Thermophilous molluscs on Svalbard during the Holocene and their paleoclimatic implications

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Five species of guide fossils from the Holocene warm period in Svalbard are considered: *Mytilus edulis*, *Modiolus modiolus*, *Arctica islandica*, *Littorina littorea* and *Zirphaea crispata*. These are now extinct in Svalbard; *Zirphaea crispata*, especially, requires considerable higher water temperatures than occur there today. Known radiocarbon dates on *Mytilus*, *Modiolus* and *Zirphata* are given. Thirty-four dates on *Mytilus edulis* show that it lived in Svalbard from before 9500 BP to about 3500 BP, and probably again around 1000 BP. Five dates on *Modiolus* and *Zirphaea* indicate a climatic optimum in Svalbard from about 8700 BP to 7700 BP. The most favourable places then had conditions similar to the northeastern coast of Finnmark, northernmost Norway, today. *Mytilus edulis* is considered a good climate indicator, and a future warming of the marine climate in Svalbard could be indicated by its eventual re-immigration into the area.

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An extensive sampling of the mollusc fauna of Svalbard (Fig. 1) took place during the second half of the last century (Feyling-Hanssen 1955 for references). Molluscs (especially *Mytilus edulis*) which are now extinct in Svalbard were found in raised beach deposits, and the term "Mytilus time" was introduced and discussed among geologists and biologists (Nathorst 1884; Högbom 1913).

Feyling-Hanssen & Jørstad (1950) and Feyling-Hanssen (1955) described the Holocene mollusc fauna of inner Isfjorden in detail and also reviewed earlier observations of mollusc species in Svalbard. Only a few additional observations have been published since then, and Feyling-Hanssen's work still provides the best general view of the Holocene mollusc fauna in Svalbard. From the abundance of species on different levels, he divided the Holocene in four climatic periods: Late-glacial cold period, Post-glacial temperate period, Post-glacial warm period and Sub-recent period. Without radiocarbon dates it was only possible to obtain tentative ages for these periods. However, some dates from these zones appeared in a later publication. (Feyling-Hanssen & Olsson 1960), Semevskij (1965) and Semevskij & Shatov (1980) have described the mollusc fauna of raised Holocene sediments in Van Mijenfjorden.

The total number of mollusc species known from Holocene deposits in Svalbard is about 100. The majority are still living along the coast and in the fjords of Spitsbergen. Nine species, however, are now extinct here (Feyling-Hanssen 1955). This points to changing sea surface temperatures during the Holocene. In an archipelago like Svalbard the temperature of the seawater has a decisive influence on the terrestrial climate. The former and present distribution variances of molluscs have been used in several paleoclimatic studies of Arctic areas (e.g. Andrews 1972; Blake 1973; Hjort & Funder 1974; Funder & Weidick 1991). The species most used in variance studies have been *Mytilus edulis* and *Chlamys islandica* which in Greenland and the Canadian Arctic had a much wider distribution during the Holocene climatic optimum than at present. Peacock (1989) has made a thorough review of marine molluscs and their potential for environmental studies, especially emphasising *Arctica islandica*. Feyling-Hanssen (1955) and Peacock (1989) are the key references for the discussion of problems dealt with in this paper.

The purpose of this paper is to present the earlier observations together with more recent ones of some indicator species in the raised beach deposits of Svalbard. The main new contribution

Fig. 1. Location map, Svalbard. The numbers show the approximate location of radiocarbon dated samples listed in Table 1.

Table 1. Radiocarbon dates on *Mytilus edulis*, *Modiolus modiolus* and *Zirphaea crispata* from Svalbard. The ages are quoted as first published or as reported from the laboratory. They are corrected to a $\delta^{13}C = -25‰$ PDB, either using standard values or measured values for $\delta^{13}C$. To correct for the reservoir effect, the apparent age for seawater in Svalbard has been subtracted. The actual dating laboratories and authors have used slightly different standard values for $\delta^{13}C$ as well as for the apparent age of seawater. This causes, however, only small differences which are of no significance for the conclusions in this paper. U 126 and U 173 have not been reservoir corrected, but when placed in Fig. 2, 440 years have been subtracted. (Note that in 1967 *The American Journal of Science* issued *Radiocarbon Measurements: Comprehensive Index, 1950–1965* with corrections for change of Uppsala standard). Information about corrections of the datings of Samtleben (1985) is lacking.

Field no.	Lab no.	Location (Fig. 1)	M a.s.l.	^{14}C age	Species	Reference
Zo-3 NIEB	Gd-1255	Kaffiøyra (22)	6	9630 ± 130	*Mytilus* (aragonite)	Goslar & Pazdur 1985
ZO-3 PERL	Gd-1257	Kaffiøyra (22)	6	9410 ± 110	*Mytilus* (calsite)	Goslar & Pazdur 1985
(ZO-2 MYT	Gd-1258	Kaffiøyra (22)	6.5	9540 ± 110	*Mytilus*	Goslar & Pazdur 1985)
Sa85-28	T-6590	Sarsøyra (23)	0	9480 ± 100	*Mytilus*	Unpublished
SL84-33	DIC-3076	Reinsdyrflya (25)	9	9375 ± 80	*Mytilus*	Forman 1990b
Sa78-17	T-3098	Gråhuken (26)	8	9360 ± 110	*Mytilus*	Salvigsen & Österholm 1982
Sa81-47	T-5029	Dicksonfjorden (15)	30	9220 ± 120	*Mytilus*	Lauritzen et al. 1989
3KAFTC	GX-10038	Kaffiøyra (22)	7.5	9195 ± 270	*Mytilus*	Forman 1990a
Sa85-79	T-6591	Blomstrandhalvøya (24)	4	9180 ± 100	*Mytilus*	Unpublished
B-47	U 173	Langgrunnodden (27)	9	9070 ± 190	*Mytilus*	Blake 1961
LAN 83-108	T-5662	Kleivdalsbekken (5)	13	9030 ± 100	*Mytilus*	Landvik et al. 1987
Sa84-36	T-6285	Erdmannflya (17)	16	8970 ± 110	*Mytilus*	Salvigsen et al. 1990
F84-329	DIC-3054	Pricepynten (21)	3	8955 ± 90	*Mytilus*	Forman 1990a
S 1988-733	T-8385	Kapp Ekholm (11)	30	8930 ± 70	*Mytilus*	Mangerud & Svendsen unpubl.
Sa81 -80	T-4411	Dicksonfjorden (14)	7	8820 ± 120	*Modiolus*	Unpublished
		De Geerdalen (6)	26	8730 ± 170	*Mytilus*	Samtleben 1985
Sa84-31	T-6535	Erdmannflya (17)	6	8670 ± 90	*Modiolus*	Salvigsen et al. 1990
Sa87-40	T-7666	Dørdalsbekken (1)	2.3	8620 ± 120	*Mytilus*	Unpublished
S 1988-323	T-8333	Kapp Ekholm (10)	25	8610 ± 120	*Zirphaea*	Mangerud & Svendsen unpubl.
Sa82-04	T-4944	Reindalen (3)	17	8550 ± 60	*Mytilus*	Unpublished
3SVATH	DIC-2908	Svartfjellstranda (19)	13	8525 ± 75	*Mytilus*	Forman 1986
KW1	Beta-11291	Kapp Wijk (13)	1	8415 ± 110	*Mytilus**	Forman 1990b
F84-410	DIC-3056	St. Jonsfjorden (20)	3.5	8265 ± 80	*Modiolus**	Forman 1989
Sa84-34	T-6284	Erdmannflya (17)	5	8210 ± 90	*Mytilus*	Salvigsen et al. 1990
Sa82-68	T-5214	Kapp Morton (4)	10	8060 ± 110	*Mytilus*	Salvigsen et al. 1990
H-E 209-83	T-5367	Bromelldalen (2)	16	7870 ± 110	*Mytilus*	Elgersma & Helliksen 1986
Sa81-48	T-6534	Dicksonfjorden (15)	5	7850 ± 130	*Modiolus*	Unpublished
B2	Lu-2137	Bohemanflya (16)	10	7690 ± 80	*Mytilus*	Salvigsen et al. 1990
Sa84-29	T-6283	Erdmannflya (17)	8	7680 ± 90	*Mytilus*	Salvigsen et al. 1990
No 350 b	U-130	Ekholmvika (10)	17	7595 ± 110	*Mytilus*	Feyling-Hanssen & Olsson 1960
A2	Gd-1898	Ebbadalen (11)	15	7440 ± 60	*Mytilus*	Klysz et al. 1988
Sa81-45	T-7015	Dicksonfjorden (14)	2	7070 ± 90	*Mytilus*	Unpublished
Sa81-20	T-4628	Gåsodden (8)	18	6440 ± 80	*Mytilus*	Salvigsen 1984
3DAU4	GX-10037	Eidembukta (18)	4	6055 ± 200	*Mytilus*	Forman 1990a
B	Gd-2394	Ebbadalen (11)	5	4780 ± 90	*Mytilus*	Klysz et al. 1988
Sa81-78	T-5030	Dicksonfjorden (14)	4	4690 ± 100	*Mytilus*	Unpublished
S1988-643	T-8334	Kapp Murdoch (7)	7	4200 ± 40	*Mytilus*	Mangerud & Svendsen unpubl.
No 343 b	U 126	Mytilusbekken (9)	6	3810 ± 90	*Mytilus*	Feyling-Hanssen & Olsson 1960
		Nordfjorden (12)	3	940 ± 75	*Mytilus*	Samtleben 1985

*Dating performed on another species in the same bed.

is, however, the presentation of radiocarbon dates (Table 1) which makes it possible to obtain an absolute age for the Holocene marine climatic optimum in Svalbard.

Physical setting

A simplified picture of the present surface currents in the Barents Sea area is shown in Fig. 2.

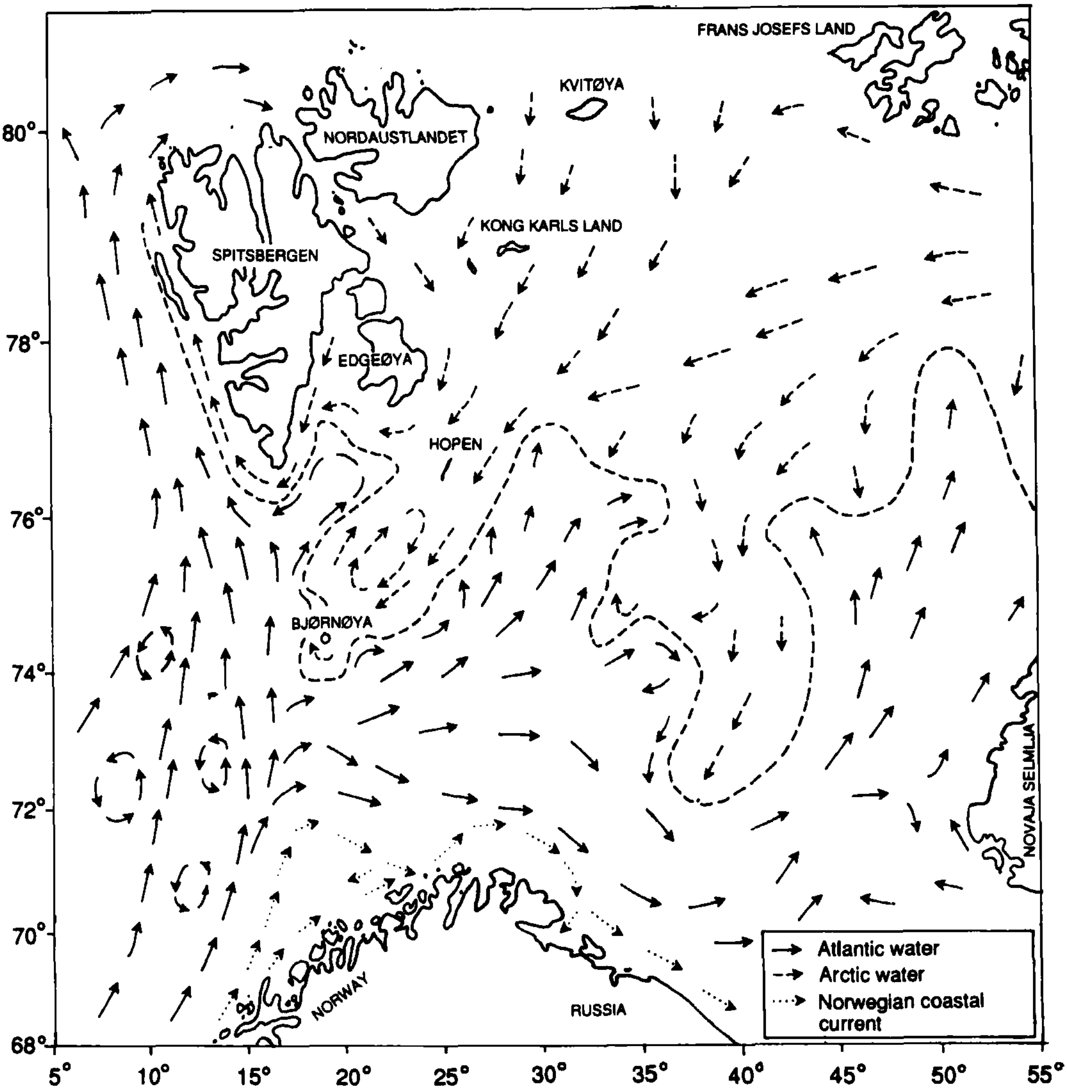

Fig. 2. Surface currents in the Barents Sea, modified from Loeng 1985.

Surface temperatures in this region are controlled mainly by the varying inflow of Arctic and Atlantic Water. This is illustrated by an example in Fig. 3 which shows the maximum sea surface temperatures during the summer of 1991.

More representative measurements show that at the northernmost mainland of Norway the summer surface temperature (SST) of Atlantic Water is about 10°C, and off western Svalbard it is 5°C or less (Gammelsrød & Rudels 1981). The SST of the inner fjords may be higher because of the atmospheric heating in sheltered areas and the small inflow of cold water, but measurements are lacking. The limited knowledge of the sea surface temperatures during the summers makes it therefore difficult to discuss present and former living conditions for the molluscs in detail.

The overall sea ice conditions are given by Vinje (1985), but statistics for the duration of sea ice cover in the inner fjords are not available.

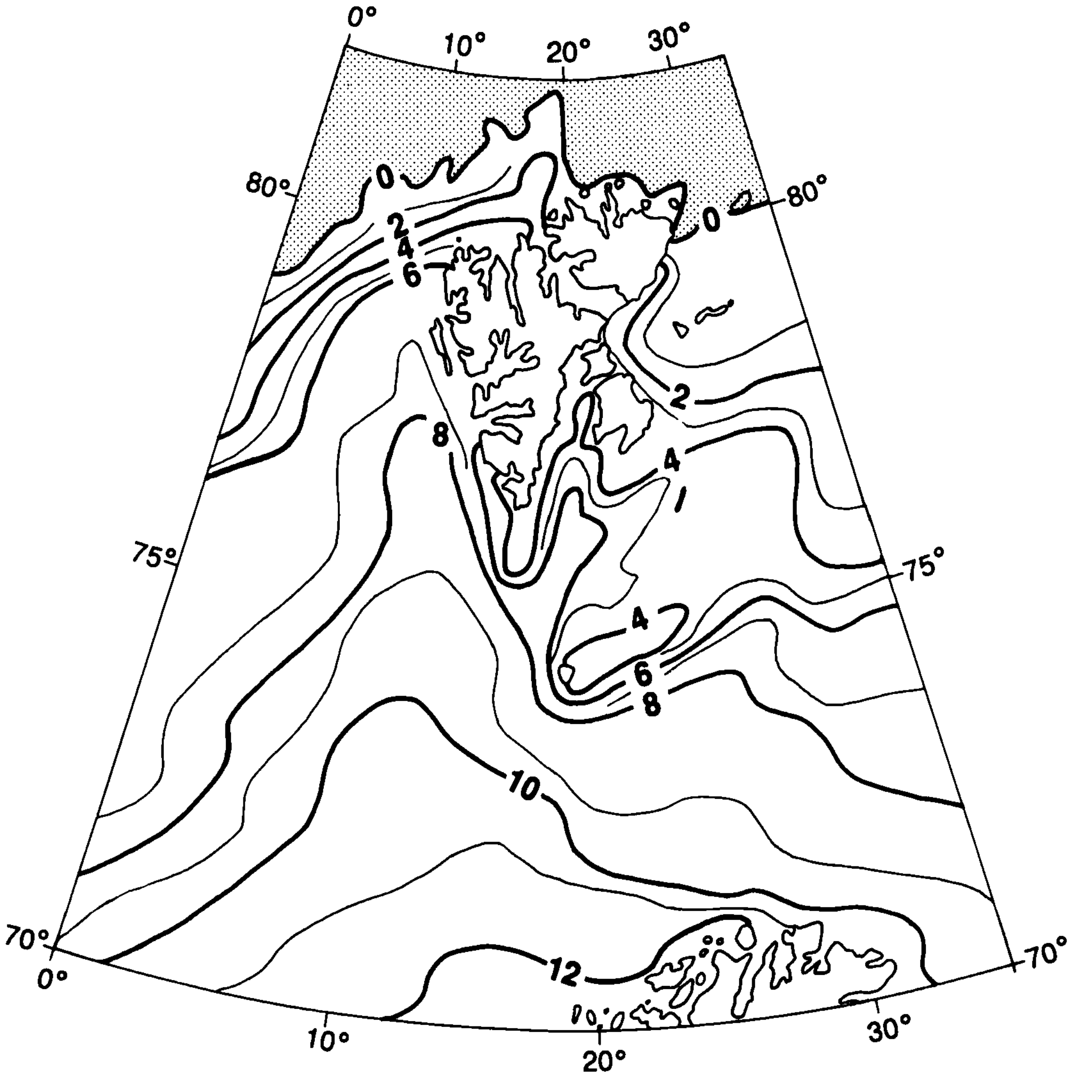

Fig. 3. Map with sea surface temperatures modified from *Iskart nr. 33/91* published by the Norwegian Meteorological Institute. Ice-covered area (shaded) and temperature isolines are based on observations from ships and satellite measurements in the period August 15–19, 1991. This period showed the highest sea surface temperatures around Svalbard that year.

Holocene distribution of thermophilous molluscs in Svalbard

Five species of conspicuous guide fossils indicating deposits from the Holocene warm period in Svalbard will be considered: *Mytilus edulis*, *Arctica islandica*, *Littorina littorea*, *Modiolus modiolus* and *Zirphaea crispata*. These species are indicator species and can be correlated with open water summer surface temperatures (Peacock 1989). Apart from Mytilus they require considerable higher water temperatures than occur around Spitsbergen today. An indication of the size of the temperature demands may be afforded by Peacock's (1989) comparison of modern distributions along the Norwegian coasts with sea surface temperatures. From this it appears that *Zirphaea crispata* is distributed in areas with summer surface temperatures above 8°C, while *Arctica islandica* and *Modiolus modiolus* occur in areas with temperatures higher than 6°C in the Barents Sea (see also Funder & Weidick 1991).

Chlamys islandica is usually regarded as a subarctic species, but it has recently been recorded alive from waters around the entire Svalbard archipelago (Bjørn Gulliksen pers. comm. 1986). It occurs in raised beach deposits on Sjuøyane in the far north (Fig. 1), as well as on Kong Karls Land (Salvigsen observations 1978–1980). The wide distribution of *Chlamys islandica* in Svalbard demonstrates that this archipelago had and still has warmer SST than areas at the same latitude in Greenland and Arctic Canada (Funder & Weidic 1991). In contrast to what is the case in Svalbard, *Chlamys islandica* in East Greenland had a much wider distribution during the Holocene climatic optimum than at present (Hjort & Funder 1974).

Mytilus edulis is now extinct in Svalbard waters but was widely distributed during the early Holocene. Its shells have been found on the west coast from Nottinghambukta north of Hornsund (Dmoch 1977) to Blomstrandhalvøya in Kongsfjorden. *Mytilus edulis* is abundant throughout the Isfjorden area, but not found in the inner parts of Van Mijenfjorden. In the northwestern corner of the archipelago there has been no positive shoreline displacement after 9500 BP and *Mytilus* can thus only be expected in submarine deposits along the shore. On the northern coast it has been recorded from Raudfjorden in the west to Langgrunnodden on Nordaustlandet (Blake 1962). It has also lived in the Hinlopenstretet area. On the eastern coast it has been reported from southwestern Edgeøya and from Svenskøya, Kong Karls Land. On Edgeøya it was only found at low levels in the southwestern part of the island (Knipowitsch 1903), and not in situ, hence age estimates are not possible. During the 1991 fieldwork of the European Science Foundation project, "Polar North Atlantic Margins, Late Ceneozoic Evolution" (PONAM) in eastern Svalbard, several observations of *Mytilus* were recorded from Edgeøya, but it was not observed on Barentsøya (different reports in Landvik 1991). Two small fragments from Svenskøya have been reported from 25 m a. s. l. (Hägg 1950). In 1979 Salvigsen visited the same locality but was unable to find any traces of *Mytilus*, nor was it found in other raised beach deposits in Kong Karls Land. Its occurrence in these islands seems therefore to have been very limited. *Mytilus edulis* has been found in raised sediments as far east and north as in Frans Josef Land (Nansen 1902) and should therefore be expected to have occurred throughout Svalbard. However, in Nordaustlandet *Mytilus edulis* has only been reported from the western area, but it should be kept in mind that the northern coast of Nordaustlandet has very few reports on shell faunas. Elsewhere, the summer surface temperature of the water has probably been too low for *Mytilus* during the Holocene. Salvigsen looked for *Mytilus* shells without success on Sjuøyane in 1978 and 1980.

Arctica islandica, *Littorina littorea*, *Modiolus modiolus* and *Zirphaea crispata* require higher temperatures than *Mytilus edulis*, especially *Zirphaea crispata* (Peacock 1989). However, all three species, are well known from Holocene sediments in the inner Isfjorden area. *Arctica islandica* has also been reported from Prins Karls Forland and Lomfjorden. Its occurrence in Lomfjorden, by Hinlopenstretet, is most remarkable and may indicate a former wider distribution than indicated by the reports. *Littorina littorea* seems to have had a similar distribution as *Arctica islandica*. It is found at many places in Isfjorden, and in the Woodfjorden area on the north coast. In addition to finds referred to by Feyling-Hanssen (1955), a single find from southern Spitsbergen, north of Hornsund, has been made by Dmoch (1977). It occurs in *Mytilus* beds on Erdmannflya in Isfjorden (Salvigsen et al. 1990). *Littorina littorea* probably had a wider distribution than hitherto reported, because it is not so conspicuous and easy to recognise in the field as the larger valves, e.g. those of *Arctica islandica* and *Mytilus edulis*. *Modiolus modiolus* had until recently only been reported from Holocene sediments in inner Isfjorden, but in 1984 it was found on Erdmannflya in outer Isfjorden, where a few fragments occurred among *Mytilus edulis* shells (Salvigsen et al. 1990). It has also been reported from sublittortal sediments at the head of St. Jonsfjorden (Forman 1986). *Zirphaea crispata* has only been reported from inner Isfjorden and seems to have had the most limited distribution in Svalbard of the here mentioned indicator species.

Dating of the thermophilous molluscs

Known dates on thermophilous molluscs from Svalbard are listed in Table 1: thirty-four dates on *Mytilus*, four dates on *Modiolus* and one on *Zirphaea*. The original purpose for most of the dating has been either dating of old, mostly isostatically elevated shorelines, or the dating of sediments. The highest lying and oldest shells have therefore often been chosen for dating. Along much of the western coast of Spitsbergen it has been possible to date only the oldest *Mytilus* shells because younger shorelines are below present sea level (Forman 1990a). But nevertheless, when seen together these dates give a great deal of information about the former occurrence of thermophilous molluscs in Svalbard, even if they are not statistically representative for the climatic optimum.

The dating results (Table 1) indicate that *Mytilus edulis* was well established in Svalbard waters before 9500 BP. The distribution of ages (Fig. 4) indicates its presence in Svalbard until at least about 3500 BP, even though no datings from between 6500 BP (T-4628) and 4700 BP (T-5030) have been obtained. Observations in the field, however, indicate that *Mytilus edulis* lived in Svalbard also during this period. Feyling-Hanssen (1955) shows that *Mytilus* occurs in all terraces in the "Post-glacial temperate Period" and the "Post-glacial warm period" in Billefjorden, but it is lacking in the terraces of the "Late-glacial cold period" and the "Sub-recent period". The most likely conclusion seems therefore to be that the climate was tolerable for *Mytilus edulis* during a continuous period of about 6000 years. Dates from the "empty" period could probably be obtained by a systematic dating of *Mytilus* shells from inner Isfjorden. The *Mytilus* terrace of Feyling-Hanssen (1955) seems also to be 5000 years or younger, and optimal conditions for *Mytilus edulis* seem to have occurred between 5000 and 4000 BP in inner Isfjorden.

A surprising dating of *Mytilus* from Spitsbergen was presented by C. Samtleben (1985 and pers. com.) who studied microstructures of *Mytilus* shells from Svalbard and other areas. Shells on the present beach of Nordfjorden in inner Isfjorden were radiocarbon dated to 940 ± 75 years. This is the first and only *Mytilus* date from Svalbard younger than 3500 BP, and it indicates that *Mytilus* lived in Svalbard about 1000 years ago during what is called the Little Climatic Optimum. A confirmation of this single date would be desirable, but probably difficult to obtain. The isostatic uplift during the last 1000 years has been insignificant, and many shells on the present shore have been washed out from older sediments, e.g.

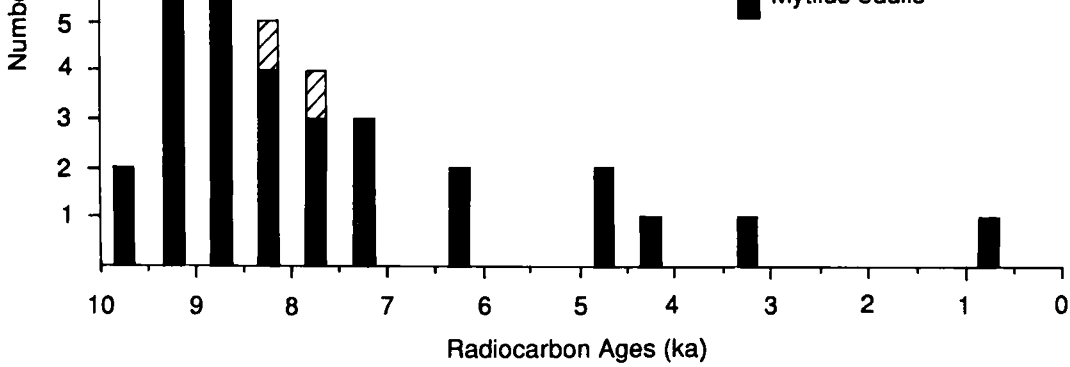

Fig. 4. Frequency distribution of radiocarbon dated thermophilous molluscs from Svalbard.

7000 year-old shells from the surface of the modern beach ridge in Dicksonfjorden, inner Isfjorden (T-7015).

Arctica islandica from Svalbard has not been radiocarbon dated, but the altitudes where it is found give some indications about minimum ages for its first occurrence. In Billefjorden it has been found at altitudes which indicate an immigration well before 8000 BP (Feyling-Hanssen 1955; Salvigsen 1984). Its highest reported level in Lomfjorden, 21 m (Kulling & Ahlmann 1936), indicates that it lived there before 7500 BP. Besides *Mytilus, Arctica islandica* is the most abundant of the indicator species in Dicksonfjorden.

Nor has *Littorina littorea* from Svalbard been radiocarbon dated, but it is found on levels from 31 m to 2 m in inner Isfjorden (Feyling-Hanssen 1955). This indicates a longlasting presence starting before 8000 BP.

Dicksonfjorden probably had the most numerous occurrences in Svalbard of *Modiolus modiolus*. It was found in situ in sublittoral sediments in a section at Kapp Nathorst. The *Modiolus* bearing layer was only about 1 m thick, indicating a relatively short presence. One valve with a weight of more than 50 g yielded the radiocarbon age 8820 ± 120 years BP (T-4411). A large fragment from another deposit in the inner part of the fjord, at Raudkollen, had the age 7850 ± 90 years BP (T-6534). It was found in a stream cut through a marine terrace, and no in situ shells were observed there. A radiocarbon date on one fragment of *Modiolus modiolus* from Erdmannflya in outer Isfjorden gave the age 8670 ± 130 years BP (T-6535). These three *Modiolus* dates, combined with field observations, indicate that it lived in Isfjorden for more than 1000 years. Forman (1986, 1989) dated paired *Mya truncata* shells from sublittoral sands in St. Jonsfjorden which among other species included *Modiolus modiolus*, *Mytilus edulis* and *Littorina littorea*. The age 8265 ± 80 (DIC-3056) indicates that the SST in the inner part of that fjord was considerably warmer before 8000 BP than today.

The only known date of the Low Arctic species *Zirphaea crispata* from Svalbard is on shells from Kapp Ekholm in Billefjorden. The age was 8610 ± 120 years BP (T-8333) (Mangerud & Svendsen unpubl.).

The dates on *Modiolus* and *Zirphaea* lead to the conclusion that Svalbard had an early Holocene marine climatic optimum with a culmination between 9000 and 7500 BP. Most of the dates are close to 8600 BP, the most probable time for the maximum SST.

Potential for the detection of climatic changes

Changes of the marine climate in Svalbard can be deduced from the composition of the past marine macro fauna. Radiocarbon dating of new appearances and extinctions of indicator species provides a chronology of climatic changes during the Holocene. The molluscs dealt with here are expected to respond quickly to SST changes. They can spread to new areas as their larvae are carried by currents. Small, fresh species of *Mytilus edulis* have also been found on seaweed at Spitsbergen (Heintz 1926; Feyling-Hanssen 1955) where they probably have drifted from southern areas. The spread and the settlement of the planktonic larvae could have been assisted by northward fluctuations of the warm Atlantic Water. Adult molluscs with their greater tolerance could then survive intervals with colder marine climate, and successful spawnings could take place in the most favourable summers (Peacock 1989).

The climatic changes can also be seen in Holocene deposits with micro- and macrofossils of plants (Hyvärinen 1970; Göttlich & Hornburg 1982; Serebarannyy et al. 1984; Birks 1991), but for the development of the flora there will always be a time lag compared with the actual climatic changes.

The exact limiting temperatures for the indicator species are not known, and it is therefore difficult to quantify temperatures for Svalbard during the Holocene. Feyling-Hanssen (1955, p. 33) discussed paleoclimatic evidence of the fossil fauna. He concluded that during the "Post-glacial warm period" the climate was "no worse than that of the low-arctic subregion of to-day, any way, no better than that of the high-boreal". He also suggested that the climatic conditions were more favourable in the beginning of this period than later in the same period. The abundance of *Mytilus edulis* on low levels in Isfjorden indicates the latest slight improvement of the climate before the final decline of the warm period. Samtleben (1985) observed microstructures in *Mytilus* shells from inner Isfjorden resembling those in living mussels from northeastern Norway, indicating similar climatic conditions. The microstructure of the shells shows strong seasonality with apparently short but favourable summer periods and relatively long winter periods. Samtleben also constructed a temperature curve from $\delta^{18}O$ values of *Mytilus* shells from Isfjorden (suggesting the same salinity as that of present time summer waters in the fjord); the curve indicated summer surface temperatures up to 10°C.

The mollusc faunas show that the marine climate in Svalbard during most of the Holocene was warmer than that of today. During the climatic optimum, in the most favourable places in Spitsbergen, it was probably similar to the present climate on the eastern coast of Finnmark, northernmost Norway. Our conclusions regarding the rise in SST during the Holocene are that *Mytilus edulis* suggests a rise of about 1°C in SST and *Zirphaea crispata* at least a 3°C rise in SST. This is in agreement with the conclusions of Funder & Weidick (1991) for Greenland during the Holocene. Funder & Weidick also emphasise that the immigration of boreal molluscs to Greenland was determined by oceanic rather than climatic change. Birks (1991), in her studies of the vegetational history of west Spitsbergen, indicates a mean July temperature for the early Holocene about 2°C higher than today.

It is obvious that the molluscs will play an important role in further studies of the mid Holocene climatic optimum in Svalbard and other Arctic areas. More remarkable, however, is the fact that the Little Climatic Optimum about 1000 years ago also seems to have had favourable conditions for *Mytilus edulis* in inner Isfjorden.

Molluscs in Svalbard reflect warmer SST, and the mollusc fauna of western Svalbard may be instrumental in detecting a possible larger supply of warm Atlantic Water to Svalbard. Molluscs respond mostly to increasing summer temperatures. They therefore can only supply limited information about the rest of the year and the mean annual temperature.

This leads to the conclusion that if a future climatic optimum develops in the Arctic, it may be detected in the mollusc fauna of western Svalbard if its character is analogous to the Holocene climatic optimum. Most greenhouse climate models show an asymmetric warming in the winter with modest or no changes during the summer (Mitchell et al. 1990). The Holocene climatic optimum thus seems at our present state of knowledge to be a bad analog for greenhouse warming in the Arctic.

Conclusions

During the Holocene, Isfjorden had the largest occurrence in Svalbard of molluscs which can be correlated with higher open water summer temperatures, indicating that this area had and still has the warmest marine climate in the archipelago.

Mytilus edulis lived in Svalbard from at least 9500 to 3500 BP and probably again around 1000 BP.

The species which require the highest temperatures, *Zirphaea crispata* and *Modiolus modiolus*, indicate optimal conditions around 8700 to 7800 BP.

The distribution of thermophilous molluscs during the Holocene climatic optimum is related to the present pattern of summer surface temperatures, although temperatures then were 1–3°C higher.

Molluscs may immigrate to Svalbard via the warm West Spitsbergen Current and are therefore able to respond quickly to climatic changes. If a global warming results in higher summer surface temperatures, *Mytilus edulis* may soon live again along the shores of Svalbard. It is considered as a reliable climate indicator and is thus useful for detection of a possible warming of the marine climate in the Arctic.

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