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Reproduction and condition of unionid mussels in the Vantaa River, South Finland

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With 13 figures in the text

Abstract

Gravidity, seasonal courses of condition indices and health were studied in *Anodonta anatina* (L.), *Pseudanodonta complanata* (ROSSM.), *Unio pictorum* (L.) and *U. tumidus* PHILIPSSON. Notes on *U. crassus* PHILIPSSON are also included. Females of *A. anatina* were gravid (bearing embryos or glochidia) from July to April or May. Gravid *U. pictorum* and *U. tumidus* were encountered from April to July and two gravid *U. crassus* in June. The non-gravid interval of *P. complanata* in June was very short. *A. anatina* matured fairly early, the youngest gravid females being 1+ year old. The marsupial gills of gravid mussels were not always full. All species fattened in proportion to shell volume in spring and early summer when water temperature was rising. This fattening partially preceded the rapid shell growth. Gravid females of *A. anatina* were fatter than males, but during the non-gravid interval of females and the normal spermatogenesis of males, males tended to be fatter. Interannual differences were noticed in the condition and gravidity period of the Vantaa mussels. All species included occasional hermaphrodites. Developing mites were common in *P. complanata* and the *Unio* spp. and less common in *A. anatina*. Seasonal prevalences of bucephalid trematode sporocysts and a pustular disease in *A. anatina*, with notes on some other diseases in the Vantaa mussels are reported.

Introduction

Shellfish monitoring has previously been generally restricted to marine aquatic systems (MIX, 1986). In Finland, the necessity arose for animals to use as monitor organisms both in fresh and in weakly brackish waters. Among freshwater mussels, *Anodonta anatina* has been introduced for this purpose by cage incubation methods (e.g. KORHONEN & OIKARI, 1987; HERVE, 1991). Although they would prove useful for monitoring studies, studies concerning the basic biology of unionid mussels in Finland are not very numerous. The distribution of unionid mussels, their growth and shell dimensions were studied by NORDENSKIÖLD & NYLANDER (1856), LEVANTO (1940), BRANDER (1954), KOLI (1961), HAKA et al. (1974), HAUKIOJA & HAKALA (1974, 1978a, 1979) and ENGLUND & HEINO (1992), ciliary activity by SENIUS (1978), effects of acidification by PYNNÖNEN (1991), and bucephalid trematode parasites by HAAPARANTA &

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Valtonen (1991), Taskinen & Valtonen (1991) and Taskinen et al. (1991). Although some aspects of the reproduction of *Anodonta anatina* were examined by Haukioja & Hakala (1978 b), Tuomi et al. (1983) and Jokela et al. (1991), the reproduction of unionid mussels in Finland is still little studied. The health and seasonal condition courses of unionid mussels are almost totally unstudied.

To fulfill some gaps in the knowledge of unionid mussels in Finland the author began a survey in the Vantaa River in autumn 1988. Koli (1958) has studied the distribution of unionid mussels in the river, but nothing has been known about the health and reproduction of the mussels. Because the Vantaa River system flows through the Helsinki metropolitan area, and the mussel population in the river is very dense, it would be interesting to know the mussels' status. Some results of this research project have already been published (Pekkarinen, 1991 a, b, c, d). Further results concerned with the annual reproductive and condition cycles and health of the mussels are presented in this paper.

Material and methods

The Vantaa River system originates as several small rivers from both oligotrophic and eutrophic lakes (Vantaanjoki-Toimikunnan Mietintö, 1985) and flows through the city of Helsinki. Eutrophication had been a problem in the river in the 1960s and 1970s. Community waste-water treatment has since then been effectively developed, and agriculture is nowadays the most marked loader in the district of the river system. The river is covered by ice from about December to March. Spring floods usually occur in April. Fig. 1 presents the river water temperatures during the period of the study.

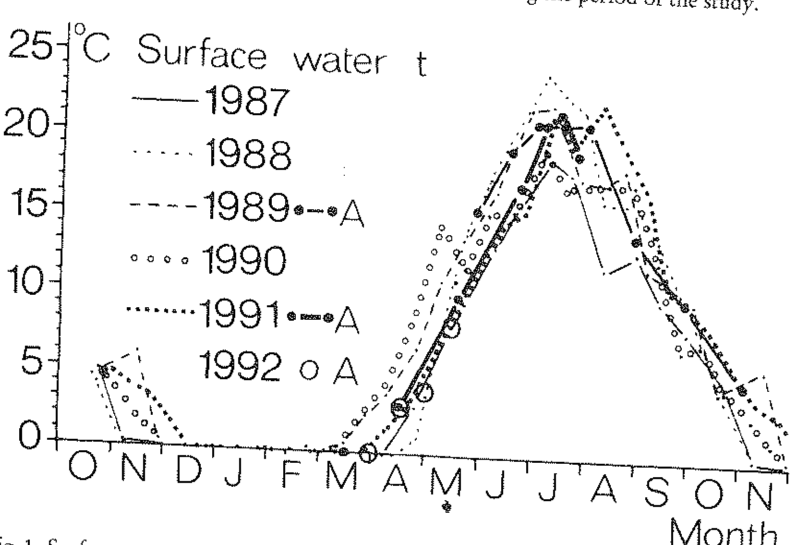


Fig. 1. Surface water temperatures at sampling site measured by author (A, large dots and circles) and measured by Helsinki City Water and Wastewater Authority a few hundred metres downstream from sampling site.

Mussels were collected by dragging the muddy or somewhat sandy slope of the river; because of the collecting method used and water-level variation, the mussels originated from a fairly wide range of depths (from about 0.5 to 3 m). Each collecting site was always a little north or south of the former site. After dragging, the mussels were usually kept in the laboratory for at least two days (very small mussels for one day) in running charcoal-filtered tap water (4 or 12 °C).

Condition indices ("fatness" indices = % soft body wet weight of weight of soft body and water in mantle cavity) were measured for some of the mussels according to PEKKARINEN (1983). All mussels' status (such as possible gravidity and marsupial filling degree, parasites and diseases) was examined under a preparation microscope. Shell length was measured on the longest axis. The sex was determined by using gonadal smears freshly and after staining, and/or histological sections. The gonadal smears were fixed in methanol and stained in diluted Giemsa. For the histological sections (used to study the gonadal cycle, to be reported on in another paper), transverse slices of mussel bodies were fixed in Bouin's fluid or a neutral glutaraldehyde-formaldehyde mixture (1 % G, 4 % F) and processed through routine histological techniques into paraffin. The sections cut from the paraffin blocks were usually stained with haematoxylin and eosin.

Results

Anodonta anatina

Among small mussels (< 30 mm in shell length) numbers of females + males + hermaphrodites were as follows, August – September 1988: 2 + 5 + 2, March 1989: 6 + 14 + 0, June 1989: 2 + 5 + 0, August – September 1989: 2 + 17 + 1. Hermaphrodites among these small mussels thus amounted to 5 %, while among larger mussels (> 40 mm) 0.5 % (5/1065) were hermaphrodites. In the latter sample of small mussels (August – September 1989) all were 0+ year old, and all the 10 individuals shorter than 20 mm were males. In these small individuals a few spermatozoa could be seen in scarce gonad follicles or canals. Oocytes in the females were small. In individuals longer than 30 or 40 mm, oocytes in the ovaries were larger even in autumn, and sperm morulae could be detected in testes. The smallest gravid female of the whole material was 36.5 mm long (2 years old, August 1989). The youngest gravid females were 1+ year old and then usually longer than 50 mm (one gravid 1+ year old female was 47.7 mm).

The percent gravidity of females longer than 50 mm is presented in Fig. 2. Gravidity lasted from July to April or May. The marsupial gills were not always full (Fig. 6); the posterior part was most often empty. The gills of the individuals shorter than 50 mm were generally only partially filled even in autumn. In order to eliminate the possibility of accidental abortion, mussels in March, April and May were opened and examined immediately after collecting.

Anodonta anatina individuals were fattest (proportion of soft body to "shell volume" greatest) in midsummer or late summer (Fig. 10). In larger size classes (> 50 mm) gravid females tended to be fatter than males. Males seemed

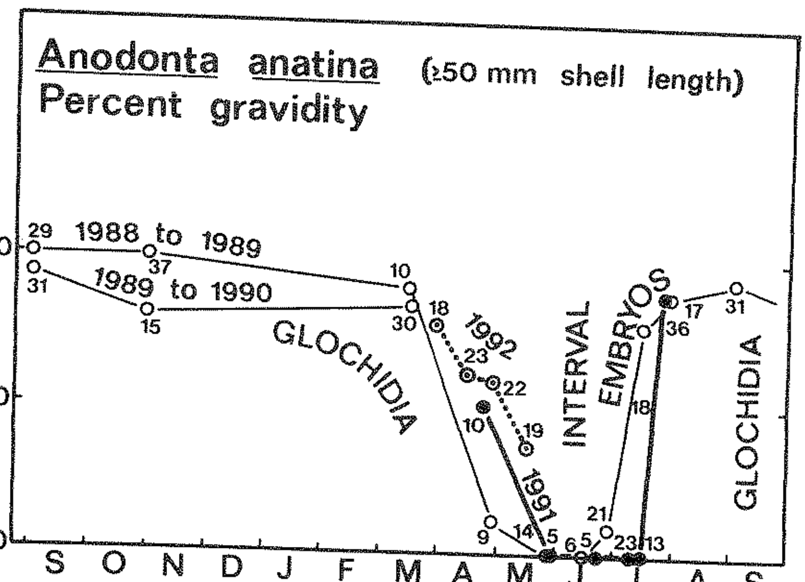


Fig. 2. Percent gravidity of *Anodonta anatina* females (numbers indicate females studied). Individuals parasitized by bucephalid trematode sporocysts (whether castrated or not) omitted.

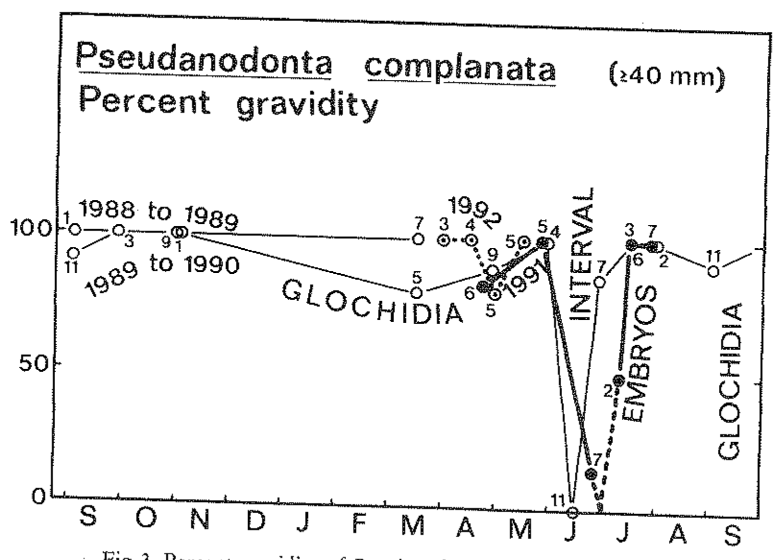
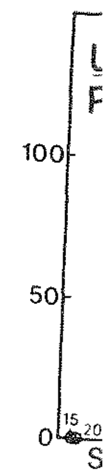


Fig. 3. Percent gravidity of *Pseudanodonta complanata* females.

to be fatter only during the non-gravid interval of females. In the size class 40–50 mm the gravidity of females was far from 100 %, and the females were not generally fatter than males. In the groups of smaller individuals, (if sexes



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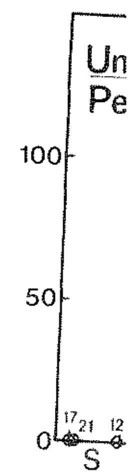

Fig. 5. Percent

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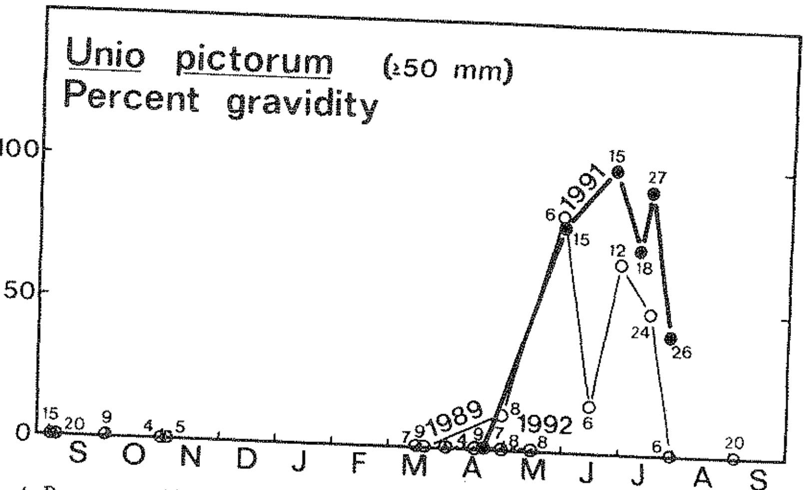


Fig. 4. Percent gravidity of *Unio pictorum* females (Sept. 1988 – March 1990, summer 1991, spring 1992).

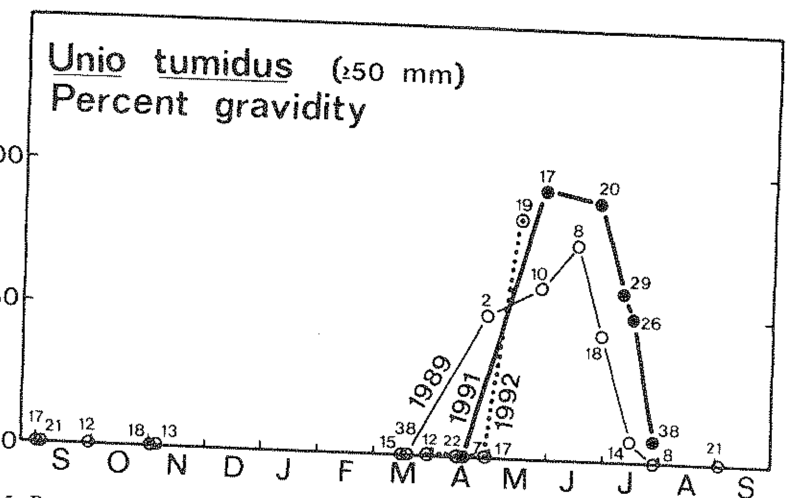


Fig. 5. Percent gravidity of *Unio tumidus* females (Sept. 1988 – March 1990, summer 1991, spring 1992).

could be determined) no differences were found between females and males. If condition indices of different years are compared, males in several groups in autumn – spring 1989 to 1990 were fatter than in autumn – spring 1988 to 1989: 40 – 50 mm, 60 – 70 mm, August – September ($p < 0.01$); 50 – 60 mm, October – November ($p < 0.001$); 80 – 90 mm, March ($p < 0.05$).

Bucephalid trematode sporocysts occurred in 3 to 17 % of *A. anatina* longer than 50 mm (Fig. 7); the smallest individual with such sporocysts was

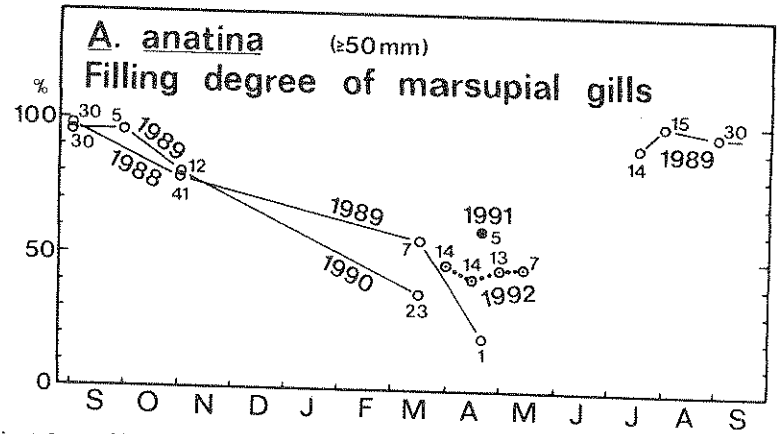


Fig. 6. Mean filling degree (%, assessed by naked eye) of marsupial gills of *A. anatina*.

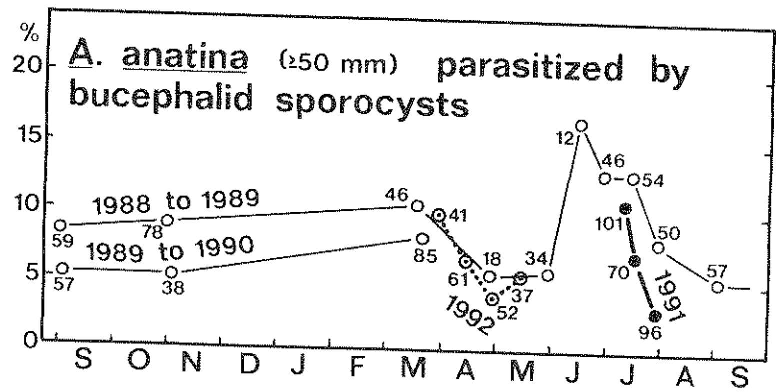


Fig. 7. Percent *A. anatina* parasitized by bucephalid trematode sporocysts.

50 mm long. The cercariae in the sporocysts were not systematically examined, but at least some cercariae with very long, contractile furcae were noticed.

A pustular disease was common among *A. anatina* (Figs. 8 and 9), being most prevalent in summer. The white or brownish pustules occurred between the mantle and the shell, most often in the posterior end or around the posterior adductor muscle. The pustules contained cellular debris and living cells and possibly some secretory matter. Chironomid larvae were sometimes encountered at the shell edge of individuals with clayey pustules or recessed mantle. The individuals with pustules showed great variation in condition indices, and they, as well as those with trematode sporocysts, have been omitted from the material in Figs. 10–13.

Developing mites were not so frequent in *A. anatina* as in the *Unio* species. In summer 1989 they occurred in gills of 18 *A. anatina* individuals and in the

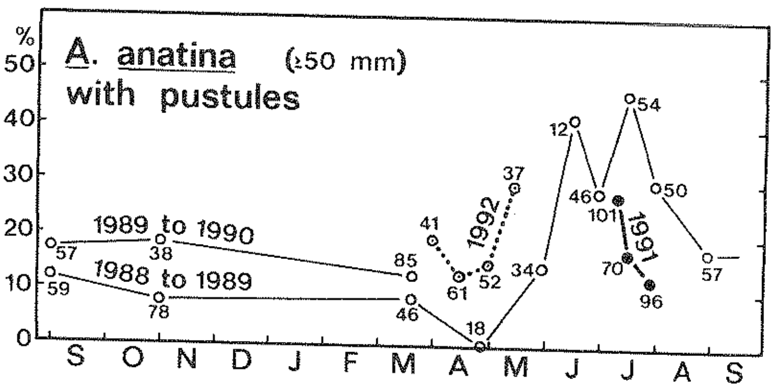


Fig. 8. Percent *A. anatina* with pustules between mantle and shell.

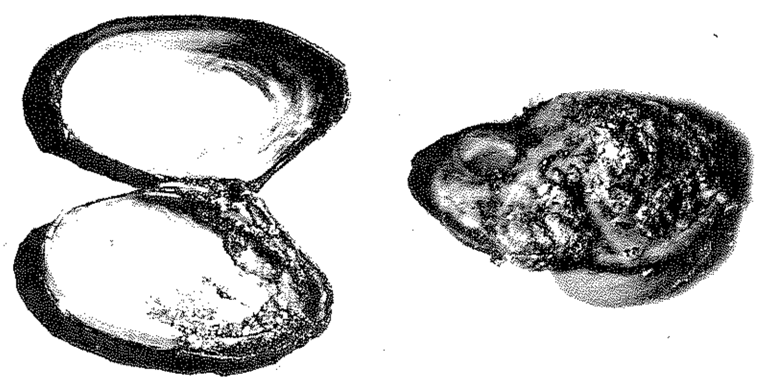


Fig. 9. Two severe cases of pustular disease in *A. anatina*.

siphonal wall of five individuals. In autumn 1989 they were found in gills of 15 individuals and in the mantle of 11. In March 1990 14 mussels had them in the mantle. One *A. anatina* had several specimens of *Paraergasilus rylovi* in its gills.

Pseudanodonta complanata

Three gravid female hermaphrodites (about 2 %) were found among 180 individuals studied (> 40 mm). The smallest gravid female was 37.5 mm (at least 3 years) and the youngest gravid females were 2 years old, and at that time not shorter than 39.7 mm. The percent gravidity of females longer than 40 mm is presented in Fig. 3. The gravidity was long, the interval in June being very short. Partially filled marsupia were common.

Because of small numbers of individuals in different size classes very accurate condition courses (Fig. 11) could not be determined. In addition, the total weight of the animal could not be measured exactly because the shell was

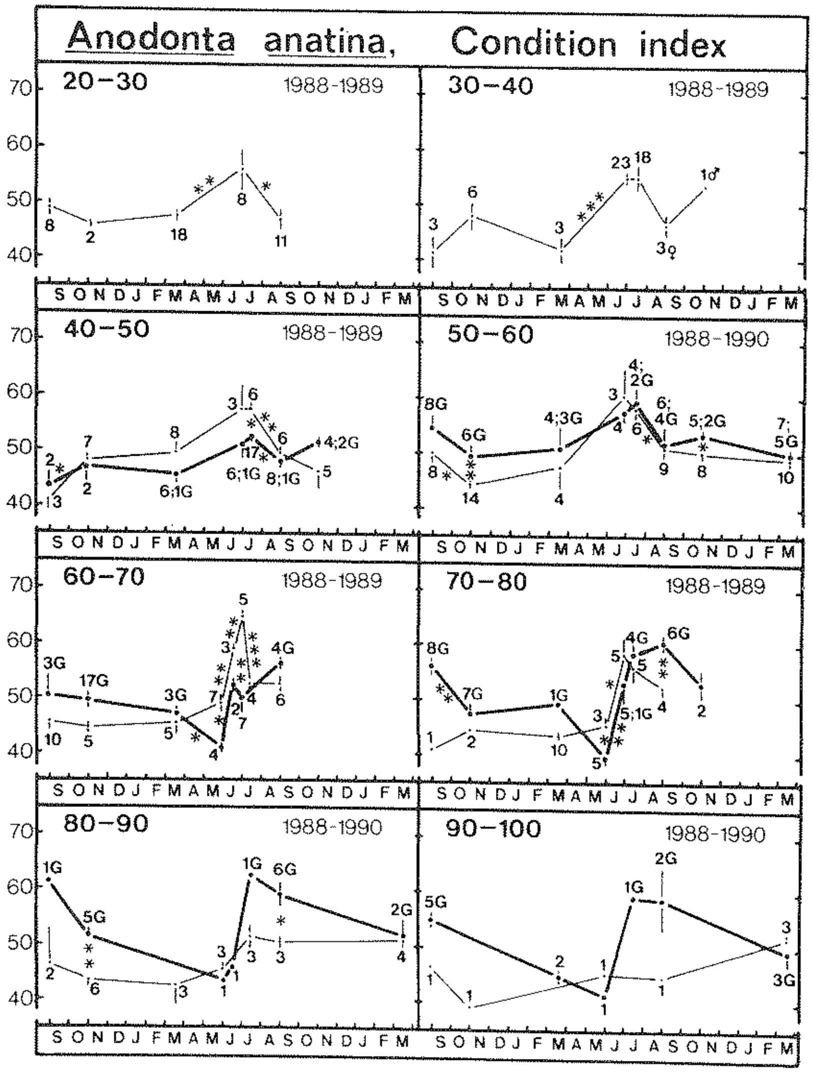
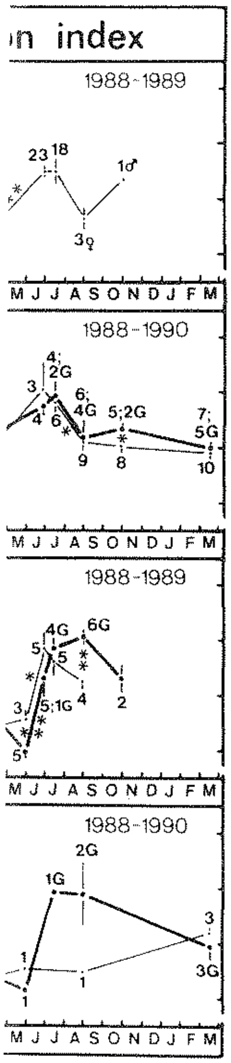


Fig. 10. Condition index of various-size (20–30 = 20.0–20.9 mm...) *Anodonta anatina* (mean ± SE). If a group in size classes 20–30 and 30–40 consists of only one sex, sex is indicated. In larger size classes: bold lines = females (G = gravid), thin lines = males. Student's t test not calculated for groups including <3 individuals (*: $p < 0.05$, **: $p < 0.01$, *** $p < 0.001$).

leaky (not closing tightly). In the size class 40–50 mm, where the numbers of females and males allowed comparison in June, males were significantly ($p < 0.05$) fatter than females, and if the size classes 50–60 mm and 60–70 mm were combined with the 40–50 mm class, then p would be < 0.001. This pe-



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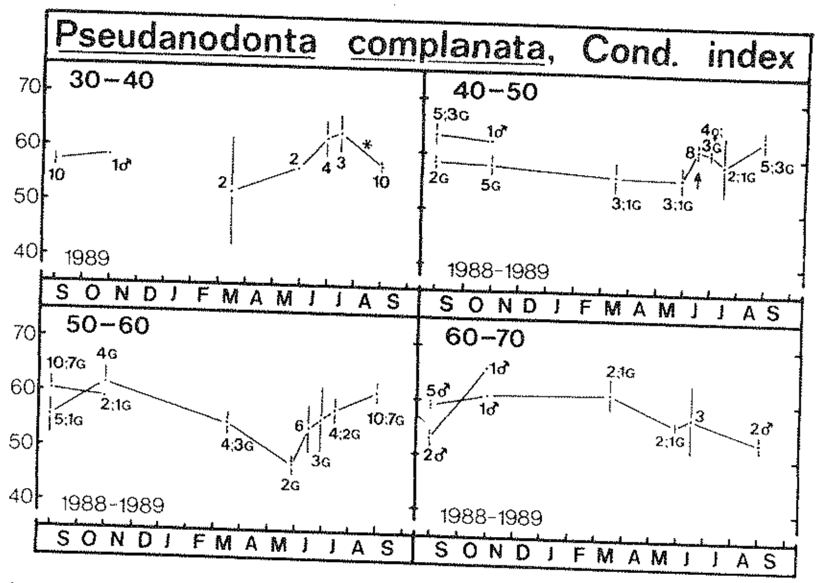

Fig. 11. Condition index of various-size *Pseudanodonta complanata* (see Fig. 10 explanation).

riod (arrow in Fig. 11, 40–50 mm class) is concurrent with the non-gravid interval of females.

One individual (53.0 mm) was parasitized by trematode sporocysts (only cercarial embryos present). Nearly all individuals had mobile mites in their mantle cavity, and some developing mites in their gills.

Unio pictorum

Among *U. pictorum* shorter than 40 mm, 4% (7/169) were hermaphrodites. The smallest gravid female was 46.5 mm in shell length. Females were gravid from late April or late May to late July, not all at the same time (Fig. 4). Furthermore, in the *Unio* spp. partially filled marsupia were common; the filling order of different parts of the gills was a little less systematic than in *A. anatina.* Early embryos were yellow. Fully developed glochidia were not detected in marsupia in April or May, and from this time onwards, in relation to embryonal stages, glochidia were found in few individuals. In late July of 1991 many females still bore early embryos.

Unio pictorum clearly fattened in spring and summer 1989 (Fig. 12). The condition index curves of small and medium-size individuals turned into decrease as early as in late summer, but remained on a higher level in autumn-spring (1989–1990) than in the previous year. Large individuals also showed this difference between the years. Males usually tended to be fatter than females (statistically significantly only in two groups).

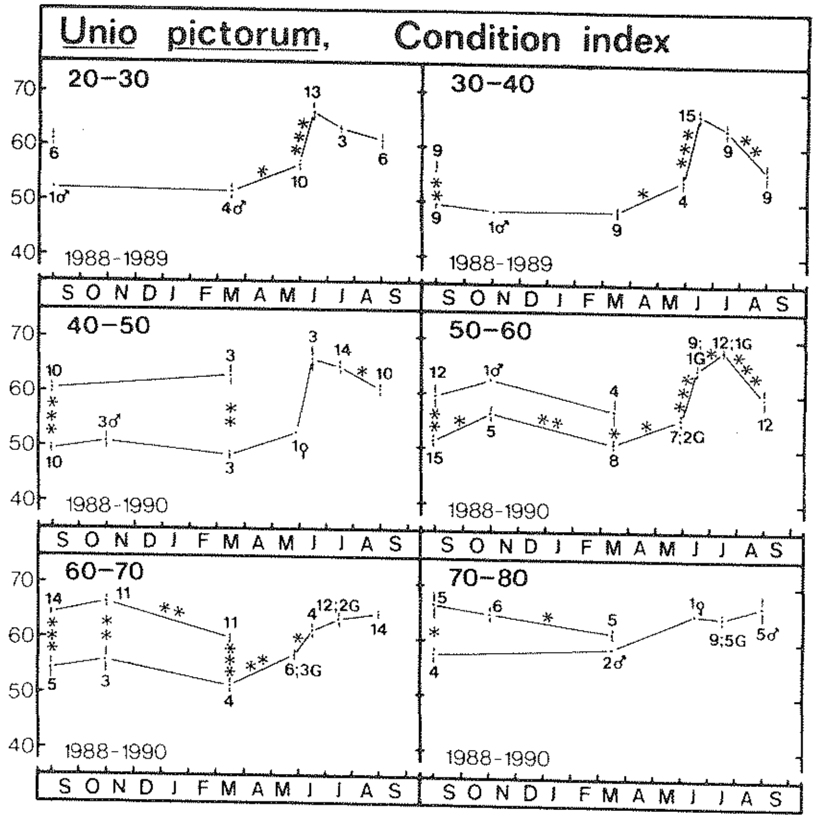

Fig. 12. Condition index of various-size *Unio pictorum* (see Fig. 10 explanation).

In May 1989 three gravid females had brown streaks in their marsupia. In histological sections of the marsupial gills, fungal hyphae and diseased embryos could be seen among normal embryos. Again, in late June 1991 some of the embryos in gravid females were degenerating and contained ciliates and unidentified organisms. Pustules were occasionally found between the mantle and the shell. All larger individuals had developing mites in their gills.

Unio tumidus

Hermaphrodites were common among small mussels (17/202 = 8 %) but infrequent among large mussels (>50 mm) (4/624 = 0.6 %). Furthermore, there were several large mussels which had a few "disturbed" follicles with characteristics of the opposite sex or both sexes (a few spermatozoa or sperm morulae in ovarian follicles). The smallest gravid female was 43.0 mm in shell length. Gravid females were encountered from late April to late July, not all gravid at the same time (percent gravidity in Fig. 5). Early embryos were whit-

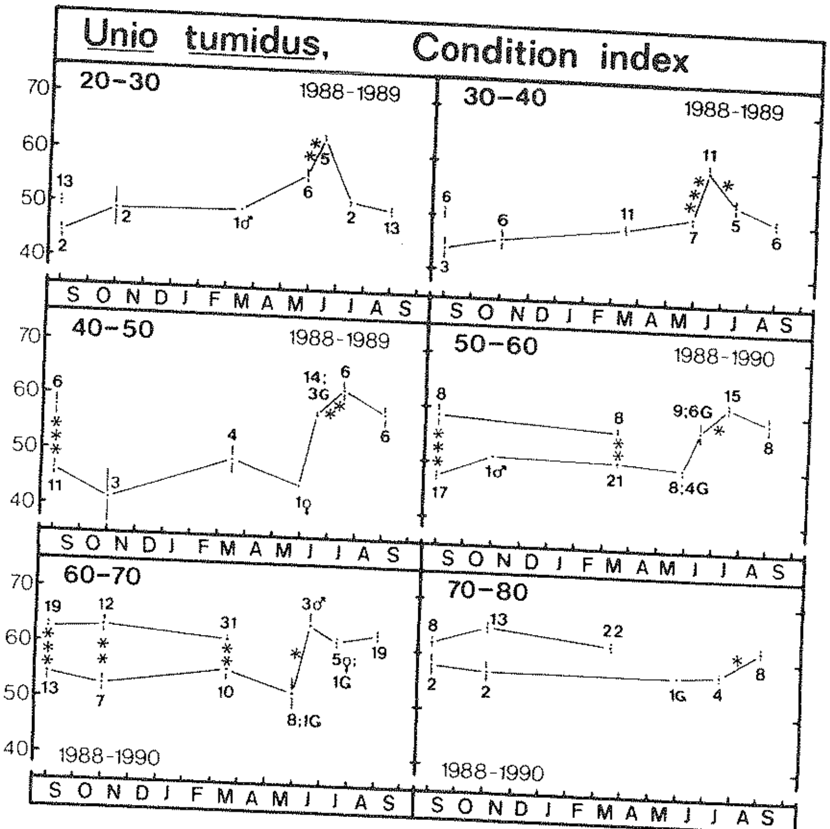

Fig. 13. Condition index of various-size *Unio tumidus* (see Fig. 10 explanation).

ish. Glochidia were first found in marsupial gills in late May (1989), and early embryos were found in one female as late as the end of July.

Unio tumidus also fattened in summer (Fig. 13). Males were significantly fatter than females in the size class 60–70 mm in October–November 1988, and the classes 60–70 mm and 70–80 mm in October–November 1989 and March 1990. In the condition index, similar interannual differences were found as in the index for *U. pictorum*.

Some females gravid in late May had in their marsupial gills degenerating embryos, fungal hyphae and ciliates. Developing mites were as common in *U. tumidus* as in *U. pictorum*. Occasional pustules were seen.

Unio crassus

Of the 12 individuals found during the study, eight were females, three males and one was a hermaphrodite. Of the eight females collected from May to September two collected in June were partially gravid with fertilized eggs or early embryos (bright orange-red or cream-coloured) in their marsupial gills. The mean condition index of six individuals (both females and males, shell lengths 29.3–70.2 mm) collected from June to September was 67.5.

Discussion

Among bivalves studied in Finland, *Mytilus edulis* occasionally shows hermaphroditism (about 3.6 %, according to PEKKARINEN, 1991 e), but hermaphrodites among *Macoma balthica* were rare (PEKKARINEN, unpublished). Among Unionidae, *Anodonta cygnea* is generally hermaphroditic (WOOD, 1974) (hermaphroditic in stagnant waters, dioecious in flowing waters, WEISENSEE, 1916), while *A. woodiana* is only rarely so (0.3 %, DUDGEON & MORTON, 1983). Large *A. anatina* in the Vantaa River were also rarely hermaphroditic (0.5 %, present study). *A. anatina* seemed to be protandric (small individuals were often males), but the number of small individuals studied was not great. The greater percentage of hermaphrodites among small *A. anatina* (5 %) (also among small *Unio pictorum* and *U. tumidus*) suggests a greater possibility of sex reversal during early life of the mussels; in small mussels gonad follicles are so scarce that only one follicle containing germ cells of the opposite sex could account for a great proportion. Among larger mussels, at least among *U. tumidus*, a few follicles showing characteristics of the opposite sex seemed to be fairly common. Such follicles may simply be disturbed, but also suggest that the mussels may have changed or will change sex. The author has found such follicles also in *Margaritifera margaritifera* (unpublished). Such mussels could be called "microhermaphrodites". Female hermaphrodites of *Pseudanodonta complanata* are capable of gravidity (present study and PEKKARINEN, 1993).

Anodonta anatina according to HAUKIOJA & HAKALA (1978 a) and the present study, and *A. woodiana* according to DUDGEON & MORTON (1983) mature quite early, while several other *Anodonta* species mature at greater ages (HEARD, 1975). As to the beginning and length of the annual gravidity period of *A. anatina,* they slightly vary geographically. In Germany, females were gravid at one site from late July to late April and at another site from August to March (MÖLLER, 1933). In Russia, fertilization in *A. anatina* has been found to be as late as September (ZHADIN, 1965). In certain rivers in southwestern Finland gravidity began in July (HAUKIOJA & HAKALA, 1978 b). In northern Finland, the gravidity of *A. anatina* in a lake lasted from early July to the third week of May (JOKELA et al., 1991). In the Vantaa River, gravid females occurred roughly from July to late April, with a variation of about half a month depending on year studied. Such time-shifting was apparent in the gravidity of *P. complanata* and the *Unio* species as well.

In *Pseudanodonta complanata* the short interval of gravidity in June is surprising. In Russia the interval is longer, lasting from July to August (ZHA-

DIN, 1965). *Anodonta* spp. which have been reported to be gravid "throughout the year", may have several reproductive cycles per year (HEARD, 1975), and the one interval or several intervals may have been overlooked. *P. complanata* in the Vantaa River has only one breeding per year and a sharp interval. Because the glochidia may grow in size (PEKKARINEN, 1991 d), they may need a long incubation period.

Fertilized eggs of *Unio* species in Massachusetts can be found from mid-June to mid-July, and glochidia are released in August or September (LILLIE, 1895). In Germany, gravidity of *Unio* may begin in March, but in cold weather not earlier than May, and all developmental stages can be found till late July (HARMS, 1909). Fertilization of *Unio* individuals thus takes place in different times. The gravidity period of *Unio pictorum* and *U. tumidus* seems to be nearly similar in the Vantaa River and in Germany (HARMS, 1909; MAASS, 1987), the UK (NEGUS, 1966) and Russia (ZHADIN, 1965), beginning in about April–May and lasting till about July–August. *U. tumidus* tended to be gravid slightly earlier than *U. pictorum* (ZHADIN, 1965; MAASS, 1987, and present study). TUDORANCEA (1969) concluded that the gestation of one individual may last about one month. From the data of NEGUS (1966), DUDGEON & MORTON (1983) inferred that in *Unio* spp. living in temperate zones, many broods per year are possible. Because the gravidity percentages of *Unio pictorum* and *U. tumidus* in the Vantaa River were fairly high in May 1991, it is possible that some females had a second brood in the summer.

In *Unio crassus* in Russia gravidity begins earlier than in *U. pictorum* and in *U. tumidus* (ZHADIN, 1965). Egg deposition and fertilization in the gills take place in late April or in the first half of May (vs. in mid- or late May in the other species). In Germany, gravid females have been found in late April or mid-May (BEDNARCZUK, 1986; MAASS, 1987). Two early gravid females were found in the Vantaa River in June.

Partially filled marsupial gills were noticed in all species. In small *A. anatina*, at least, the gills were not full even at the beginning of gravidity. As early as in 1895 LILLIE found that in *A. anatina* in Massachusetts often only the compartments of the posterior half or two thirds of the marsupial gills were used for incubation. MÖLLER (1933) also found empty compartments in anterior or posterior parts of *Anodonta* gills in Germany. Glochidia of *A. anatina* are well developed in early autumn and do not seem to grow thereafter (JOKELA et al., 1991; PEKKARINEN, 1991 d). HARMS (1909) found in Germany that glochidia of *A. anatina* were capable of infection in winter, and thought that the unfavourable weather of winter is the reason why glochidia overwinter in the marsupium. In the UK the release of *A. anatina* glochidia may begin as early as February (NEGUS, 1966), but it is not known whether they can be released even earlier. Glochidia of *A. cygnea* have been found in three-spined stickle-backs in the UK as early as in December (DARTNALL & WALKEY, 1979). HUEBNER (1980) found empty or relatively small marsupia in *A. cygnea* females collected in Canada in February and wondered whether the mussels had aborted their glochidia prematurely.

In *Unio* spp. embryos are held together by secretion from the marsupial wall (Lefevre & Curtis, 1910). The conglutinates may be aborted when the mussels are disturbed (Utterback, 1915; Maass, 1987). During the present study *Unio crassus* females were found to abort conglutinates in the laboratory.

Two colour-morphs of *U. crassus* have previously been found in Germany (Brander, 1954), and in the *U. crassus* females from the Vantaa River the gonadal/embryonal colour could be orange-red or creamy (Pekkarinen, 1991 b, d). Pigment is found in the marsupia of some unionacean species (Baker, 1928; Smith, 1979). The brown pigment found in the *Unio* marsupia in the present study may result from fungal infection. Lefevre & Curtis (1910) found in the USA that unfertilized eggs with stratified contents were especially common in *Quadrula* marsupia. Such unfertilized or otherwise abnormal eggs or embryos in the *Unio* spp. studied in the Vantaa River in cold early summer may have attracted ciliate and other infections.

The period when gravid *U. pictorum* and *U. tumidus* females were found correlated with rising and maximal water temperature. In *A. anatina* and *P. complanata* the interval coincided with rising temperature, and the next period of gravidity began while the temperature was still high. The condition indices of all species rose concomitantly with the rise of water temperature. Rapid shell growth began in small individuals in mid-June and in larger ones in late June or in July (Pekkarinen, 1991 c). Rapid soft-body growth thus slightly preceded rapid shell growth. Increase in the proportion of soft body to shell volume was clearly visible even in small individuals, in which the involvement of the gonad maturation was negligible or of a minor importance. Thus the somatic body and shell at least partially grow allometrically.

Negus had already found in 1966 that gravid female *A. anatina* were considerably heavier than others. According to the present study, at one time the situation between the sexes was reversed, namely the time before fertilization, when normal spermatogenesis in the testes of males was vigorous and the testes were full of spermatozoa (late June, according to Pekkarinen, 1991 a). *Anodonta grandis* in Canada is non-gravid in May, the time when it is heaviest, and in July, when females bear embryos, it is lightest (Huebner, 1980). In *A. grandis* the marsupium with its contents most markedly accounts for the female dry weight in October. Of the *Unio* spp. in the present study, males usually tended to be heavier than females. It is to be noted that the testes of the *Unio* spp. held plenty of spermatozoa even early in autumn. In this respect the *Unio* spp. thus resemble *Anodonta woodiana* (in Hong Kong), in which testes are mature throughout the year (Dudgeon & Morton, 1983).

There were clear interannual differences in the condition indices for *A. anatina* and the *Unio* spp. HAUKIOJA & HAKALA (1978 b) also found clear variations in the condition of *A. anatina* in different years. In the present study, male *A. anatina* mostly accounted for the average better condition from autumn to spring 1989 – 1990. Shell growth, especially in larger shells, remained less than expected in the growing season of 1989 (PEKKARINEN, 1991 c). In spring 1989, water temperature began to rise earlier than in 1988, which may have favoured soft body growth and preparation for reproduction, both of which functions slightly precede shell growth. Because shell growth remained small in that year, the condition index, calculated as "soft body percentage of shell volume", still remained high in the following autumn – spring. The energy stored in the soft body (not the shell material) can be exploited for gametogenesis of the next cycle. In *Unio* spp. (at least in males) this energy may very early be allocated for gametogenesis and therefore be lost from shell growth.

Although water mites occurring in lakes in Finland have been studied (e.g. BAGGE, 1989), knowledge of mites in mussels is scarce. In Germany, HEVERS has studied mites, including mussel mites (1980). The mites in this study were not identified to species.

The prevalences of bucephalid trematode sporocysts in *A. anatina* in southwestern Finland varied between 0 and 50 % in different populations (HAKALA, 1979). In a lake in central Finland 33 % of *A. anatina* were infected by type A sporocysts and 1 % by type B (both *Rhipidocotyle;* TASKINEN et al., 1991). The taxonomy of *Rhipidocotyle* and *Bucephalus* species is still rather confused. In the Vantaa mussels cercariae at least resembling type A were noticed. According to TASKINEN & VALTONEN (1991), the emergence of type A larvae occurred between July and September. *Rhipidocotyle fennica* has been supposed to cause the death of its molluscan host (TASKINEN & VALTONEN, 1991; HAAPARANTA & VALTONEN, 1991). In the present study the prevalence of parasitized mussels clearly decreased in late summer. The infected mussels were omitted from the condition calculations as were those of HAUKIOJA & HAKALA (1978 b). The condition of the parasitized mussels did not invariably seem to be lower than of others, as was found by HAUKIOJA & HAKALA (1978 b). The reason for the present differing result may be the method by which the condition was measured: in this study wet weight of the body was used instead of dry weight. Water content of the bivalve body varies greatly, for example seasonally (PEKKARINEN, 1983, 1991 e), and parasitized mussels sometimes are very watery. In this study the amount of water in the tissues affects the "fatness" index. It was not possible to measure the dry weight. Heavy parasite mass may also account for great mussel weight. Among the other species studied, only one *P. complanata* individual had trematode sporocysts in its tissues.

Paraergasilus rylovi sensu Chernysheva & Purasjoki, 1991, was described in *A. anatina* from a lake near Leningrad. Only one individual of *A. anatina* from the Vantaa River was found to bear these copepods in its gills.

Pustules occurring between the mantle and the shell were very common, especially in *A. anatina* and in warm periods. The disease retards or stops shell growth (Pekkarinen, 1991 c) and may be fatal. Those individuals with this disease were omitted from the condition calculation, because their condition varied greatly. Due to the discarding of many mussel individuals because of trematode sporocysts and pustules, the sizes of groups often became too small for statistical calculations to be reasonable. The etiology of the pustular disease is not known, and further studies are needed for its clarification. Otherwise the mussels of the study appeared fairly healthy.

Summary

Anodonta anatina in the Vantaa River matures fairly early; the youngest gravid females were 1+ year old (at that time usually not shorter than 50 mm). The smallest gravid female was 36.5 mm long (2 years old). The smallest gravid females of *Pseudanodonta complanata, Unio pictorum* and *U. tumidus* were 37.5 mm, 46.5 mm and 43.0 mm, respectively.

Females of *A. anatina* were gravid from July to April or May (Fig. 2). In *P. complanata* the non-gravid interval in June was very short (Fig. 3). Gravid *U. pictorum* and *U. tumidus* were encountered from April to July (Figs. 4 and 5), and two gravid females of *U. crassus* were found in June. Slight interannual differences occurred (about half a month) in the timing of the gravidity periods. Because the gravidity percentages of *Unio* spp. in 1991 were fairly high, and the larvae in the marsupia were in different developmental stages, it is possible that some females bore two broods in the summer.

The marsupial gills of gravid females were not always full; in *A. anatina*, for example, the marsupia, on average, were only half-filled in March (Fig. 6).

All species fattened in proportion to shell volume in spring and early summer when water temperature was rising (Figs. 10 – 13). This fattening partially preceded fast shell growth. Gravid females of *A. anatina* tended to be fatter than males, but during the non-gravid interval of females and the normal spermatogenesis of males, males tended to be fatter. This results from the full testes of males and the absence of glochidia in female gills. Males of *P. complanata* also seemed to be fatter before the sperm discharge. Males of *U. pictorum* and *U. tumidus* generally seemed to be fatter than females, which may result from their long non-reproductive period, during which time testes already contain many spermatozoa. Interannual differences were noticed in the condition index of mussels. Usually the males accounted for the fatter average condition in autumn – spring 1989 – 1990 as compared with autumn – spring 1988 – 1989. In *Unio* spp. energy may very early be allocated for testis growth, and that energy is lost from shell growth.

All species included occasional hermaphrodites; these were more common among small than large individuals. So-called microhermaphrodites (having one or a few disturbed follicles with signs of the opposite sex or both sexes) were common among *U. tumidus*.

Different stages of mites were frequently found in *P. complanata* and the *Unio* spp. and less frequently in *A. anatina*.

Bucephalid trematode sporocysts occurred in 3 to 17 % of *A. anatina* in different seasons (Fig. 7), with prevalence clearly decreasing in late summer. Among the other

species studied, only one *P. complanata* individual had trematode sporocysts in its tissues.

Several individuals of *Paraergasilus rylovi* were found in one *A. anatina*.

In spring and early summer fungus and ciliate infections occurred in marsupia of *Unio* spp.

Anodonta anatina (and *Unio* spp. to a smaller extent) in the Vantaa River suffers from a pustular disease. The disease occurs between the mantle and the shell and is most prevalent in the warmth of summer (Figs. 8 and 9). The disease stops or retards shell growth and may be fatal to some individuals. Otherwise the Vantaa mussels were fairly healthy.

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