Pl. 1, Fig. 5, and the outline of a tube is indicated in Pl. 1, Fig. 6. A piece of rope of pound-net and a boat's bottom which were heavily fouled with such tubes are also shown in Pl. 1, Figs. 7 and 8, respectively. In the former case the fouling mat was as thick as about 25mm, while in the latter it was 10—15mm thick.

Such abundant appearance of *C. acherusicum* indicates that the environmental conditions of the area may be very suitable for the species. The tubicolous amphipods are reported to live abundantly in waters having a high turbidity coincident with favorable dissolved oxygen and temperature conditions[7)]. It is suggested from the hydrographic data of Fukuyama Harbor[18)] that the waters of the area may satisfy these conditions.

An experiment on the resistance of *C. acherusicum* to reduced salinity demon-



Text-fig. 2. Sexual difference in length of antenna 2, segment 4. Open circles: females; solid circles: males; crosses: juveniles.

strated that they could survive even in low salinity water as chlorinity 3.6‰ for 48 hours. The fact shows that this species may be hardly affected by the temporary fall in salinity, which often observed in such inshore waters.

3) Seasonal Fluctuation in Population Density

In the studies of benthic fauna, the population density is usually expressed by the number of animals per unit area. However, such analyses were impossible in the present study except a few cases, because of the difficulties encountered in sampling the materials. Abundance was, therefore, expressed in terms of number of individuals per unit weight of dried mud, since the mud was derived mainly from the tubes of the amphipod. The monthly means for such determinations are listed in Table 1.

The population density increased from early spring and reached the maximum showing a prominent peak in June. Individuals of more than 1,000 per gram dried mud were recorded in the month. Thereafter, they decreased in numbers. In September and October, the density fell to about 500 individuals, being about 50% of the maximum in June.

Seasonal fluctuations of *C. acherusicum* in California have been observed in the studies of benthic fauna[10] and fouling organisms[12]. It is interesting that the result of the present observation corresponded to theirs in showing a single peak in density at nearly the same period in a year.

Table 1. Abundance of *C. acherusicum* in 1956, expressed in terms of number of individuals per gram dried mud

Month	Number of samples	Abundance
March	2	350
April	3	532
May	2	556
June	3	1,115
July	3	731
August	1	710
September	2	513
October	2	491

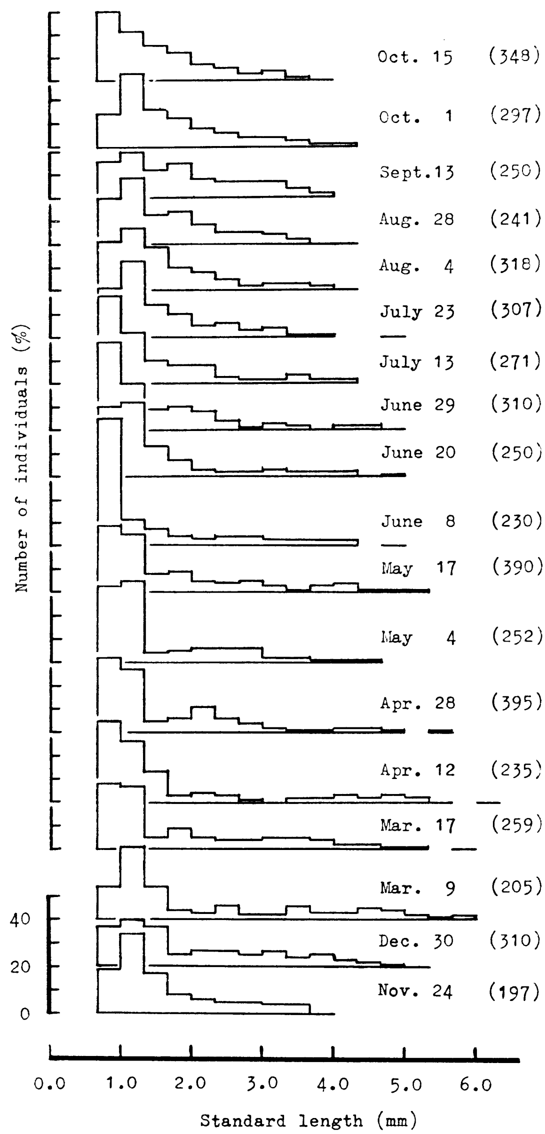
GUNTER and GEYER[5)] recorded the densities of *Corophium* (species name not given) of about 1,200—7,500 per square foot (about 12.9×10^3—$80.6 \times 10^3/m^2$) on the test-blocks in their fouling-organism investigation in the Gulf of Mexico. ITO and KATAOKA[8)] found abundant *C. crassicorne* in the fouling communities in Matsuyama, Japan, estimating the density at about $11.3 \times 10^3/m^2$ (read from their Fig. 4A). BARNARD[7)], in his study on the tubicolous amphipods in Los Angeles—Long Beach Harbors, showed that the maximum number of *C. acherusicum* recovered from test-blocks ($6 \times 2 \times 2$ inches) which had been exposed for 16 weeks was as many as 13, 177. The surface area of the block being calculated at 56 square inches, this figure can be converted into about $365 \times 10^3/m^2$. In the present study, there were only two data which could be compared with the above figures. The density of these samples were estimated $143 \times 10^3/m^2$ for April-12 sample and $279 \times 10^3/m^2$ for June 8.

Although these results show a wide range of differences, it can be noted that *Corophium* can reach unusually high population densities in some particular environments.

4) Size Frequency Distribution

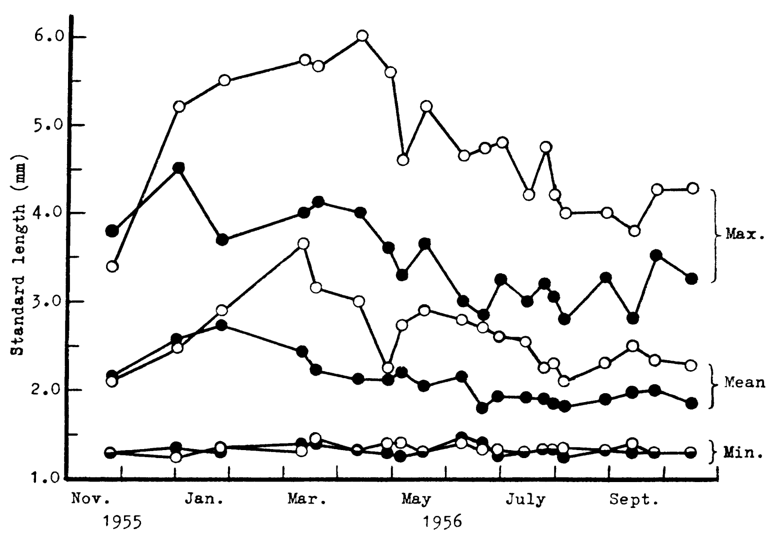
A number of individuals were measured at different times throughout most of a year. The results are summarized in Text-fig. 3. One of the most striking features of the figure is the dominance of the juvenile individuals smaller than 1.3mm in length in every sample. This pattern of size frequency distribution undoubtedly suggests the continuous supply of juveniles resulting from continuous breeding activity.

There is a marked seasonal variation in size of both sexes (Text-fig. 4). The females were always larger than the males, except the sample in November in which sufficient number of individuals could not be obtained. The largest female appeared



Text-fig. 3 Size frequency distribution in samples taken at different times throughout most of the year, 1955—1956.
Figures in parentheses indicate number of individuals examined.

in April (6.00 mm), whereas the largest male was observed in December (4.50 mm). Except this discrepancy, the size of both male and female varied in much the same way throughout the year; *viz.*, a gradual diminution in size occurred towards summer, and the size increased towards colder months. From these size variations it is assumed that the population of *C. acherusicum* may be divided roughly into two groups: the small-sized (short-lived) summer generation and the large-sized (long-lived) overwintering generation. It is difficult, however, to separate these two generations at a



Text-fig. 4. Seasonal variation in size of both sexes. Open circles: females; solid circles: males.

definite point, since the succession from one generation to another occurs gradually and many intermediate generations lie between them.

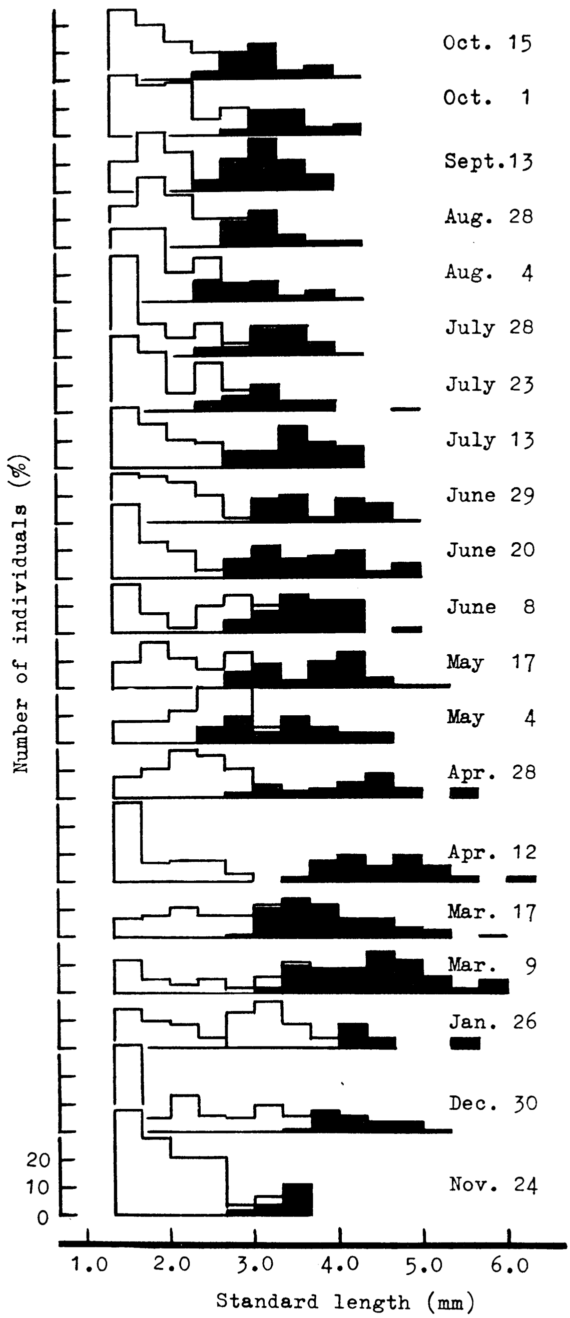
The number of generations in a year, and the duration and growth of each generation cannot be estimated by only such consecutive sampling method as employed here. These interesting problems are still unsolved at the present time.

5) Breeding

The size variation of females is shown in Text-fig. 5. The black parts represent the ovigerous individuals. The breeding seems to continue throughout the year, since ovigerous females were found in every sample.

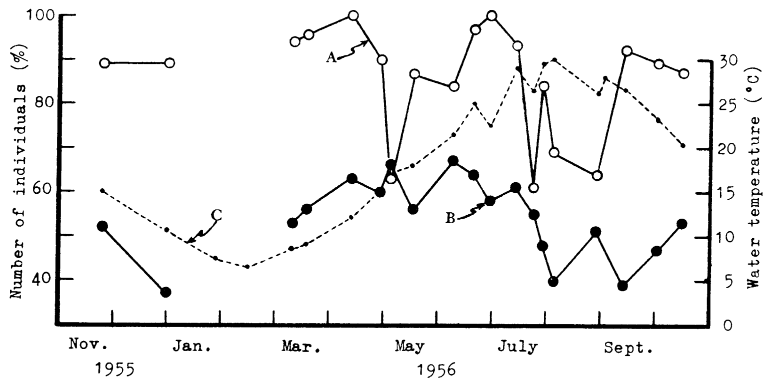
In accordance with the marked seasonal variation in size of females, the size at which a female becomes sexually mature varied also with seasons: larger in winter and smaller in summer. In December sample, the smallest ovigerous one was as long as 3.60mm (on January 26, the smallest was 4.30mm, but the numbers examined were not many), while in the two samples of July 23 and August 28, the animals of 2.20mm in length were found already ovigerous.

Although this species breeds all the year round, the breeding activity will vary more or less with seasons because it may be affected strongly by environmental factors such as water temperature. The percentage of ovigerous females to all the females larger than the biological minimum size within each sample (A) and the percentage of juveniles to total animals examined (B) are plotted against season, with changes in water temperature (C), in Text-fig. 6. These values must be reflecting directly or indirectly the value of breeding activity of the animal. The former (A) fluctuated seasonally. It showed high values more than 80% except one case from March to mid-July and fell to 60—70% from late July to August, then rose again. The phenomenon may suggest the presence of seasonal rhythms in the breeding ac-



Text-fig. 5. Seasonal variation in size of females.
Black parts represent ovigerous ones.

tivity. On the other hand, in the latter (B), which reflects directly the activity, two peaks, one is in May to June and another is in October to November, were observed



Text-fig. 6. Seasonal fluctuations in the percentage of ovigerous females to all females larger than biological minimum (A) and the percentage of juveniles to total animals examined (B), in relation to temperature changes (C).

in a year, and the peak in May to June was higher than the other one. The low values in August seem due to declining in breeding activity by high temperature of surrounding water. Unfortunately the data are lacking in winter season, it might be possible, however, to consider that the activity declines also in the winter season by low water temperature.

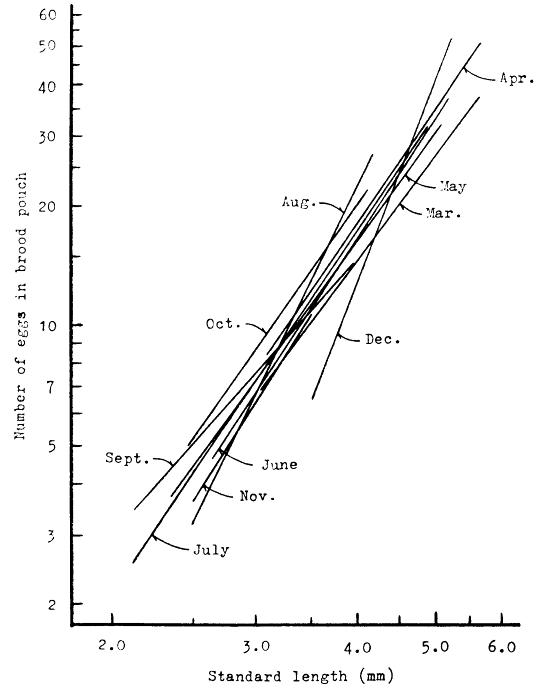
The number of eggs and embryos in brood pouch varied greatly with size of the mother animal and within the same size group also, exhibiting a high individual variation. But, from average values, the relationship between the number of eggs and the size of mother can be expressed by a straight line on a double logarithmic paper. Monthly changes in the relationship are shown in Text-fig. 7. In the figure, the regression lines overlap one another and seasonal change in the relationship is not clear. For all the samples, an equation, $N = 0.28\ L^{2.98}$, can be applied, where N and L represent the number of eggs and the standard length in mm, respectively. The maximum number of eggs recorded in the present observation was 71.

6) Sex-Ratio

Preponderance of females over males is generally known among amphipods. On *C. acherusicum*, CRAWFORD[3] simply stated that "the female is rather the commoner". In all the present samples, except that of November 24, females were from 1.2 to 2.5 times more than the males. On November 24, the former was slightly less in number than the latter (0.9 female: 1 male). The sex-ratio for all the samples was 1.6: 1 in average, which seemed to agree with CRAWFORD's statement.

7) Ecological Significances of *C. acherusicum*

Forty-six species have been recorded of the amphipods of the genus *Corophium*[17) 19)], most of them being known to burrow in bottom mud or to build tubes upon sessile objects. *C. acherusicum* belongs to the latter type, and often occurs in the fouling communities. In ordinary fouling communities, large sessile animals such as



Text-fig. 7. Monthly changes in the relationship between number of eggs and size of ovigerous females.

mussels, oysters, barnacles, bryozoans, tunicates, etc. occupy the greater part of the organisms, while tubicolous amphipods, if present, are not so important in terms of biomass because of their minute size. But in areas offering favorable conditions for the amphipods, their tubes made of suspended matters attain sizable mass which eventually causes heavy fouling. In this connection, BARNARD[7)] investigated the fouling organisms in Los Angeles—Long Beach Harbors. He found that the tubicolous amphipods comprised one of the most abundant fouling organisms in turbid water, and discussed on several interesting and important problems concerning the role played by them as the fouling members.

According to ITO and KATAOKA's observation[8)] on the fouling communities, *C. crassicorne* were found to be the most abundant settler on fresh surface. They assumed that the presence of the sticky amphipod-tubes might facilitate the attachment of the larvae of *Mytilus edulis*, and other important fouling organisms, accelerating finally the growth of these foulers. On the contrary, the submerged surface of the buoy from which the present samples were collected was completely covered with thick fouling mat of *C. acherusicum* for at least more than a year. No remarkable fouling by other organisms was observed during the period. The fact led the author to conclude that in this case the amphipod-tubes rather prevented than facilitated the attachment of the larvae of other large organisms. As BARNARD[7)] already suggested, a surface once covered with amphipod-tubes "may be unsuitable" for other fouling-organism larvae, especially in areas where "a relatively continuous settling pressure is maintained by the tubicolous amphipods".

IRIE[6] reported that the production of an edible brown alga, *Undaria pinnatifida*, decreased considerably by the formation of the fouling tubes of the amphipods, composed mainly of *Erichthonius brasiliensis** and *C. acherusicum*, on the thalli of the alga. So far as the author knows, this is perhaps the only authentic record of the harmful effect on the fishery caused exclusively by the tubicolous amphipods. He supposed that the accumulation of mud on the ground of the alga by heavy inflowing of land water in June provided a very favorable condition for the amphipods. On the basis of the data presented herein, the time might coincide with the most active breeding period of the amphipods. This may be another contributing factor to their enormous thriving.

Another ecological significance of the tubicolous amphipods may be the role as important food for fishes. Indeed, considerable records on the fishes which fed on *Corophium* have been found scattered through literature[1)~4),20)]. The early observations made from January through April, 1955, in Fukuyama Harbor clarified that *C. acherusicum* was dominant in the stomachs of several species of fishes such as *Sebastes inermis*, *S. oblongus*, *Hexagrammos otakii*, *Rhinogobius pflaumi*, *Enedrias nebulosus*, etc.

In 1961 and 1962, an opportunity arose to investigate on the catch of fishes of the neighboring waters of Fukuyama Harbor[21)]. The results of the stomach-content examinations of the ten commonest species of fishes caught on June 21 and 29, 1961 are shown in Table 2. The stomach contents were classified into ten food items, and

Table 2. Food composition of the ten commonest species of fishes taken during June, 1961[21)], in the neighboring waters of Fukuyama Harbor

Fish species	Number of fish examined	Standard length (mm)	Food items										Empty stomach
			Fishes	Cephalopods	Brachyurans and macrurans	Mysids	Isopods	Amphipods	Other crustaceans	Polychaetes, gastropods, etc.	Diatoms	Digested food, unidentified	
Trichiurus leptulus	10	320-530	53.8	—	38.5	—	—	—	—	—	—	—	7.7
Pseudoblennius cottoides	13	57-112	31.6	—	10.5	—	5.3	26.3	5.3	—	—	15.8	5.3
Apogon lineatus	32	40- 63	5.3	—	36.8	2.6	—	10.5	—	2.6	—	7.9	34.2
Limanda yokohamae	36	60-116	—	—	2.0	—	—	47.1	7.8	7.8	—	25.5	9.8
Hexagrammos otakii	15	104-136	3.1	6.3	9.4	—	6.3	46.9	3.1	12.5	—	12.5	—
Lateolabrax japonicus	10	64- 87	16.7	—	8.3	—	—	41.7	8.3	—	—	25.0	—
Kareius bicoloratus	23	54- 96	—	—	—	—	—	41.4	3.4	—	—	10.3	44.8
Sebastes inermis	13	43- 56	—	—	—	—	—	29.4	35.3	5.8	—	11.8	17.6
Leiognathus nuchalis	9	68- 83	—	—	8.3	—	—	8.3	16.6	—	—	66.7	—
Engraulis japonica	10	85-110	—	—	—	10.5	—	—	15.8	31.6	15.8	26.3	—

* This species has recently been revised as *E. pugnax* by NAGATA[17)].

the food composition of each fish was determined by the percentage frequency of occurrence of each food item according to HATANAKA and IIZUKA[22]. Eight species of fishes out of ten fed on amphipods. Amphipods occupied the dominant part of food in the following four species of fishes: *Limanda yokohamae*, *Hexagrammos otakii*, *Lateolabrax japonicus* and *Kareius bicoloratus*. It is also shown in Table 3 that

Table 3. Rates of feeding on Amphipoda and *Corophium* in several fishes listed in Table 2

Fish species	Number of fish examined (N)	Number of fish fed on Amphipoda (A)	Rate of feeding on Amphipoda (A/N, %)	Number of fish fed on *Corophium* (B)	Rate of feeding on *Corophium* (B/N, %)
Hexagrammos otakii	15	15	100.0	9	60.0
Limanda yokohamae	36	24	66.7	21	58.3
Kareius bicoloratus	23	12	52.2	10	43.5
Lateolabrax japonicus	10	5	50.0	3	30.0
Sebastes inermis	13	5	38.5	3	23.1
Pseudoblennius cottoides	13	5	38.5	3	23.1
Apogon lineatus	32	4	12.5	2	6.3
Leiognathus nuchalis	9	1	11.1	0	0.0

amphipods were preyed upon by all the individuals of *H. otakii*, 67% of *L. yokohamae*, 52% of *K. bicoloratus* and 50% of *L. japonicus*. Of these amphipods, *Corophium** were the most important food. They were taken by 60%, 58%, 44% and 30% of the above four species of fishes, respectively.

As seen in Table 2, all these fishes were juvenile or small-sized forms which composed of the greater catch of the fishes of the area[21]. Judging from the result of the foregoing pages, the period of the present investigation on feeding habits of fishes presumably corresponded to the time when the population density of *C. acherusicum* was at the highest. Therefore, the amount of predation upon *Corophium* was probably in direct proportion to their relative abundance. It can be concluded, however, that the role played by the amphipods including *Corophium* as prey for fishes, especially young fishes, is of great importance at least within this limited period of time.

* Most of *Corophium* were difficult to identify due to digestion, but several intact specimens were all found to be *C. acherusicum*.

This work was initiated with the suggestions of the former Professor Daijiro KUSAKABE, to whom the author's grateful thanks are due. The author also wishes to express his sincere thanks to Professor Yutaka MURAKAMI for his valuable criticism and continuous encouragements in the course of the work.

SUMMARY

Observations were made on the population of a marine tubicolous amphipod, *Corophium acherusicum* COSTA, which was found in greatest abundance in Fukuyama Harbor, Inland Sea of Japan. The results obtained are summarized as follows:

1) Abundance in population density, as expressed in terms of the number of individuals per unit weight of dried mud-tubes of *C. acherusicum*, fluctuates seasonally, showing a single prominent peak in June.

2) There is a remarkable seasonal variation in size of both male and female, being larger in colder season than in summer season. This fact suggests the presence of large-sized over-wintering generations and small-sized summer generations. In general, the females are larger in size than the males.

3) Breeding continues throughout the year. But, there is an indication that the breeding seems most active in March—mid-July and next, October—November. Both in the coldest and the warmest seasons breeding activity may be suppressed.

4) The relationship between the number of eggs incubated in brood pouch (N) and the standard length of mother animal (L, mm) can be expressed as $N = 0.28L^{2.98}$.

5) The females are commoner than the males. The average sex-ratio is 1.6 (females) : 1 (male).

6) Importance of the amphipod as the member of fouling community and the prey for some littoral young fishes is described.

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福山港付近における管棲端脚類，アリアケドロクダムシ，に関する二・三の観察

遠　部　　卓

アリアケドロクダムシ* (*Corophium acherusicum* Costa) はヨコエビ亜目 (Gammaridea)，ドロクダムシ科* (Corophiidae) に属する端脚類であって，内湾などに多くみられる．本種はいわゆる管棲端脚類の一種で，海中の浮泥などを用いて棲管を形成し，その中に棲息するという特異な生活様式を有する．

福山港付近において，本種の極めて高密度な群集が認められたので，連続的採集，観察を行なった結果，次のような生態的知見が得られた．

1) 棲管の乾燥重量 1 *g* 当りの個体数をもって示した群集密度には，季節的変動が認められ，6月に顕著なピークを形成する．この時期には 1 *g* 当り 1,000個体以上という極めて高い密度を示す．

2) 雌雄とも，体長は冬期に大きく夏期に小さい．このことから年間を通じてみると，体長が大きく寿命の長い越冬世代（大型長期世代）と，体長が小さく寿命の短かい夏世代（小型短期世代）の二者に大別することができる．

3) 産卵は周年ひき続いてみられる．しかし産卵活動は 3 月～7 月中旬に最も活発で10月～11月がこれに次ぎ高く，盛夏および厳寒時には，かなり低くなる傾向がみられる．

4) 抱卵雌の体長 (L, mm) と抱卵数 (N) との関係は $N=0.28L^{2.98}$ なる指数式で示される．

5) 性比は年間を通じて平均すると雌1.6：雄 1 の割合であり，雌の方が常にやや多い．

6) 管棲端脚類の生態的意義について，主として汚染生物および餌料生物としての重要性を中心に，述べた．

* これらの和名は永田[15]によった．

EXPLANATION OF THE PLATE

Fig. 1. *Corophium acherusicum* Costa: adult female (ovigerous), 5.52mm. Side view. ×14.

Fig. 2. Dorsal view of the same. ×14.

Fig. 3. *Corophium acherusicum* Costa: adult male, 4.05mm. Side view. ×14.

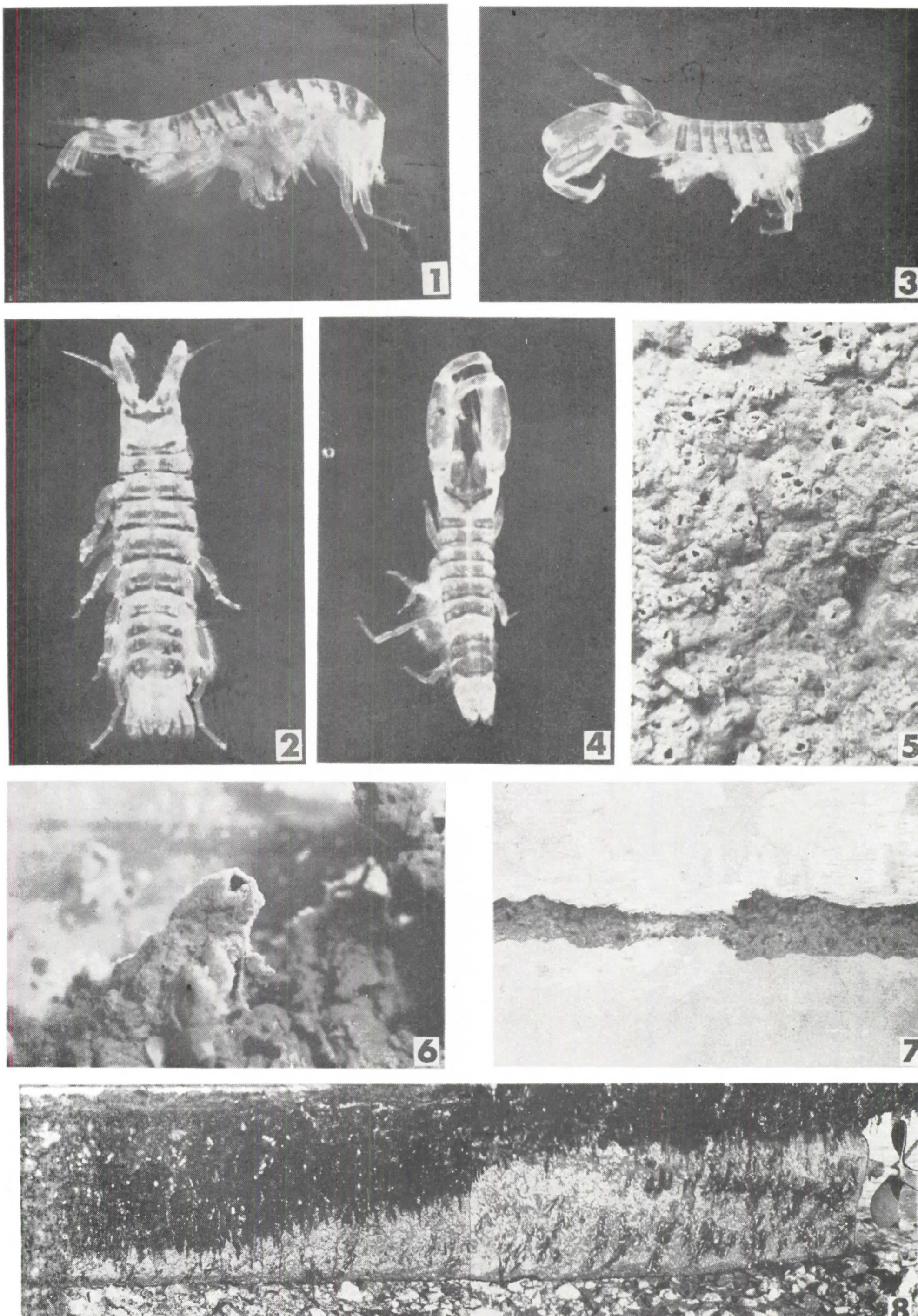
Fig. 4. Dorsal view of the same. ×14.

Fig. 5. Part of a fouling mat made up with many tubes of *Corophium acherusicum* Costa. ×2.

Fig. 6. Outline of a tube built by *Corophium acherusicum* Costa. ×4.

Fig. 7. A piece of rope of set-net, on which layers of amphipod-tubes are formed. ×1/7.

Fig. 8. A boat's bottom heavily fouled with amphipod-tubes. ×1/25.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