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TRANSPLANTATION OF EUROPEAN FLAT OYSTER, *O. EDULIS*, INTO JAPANESE WATER AND ITS BREEDING IN TANKS.*

By

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In the spring of 1952, European flat oysters, *Ostrea edulis* L., and Portuguese oysters, *O. angulata* Lam., were transplanted from Holland to Onagawa Bay in Japan, by courtesy of Dr. P. Korringa of Fisheries Laboratory, Bergen op Zoom, Holland.** They were cultured in Onagawa Bay and used for breeding experiments during the following summer. This paper is a report on the records of culture of these flat oysters, *O. edulis*, and the results of their artificial breeding in tanks. The results of breeding of Portuguese oysters, *O. angulata*, and their cross with Japanese Common oyster, *O. gigas*, will be reported at a later date.

Transplantation and Culture

A wooden case containing sixty-nine flat oysters and fifty-one Portuguese oysters, well protected from desication and heat by oil paper and cork plate, was shipped from Amsterdam to Tokyo on 1st of April by air mail via the K. L. M. Airline. During the voyage, good care was taken not to expose the package to heat. As soon as it reached Tokyo, after 72 hours' flight, it was transshipped to Onagawa by train, and 24 hours later the oysters were returned to sea water in Onagawa Bay. They were placed together in a wire basket and hung under a culture raft.

Among the flat oysters, twenty-seven were four-winter oysters born in 1948 in Morbihan District, France, while the rest (forty-three) were two-winter oysters born in 1950 in Oostershelde, Holland. No mortality occurred during transportation, but a few of the older oysters showed gaping on arrival. As time passed older ones died one by one, and by 11th October twenty oysters, 74%

* Contribution from Onagawa Fisheries Laboratory, Tohoku University.

** We wish to express our hearty gratitude to Dr. P. Korringa for the shipment of European oysters.

of the group, were lost. The mortality was specially high in early summer at the season of gonad maturation and spawning. None of the two-winter group died during either transportation or culture. Mortality records are summarized in Table 1.

Table 1. Mortality records of European flat oysters in Onagawa Bay. (1952).

Date of Observation.	Four-Winter Oyster			Two-Winter Oyster	
	No. of Living	No. of Death	Total Death	No. of Living	No. of Death
April 5	27	0	0	43	0
April 7	25	2	2	43	0
April 12	21	4	6	43	0
May 16	19	2	8	43	0
June 10	9	10	18	43	0
July 10	9	0	18	43	0
Aug. 3	8	1	19	43	0
Sept. 6	7	1	20	43	0
Oct. 11	7	0	20	43	0

The high mortality among the older oysters may suggest that their resistance could not bear the handling in shipment and exposure to air and also that their adaptability to new environment was low as compared to younger ones'. Such low adaptability to new environment was also revealed in their rate of growth, fattening and spawning. The growth of flat oysters after transplantation in Onagawa Bay is shown in Fig. 1, with records of water temperature and salinity.

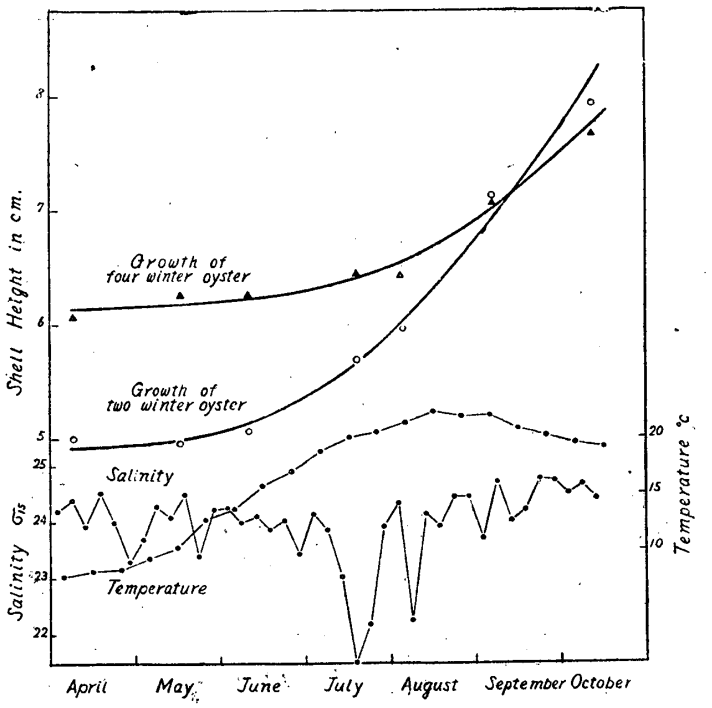

Fig. 1. Growth of European flat oysters in Onagawa Bay.

The size is expressed by height of the shell in centimeters. At the time of transplantation the average height of older oysters was 6.1 cm., and that of younger ones was 5.0 cm. The latter showed much more rapid growth as water temperature rose, while the former gained only slightly in growth. In October, after six months of culture, the younger oysters exceeded the older ones in height. Moreover, the meat of the older oysters not only remained thin but their gonad also did not get matured sufficiently to make breeding experiments possible.

Breeding in Tanks

For the reason already mentioned, only two-winter oysters were used for breeding experiment in tanks. On 10th of June, when the water temperature rose as high as 15°C., twenty-five of them were transferred from the culture raft in the bay to the tank, set just outside of the laboratory. In the tank, the oysters were suspended on a bamboo mat in the middle layers, 50 cm. from the surface. Water from the bay was introduced into the tank for about four hours a day. First swarming occurred between 28th and 29th of June, second between 4th and 5th, third between 7th and 8th and fourth between 11th and 12th of July. No further swarming was recorded with this group. In total, one million and six hundred thousand larvae were liberated in tank. The records of swarming are summarized in Table 2 and Fig. 2, with records of temperature and hydrogen ion concentration of the tank water. Salinity remained fairly constant within the range of $\sigma_{15}=23.05$ and 24.15 during the period.

Table 2. Swarming of larvae of European flat oysters in tanks.

Number	1	2	3	4
Date	June 28–29	July 4-5	July 7-8	July 11-12
Increase of water temperature (°C) on the day of swarming.	1.3	0.7	Not recorded	0.7
Change in pH.	8.25–8.27	8.29–8.25		8.25-8.25
Number of larvae liberated.	90,000	440,000	430,000	670,000
Average size of larvae at swarming in μ. (Height × Length)	186.4 × 206.0	171.4 × 194.8		166.9 × 187.7

The records indicate that the swarming of the larvae was possibly induced by a rise of temperature in tank water which amounted from 0.7 to 1.3°C. a day. The average size of larvae at liberation varied from 186.4 to 166.9 μ in height and from 206.0 to 187.7 μ in length. This range of size was close to the figures reported by Erdman (1934) and Korringa (1940). As to the fact that the size at liberation gradually diminished as swarming repeated, it is hard to

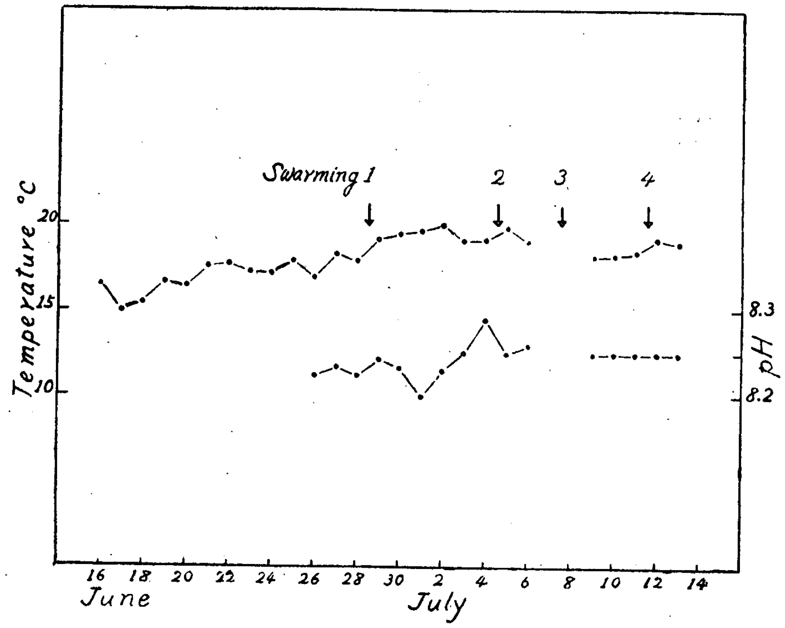

Fig. 2. Records of temperature and hydrogen ion concentration of tank water during swarming.

say if this was due to the rise of temperature as was suggested by Erdman (1934) or simply to the seasonal tendency of repeated swarmings as was stated by Hagmeier (1916) and Korringa (1940).

The larvae liberated at the second and fourth swarming were used for rearing in tanks in order to obtain seed oysters. The method of culture was practically the same as already reported in our previous paper (Imai et al, 1950). The larvae were fed with non-colored naked flagellate, *Monas* sp. No. 34, which had been inoculated into water newly pumped to the tank, and kept its density at a level over 1,000 flagellate per cc. of water with organic enrichment of cooked soluble starch. The top of the tank was coverd with canvas and screen net so that the intensity of light was reduced to less than 5% of the direct illumination of the sun. Thus it was possible to restrain the growth of diatoms and other colored phytoplankton to a very low level. Gentle plunger stirring was given intermittently by motor for a total of approximately four hours a day. When the larvae were fully grown, the Pecten and oyster shells, strung by wire through a hole, were hung in the tanks as cultch and the seeds were collected on them.

The results of breeding experiments are shown in Table 3 and Figures 3 and 4 together with records of culture conditions.

In culture No. 1, the water temperature remained within the narrow range from 18 to 21°C. most of the time as is seen from Fig. 3. Both pH and salinity were within the narrow favorable ranges. The density of *Monas* was sustained at over 1,000 per cc. of tank water most of the time. In this culture the larvae reached fully grown size and began to set on cultch on 11th or 12th day of culture. The rate of growth in this case seemed to be normal if we take the data on length of pelagic life given by Cole (1936) and Korringa (1940) as a standard.

Table 3. Results of breeding experiment of flat oysters in tanks.

Culture number	1	2
Tank number	C-6	C-5
Capacity in litre	8,900	8,900
Number of larvae set in tank	440,000	670,000
Tank water condition		
Temperature °C.	18.0-22.2	19.3-23.3
Chlorinity ‰	17.9-18.1	18.1-18.2
pH	8.20-8.26	8.17-8.26
Number of *monas* per cc.	700-2,100	300-2,500
Grams of starch added (with date of enrichment)	5 (5) 5(12)	5 (5) 5(11) 5(17)
Estimated number of grown larvae	240,000	240,000
Percentage of survivals	54.5	35.8
Minimum duration of pelagic life in days.	11-12	16-17
Number of spat on cultch	73,000	4,400
Average number of spat on single shell	220	44

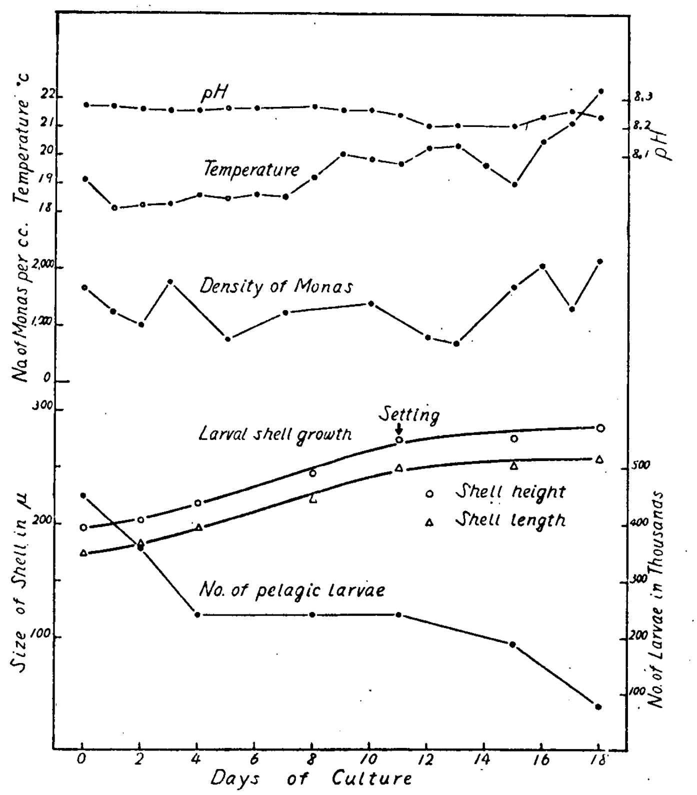

Fig. 3. Records of tank breeding. No. 1.

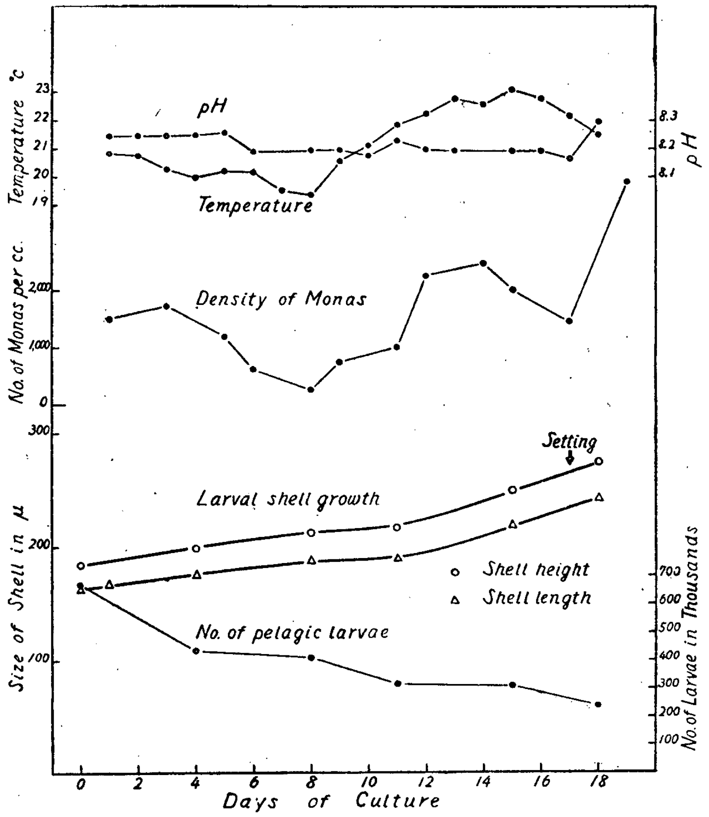

Fig. 4. Records of tank breeding. No. 2.

In culture No. 2, it took 17 days before some spat were found on the cultch, in spite of the high temperature condition. The record of shell growth in Fig. 4 indicates that the growth was suppressed in early stage of development, particularly from 8th to 11th day of culture and recovered again in later development. The cause of such retard of growth may not be simple, but the record suggests that low density of food organism as expressed by number of *Monas* from 6th to 11th day might possibly be the limiting factor.

On being liberated, black sick larvae were D-shaped and the umbone began to appear on the third or fourth day when the shell length reached 210 μ or so. In both cases the mortality was noticed to be rather high before this stage of development was attained. This facts reminds us that the high mortality in Japanese oyster, *O. gigas*, (1950) occurs just before the umbone begins to appear. It may be considered as a critical period of larval growth common to oysters.

The development of umbone resulted in the assymmetric shape of two shell valves. But the projection of umbone was not so marked and dimentionally the shell height never exceeded the length as in the case of oviparous Japanese oyster, *O. gigas*. The larvae began to crawl on the substratum with their developed feet when the shell height reached approximately 270 μ and sooner or later they began to set on the cultch. None of the pelagic larvae in our culture reached over 300 μ in height as shown in Table 4 and 5.

Table 4 Percentage of population in 0.01 mm. size group in culture No. 1. Size of sample was 10.

Size	July 6	8	10	14	17	21	24
0.16	30	10					
0.17	60	10					
0.18	10	80	40				
0.19			50	10			
0.20			10	10			
0.21				30		10	
0.22				40			
0.23				10	30	20	10
0.24					10	20	10
0.25					40	30	50
0.26					10		10
0.27					10	20	20

Table 5. Percentage of population in 0.01 mm. size group in culture No. 2. Size of sample was 10.

Size	July 13	17	21	24	28	31	Aug. 4
0.16	60	20	10				
0.17	40	30	20	20			
0.18		40	20	20			
0.19		10	20	40	10		
0.20			20	20	30		
0.21			10		20	20	10
0.22					10	10	
0.23					10	30	10
0.24					20	10	20
0.25							40
0.26						10	
0.27						10	10
0.28							10
0.29						10	

The number of grown larvae in the tank on the first day of setting was estimated by sampling at 55% and 36% of the total larvae with which the culture was started. However, only a small portion of them actually set on the cultch. The rest of them settled heavily on the walls and bottom of the tanks. We could have collected greater number of spat, if we had prepared more cultch for collection.

The development of pelagic larvae and the spat just settled are shown with photographs in Fig. 5 and 6. Collected seeds were kept in running water in tanks for nearly two months and then were transferred to the culture raft in the bay after it had been confirmed that no danger of additional set of Japanese

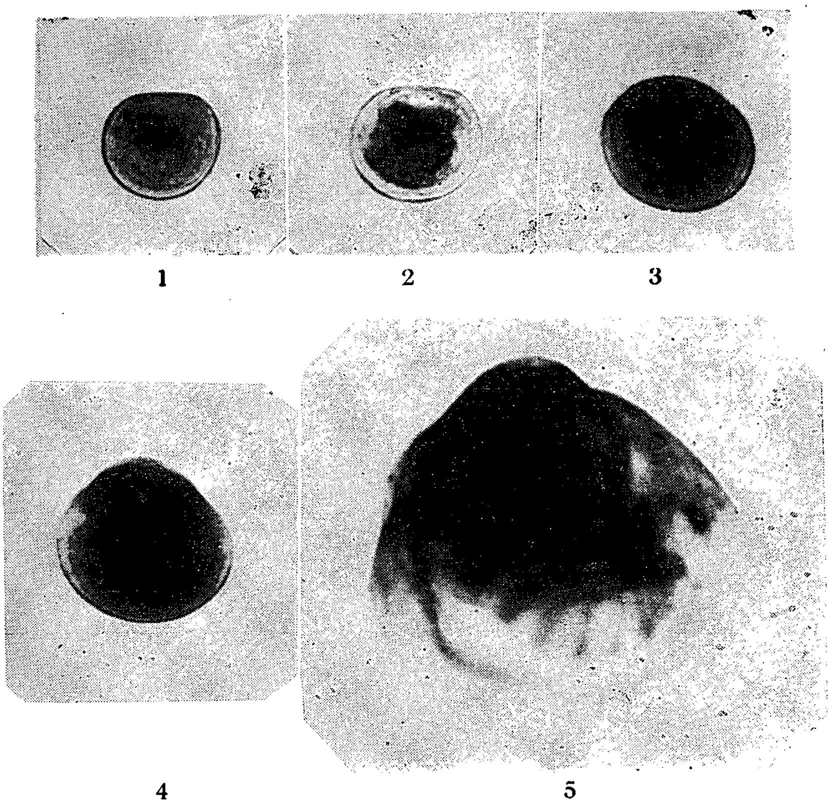

Fig. 5. Developmental stages of flat oyster in tank culture No. 1.

1.	Pelagic larva at liberation	162×189 μ
2.	〃 on the 2nd day of culture.	175×200 μ
3.	〃 〃 8th 〃	203×252 μ
4.	〃 〃 11th 〃	252×270 μ
5.	Spat three days after settled.	576×590 μ

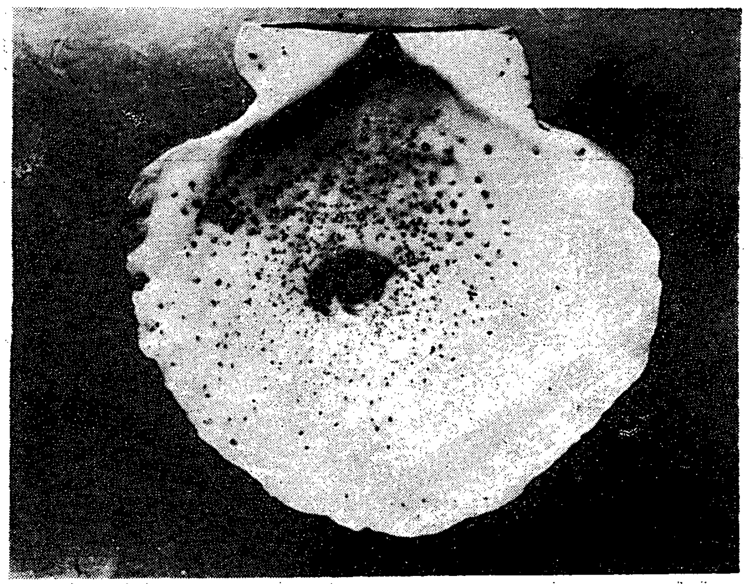

Fig 6. Showing heavy set of spat on a collecter three days after settled.

oyster would occur in the bay. So far the mortality has been very low. These seeds will be used for culture experiment in various oyster beds in Japan.

Conclusions of the Experiment and Considerations on the Possibility of Establishing Natural Stock of European Flat Oyster in Certain Localities of Japanese Water

European flat oysters were transplanted into Japanese water and were successfully bred in tanks by use of the non-colored naked flagellate. Culture in Onagawa Bay proved that they could grow in the northern Japanese water and this fact suggests that if ample seeds be obtainable, this species can become a new addition to the Japanese oyster industry.

At present *O. gigas* is the main oyster under culture in Japan and its culture is distributed in all suitable Japanese waters. Besides *O. gigas*, two other species are used for culture, namely larviparous *O. densellamelosa* and oviparous *O. rivularis*. But their culture is on a very small scale and their ditsribution is limited to small areas in the southern warm waters. Experimental transplantation of these oysters to Onagawa Bay was totally a failure (unpublished). Thus, at present *O. gigas* is used exclusively for culture in the cold waters of northern Japan. According to the genetic study of Japanese oyster (Imai et al.)*, *O. gigas* is distributed widely all over Japan, but the species shows different local characteristics both morphologically and physiologically which persist for generations even if bred and cultured under exactly the same conditions.

In Hokkaido, northernmost of the Japanese Islands, native *O. gigas* are produced. Though this local race spawns at lower temperature as compared with the southern ones, its natural propagation occurs only once in several years when the water temperature reaches high enough for massive spawning and healthy larval growth. Therefore, the culture industry in Hokkaido has to depend on transportation of seeds from southern seed-producing areas such as Miyagi Prefecture. The same is also true of many important culture beds in waters north of Miyagi Prefecture. These oysters transported from the south spawn at higher temperature than the northern races such as Hokkaido ones. Therefore majority of them fail to spawn during summer and accordingly suffer from the delay of fattening in fall. This is the greatest disadvantage to oyster culture in the cold waters of Northern Japan. Under such circumstances it should be desired to introduce suitable oysters of better quality which can propagate and grow well in cold waters. So far as the growth of transplanted

* Papers on the subject were read at the annual meeting of Japanese Society of Scientific Fisheries in 1946, '47, '48, '49, '51 and '52.

specimens, as well as of spat, is concerned, European flat oysters can be grown on commercial scale in Japanese waters. And judging from the natural habitat in Europe it is reasonable to suggest that they ought to survive and grow well even in Hokkaido waters. The chance of their natural propagation seems to be by no means small, because water temperature reaches 21°C. or a little over during summer, which is high enough for flat oysters to reproduce but not for *O. gigas*. The problem, then, is whether or not we can introduce enough seeds to build up a new stock large enough to produce seeds available for the industry.

Our experiment in tank culture proved that flat oyster can be reared easily by method of non-colored naked flagellate. Two small tanks were used and over 70,000 spat were collected. This was by no means a great success, but we are sure that we could have collected several times that quantity of seeds if we had prepared more cultch. It will not be difficult to catch a couple of million seeds in one season with the present facilities of the laboratory. It may be worthwhile for us to continue the experiment in the hope of finding out the possibilities of building a new natural stock of flat oyster for the cold waters of northern Japan as an extension of the study of tank breeding.

Summary

1. European flat oysters were transplanted from Holland to Japan in spring of 1952 by air mail and were cultured in Onagawa Bay.

2. Two-winter oysters survived and grew well in Japanese waters and liberated healthy larvae which were used for tank breeding. Four-winter oysters showed high mortality and poor growth, indicating the poor adaptability to the new environment.

3. Liberated larvae were reared in tanks and many spat were collected. They will be used for culture experiments in oyster bed in various parts of Japan.

4. Possibility of stocking flat oysters in Japan, particularly in cold water region, was discussed.

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