Validation of chironomid-inferred temperature reconstructions in Iceland: the potential for reconstructing quantitative changes in Holocene climate

Autor(en): Holmes, Naomi
Objekttyp: Article
Zeitschrift: Geographica Helvetica: schweizerische Zeitschrift für Geographie = Swiss journal of geography = revue suisse de géographie = rivista svizzera di geografia
Band (Jahr): 63 (2008)
Heft 1: Physical geography and environmental change = Physiogeographie und Umweltwandel = Géographie physique et changement environnemental

PDF erstellt am: 08.09.2020
Persistenter Link: http://doi.org/10.5169/seals-98926

Nutzungsbedingungen

Haftungsausschluss
Alle Angaben erfolgen ohne Gewähr für Vollständigkeit oder Richtigkeit. Es wird keine Haftung übernommen für Schäden durch die Verwendung von Informationen aus diesem Online-Angebot oder durch das Fehlen von Informationen. Dies gilt auch für Inhalte Dritter, die über dieses Angebot zugänglich sind.
Validation of chironomid-inferred temperature reconstructions in Iceland: the potential for reconstructing quantitative changes in Holocene climate

Naomi Holmes, Exeter

1 Introduction

Concern over the extent to which anthropogenic activity has forced recent changes in climate and could contribute to future climatic change has been the focus of many recent studies (INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, IPCC, 2001, 2007). To try to evaluate this it is essential to understand past natural climatic variability. Instrumental meteorological records are only available for c.150 years so it is necessary to obtain proxy climate data for periods prior to this in order to validate climate models that predict climatic changes. The study of biological proxy data also has the potential to provide information on the possible ecological effects any future climatic changes may have on lake ecosystems and their biota (e.g. QUINLAN et al. 2005).

Chironomids (Insecta; Diptera; Chironomidae) are a biological proxy frequently used in palaeoenvironmental and palaeoecological studies. The chitinous head capsules (see Figure 1) of chironomid larvae preserve in lake sediments and can be isolated from the sediment and analysed to provide information about past environmental conditions within the lake and local environment (PORINCHU & MACDONALD 2003). The potential of subfossil chironomids to reconstruct past changes in temperature has been demonstrated by a number of Lateglacial studies undertaken in the northern hemisphere (e.g. BEDFORD et al. 2004; BROOKS & BIRKS 2000a, b; PORINCHU et al. 2003). Recently, chironomid studies have been used to reconstruct Holocene palaeoclimatic changes (e.g. KUREK et al. 2004; LANGDON et al. 2004; VELLE et al. 2005a); however, the magnitude of temperature change in the Holocene is much smaller than over the last Glacial – Interglacial Transition, and much debate surrounds the use of subfossil chironomids to produce reliable temperature reconstructions for this period (e.g. LAROCQUE & HALL 2003; VELLE et al. 2005b). CASELDINE et al. (2003) produced the first quantitative palaeolimnological study from Iceland, using the Norwegian chironomid-mean July air temperature transfer function (BROOKS & BIRKS 2001; unpub.) showing the potential of subfossil chironomids present in Icelandic lakes as a climate proxy. The recent development of a chironomid-inferred mean July air temperature calibration model for Iceland (CASELDINE et al. 2006; LANGDON et al.) provided the opportunity to try to evaluate and validate the technique within Iceland.

2 Methods

2.1 Site selection and fieldwork

Cores were obtained from two lakes situated in western Iceland, Baulárvallavatn and Saurarvatn, near to the meteorological station at Stykkisholmur which has the longest instrumental temperature record for Iceland (Figure 2). Baulárvallavatn is a relatively deep lake (Zmax 46 m) situated at 193 m above sea level, while Saurarvatn has a maximum depth of 14.3 m and is located close to sea level. The study sites were initially selected and sampled during the development of the Icelandic chironomid training set (LANGDON et al.). Detailed bathymetries were produced and short cores obtained from each lake (Figure 3). Cores were taken using a Renberg corer (RENBERG 1991) and subsampled in the field. At Baulárvallavatn the cores were taken from a relatively flat bottomed part of the lake at c.20 m depth as the lake bottom shelved quite steeply in deeper areas. Other data from Baulárvalvatn suggest that the depth of sampling location does not influence the chironomid data obtained (HOLMES 2006). At Saurarvatn, the core was obtained from the largest of the three basins in the lake. Information about the physical characteristics of the lakes is detailed in Table 1.

2.2 Laboratory methods

Sedimentological and dating analyses. A subsample from each sample was analysed for CN (total %C, total %N and CN) using a Carlo Erba Elemental Analyser model NA2500. Particulate size was analysed using a Saturn DigiSizer, and magnetic susceptibility measured using a Bartington MS2 Susceptibility system. Radiocarbon analyses were carried out at the University of Exeter and National Oceanography Centre, Southampton. Samples were analysed for 206Pb, 207Pb (Southampton), 226Ra (Exeter), and 14C by gamma spectrometry in order to derive chronological information about the lake sediments (APPLEBY 2001).

Chironomid analysis. Samples were prepared for chironomid analysis using standard techniques with ultrasound treatment used to clean the head capsules in order to aid identification (LANG et al. 2003; WALKER 2001). Chironomids were identified using OLIVER & ROUSSEL (1983), WIEDERHOLM (1983), RIERADWALL & BROOKS (2001), and BROOKS’ Tanytarsini identification key (unpub.) and taxonomy has been updated following BROOKS et al. (2007). Chironomid diagrams were produced using TGVView 2.0.2 (GRIMM 2004). Chirono-
mid assemblage data were analysed using CANOCO (TER BRAAK & SMILAUER 2002). Chironomid-inferred temperatures (C-ITs) were produced by applying the chironomid-inferred mean July air temperature transfer function for Iceland (r² = 0.66, RMSEP = 1.10 °C; LANGDON et al.) to each sample using C2 (JUGGINS 2003).

3 Results

3.1 Core chronologies

137Cs and 209Pb provided chronologies for the cores from Baulárvallavatn and Saurarvatn. The core from Baulárvallavatn covers a period of about 130 years (back to c.1870 AD). A peak in 137Cs at 9.25 cm represents the 1963/64 fallout maximum, while the 209Pb data suggest sedimentation rates of 1.25 mm year⁻¹ (4-10 years cm⁻¹), with higher sedimentation rates at the top of the core, perhaps due to a relative lack of compaction at the top of the core. There is close agreement between the 137Cs and 209Pb ages which suggests the 209Pb chronology is accurate. The core from Saurarvatn is thought to represent the period c.1950-2003 with a clearly defined 137Cs peak representing the 1963/64 weapon’s fallout maximum at a depth of 20.5 cm. The 209Pb data suggest a linear sedimentation rate of 0.2 mm year⁻¹ (5 years cm⁻²) between 14-23 cm and that the upper 14 cm covers the period 1995-2003, with a very high average accumulation rate of 1.75 cm year⁻¹, probably due to increased inputs of sediment from the lake catchment.

3.2 Sedimentological analyses

Values of both %C and %N (Figure 4a) are relatively low in Baulárvallavatn, reflecting the low productivity of the lake, and allochthonous origin of most of the sediment within the lake. Increases in both elements in the upper sediments are thought to be due to the greater proportion of undecomposed organic matter found here, but possibly reflect nutrient increases within the lake/catchment. The levels of %N and %C (Figure 4b) are higher in Saurarvatn reflecting its slightly more productive nature. %N shows an increasing trend up the core, while %C values remain fairly constant. Variability in both elements near the top of the core is thought to reflect inflow from the catchment which is responsible for the higher sedimentation rates in this part of the core.

3.3 Chironomid assemblages

At Baulárvallavatn the chironomid stratigraphy (Figure 4a) is dominated by Heterotrissocladius grimshawi-type, a cold stenotherm indicative of oligotrophic lakes, with values of between 40-67%. A number of rheophilic taxa, such as Eukiefferiella spp. and Diamesinae, are present, which along with the Simuliidae suggest some riverine influence on the lake. At Saurarvatn Psectrocladius sordidellus-type, Chironomus anthracinus-type, and Heterotrissocladius grimshawi-type are the most common taxa present throughout the core (Figure 4b). Taxa, such as Chironomus anthracinus-type, Cricotopus sylvestris-type and Orthocladius oliveri-type, which are thought to live in more productive ecosystems where macro-

Fig. 1: Two subfossil chironomid head capsules: Hydrobaenus (left), Orthocladius type I (right)
Zwei subfossile Chironomid-Kopfkapseln: Hydrobaenus (links), Orthocladius Typ I (rechts)
Deux capsules céphaliques subfossiles de chironomides: Hydrobaenus (gauche), Orthocladius type I (droite)
Photos: N. Holmes
phytes are present, occur throughout the core, as do *Chara* oospores. Macrophytes were observed in Saurarvatn during fieldwork.

3.4 Chironomid-inferred temperatures

*Baulárvallavatn.* The chironomid-inferred temperature (C-IT) reconstruction from Baulárvallavatn shows little variation through the core, with low temperature variability (0.78 °C). No changes in temperature are greater than the sample specific prediction errors (SSPEs) and so are not significant statistically. The overall pattern is a slight warming trend. The C-IT reconstruction is compared to the instrumental meteorological temperature record from Stykkishólmur (Figure 5a). The Stykkishólmur temperature data have been adjusted to the altitude of Baulárvallavatn (c.200 m) by applying a lapse rate of 0.65 °C 100 m. Both records show a cooling from 1900-c.1920 followed by a temperature increase between 1925-1940 and then decreasing temperatures until c.1960. A warming trend from the mid-1980s to mid-1990s is also evident in both records. The C-IT reconstruction consistently underpredicts the temperatures, although for every sample the meteorological temperature values fall within the SSPEs.

*Saurarvatn.* The range of reconstructed temperatures is 1.1 °C, smaller than the mean SSPE of 1.12 °C, and as a result, none of the temperature changes are significant statistically. However, when the C-IT reconstruction is plotted alongside the temperature data from Stykkishólmur (Figure 5b) it can be seen that there are many similarities between the two records. Again the C-ITs consistently underpredict the meteorological data, although the predicted values (including SSPEs), in most cases, overlap with the meteorological data values. Both records show cooling during the 1950s-1970s followed by a period of warming in the early-1980s. A temperature decrease from the late-1980s to the early-1990s is also evident in both records, and the late-1990s to early 2000s warming trend seen in the chironomid data matches very well with the instrumental data in terms of pattern and magnitude of changes.

4 Discussion

The comparison of the C-IT reconstructions with the Stykkishólmur meteorological data suggests that the subfossil chironomids from Iceland do respond to, and are able to successfully reconstruct the relatively small magnitude variations in temperature that have occurred during the recent period, despite the observed temperature changes in the meteorological record being close to the error limits of the chironomid-mean July air temperature calibration model. However, at present, the reconstructions produced for the two sites studied here are underpredicting actual values, although at Baulárvallavatn all the reconstructed temperatures and their SSPEs are deemed similar to the running mean of the meteorological data.

4.1 Factors influencing the midges

Since early work on quantitative C-IT reconstructions the question of whether midges are really responding to climate, either directly or indirectly, has been raised (Hann et al. 1992; Larocque & Hall 2003; Velle et al. 2005a; Walker & Matthews 1987; Walker et al. 1992; Warner & Hann 1987). The data presented in this paper do suggest the chironomids are responding to and therefore reconstructing changes in past temperatures, however, as is the case in the majority of chironomid studies, multiple factors could be influ-
encoring the midges, and as a result a multi-proxy study should be used where possible (Battarbee 2000). For both sites the patterns of the C-IT reconstructions are very similar to those in the meteorological data. However, over the short timescales covered by this study, it could be possible that changes in nutrient status within the lake are greater than the changes in climate, and therefore that the chironomids are responding to the changing nutrient levels (Dalton et al. 2005; Velle et al. 2005a). The location of these two oligotrophic lakes in the west of Iceland limits the effects of anthropogenic influences on the lakes, and as a result any variations in nutrient levels could be seen to be a result of changing climate. Changes in %N and %C in both lakes are very slight, although the uppermost samples from Baulárvallavatn show an increase in both elements. This may result from a higher proportion of undecomposed matter at the top of the core.

### 4.2 Underprediction of temperatures by the chironomid data

The C-IT reconstructions underpredict the temperatures as recorded by the meteorological data. There are a number of possible reasons for this. Baulárvallavatn and Saurarvatn occur near the upper end of the temperature gradient of the Icelandic training set (Langdon et al.), and many transfer functions underpredict temperatures at the upper limit of the gradient covered (Brooks & Birks 2000b). This can be overcome by increasing the number of sites in the training set and the length of gradient these sites cover; this would also act to lower the error terms of the model. It is also possible that the nature of the climatic data used caused the underprediction. The climatic data used in the calibration model is from the period 1961-1990. Post-1980, temperatures have been increasing, and using climatic data from Stykkishólmur, it is thought this could account for c.0.5 °C (nearly 50%) of the underprediction (Holmes 2006).

Dalton et al. (2005) found that C-ITs for a Scottish loch were lower than those inferred from vegetation

---

### Tab. 1: Physical properties of the two study lakes

<table>
<thead>
<tr>
<th></th>
<th>Baulárvallavatn</th>
<th>Saurarvatn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude (°N)</td>
<td>64°54'</td>
<td>65°01'</td>
</tr>
<tr>
<td>Longitude (°W)</td>
<td>22°53'</td>
<td>22°43'</td>
</tr>
<tr>
<td>Altitude (m asl)</td>
<td>193</td>
<td>11</td>
</tr>
<tr>
<td>July air T (°C) (Björnsson 2003)</td>
<td>9.62</td>
<td>10.15</td>
</tr>
<tr>
<td>$Z_{max}$ (m)</td>
<td>45.6</td>
<td>14.3</td>
</tr>
<tr>
<td>Surface area (km²)</td>
<td>1.6</td>
<td>0.29</td>
</tr>
</tbody>
</table>

---

Fig. 3: Bathymetric maps of the lakes studied. Coring locations are shown: a) Baulárvallavatn, b) Saurarvatn

**Bathymetrische Karten der untersuchten Seen. Lage der Bohrungen: a) Baulárvallavatn, b) Saurarvatn**

**Cartes bathymétriques des lacs étudiés. Les sites des forages sont indiqués: a) Baulárvallavatn, b) Saurarvatn**

**Cartography: N. Holmes**
Fig. 4a: Chironomid percentage diagram and C and N data, Baulárvallavatn

Chironomid-Prozent-Diagramm sowie C und N Daten, Baulárvallavatn

Diagramme montrant le pourcentage de chironomides et données C et N, Baulárvallavatn
Validation of chironomid-inferred temperature reconstructions in Iceland
Naomi Holmes

Fig. 4b: Chironomid percentage diagram and C and N data, Saurarvatn
Chironomid-Prozent-Diagramm sowie C und N Daten, Saurarvatn
Diagramme montrant le pourcentage de chironomides et données C et N, Saurarvatn
reconstructions and noted that snowbeds are present in the catchment for much of the year, suggesting that summer snowmelt may keep the loch water cooler during the summer. This would lead to the presence of chironomid assemblages representative of areas with cooler mean July air temperatures (Dalton et al. 2005). At Baulärvalvatn, snowbeds are present within the catchment and melt from these might cause a slight reduction in the temperature of the lake water in relation to the air temperature. Saurarvatn, located near to sea level, is not influenced by snowbeds, so this would not account for the underprediction at this site.

Such underprediction was also seen by Granados & Toro (2000) who found that their chironomid temperature reconstruction showed the same general trends as local meteorological data, although the actual values produced were not reliable. Heiri et al. (2003) found that the most recent samples in a core from Hintburg-see produced C-ITs that were too high, possibly due to anthropogenic impacts on the lake ecosystem; this is thought unlikely at the Icelandic sites. In contrast, a number of studies have found very little discrepancy between modern observed temperatures and C-ITs. Apart from the study by Granados & Toro (2000), the only other example of quantitative chironomid records being compared to meteorological records is the study by Larroque & Hall (2003) in which C-IT reconstructions from four Swedish lakes were compared to local instrumental climate data. In their study, the majority of the C-ITs were considered to reconstruct relatively accurately, as in most cases the instrumental data fell within the SSPEs of the reconstructed temperatures. Brooks & Birks (2001) reconstructed the modern tem-
temperature of Lochan Uaine at 10.5 °C while instrumental data recorded a temperature of 10.7 °C and Lango
don et al. (2004) produced a reconstructed temperature of 14.6 °C for Talkin Tarn which compared well with
the present mean July air temperature of 14.8 °C.

4.3 Holocene timescale studies

The data presented above suggest that the subfossil
chironomids produce useful temperature reconstruc
tions during the instrumental period. It is important to
know whether this is also the case over Holocene and
longer timescales, when the need to reconstruct climate
is greater as there are no instrumental records avail-
able. It is possible that factors influencing the midges
have changed through the Holocene (Larocque &
Hall 2003; Velle et al. 2005a), and it is therefore nec-
essary to carry out some kind of validation of the C-IT
reconstructions produced for the Holocene. This can
be done by comparison with other terrestrial data, and
also with marine and ice core data.

Chironomids from two sites in the north of Iceland, Hámundarstaðaháls and Vatnamiðri (see Figure 2)
were analysed and the C-IT reconstructions produced were remarkably similar both in terms of patterns
and values, even though the actual chironomid assem-
blages present in the two sites did differ (Caseldine
et al. 2006). When the chironomid data are compared
with offshore records it is also clear that the patterns
and magnitude of changes are very similar in the
terrestrial and marine proxy records (Caseldine et al.
tions from three sites in northern Iceland (Figure 2).
The reconstructions produced similar trends although
there were some differences, particularly in the late
Holocene (Axford et al. 2007). These data were
compared with that from Efstadalssvatn, NW Iceland
(Figure 2) and a similar pattern of Holocene tempera-
ture development was seen (Axford et al. 2007).

The fact that a number of temperature reconstructions
from lakes located in different areas of Iceland are
producing similar trends and magnitudes of changes in
temperature suggests that the changes in chironomid
assemblages are being driven by regional changes in
temperature rather than by other, site specific, factors
such as lake ontogeny and catchment development.

Although the validity of the Holocene sequences is
supported it is difficult to evaluate the actual figures
produced. New high resolution reconstructions of sea
surface temperatures (SSTs) (e.g. Bendle & Rosell-
Melé 2007) will provide further opportunities to
evaluate Holocene timescale chironomid tempera-
ture reconstructions. SST reconstructions would be
expected to show similar patterns of Holocene climate
development to the chironomid sites studied, due to
the near-coastal location of these sites.

5 Conclusion

These results suggest that subfossil chironomids can
provide a reliable estimate of July air temperatures,
especially temperature trends, even though the error
limits of the chironomid-inferred mean July air tem-
perature calibration model overlap with the magni-
tude of recent Holocene temperature changes. It is
possible the error terms will be reduced by the future
expansion of the training set. The chironomids seem
capable of reconstructing both small magnitude tem-
perature changes as experienced during recent times,
and larger magnitude changes as experienced earlier
in the Holocene. They are however best used as part of
a multi-proxy, multi-site study where other proxies are
able to support the relatively subtle changes inferred
based on analysis of the subfossil chironomids.

Acknowledgements

Chris Caseldine, Pete Langdon and Zoë Ruiz are
thanked for their help with fieldwork. Thanks to
Yarrow Axford, Thóra Hrafnndóttir and Pete Lang-
don for helpful discussions about Icelandic subfossil
chironomids. Funding was provided by the Natural
Environment Research Council (NERC) (Student-

References

in recent sediments. – In: Last, W.M. & J.P. Smol (eds):
Tracking environmental change using lake sediments.
Basin analysis, coring, and chronological techniques.

Axford, Y., Miller, G.H., Geirsdóttir, Á. & P.G.
Langdon (2007): Holocene temperature history of
northern Iceland inferred from subfossil midges. – In:
Quaternary science reviews 26: 3344-3358.

to climate change, with special regard to the biological

Bedford, A., Jones, R.T., Lang, B., Brooks, S. & J.
Marshall (2004): A Late-glacial chironomid record
from Hawes Water, northwest England. – In: Journal
of Quaternary science 19: 281-290.

Bendle, J.A.P & A. Rosell-Melé (2007): High resolu-
tion alkenone sea surface temperature variability on
the North Icelandic Shelf: implications for Nordic Seas
palaeoclimatic development during the Holocene. – In:

Bórnsson, H. (2003): The annual cycle of tempera-
ture in Iceland. – Report 03037, Reykjavik: Véðurstofa
Islands.

Brooks, S.J. (2006): Fossil midges (Diptera: Chirono-
midae) as palaeoclimatic indicators for the Eurasian
Validation of chironomid-inferred temperature reconstructions in Iceland: the potential for reconstructing quantitative changes in Holocene climate

Subfossil chironomids in Iceland can be used to reconstruct the relatively small magnitude temperature changes of the last few hundred years, and also the larger magnitude changes experienced earlier in the Holocene.

Keywords: Iceland, subfossil chironomid, palaeolimnology, climate, Holocene

Zusammenfassung: Mit Hilfe von Chironomiden abgeleitete Temperaturrekonstruktionen in Island: quantitative Rekonstruktion von holozänen Umweltveränderungen


Schlüsselwörter: Island, Subfossiles Chironomid, Paläolimnologie, Klima, Holozän

Résumé: Validation des reconstructions de températures basées sur les chironomides en Islande: un potentiel de reconstruction des changements climatiques holocènes

Des chironomides subfossiles extraits de forages peu profonds provenant de deux lacs de l’ouest islandais ont été analysés. Une fonction de transfert basée sur la température de l’air moyenne du mois de juillet établie par les chironomides a été appliquée de manière à produire des reconstructions de températures pour le passé récent. Ces reconstructions ont été comparées aux données météorologiques locales dans le but de tester la technique en Islande. Ces reconstructions basées sur les chironomides montrent des évolutions et des magnitudes de changement similaires à celles enregistrées par les instruments de mesure, cependant les reconstructions sous-estiment légèrement les températures observées. Cela suggère que les chironomides permettent de reconstruire des évolutions de séquence de changement de température, bien que la
La précision des résultats produits nécessite d’être questionnée. Les chironomides subfossiles d’Islande peuvent être utilisés pour reconstruire les changements climatiques de faible magnitude de ces dernières centaines d’années ou des périodes plus anciennes de l’Holocène.

Mots-clés: Islande, chironomides subfossiles, paléolimnologie, climat, Holocène

Dr. Naomi Holmes, Department of Geography, University of Exeter in Cornwall, Treliever Road, Penryn, Cornwall, TR10 9EZ, United Kingdom.
N.Holmes@ex.ac.uk

Manuskripteingang/received/manuscrit entré le
25.9.2007
Annahme zum Druck/accepted for publication/accepté pour l’impression: 6.3.2008