



Evaluation of the IKEU programme. An evaluation of the programme's organization, its organs, financing and contributions



REPORT

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<p>Summary</p> <p>IKEU (Integrated Studies of the Effects of Liming Acidified Waters) is the national monitoring programme for long-term effects of liming in Sweden. The main focus of IKEU is to study the long-term effects of liming on lakes and streams in order to improve the knowledge base for the liming activity. The main aim of this report is to evaluate the current programme structure and IKEU's fulfilment of the four main objectives since the last evaluation in 2009. The evaluation includes an assessment of scientific quality, the usefulness of the long-term monitoring series produced by the programme, whether the programme produces relevant knowledge for decision making, and to what extent decisionmakers implement the knowledge produced by the programme.</p>

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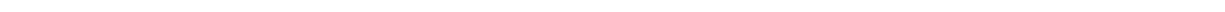
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Evaluation of the IKEU programme

An evaluation of the programme's organization, its organs, financing, and contributions



Preface

The procurement related to evaluation of IKEU was announced by the Swedish Agency for Marine and Water Management (SwAM) during the summer of 2022. The Norwegian Institute for Water Research (NIVA), in collaboration with the Norwegian Institute for Nature Research (NINA), submitted an offer on 16 September 2022 and was awarded the assignment on 5 October 2022.

The project group has consisted of senior research scientist Ann Kristin Schartau from NINA, chief research scientist Rolf David Vogt, senior research scientist Heleen de Wit and senior research scientist Øyvind Kaste, all from NIVA. Senior research scientist Kari Austnes, NIVA, has been responsible for quality assurance of the final report.

We would like to thank representatives from IKEU's research group, IKEU's reference group, and the reference group for our assignment, for valuable information and useful discussions during several digital meetings held under winter/spring 2023.

We also would like to thank our contact persons for the assignment at SwAM, Michael Pohl and Erik Boström, for good coordination and communication throughout the project.

Oslo, September 2023

Øyvind Kaste

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Summary

The IKEU¹ programme commenced in 1989 and is the national monitoring programme for long-term effects of liming in Sweden. The main focus of IKEU is to study the long-term effects of liming on water chemistry and biology in lakes and streams in order to improve the knowledge base for the liming activity. The programme was last evaluated in 2009, and the main aim of the current report is to evaluate the IKEU's programme structure and fulfilment of its four main objectives (long-term monitoring, research & development [R&D], management support, and communication) since 2009. The evaluation includes an assessment of the usefulness of the long-term data series, the scientific quality, whether the programme produces relevant knowledge for decision making, and to what extent decision-makers implement the knowledge produced.

Main findings

Long-term monitoring: IKEU's combination of long-term (>30 yrs.) water chemistry data and whole-ecosystem biological data makes the programme highly suitable to address effects of acidification and liming in combination with other environmental pressures. The current number of limed sites and references must be regarded as a minimum, where further reduction will produce little else than anecdotal evidence from the program. However, it is questionable whether further monitoring of lakes and streams where liming was terminated more than 15 years ago will provide more knowledge regarding effects of reduced liming than what is already obtained. Also, the link between liming and mercury levels in perch appears to be adequately documented. The arguments for sustaining this subprogramme within IKEU is thus less convincing today than 15-20 years ago.

R&D: IKEU's time series have been employed in research, both in terms of reports and scientific papers, but not to their full extent and potential. The dissemination activity has decreased over time, mainly due to cuts in funding. In later years, there is a lack of integration across disciplines, i.e., studies within IKEU that take a whole-ecosystem approach. Also, there are hardly any examples of integrated analyses within IKEU that connect lime treatment methodology to achievement of chemical and biological goals. After 2009 few data analyses have been reported by IKEU. It appears that the IKEU monitoring data may have been used in scientific analyses and reports, but IKEU is often not credited on websites and in reports from national monitoring programmes where IKEU data are used. This reduces the visibility of IKEU within national and regional environment agencies, as well as towards the general public.

Management support and communication: There is still a high demand among water managers for knowledge related to liming of acidified waters. However, IKEU seemed to interact more closely with the environmental authorities regarding liming questions 10-15 years ago than today. This appears mainly to be caused by the significant budget reductions and a weaker connection to the current leading governmental body (the Swedish Agency for Marine and Water Management - SwAM). Since IKEU no longer has funds to run R&D projects, the amount of new knowledge that is presented from IKEU is limited. This is an apparent paradox given that more knowledge is needed to reduce liming in accordance with environmental targets, and that the required competence for making such knowledge-based assessments actually exists within IKEU. A continuation of IKEU's data series in limed lakes and streams, including reference sites, holds the potential of generating new and updated knowledge related to several emerging areas with great relevance both for the liming community and environmental management in general.

¹ IKEU - Integrated Studies of the Effects of Liming Acidified Waters (in Swedish: Integrerad KalkningsEffektUppföljning)

Programme organisation and format: IKEU's organisation is potentially suitable to meet all the four main objectives, but due to budget cuts the activity has been limited to just operating the basic programme. The transfer of responsibility for the national liming operations from the Swedish Environmental Protection Agency (NV) to SwAM in 2011 seemingly resulted in a shift in the environmental authorities' relationship to IKEU. The responsibility for IKEU is now split between two units at SwAM, of which none of them seem to take full ownership of the programme. Thereby SwAM and the County Administrations also miss an opportunity to take full advantage of the resources and potential embedded in the programme.

Recommendations

The basic programme with limed lakes/streams and reference lakes/streams should be continued at today's level to maintain the valuable long-term data records. As termination of liming will be an important topic in coming years it is recommended to strengthen IKEU's sub-programme on this theme with more sites where liming is planned to stop within the next few years. At the same time, one should consider removing sites where liming was terminated >15 years ago from the sub-programme and instead regard them as new reference sites. Sub-programme 4 (Mercury in perch) is proposed to be taken out from IKEU's basic programme, but as mercury in fish will be a concern for a long time to come, we strongly recommend that the monitoring should continue under a different umbrella.

IKEU's activities must be expanded from pure data collection to include data processing and dissemination of results to a wide audience. Hence, more funds should be allocated to annual reporting of main results from the monitoring activities and R&D projects that aim for larger integrated syntheses and scientific publications. The competences within IKEU should be better utilised by national and regional water authorities by providing funds for R&D projects that address pressing knowledge needs within the liming sector. In cases where the number of IKEU stations are too few to make regional assessments of e.g., the potential for reduced liming, IKEU's competences could still be utilised by combining IKEU data with regional monitoring data from limed lakes and streams.

The ownership to IKEU should be clarified in SwAM's organisation. Moreover, the roles and mandates of IKEU's Project Group (where SwAM and NV are represented) and the Reference Group (with representatives from NV and the County Administrations) should be clarified and documented on SwAM's website. The resources and competences within IKEU should be better utilised by the liming community at the national and regional level. IKEU still has important tasks to attend to, and the funding should be increased or at least maintained at the current level. Should it prove impossible to increase the funding, we suggest an amendment of sub-programme 3 (stations with terminated liming) and that sub-programme 4 (mercury in perch) is removed from IKEU but continued elsewhere within the national monitoring framework.

All the four objectives of IKEU are still regarded as important and relevant, but we suggest a minor adjustment of objective 1 (long-term monitoring), and that objective 3 (management support) and 4 (communication) are merged. However, maintaining objectives 2 (research and development), 3 and 4 requires IKEU to be provided with financial resources to implement them, and that the authorities actually employ IKEU to cover their knowledge needs. It will not be meaningful to reduce the funding from today's level, which in reality only covers data collection and gives IKEU very little chance to serve as a national competence centre for liming of acidified waters.

Swedish summary

Tittel: Utvärdering av IKEU-programmet. En utvärdering av programmets organisation, dess organ, finansiering och bidrag.

År: 2023

Forfatter(e): Øyvind Kaste, Ann Kristin Schartau, Heleen de Wit, Rolf David Vogt

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Programmet Integrerad Kalkeffektuppføljning (IKEU) startades 1989 är Havs- och vattenmyndighetens (HaV) program för nationell oppføljning av effekter av kalkning i sjöar och vattendrag. Huvudmålet med programmet är att undersöka de långsiktiga effekterna av kalkning i sjöar och vattendrag och att bidra med kunskap till att utveckla kalkningsverksamheten. Programmet utvärderades senast 2008 och resultaten sammanfattades i en omfattande rapport som publicerades 2009.

Den här rapporten redovisar resultaten av en utvärdering som genomfördes under 2022/2023 som syftar till att utvärdera om och hur programmet uppnår de fyra målsättningar för programmet som formulerades 2009. Detta med särskild hänsyn till de kontinuerliga budgetneddragningar programmet drabbades av under de senaste åren. Målsättningen från 2009 är:

- nationell oppføljning av långsiktiga effekter av kalkning (Miljøovervaking).
- ökar kunskapen om försurning och kalkning (Forskning og utvikling).
- bidrar till en väl fungerande, effektiv och anpassad kalkningsverksamhet som vilar på vetenskaplig grund (Myndighetsstöd).
- Kommuniserer resultat, kunskaper och slutsatser (Kommunikation).

Denna utvärdering granskar också nytta och nyttjandet av IKEU-programmets långa tidsserier och övervakningsdata, den vetenskapliga kvaliteten i samband med publikationer samt framtagandet och analys av övervakningsdata som genererats inom programmet. Rapporten utvärderar också IKEU-programmets relevans för förvaltningen och hur kunskap som tagits fram inom IKEU används inom förvaltningen och kalkningsverksamheten.

Slutsatser

Miljøovervaking: Kombinationen av långa tidsserier och ekosystemansatsen med övervakning av både vattenkemi och biologi gör att data från IKEU lämpar sig väl för oppføljning av försurning, kalkning och långsiktiga miljöförändringar. Nuvarande omfattning av programmet är ett minimum för att svara mot programmets målsättningar, en minskning av antalet stationer skulle resultera i att programmet inte längre kan leverera pålitliga data. Dock är det en öppen fråga om fortsatt övervakning av vatten där kalkningen avslutades för mer än 15 år sedan har potential att generera ny kunskap. Dessutom är sambandet mellan kalkningen och halterna av kvicksilver i abborre tillräckligt undersökt. Denna del av IKEU är därför inte lika viktigt idag som det har varit för 15-20 år sedan.

Forskning og utvikling: Data som tagits fram inom IKEU har använts vid flera publikationer av rapporter och artiklar. Dock har inte data, och särskilt de långa tidsserierna används till sin fulla potential. Användandet av IKEU-data har minskat över tid och här finns det ett samband med minskad finansiering av IKEU. De senare åren har det funnits brist på integration mellan olika områden inom IKEU, till exempel studier som tar ett helhetsperspektiv på ekosystem. Dessutom finns

det knappt några exempel på integrerade analyser som kopplar ihop metoderna för kalkning med uppnåendet av kemiska och biologiska mål. Ett annat problem som identifierades av utvärderingen är att det oftast inte refereras till IKEU på olika webbsidor och rapporter där det också används data från andra nationella program för övervakning av miljön.

Detta leder till att IKEU inte är särskild synlig för varken allmänheten, regionala- och nationala myndigheter eller forskningen.

Myndighetsstöd och kommunikation: Det finns fortfarande stort behov av kunskap om kalkning och försurning, dock var IKEU mer involverat i framtagandet av relevanta kunskapsunderlag för förvaltningens arbete för 10 – 15 år sedan. Detta verkar vara konsekvensen av konstanta budgetneddragningar och en lösare anknytning till ansvarig myndighet (SwAM) jämfört med hur det tidigare har varit med Naturvårdsverket (NV) som ansvarig myndighet. Eftersom det inte finns utrymme för forskningsprojekt inom rådande budget är antal nya forskningsresultat som IKEU levererat de senaste åren begränsat. Detta kan uppfattas som paradoxalt eftersom mer kunskap behövs för att besluta om och under vilka omständigheter kalkningen borde reduceras eller avslutas samt att kompetensen för detta finns samlat och koordinerat inom IKEU. En fortsättning av IKEUs tidserier av kalkade och referensvatten har stor potential att generera ny kunskap och uppdatera befintlig kunskap om flera framtida utmaningar med relevans för både kalkningsverksamheten och miljöövervakningen.

Programorganisation och upplägg: IKEUs upplägg möjliggör i teorin uppnåendet av alla fyra målsättningarna. De upprepade nedskärningarna av budgeten har dock lett till att bara övervakningsdelen av programmet kan utföras. Överföringen av ansvaret från Naturvårdsverket till Havs- och vattenmyndigheten 2011 verkar ha bidragit till ett skifte i förhållandet mellan beställande myndighet och IKEU. Ansvaret för IKEU inom SwAM är nu uppdelat mellan två olika avdelningar av vilka ingen tar fullt ansvar för programmet. Detta leder till att kalkningsverksamheten men också myndigheten går miste om möjligheten att dra full nytta av resurserna och potential som finns i programmet.

Rekommendationer

Den del av IKEU som omfattar övervakningen av kalkade och referensvatten borde fortsätta på minst 2022 års nivå avseende antal stationer för att bibehålla de värdefulla långa tidsserierna. Eftersom vilande kalkning/kalkavslut kommer bli mer aktuellt de kommande åren så rekommenderas en ökning av antal stationer i vatten med kalkavslut. Samtidigt bör man överväga att ta bort vatten där kalkning avslutades för över 15 år sedan från delprogrammet och istället betrakta dem som referensvatten. Del Kvicksilver i abborre föreslås tas bort från IKEUs grundprogram, men eftersom kvicksilver i fisk kommer vara ett aktuellt tema under lång tid framöver rekommenderas starkt att övervakningen fortsätter under ett annat nationellt övervakningsprogram.

IKEU:s verksamhet bör utökas från ren datainsamling till att inkludera datahantering och kommunikation av resultat till en bred publik. Därför måste mer medel avsättas för kommunikation samt fokusprojekt som syftar till synteser och vetenskapliga publikationer med ekosystemansats för att nyttja IKEUs fulla potential. Kompetenserna inom IKEU bör nyttjas i större utsträckning av nationella och regionala myndigheter genom att dessa tillhandahåller medel för fokusprojekt som adresserar kunskapsbehov inom kalkningssektorn. I de fall där den geografiska täckning av IKEU:s stationer är för låg för att göra regionala bedömningar av t.ex. potentialen för minskad kalkning, kan IKEU:s data fortfarande användas genom att kombinera den med övriga övervakningsdata. Här kan regionala övervakningsdata från kalkade sjöar och vattendrag samt data från andra övervakningsprogram användas.

Ansvar för IKEU programmet inom SwAM borde förtydligas samt förankras i myndighetens verksamhet. Dessutom bör mandat, upplägg och syfte med IKEUs styrning, referensgrupp och projektgrupp tydliggöras och dokumenteras. Detta skulle leda till att kompetensen inom IKEU nyttjas bättre av myndigheter och kalkningsverksamheten på nationellt, regionalt och lokal nivå. IKEU har fortfarande en viktig roll att uppfylla och frågor att besvara. Budgeten för IKEU borde utökas så att minst nuvarande nivå av programmet kan bibehållas framöver. Skulle det visa sig vara omöjligt att utöka budgeten, så rekommenderas en anpassning av delprogram gällande vatten med kalkavslut och referensvatten samt avveckling av delprogram gällande kvicksilver i abborre. Det bör dock poängteras att tidsserier av kalkavslutade vatten är värdefulla ur miljöövervakningens synpunkt och borde fortsättas. Övervakningen av kvicksilver i fisk bedöms även framöver vara viktig fast inte inom ramen för kalkningen och kalkningseffektuppföljningen.

Alla fyra mål för IKEU är fortfarande viktiga och relevanta, men det föreslås en mindre justering av mål 1 (miljöövervakning), och att mål 3 (myndighetsstöd) och 4 (kommunikation) slås samman. Dock krävs det att IKEU tillhandahåller finansiella resurser för att uppnå mål 2 (forskning och utveckling), 3 och 4, samt att myndigheterna faktiskt använder sig av IKEU för att täcka sitt kunskapsbehov. Det kommer inte att vara meningsfullt att minska finansieringen från dagens nivå, vilket i praktiken endast täcker övervakningsdelen och ger IKEU mycket liten möjlighet att fungera som ett nationellt kompetenscenter för kalkning av försurade vatten.

1 Introduction

1.1 Acidification in Sweden

Monitoring of water chemistry of Swedish lakes and streams commenced during the 1970s to increase the understanding of causes and effects of airborne pollutants (acidification) on surface waters. During the 1970s and 1980s this contributed to the underpinning of international policy regarding abatement of atmospheric pollution. Moreover, the importance of long-term monitoring records to distinguish interannual variation from trends was established. The development of the Swedish monitoring programme for surface waters is extensively described by Fölster et al. (2014a). Lake surveys, used for regional acidification assessments, were repeated every fifth year from 1985 until 2005 (Henriksen et al. 1998; Skjelkvåle et al. 2001; Stoddard et al. 1999). Since 2007, lake surveys have been conducted annually with one-sixth of the total of 4 800 lakes sampled each year (Fölster et al. 2014a). A national liming programme to mitigate the effects of acidification in surface waters started with governmental support in 1977 (Lessmark & Thörnelöf 1986). The national programme for monitoring of effects of liming in lakes and rivers (IKEU) began in 1989.

Since then, extensive chemical recovery of rivers and lakes in Sweden has been documented (Futter et al. 2014; Garmo et al. 2014; Fölster et al. 2014b). However, due to depletion of base cations in the soils by acid rain, it is not certain that the lakes will return to reference conditions. Also, there has been an increase in dissolved organic matter, which in the past has mainly been due to the decline in acid rain. This has led to a browning of lakes (Monteith et al. 2007) and increases in natural organic acidity that partly compensates for the decrease in mineral acidity from declining air pollution (Futter et al. 2014). In recent years, climate change has also had an impact on the chemical conditions in lakes and rivers, and thereby also affected their ability to return to their original reference state.

Despite a clear recovery of the water chemistry in Scandinavian lakes and rivers during the last 20-30 years, the observed records only document weak, or no, trends in biological recovery (Holmgren 2014). Assessments of biological recovery is hampered by the lack of long-term data that started early enough to include the period of strong chemical recovery. Furthermore, biotic recovery depends on several factors, including the persistence of acidification and altered colour by the increased levels of organic compounds. Additional confounding effects of other stressors and environmental constraints such as climate change and decreased calcium levels, the ability of species to re-colonise the previously acidified system as well as food-web interactions also influences the rate of biotic recovery (Leach et al. 2019; Grey & Arnott 2012; Ross & Arnott 2022). Still, some examples of biological recovery, related to single lakes or regions, have been reported from Canada (e.g., Gunn and Sandøy 2003; Grey et al. 2012), USA (Jiang et al. 2022), UK (e.g., Battarbee et al. 2014) and Scandinavia (Hesthagen et al. 2011; Lund et al. 2018; Schartau et al. 2021).

The acidification status of surface waters in Europe and North America has been assessed by Austnes et al. (2018). For this report, Sweden contributed with data (2010-2016) from acid-sensitive water bodies in catchments smaller than 1 000 km². Critical load maps show considerable exceedances in Sweden based on the deposition level in 2015, although the exceedance level is relatively low (**Figure 1**). However, there is a considerable regional bias in the acidification status of lakes, where almost 45% of all lakes in southern Sweden remain acidified, i.e., have a pH which is 0.4 units lower than the preindustrial lake pH in 1860 (**Figure 2**).

Thus, evidence from several sources indicates that chemical recovery from acidification has been substantial for Swedish water bodies, although a significant proportion of lakes remains acidified, especially in southern Sweden. Biological studies of non-limed acidified lakes and rivers in Sweden are limited but indicate that the biological recovery follows the trend from other Scandinavian lakes and rivers. While some groups, such as zooplankton and benthic invertebrates, show increased species richness in some waters, the recovery is delayed and halted for other groups in other waters (Holmgren 2014).

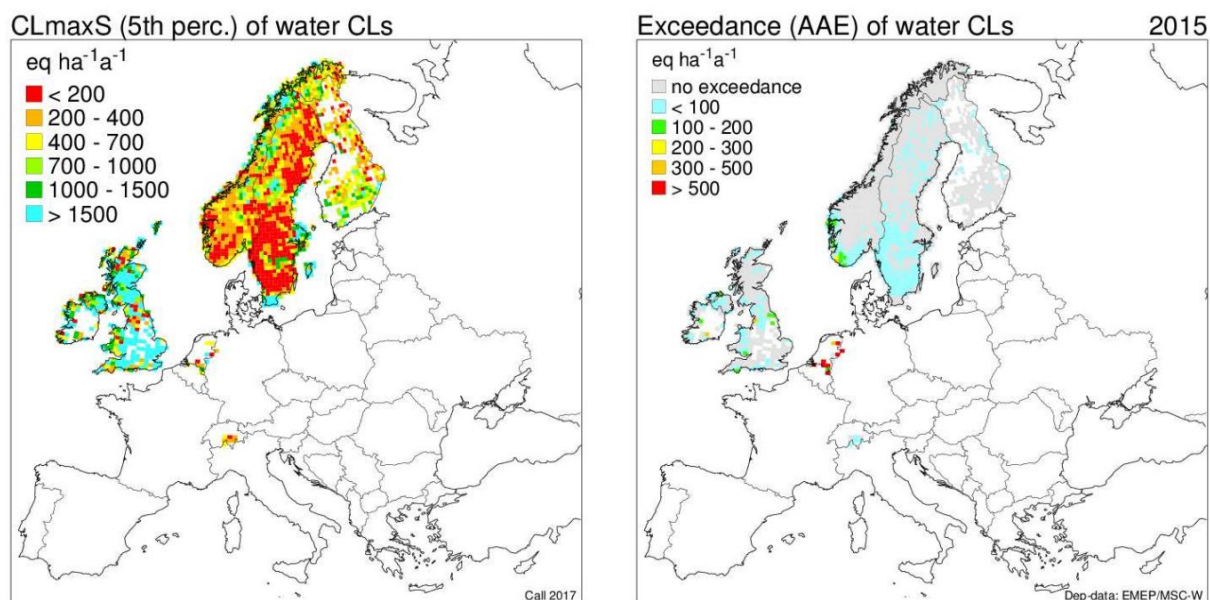


Figure 1. *Left:* Critical loads (CLs) for acidification of surface waters due to sulphur deposition for some European countries. The colour of each grid cell represents the 5th percentile of the distribution of critical loads reported for the grid cell. *Right:* Exceedance of critical loads for acidification of surface waters for some European countries, based on the deposition in 2015. AAE = Average accumulated exceedance (AAE) is the area weighted average exceedance for the different reported areas per grid cell (i.e., not necessarily adding up to the total area of the grid cell). From Austnes et al. (2018).

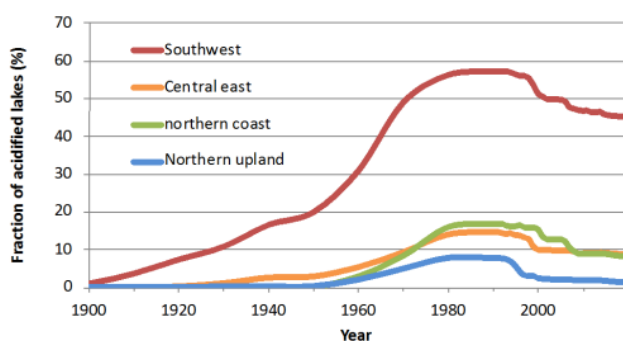


Figure 2. Regional patterns in development of acidification in lakes since 1860 in four regions in Sweden. The estimate is based on 5 084 lakes selected by a random stratification of all 96 000 lakes > 1 ha in Sweden. From Austnes et al. (2018).

1.2 Liming of lakes and rivers

State grants for liming acidified water in Sweden have existed for more than 40 years. The number of limed waters expanded rapidly during the 1980s, with a peak in lime consumption around 2000, when around 200,000 tonnes were spread annually (**Figure 3**). Between 2002 and 2016 consumption was halved with only about 100,000 tonnes distributed annually during the last five years. Correspondingly, the state grant for liming decreased from around 220 mill SEK during 2002-2008 to around 165 mill SEK after 2012 (**Figure 4**). The figures after 2012 only comprise grants distributed to the County Administrative Boards (Länsstyrelsen²), i.e., not the national costs and the funding for IKEU. **Figure 5** shows how the County Administration's grants were allocated to different activities.

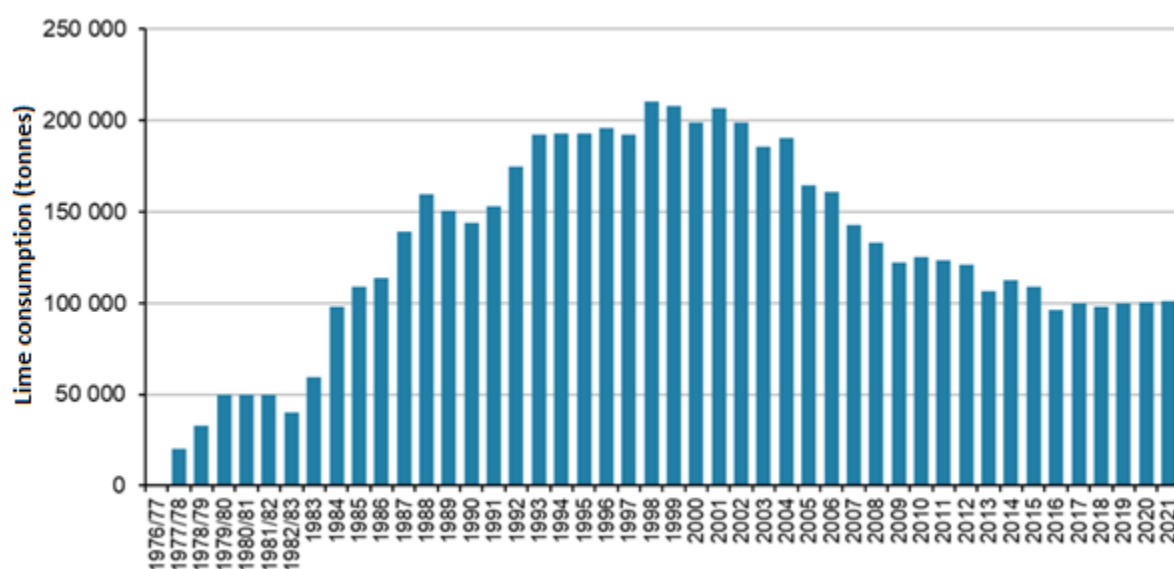


Figure 3. Lime consumption during the period 1976- 2021. Figure copied from SwAM (2022).

² Hereafter referred to as the 'County Administrations'

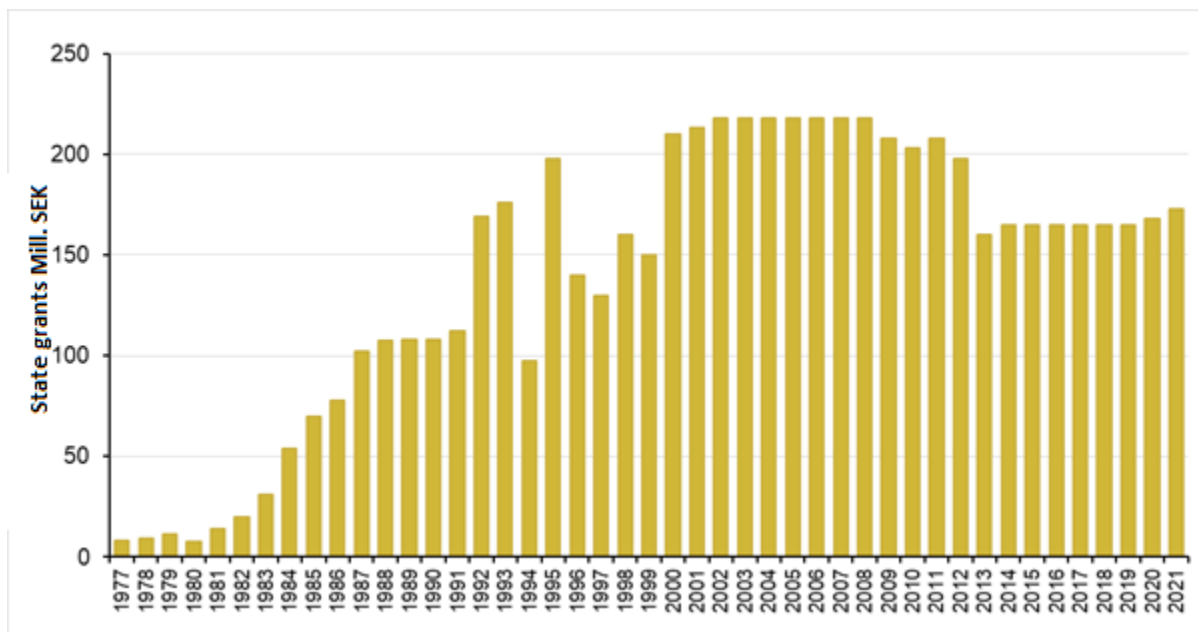


Figure 4. The state grants for the liming of lakes and waterways for the period 1976 - 2021. From 2013, the funds are distributed as an integrated grant to the County Administrations. Up to and including 2012, national costs are included, including for the national follow-up (IKEU). After 2012, the graph only refers to what was distributed to the County Administrations. Figure copied from SwAM (2022).

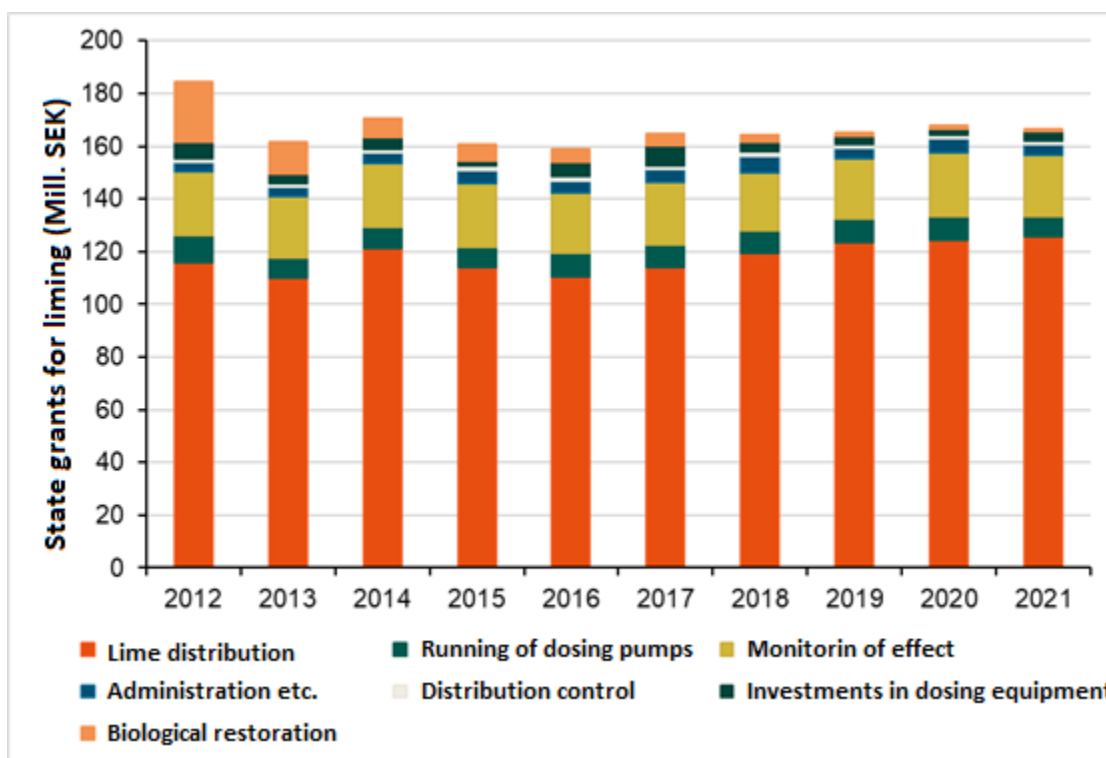


Figure 5. Distribution of state grants for liming (mill SEK) on different activities, 2012- 2021. Based on data from the County Administrations' reporting. Figure copied from SwAM (2022).

1.3 The IKEU programme in short

The IKEU programme, that commenced in 1989, is the national monitoring programme for long-term effects of liming (Drakare et al. 2022) that started in Sweden in 1977 (Lessmark & Thörnelöf 1986). The main focus of IKEU is to study the long-term effects of liming on lakes and streams in order to improve the knowledge base for the liming activity. Regarding biological effects this entails to determine if liming restores the species composition and biodiversity that existed prior to acidification and if there are any unwanted effects of liming. During the past decade, effects of terminated or decreased liming on chemistry and biota is also included as a focus point.

The programme was last evaluated by Munthe & Jöborn (2009); see more details in Chapter 1.4. Based on the evaluation, the programme was restructured in 2010 with the aim of addressing the following four main objectives:

1. Monitor long-term effects of liming on lake and river ecosystems on a national basis.
2. Carry out scientific studies that increase our knowledge of acidification and liming issues.
3. Produce knowledge for national and regional authorities that contributes to efficient and science-based management of liming activities.
4. Communicate results, knowledge, and conclusions from the programme in ways that are adapted to the users' needs.

The new structure resulted in an expanded basic programme, supplemented with focal studies and communication projects. An annual cycle was established with regular meetings with the steering group and reference group, in addition to research seminars and stakeholder meetings. The organisation of IKEU is further described in Chapter 4.1.

IKEU currently consists of four sub-programmes:

1. Effects of liming in lakes
2. Effects of liming in streams
3. Terminated liming in lakes and streams
4. Mercury in perch

When IKEU was launched in 1989, an annual budget of just under SEK 2 million was set aside. A decade later, the programme was expanded to cover just over SEK 6 million per year. From 2004 to 2008 the grant to IKEU increased significantly to around SEK 16 million (Munthe & Jöborn 2009). Since 2012, the IKEU programme has been subject to annual financial cuts (**Table 1**). The diminishing financial support makes it difficult to maintain the level of ambition from 2010, i.e., the ability to achieve the four project objectives. Currently, funding of IKEU is provided by the Swedish Agency for Marine and Water Management's (SwAM) via the 1:11 grant. The 1:11 grant is intended for implementing the government's policies regarding lakes, waterways and seas. National liming activities are also paid for via this grant.

Table 1. IKEU funding (SEK) granted each year from 2008 to 2021. Columns: Basic programme, focus (R&D) projects & web, project management, client, and number of focus projects. Table copied from Drakare et al. (2022).

År	Basprogram	Fokusprojekt och webb	Projektledning	Beställare	Fokusprojekt (antal)
2008	13 400 000	1 970 000	290 000*	NV	6
2009	14 441 000	1 389 000	300 000	NV	6
2010	11 986 000	1 670 000	303 000	NV	7
2011	11 546 000	1 252 000	310 000	NV	7
2012	11 701 000	1 213 000	309 000	HaV	9
2013	8 203 000	1 004 000	282 000	HaV	7
2014	8 211 000	484 000	282 000	HaV	4
2015	7 730 000	-	270 000	HaV	-
2016	7 484 000	247 000	270 000	HaV	1
2017	7 100 000	856 200	277 000	HaV	3
2018	7 311 000	100 000	277 000	HaV	-
2019	7 043 000	-	210 000	HaV	-
2020	7 035 000	-	215 000	HaV	-
2021	7 072 000	-	220 464	HaV	-

1.4 Recommendations from the 2009 evaluation and how they were followed up

The last evaluation of the IKEU programme was carried out by Munthe & Jöborn (2009). The evaluation was covering the period 1990 to 2006 and comprised two main parts: (1) Long-term effects, and (2) Organisation and efficiency.

The first part was an evaluation of IKEUs fulfilment of the first three objectives at that time: (i) Long-term effects of liming, (ii) Ecosystem restoration, and (iii) Possible undesirable effects of liming (cf. **Appendix A1**). The review was to a large extent based on 22 background reports produced by an appointed reference group.

Three main questions were addressed under this part:

- What chemical and biological effects can the IKEU data show that lime treatment leads to?
- How has IKEU showed that/and if lime treatment has been adjusted to the acidification development (termination of lime treatment, etc.)?
- Does IKEU show that lime treatment lead to unwanted effects and if so which effects?

The evaluation's conclusions: "the environmental monitoring part is largely managed in a very good way. Evaluation and research on the effects of liming is also of high quality but is focused too much on detailed knowledge rather than generalisations and synthesis".

Some of the recommendations given under this part were:

- More focus on coupling between biotic and abiotic factors.
- More attention should be devoted to effects of external factors such as lime treatment methodology, lime dosage, climate, etc.

- IKEU should continue to play a key role in producing information and recommendations for future cut downs in lime treatment as motivated by the decreased acid load.

The second part was an evaluation of IKEU's fulfilment of the last three objectives, which were about provision of data and support to the Swedish Environmental Protection Agency (Naturvårdsverket³) and the County Administrations (cf. **Appendix A1**). The evaluation was focusing on IKEU's structure, organisation, administration, as well as the utilisation of results within the larger liming community.

The main questions addressed under this part were:

- Has IKEU the correct objectives?
- Is IKEU purposively organised?
- Does the management chain function well?
- How can IKEU be optimised?

The evaluation's conclusions: "IKEU's organisation is mainly adapted to conduct environmental monitoring of high scientific quality. On the other hand, the organisation is not as well adapted to carry out integrated analyses and knowledge syntheses or communication with users". The evaluators also added that: "the communication part is vastly neglected and only a small proportion of the knowledge is used to inform the on-going lime treatment venture in Sweden".

Some of the recommendations given under this part were:

- objectives should be reformulated.
- Create opportunities for IKEU to fulfil the objectives related to management support (objective 4-6 in **Appendix A1**).
- Adapt the organisation to the current tasks within the programme.
- Welcome the main target groups to participate in planning, implementing and follow up.
- Identify the main target groups' need of knowledge and adjust the tasks and communication accordingly to suit these needs.
- Create an advisory group with responsibility for supporting the future development of IKEU.

Based on the evaluation, the programme was revised in 2010 addressing the four main objectives which still apply today (cf. chapter 1.3). A reference group with representatives from the County Administrations and NV was established, and annual IKEU conferences with representatives from SwAM, NV, and the County Administrations were arranged.

1.5 Objectives for the current evaluation

The main aim of this report is to evaluate IKEU's programme structure and its fulfilment of the four main objectives since 2009.

The evaluation includes an assessment of scientific quality, the usefulness of the long-term monitoring series produced by the programme, whether the programme produces relevant

³ Hereafter abbreviated to NV

knowledge for decision making, and to what extent decisionmakers implement the knowledge produced by the programme.

The Swedish Agency for Marine and Water Management (SwAM) has specified the evaluation themes through 14 questions, which we have addressed in our assessment. Based on the evaluation results, we have given recommendations regarding further operation of the programme.

The 14 questions are:

1. How does the structure and results of IKEU correspond to the four main objectives of the programme (listed in Chapter 1.3)?
2. What are the general knowledge needs of SwAM, the County Administrations and the liming community⁴ in relation to long-term effects of liming, development of existing liming practices, and the regional follow-up of liming effects, and what role does the IKEU programme have in this?
3. Is the structure of the IKEU programme effective in terms of steering/leadership, organisation, administration, and communication?
4. Are IKEU's objectives, which were identified in 2010, still correctly formulated regarding today's needs and state of knowledge?
5. What would be the minimum format of the programme in order to meet the needs required by SwAM and the liming community in general?
6. Consequence analysis of possible effects if the IKEU programme is increased, maintained, reduced, or terminated?
7. To what extent have IKEU's data (time series) been used in environmental monitoring, and are the generated data sets compatible with the environmental monitoring programme area 'Freshwater'?
8. To what extent has knowledge generated within IKEU been used by the liming community and other management areas?
9. Does the programme maintain good scientific quality?
10. Are the results from the programme generalisable to operational liming activities?
11. Are the research methods adequate and well justified in relation to the aim and objectives of the programme?
12. To what extent has the data (time series) generated within IKEU been used in research?
13. Will a continuation of the time series add new knowledge about the long-term effects of liming, and if so, which time series?
14. Will a continuation of the time series add new knowledge about other knowledge areas such as diffuse anthropogenic influences, eutrophication, climate changes, acidification, etc.?

⁴ Corresponding to the Swedish term "Kalkningsverksamheten"

2 Material and methods

2.1 Methodological approach

The project is carried out by a stepwise approach:

1. Collection of data / documentation:
 - a. Background information: Long-term trends and current status of (i) acidification in Sweden, (ii) number of limed lakes and rivers, (iii) tons of limestone dispersed each year, (iv) IKEU funding granted each year.
 - b. Dissemination: Relevant written information and documentation related to the IKEU programme (reports, scientific publications, strategy documents, online publications, etc.).
2. Stakeholder interview meetings (with SwAM, IKEU's reference group, IKEU's project group) to identify knowledge needs within the liming community and how the needs are met by the IKEU programme.
3. Evaluation:
 - a. Assess written information and inputs from stakeholder meetings.
 - b. Evaluate IKEU's fulfilment of the four main objectives (Chapter 1.3).
 - c. Respond to the 14 questions raised by SwAM (Chapter 1.5).
 - d. Summarise major findings and make recommendations.

2.2 Background material

Written information and documentation that are reviewed (reports, scientific publications, strategy documents, online publications, etc.) are listed in the reference list (Chapter 6) whereas links to referred web sites are included in the running text.

Reports and scientific publications related to the IKEU programme are made available on IKEU's web site hosted by the Swedish University of Agricultural Sciences (SLU) (<https://www.slu.se/centrumbildningar-och-projekt/ikeu/>).

2.3 Stakeholder meetings

The following stakeholder meetings have been held during the project period:

- Start-up meeting with SwAM and representatives from the IKEU project.
- Interview meeting with SwAM.
- Interview meeting with IKEU's reference group.
- Interview meeting with the IKEU's project group.
- Meeting with the project's reference group.

Participants in the meetings are listed in **Appendix A2**.

2.4 Structure of report

The four main objectives listed in Chapter 1.3 and the 14 questions from SwAM are addressed in three consecutive sub-chapters under Chapter 3 (“Programme performance in relation to objectives”). Chapter 4 contains an evaluation of programme organisation and format, whereas the evaluation is concluded in chapter 5 (overall assessment and recommendations).

3 Programme performance in relation to objectives

3.1 Long-term monitoring

IKEU's first main objective is to "Monitor long-term effects of liming on lake and river ecosystems on a national basis". Question from SwAM (cf. section 1.5) addressed in this section:

Q11: Are the research methods adequate and well justified in relation to the aim and objectives of the programme?

3.1.1 Database

The IKEU database comprises data from 74 lakes and 70 streams, where the earliest data collection started in 1989 (Drakare et al. 2022). However, the number of water bodies with active monitoring has declined over the years. The monitoring in 2010 included 29 lakes and 42 streams (Drakare et al. 2022). In addition, there are data from 26 lakes and 36 streams that were extensively monitored (only water chemistry sampling) between 2005/6 to 2010, and further 10 lakes that were part of the lime overdosing project ("Överkalkning") that was conducted in 2006-2010.

Currently (2022) 20 lakes and 29 streams are still being monitored. The ongoing lake monitoring includes 7 limed lakes, 7 lakes where the liming is stopped, and 6 reference lakes. Compared with 2010, the monitoring is no longer on-going at 7 of the limed, 1 where the liming has ended, and in 1 of the reference lakes. The stream data are from 12 limed streams, 6 rivers where the liming is halted, and 11 reference sites. Compared with 2010, the monitoring is no longer on-going at 5 of the limed and in 8 of the reference streams. All data are made available at SLU's databank (<https://miljodata.slu.se/mvm>).

The more limited number of monitoring stations reduces the value of the dataset in terms of regional representativeness. However, the IKEU monitoring programme contains enough stations to still be able to address effects of acidification and liming on water chemistry and biology. In that sense the current number of limed sites and references must be regarded as a minimum, where further reduction will produce little else than anecdotal evidence.

The water chemistry programme includes a comprehensive list of physicochemical parameters (Drakare et al. 2022) that enables assessments of status and trends regarding acidification, effects of liming, dissolved organic matter, metals and eutrophication in lakes and rivers. The biological programme contains analyses of a large number of ecosystem compartments (**Table 2**). It is worth to note that long-term combined water chemical and biological datasets (starting as early as 1989, thus including a period with significant recovery from acidification) are rare, also in an international context (Velle et al. 2016).

A review of intercalibration results for water chemistry shows no systematic difference between the laboratories' results. Quality control of chemical and biological analyses and data reporting follows procedures that are described by the individual laboratories responsible for the specific analyses. These detailed descriptions are not readily available but possible to obtain. For each component, a

description of the general procedures for quality control are available (in Swedish) at: [Metoder för provtagning och analys | Externwebben \(slu.se\)](#). The assessments of IKEU data are mainly led by high standing and renowned scientist and their studies are generally of good scientific quality.

3.1.2 Evaluation of methods

Compliance with standard methods and protocols

The chemical and biological monitoring (**Table 2**) are in general based on standardised methods (European and Swedish standard) for sampling and sample processing, specified in nationally prepared sampling protocols. The only exception is for phytoplankton due to low sampling frequency (see below) and benthic (littoral) macroinvertebrates in rivers and littoral macroinvertebrates in lakes which follows a separate sampling protocol (M42). Furthermore, because the responsibility for the littoral benthic surveys was previously shared between two different institutions (IVM and ITM), two different methods have been used and for some of the lakes there has been a shift of sampling method during the monitoring period. From 2006, all littoral lake samples, as for rivers, have been collected using the M42 method.

Table 2. Components monitored in IKEU's basic programme (Drakare et al. 2022)

	Lakes	Streams
Water chemistry	x	x
Phytoplankton & zooplankton	x	
Benthic diatoms		x
Littoral macroinvertebrates	x	x
Sub-littoral macroinvertebrates	x	
Fish (electro)		x
Fish (gillnet)	x	
Hg in perch	x	

For lakes the M42 method has been compared with the standard kick-sampling method used within the other national monitoring programmes in Sweden, through a period of double sampling and harmonisation of the two methods (Sandin, 2003). These two sampling methods are not comparable as both the sampling effort and the mesh size of the hand-net/sieve differ. The description of the M42 method also gives the impression that it makes greater demands on the sampler's knowledge of local conditions and especially of the benthic communities. We are therefore unsure whether the M42 method contributes to a larger sampling variance than what the standardised method does. However, Sandin (2003) found no significant differences between methods in terms of species numbers or in index values. As far as we know, no similar comparison of the two sampling methods has been made for rivers. The M42 method has been retained to avoid breaking the long time series established through the IKEU programme (Drakare et al. 2022).

Using two different sampling protocols means that macroinvertebrate-trends at IKEU monitoring sites cannot be directly compared with trends in other monitoring programmes. However, we do not know whether the methodological differences have had an impact on the use of the IKEU data, i.e., that they are used to a lesser extent than they would otherwise be.

During the monitoring period, there have also been changes in some of the other methods. This is, for example, the case for the gill-net method used in the fish surveys for lakes. From 1994, series of gillnets with single mesh-size were replaced with multi-meshed nets, which is known to have a significant effect on population estimates and the size distribution of fish stocks (see bibliography in

EN 14757:2015). Our impression is that the effects of such changes have been examined using both old and new methods over a few years. Depending on the results of these comparisons, trend analyses are limited to the period with comparable results (such as for fish where the trend analyses are based on data from 1994, while fish data from 1988-1993 are not included).

Sampling frequency

Sampling frequency and taxonomic resolution follows the national protocol and seems to be well justified, with a possible exception for phytoplankton. The IKEU programme generally has a higher sampling frequency for chemical and biological parameters than the other national monitoring programmes.

The sampling frequency for phytoplankton in lakes has been reduced twice during the monitoring period; from seven to four sampling occasions per year in 2009 and then from four to only once a year from 2013 (except for stations with terminated liming where the phytoplankton samples are still taken four times a year- 2022). This is in accordance to changes in the national protocol for monitoring of trend stations in lakes ("Trendstationer sjöar"). The consequence of a shift from seven to four sampling occasions per year has been tested and resulted in an average of 20% fewer species in the samples, while the composition of common species did not change (Sundbom 2009a; Drakare 2010). The consequence of further reduction in sampling frequency has not been tested. However, the phytoplankton sampling protocol is no longer in line with recommendations in the European and Swedish standard, and the use of phytoplankton data in the ecological status classification (cf. WFD) of these lakes is not recommended.

Taxonomy

For most biological quality-elements there have been shifts in executive contractor/taxonomical expert during the monitoring period. Evaluation within IKEU confirms that replacement of taxonomical experts often has greater consequences for the results than a change in sampling methodology (Sandin 2003; Sundbom 2009a). On the other hand, replacement of experts is difficult to avoid in long-term monitoring programmes.

3.1.3 Data from other IKEU sub-programmes

Stations with terminated liming (sub-programme 3)

The current programme includes 7 lakes and 6 streams where liming has been temporary or permanently halted (Drakare et al. 2022). At most locations the liming was terminated more than 15 years ago, and it is therefore a question of whether further monitoring of these will provide more answers to the effects of reduced liming. Here, the monitoring can either be stopped or they can be regarded as new reference sites. As termination of liming will be an important topic in coming years, IKEU's sub-programme 3 should be strengthened with more sites where liming has recently been stopped or is planned to stop within the next few years. This will provide better support for decision-making related to reduced liming than continuing the monitoring of stations where the liming effect is no longer traceable. It is a big difference to stop liming at today's level of acid deposition, compared to 15-20 years ago when the deposition levels were much higher.

Mercury in perch (sub-programme 4)

High mercury (Hg) levels in the environment have been of concern in Sweden for many decades (Åkerblom et al. 2014). Annual measurements of mercury in small perch have been part of IKEU's

programme since 1990 (Sundbom 2009b). Currently (2022), 13 IKEU lakes (limed, previously limed and references) as well as 4 references from the national “trend lake” programme is monitored for Hg in perch. IKEU's long time series for mercury in perch show that liming reduces the levels of Hg in perch, and if liming stops, the fish's Hg content may increase again if the lake is reacidified (Sundbom 2016). The link between liming and mercury levels in perch appears to be well documented, and the rationale for keeping the subprogramme within IKEU seems less obvious today than 20 years ago. However, mercury in fish will surely continue to be a concern in the future and should be followed up in other national environmental monitoring programmes.

3.1.4 Summary

Observations / assessment:

- The cut down in the number of stations over the past 10-15 years reduces the value of the dataset in terms of regional representativeness, but the programme still contains enough stations to be able to address long-term effects of acidification and liming on water chemistry and biology.
- The current number of limed sites and references must be regarded as a minimum, where further reduction will produce little else than anecdotal evidence.
- Such comprehensive, long-term combined water chemical and biological datasets are extremely rare, also in an international context.
- Data collection in IKEU is done according to well-established methods and the data are of good scientific quality.
- Except for littoral macroinvertebrates, which follows a separate sampling protocol (M42), and phytoplankton (see below), IKEU data are compatible with other national environmental monitoring.
- The phytoplankton sampling protocol, with only one sampling occasion per year, is not in line with recommendations in the European and Swedish standard, which means that the phytoplankton data do not meet the requirements for ecological status classification (cf. WFD).
- It is a question of whether further monitoring of lakes and streams where liming was terminated more than 15 years will provide more knowledge regarding effects of reduced liming.
- The link between liming and mercury levels in perch appears to be well documented, and the rationale for keeping subprogramme 4 within IKEU seems less obvious today than 20 years ago.

Recommendations:

- The basic programme with limed lakes/streams and reference lakes/streams should be continued at today's level to maintain the long-term data records.

- If liming is terminated at some of the currently limed IKEU sites the monitoring should continue, but then under sub-programme 3 “Terminated liming in lakes and streams”.
- As termination of liming will be an important topic in coming years it is recommended to strengthen IKEU’s sub-programme 3 with more sites where liming is planned to stop within the next few years. At the same time, one should consider removing sites where liming was terminated >15 years ago from sub-programme 3. Here, the monitoring can either be stopped or they can be regarded as new reference sites.
- Sub-programme 4 “Mercury in perch” is proposed to be taken out from IKEU’s basic programme, but as mercury in fish will be a concern for a long time to come, we strongly recommend that the monitoring should continue under another umbrella.
- If it is decided to phase out sub-programme 4 from IKEU, it is recommended that released funds are allocated for reporting / publishing results for the entire monitoring period (final report on mercury in perch, other thematic reports, etc.).

3.2 Research and development (R&D)

IKEU’s second main objective is to “Carry out scientific studies that increase our knowledge of acidification and liming issues”. The questions from SwAM (cf. section 1.5) addressed in this section are:

Q9: Does the programme maintain good scientific quality?

Q12: To what extent has the data (time series) generated within IKEU been used in research?

3.2.1 Use of IKEU data in research

To assess to what extent the IKEU time-series data are used in research we have reviewed the reports and research articles listed on the IKEU [homepage](#), as well as other scientific articles that are open access or otherwise available (**Figure 6**).

Number of publications over time

The highest number of reports and publications were published in the period between 1995 and 2009. Most of the reports and scientific publications were produced in relation to the Acid Rain conference in Gothenburg in 1995 and the last evaluation of IKEU in 2009. As a part of the evaluation of IKEU in 2009 the monitoring data were extensively assessed in the form of 22 sub-reports attached to the main report by Munthe & Jöborn (2009).

During the last ten years (2013-2022) only four reports and two scientific articles using the IKEU monitoring data are published. After the termination of the R&D focus projects since 2017, no scientific articles based on IKEU data have been produced (according to the literature list on IKEU’s webpage). Except for fish (e.g., Holmgren & Peterson 2021) there are hardly any publications based on biological data from the IKEU programme after 2009. More recent reports addressing effects on biology are based on regional data from limed sites (Degerman et al. 2015; Ahlström 2018). It is not clear whether data from the IKEU programme are included in the analyses together with data from the regional monitoring.

Not all reports and publications listed on the IKEU homepage are based on IKEU's data alone. In some cases, the publications are produced by IKEU researchers but also based on data from other programmes/sources (e.g., datasets from other national monitoring programmes or the regional follow-up programmes on liming effects). There are also cases where IKEU's data are used but not referred to.

As the monitoring data from IKEU are publicly available together with data from other monitoring programmes in SLU's dataportal "Miljödata", the IKEU programme is often not credited on websites, in scientific articles, or in reports from local and national monitoring programmes where IKEU data are used. This reduces the visibility of the programme within national and regional environment agencies, as well as towards the general public. The IKEU programme could for instance increase its visibility by publishing links to their data in the national database on their own website.

Research institutions involved in publishing

Most reports and scientific publications shown in **Figure 6** are produced by researchers from SLU and Stockholm University⁵. The reports are led by 20 researchers at the SLU, SU ACES, the former Agency for Fisheries (Fiskeriverket), Uppsala University, Umeå University, and the County of Gävleborg. The scientific publications are led by 11 researchers at three Swedish universities: i.e. SLU, SU ACES, and Umeå University. Many of the scientific publications and reports are produced in connection with the R&D focus projects that were awarded from NV until 2011 and SwAM until 2017.

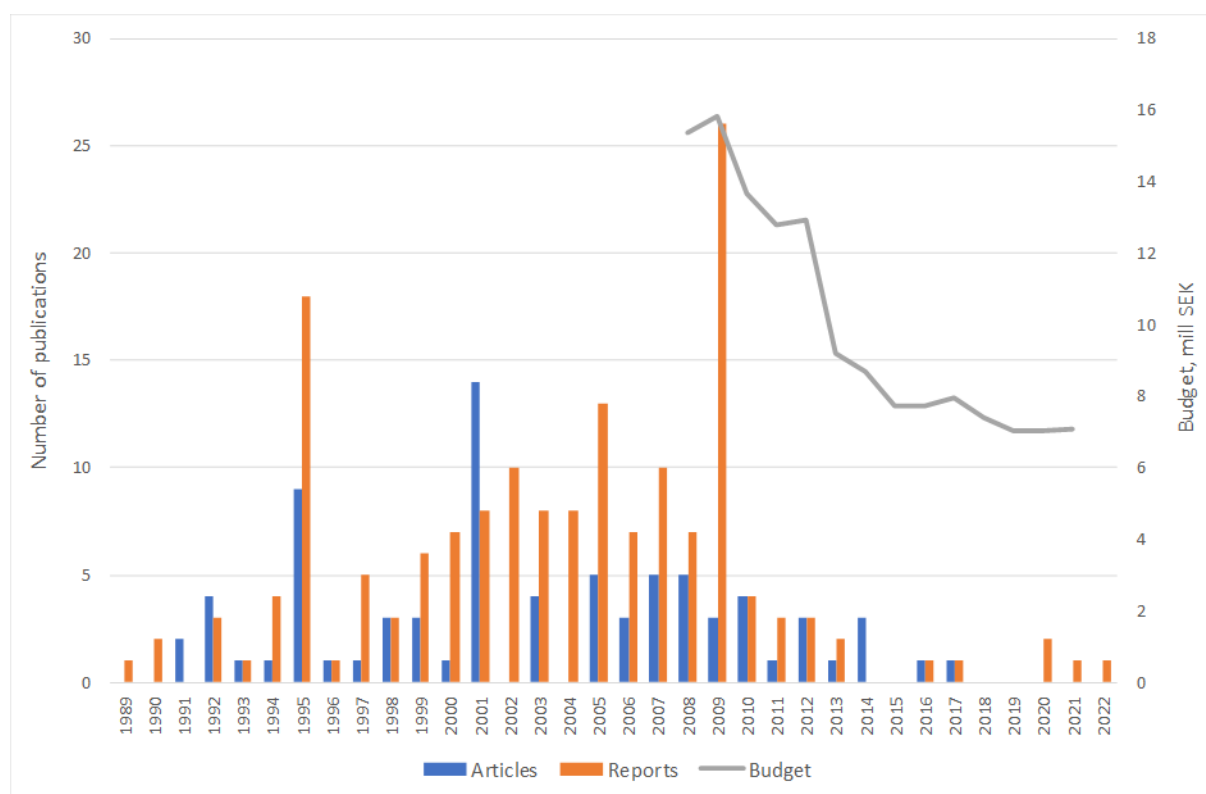


Figure 6. Number of reports and scientific articles per year listed on IKEU's home page. IKEU's annual budget 2008-2021 is indicated on the second y-axis.

⁵ Department of Analytical Chemistry and Environmental Science (hereafter abbreviated to SU ACES)

Research themes addressed in the publications

Key issues of the scientific studies have been on the effect of liming on water chemistry and sediment pools, species composition (lakes: plankton, littoral invertebrates, fish; rivers: diatoms, benthic invertebrates, fish), community structure/biodiversity, and productivity. The monitoring data are also compared with paleolimnological data.

There are several reports on mercury in perch and results from test fishing and electrofishing. Other key issues assessed in the reports are on the effects of excessive liming, termination of liming and acid episodes on water chemistry, including aluminium fractions. The reports to some extent also include recommendations for future liming activities considering the decreased deposition of acid rain.

3.2.2 Scientific quality

Scientific publications that have undergone peer-review are already proved to be of good quality.

Regarding reports, it is beyond the scope of this evaluation to assess the quality and reliability of each individual piece of work. Some general thoughts/observations:

- A possible weakness is that the IKEU project group apparently lack control on whether liming practices at the IKEU sites are carried out in an optimal way. If the water chemistry targets are not achieved (or over-achieved) due to insufficient liming (or over-liming), evaluation of biological target achievement becomes somewhat meaningless.
- Reports and publications seem a bit "biased" towards specific themes (e.g., fish), whereas other topics are less represented. We would also have liked to see more integrated assessments across disciplines, i.e., taking an ecosystem approach rather than focusing on individual groups. The IKEU programme structure provides a huge potential in this regard, which is not fully utilised.
- A limiting factor related to international publication is that large-scale liming of acid water mainly takes place in Sweden and Norway. Hence, the topic may therefore have limited interest among scientific journals which targets a broad international audience.

3.2.3 Summary

Observations / assessment:

- IKEU time series have been employed in research, both in terms of reports and scientific papers, but not to their full extent and potential.
- The dissemination activity has decreased over time, mainly due to cuts in funding. Only four reports and no papers are published by IKEU since 2017.
- In later years, there is a lack of integration across disciplines, i.e., IKEU studies that take a whole-ecosystem approach. Chemistry, phytoplankton/diatoms, invertebrates and fish are often treated separately.

- Also, there are hardly any examples of integrated analyses within IKEU that connect lime treatment methodology to achievement of chemical and biological goals.
- After 2009 few data analyses have been reported by IKEU. It appears that the IKEU monitoring data may have been used in scientific analyses and reports, but that they were not accredited to IKEU.
- The lack of use is not related to the scientific quality of IKEU's data, which is overall high, but probably rather due to the lack of knowledge of their existence.
- IKEU is often not credited on websites and in reports where in addition to data from national monitoring programmes IKEU data were used. This reduces the visibility of the programme within national and regional environment agencies, as well as towards the general public.

Recommendations:

- IKEU's activities must be expanded from pure data collection to include data processing and dissemination of results to a wide audience.
- More funds should be allocated to annual reporting of main results from the monitoring and R&D projects that aim for larger integrated syntheses and scientific publications.
- The IKEU programme could increase its visibility by more actively publish information and links to their data repositories on their own website.

3.3 Management support and communication

IKEU's third and fourth main objective (management support and communication) are closely linked and will be assessed together in this chapter.

The third main objective is to "Produce knowledge for national and regional authorities that contributes to efficient and science-based management of liming activities", whereas the fourth main objective is to "Communicate results, knowledge, and conclusions from the programme in ways that are adapted to the users' needs". The questions from SwAM (cf. section 1.5) addressed in this section are:

Q2: What are the general knowledge needs of SwAM, the County Administrations and the liming community in relation to long-term effects of liming, development of existing liming practices, and the regional follow-up of liming effects, and what role does the IKEU programme have in this?

Q7: To what extent have IKEU's data (time series) been used in environmental monitoring, and are the generated data sets compatible with the environmental monitoring programme area "Freshwater"?

Q8: To what extent has knowledge generated within IKEU been used by the liming community and other management areas?

Q10: Are the results from the programme generalisable to operational liming activities?

Q13: Will a continuation of the time series add new knowledge about the long-term effects of liming, and if so, which time series?

Q14: Will a continuation of the time series add new knowledge about other knowledge areas such as diffuse anthropogenic influences, eutrophication, climate changes, acidification, etc.?

3.3.1 How has IKEU contributed to fill the knowledge needs?

Knowledge needs identified from stakeholder meetings

Based on interview meetings with Swedish Agency for Marine and Water Management (SwAM) and the reference group for IKEU (**Appendix A2**), we have identified the following knowledge needs:

- Acidification assessment related to the national environmental monitoring programme area “Freshwater” (“Sötvatten”) and follow-up of the environmental goal “Only natural acidification”.
- Better tools to differentiate between natural acidity and anthropogenic acidification.
- Criteria for reducing or terminate liming in lakes and rivers.
- Protocols for how to assess ecological status in limed lakes and streams. Generally, the knowledge is better for water chemistry than for biology. Specifically, more knowledge is needed on the sensitivity to acidification of different life-stages of biological target organisms.
- Combined effects of acidification and other pressures (e.g., climate, alien species, increasing TOC levels, decreasing Ca levels and hydromorphological alteration), and how the liming strategy and environmental targets should be adjusted to meet these new challenges.
- How different drivers, including increased forest growth and more intensive forestry, contribute to acidification – and how it can be mitigated.

Science-based advice related to reduced liming

IKEU's main function is to investigate the long-term effects of liming on aquatic ecosystems and to improve liming operations and practices. The effects of liming on the ecosystem-level in lakes and streams are well described in numerous reports and scientific publications, whereas IKEU's role as adviser in questions regarding improvement of ongoing liming operations and practices are less documented. The role as adviser for operational liming activities seemed to be more prominent 15-20 years ago, than the situation is today.

The national liming strategy in the late 1990s and early 2000s was that if someone had started liming, the liming would continue without requirements for an acidification assessment. Until that time, the annual lime consumption in Sweden had not been reduced in line with the reductions in the deposition of acidifying compounds, which resulted in excessive liming of many lakes and rivers. This practice started to change around 2002-2004 and resulted in a reduction of annual lime consumption by around 40% from 2002 to 2009 (**Figure 3**).

During that time, NV collaborated closely with IKEU to adapt the liming efforts to the actual acidification state of the waterbodies. IKEU applied their data series back to 1989 to make acidification assessments, which at that time was difficult to carry out by the regional authorities due to lack of long-term data. Hence, IKEU played an important role to support decisions on liming cuts

based on acidification assessments. These studies were conducted in connection with EU's WFD that requires ecological status assessment of all surface waters in Europe.

Around 2005, there was quite a bit of debate regarding liming in Sweden. Acidification assessments were now performed by several parties, including the Water management boards which had been established in relation to the WFD implementation. According to the WFD the assessments should now include acidification status relative to reference conditions – not just the actual acidity. This led to adaptation of liming practices, now focusing on anthropogenically acidified, rather than naturally acidic water bodies. IKEU was an active part in this process as premise provider to NV. Lime consumption levelled off after 2015, but further cuts may be relevant since there are still a considerable number of acidic lakes and streams that are limed even though they are not anthropogenically acidified (“Målsjöundersökningen”, Fölster et al. 2011; “Målvattendragsundersökningen”, Fölster et al. 2020).

Present situation

Management support and communication (Objectives 3 and 4) are not financed separately but must be covered by the project management budget (**Table 1**). This means very little resources can be set aside for reporting and web updating, which are major communication channels for a project like IKEU. It is still expected that IKEU is represented at national liming meetings (“Kalkhandläggarräff”) and Norwegian-Swedish acidification/liming seminars, but without extra funding for R&D projects there have been little new results to present at these meetings.

IKEU's visibility and role as knowledge provider to the national and regional authorities responsible for liming of acidified waters has gradually decreased over the past 10 years. Several factors may have led to this, especially the reduced funding of the programme since 2013 (**Table 1**). Also, the shift in project ownership from NV to SwAM in 2011 seems to have weakened the links between IKEU and those who currently are responsible for preparing strategies and making decisions related to the operational liming activities.

Today, the authorities responsible for the liming activities (SwAM and the County Administrations) to a greater extent tend to engage other actors instead of engaging competences within IKEU (Drakare et al. 2022). There might be several reasons for this but omitting the IKEU researchers from these types of assessments has over time weakened the role of IKEU as a national competence centre on liming of acidified waters.

The number of R&D focus projects (integrated assessments, syntheses) decreased significantly after 2013, and since 2017 no focus projects have been awarded (**Table 1**). Such projects are prerequisites to properly assess whether the existing liming strategies serve their purpose, and thereby to meet the chemical and biological targets of the waterbodies.

In the current situation, the IKEU programme can only to a limited degree address the knowledge needs among regional and national environmental authorities due to budget restrictions and possibly also a reduced priority of IKEU within SwAM's organisation. Even though acid deposition has decreased significantly over the past few decades, there is still a significant knowledge requirement related to how to achieve the most optimal ecological and economic liming strategies in a time with a gradually reduced liming demand.

3.3.2 Applicability of IKEU results for operational liming activities

Since IKEU no longer has resources to run R&D projects, the amount of new knowledge that is presented from IKEU is limited. This is an apparent paradox given that more knowledge is needed to reduce liming in accordance with environmental targets, and that the necessary competence for making such assessments actually exists within IKEU. Also, IKEU's reference group expresses that IKEU should be involved more in the assessments regarding the need for liming than they are today.

IKEU's reference group characterises the meetings with IKEU as good in the way that they give a good overview of what IKEU is and where it can contribute. According to the reference group, knowledge about IKEU seems to be rather limited in many County Administrations, especially among the recently employed staff. It appears that IKEU is somewhat isolated and forgotten, with limited opportunity to present its expertise and knowledge to a wider audience of environmental managers and liming operators. This is seriously hampering the applicability of IKEU's results and competences for the operational liming activities.

The limited resources allocated to IKEU makes it difficult for them to provide expert advice to actors within the liming community. It also appears more natural for the County Administrations to ask for expert advice from SwAM directly, for example about where and when to reduce or stop liming. Alternatively, they carry out the assessments themselves or assign R&D projects to external consultants instead of engaging researchers within IKEU.

Data from IKEU are generalisable to assess the long-term effects of liming and water quality requirements of different target organisms. Results from sub-programme 3 (stations with terminated liming) can to some degree be generalisable to give advice related to reduced liming, but with the relatively limited number of lakes and streams included in the sub-programme it is not very suitable for regional assessments of the potential for reduced liming. Therefore, it is suggested in Chapter 3.1 to strengthen IKEU's sub-programme 3 with more sites where liming is planned to stop within the next few years. To take full advantage of the competences that lies within IKEU it is also an option to make new assessments based on IKEU's data supplemented with regional monitoring data from limed lakes and streams, as previously done by Fölster et al. (2011; 2020).

3.3.3 Use of IKEU's data together with data from other national monitoring programmes

Limed stations and reference stations (sub-programme 1 & 2)

Data from IKEU's non-limed reference stations (6 lakes and 11 rivers) are often used together with data from other trend stations, where the latter are sampled in two sub-programmes under SwAM's Monitoring Programme Area "Freshwater" ("Sötvatten"):

- Trend stations, rivers ("Trendstationer vattendrag"). Number of sites: 67.
- Trend stations, lakes ("Trendstationer sjöar"). Number of sites: 110.

In addition, IKEU lakes were included in the 2007-2008 survey of ca. 3 000 limed lakes with mitigation targets ("Målsjöundersökningen", Fölster et al. 2011). And correspondingly, IKEU streams were part of the 2010-2016 survey of ca. 1 500 limed streams with mitigation targets ("Målvattendragsundersökningen", Fölster et al. 2020).

The follow-up of the environmental goal “Only natural acidification” (“Bara naturlig försurning”)⁶ is based on data from several national and international monitoring programmes (Naturvårdsverket 2022). Among other things, the assessment of the scope of surface water acidification in Sweden made by Fölster et al. (2014b) served as a basis for an in-depth evaluation of the environmental goal. Here, IKEU’s non-limed reference stations were included as one of the datasets.

The IKEU sites are fewer and less representative (re. geographical distribution and freshwater types) than sites included in the large national monitoring programmes like the rotating lake survey and the trend stations in lakes and rivers (Fölster et al. 2014a). However, a major strength of the IKEU data is the long time series (>30 yrs.), which captures the period of significant recovery from acidification during the 1990s, and that it combines water chemistry data with extensive sampling of biota, which allows assessment of ecosystem-level effects. Furthermore, the acid reference sites in IKEU represent a special value, because there are few (non-limed) acidified sites with long-term comprehensive biological monitoring (Fölster et al. 2009).

Moreover, IKEU sites generally had higher sampling frequency compared with other sites included in “Målsjöundersökningen” and “Målvattendragsundersökningen”. Here the long-term IKEU data was important to evaluate between-year variations and uncertainties related to sampling frequency (Målsjöundersökningen: water chemistry sampled 8 times/year in IKEU lakes vs. 2 times/year in the other lakes, Målvattendragsundersökningen: IKEU streams sampled monthly vs. 6 times/year in the other streams).

With the long time series, high sampling frequency and the combination of chemistry data with extensive data on biota, IKEU also provides an added value to the regional follow-up programmes on liming effects, which in general have less frequent sampling, and fewer biological groups monitored, as well as shorter and less consistent time series.

3.3.4 Will a continuation of the time series add new knowledge?

IKEU’s combination of long-term (>30 yrs.) water chemistry data and whole-ecosystem biological data is quite unique, both in a national and an international context. This is an important argument in itself for continuing the monitoring of limed lakes and streams, including the reference sites at today’s level. In addition, a continuation of IKEU’s data series can generate new and updated knowledge related to several emerging areas with great relevance both for the liming community and environmental management in general (cf. the knowledge needs listed in Chapter 3.3.1).

3.3.5 Summary

Observations / assessment:

- There is still a high demand among water managers for knowledge related to liming of acidified waters; especially regarding (i) tools to differentiate between natural acidity and anthropogenic acidification and (ii) criteria for reducing or terminate liming in a safe and knowledge-based manner.
- IKEU seemed to interact more closely with the environmental authorities regarding liming questions 10-15 years ago than is the case today. This appears mainly to be caused by the

⁶ Administered by the Swedish Environmental Protection Agency (Naturvårdsverket)

significant budget reductions and a weaker connection to the current leading governmental body (SwAM).

- Since IKEU no longer has funds to run R&D projects, the amount of new knowledge that is presented from IKEU is limited.
- This is an apparent paradox given that more knowledge is needed to reduce liming in accordance with environmental targets, and that the necessary competence for making such assessments actually exists within IKEU.
- Major strengths of the IKEU data are the long time series, the relatively high sampling frequencies (e.g. compared with "Målsjöundersökningen" and "Målvattendragsundersökningen") and that it integrates water chemistry with several biological components.
- Data from IKEU's non-limed reference stations are often used together with data from two sub-programmes under SwAM's Monitoring Programme Area "Freshwater" ("Sötvatten") and were also included in the surveys of limed lakes and streams with mitigation targets ("Målsjöundersökningen" and "Målvattendragsundersökningen").
- Data from IKEU are generalisable to assess the long-term effects of liming, water quality requirements of different target organisms and are also to some degree generalisable to give advice related to reduced liming.
- A continuation of IKEU's data series (limed lakes and streams, including reference sites) can generate new and updated knowledge related to several emerging areas with great relevance both for the liming business and environmental management in general.

Recommendations:

- The competences within IKEU should be better utilised by national and regional water authorities by providing funds for R&D projects that address pressing knowledge needs within the liming sector.
- Introducing a simple annual reporting of main results from the monitoring activities will also be an efficient way to communicate recent results to HaV, the County Administrations and the general public.
- In cases where IKEU's stations are too few to make regional assessments of e.g., the potential for reduced liming, IKEU's competences could still be utilised by combining IKEU data with regional monitoring data from limed lakes and streams.

4 Programme organisation and format

Questions from SwAM (cf. Chapter 1.5) addressed in this section are:

Q1: How does the structure and results of IKEU correspond to the four main objectives of the programme (listed in Chapter 1.3)?

Q3: Is the structure of the IKEU programme effective in terms of steering/leadership, organisation, administration, and communication?

Q4: Are IKEU's objectives, which were identified in 2010, still correctly formulated regarding today's needs and state of knowledge?

Q5: What would be the minimum format of the programme in order to meet the needs required by SwAM and the liming community in general?

Q6: Consequence analysis of possible effects if the IKEU programme is increased, maintained, reduced, or terminated?

4.1 Programme organisation in relation to objectives

Current organisation

The IKEU programme involves a number of researchers from two departments at SLU (Dept. of Aquatic Sciences and Assessment, Dept. of Aquatic Resources) and SU ACES. The programme is led by two scientific project managers and one deputy project manager.

The external organisation consists of a **project group** and a **reference group**.

The **project group** for IKEU includes two representatives from SwAM, one representative from NV, and three representatives from the research group. The project group meets at least once a year to discuss plans, programme and budget for next year's activity. The mandate of the project group is to review results from the past year, make plans for the coming year, and to address possible problems that might arise. It can also be a forum to discuss possible R&D projects and adjustments in the programme. The project group is not considered as a steering body. The formal decisions regarding project scope and funding sits with the directors for the Department of Environmental Analysis and Department of Water Resources Management at SwAM.

The **reference group** for IKEU includes two representatives from the County Administrations and one representative from NV. The mandate of the group is not formally defined, but the main function is to serve as a forum for information exchange and communication of knowledge needs from the water management's side. There is one regular meeting between the reference group and IKEU's research group each year.

Suitability of current organisation to meet the programme objectives

IKEU's organisation is potentially suitable to meet all the four main objectives, but due to budget cuts the activity has been limited to just operating the basic programme (i.e., objective number 1). In other words, very little resources have been available to the main goals 2-4.

4.2 Efficiency of organisation in terms of steering and leadership

The transfer of responsibility for the national liming operations from NV to SwAM in 2011 seemingly resulted in a shift in the environmental authorities' relationship to IKEU. While IKEU seemed well anchored in NV's organisation related to their responsibility for acidification issues and liming, IKEU's role is less clarified in SwAM's organisation.

The responsibility for IKEU lies now with The Environmental Analyses Department, where the responsibility for the national environmental monitoring related to water lies. The Department for Water Resources Management, which, among other things, is responsible for the national liming operations is only sparsely involved with IKEU. This division is in a way logical in that IKEU is both about long-term monitoring and follow-up on effects of liming. However, none of the departments seem to take full ownership, even though representatives from both units (via the sections "Environmental monitoring" and "Aquatic biodiversity") are part of IKEU's project group. Thereby, they also miss the opportunity to take full advantage of the resources and potential that are embedded in the programme.

By having the national responsibility for liming of lakes and streams, the section for Aquatic Biodiversity at SwAM has close contact with the County Administrations that coordinate both the regional liming activities and the monitoring of liming effects. This provides SwAM with updated information on status and trends related to operational liming and a good overview of the regional monitoring programmes and the actors that are involved. Perhaps this leads SwAM to use some other resources (consultants, staff from the County Administrations) instead of IKEU, to investigate issues and provide decision support related to the operational liming activities.

As IKEU's monitoring programme is not directly linked to the operational liming activities nor to the effect-monitoring on the county level, it might be perceived somewhat isolated, distant, and perhaps in some cases also less relevant for actors within the liming community at national, regional, and local level.

If this is the case, it is unfortunate for several reasons. There are probably too few resources among the County Administrations to process and analyse data from the regional follow-up programmes. In addition, the liming community misses an opportunity to utilise the resources and knowledge that IKEU has acquired through more than 30 years of monitoring and assessment in limed lakes and streams.

4.3 Are IKEU's objectives still correctly formulated?

All four objectives are still regarded as important and relevant, but as elaborated on earlier in this report, limited funding over the past 10 years have made it difficult to fulfil objectives 2, 3 and 4. We suggest some minor adjustments in the project objectives:

- Modify objective 1 to: "Monitor long-term effects of liming on **selected** lake and river ecosystems on a national basis".
- Objective 3 and 4 are somewhat overlapping, and we suggest that they are merged into one objective: "Produce and communicate knowledge that contributes to efficient and science-based management of liming activities".

4.4 Is the programme format suitable to meet future needs?

The present format of the basic programme is close to a minimum, and there is already too little funding for data processing and reporting to main stakeholders at the national and regional level.

Should it prove impossible to increase the funding to allow more data processing and reporting, we suggest an amendment of sub-programme 3 (stations with terminated liming) and that sub-programme 4 (mercury in perch) is removed from IKEU but continued elsewhere in the national monitoring framework. A more detailed justification for the suggested changes in the programme structure is given in Chapter 3.1.

IKEU's combination of long-term (>30 yrs.) water chemistry data and whole-ecosystem biological data makes the programme highly suitable to address effects of acidification and liming in combination with other environmental pressures as climate change, intensified forestry and hydromorphological alteration. It is not clear if, or to what extent, the IKEU sites are affected by forestry, but it could be useful to carry out a mapping of land use in the catchments to find out. Although it is assumed that the forestry affects recovery from acidification, and the extent of the forestry has increased in recent decades, there is very little research on this. As a result, knowledge of how the forestry affects the need for liming is weak or absent.

A simple consequence analysis of different funding scenarios is given in **Table 3**.

Table 3. Simple consequence analysis of different funding scenarios for IKEU

<p>Increased funding:</p> <ul style="list-style-type: none"> - Annual reporting can be implemented. - Re-introduction of focus projects (R&D). - Expansion of sub-programme 3 with new sites with terminated liming. - Possible to take onboard new scientific issues (effects of climate, forestry, etc.). - IKEU's role as a national competence centre for liming of acidified waters will be strengthened. 	<p>Maintained funding:</p> <ul style="list-style-type: none"> - <i>Alternative 1:</i> Funding for annual reporting and new R&D projects must be allocated from other project activities, for instance a reduction or termination of sub-programme 3 and 4 (our recommendation; will strengthen IKEU's role as knowledge provider). - <i>Alternative 2:</i> "Business as usual". Maintenance of the basic programme, but with no annual reporting and R&D projects (not our recommendation).
<p>Reduced funding:</p> <ul style="list-style-type: none"> - The present format of sub-programme 1 and 2 (effects of liming in lakes and streams) is at a minimum in terms of number of sites and sampling frequencies (biological sampling every second year is not recommended). - Funds will be insufficient to implement annual reporting or re-introduce R&D projects, even if sub-programmes 3 and 4 are terminated. - It will not be meaningful to reduce the funding from today's level, which in reality only covers data collection and gives IKEU very little chance to serve as a national competence centre for liming of acidified waters. 	<p>Terminated funding:</p> <ul style="list-style-type: none"> - Valuable long-term data series will be lost. The combination of long-term (>30 yrs.) water chemistry data and whole-ecosystem biological data is unique. Very few such data series exist internationally. - SwAM and the County Administrations will lose a national competence centre for liming of acidified waters. - Maintenance and transfer of competences related to liming is extra important today, as many experienced researchers and water managers are approaching retirement.

4.5 Summary

Observations / assessment:

- IKEU's organisation is potentially suitable to meet all the four main objectives, but due to budget cuts the activity has been limited to just operating the basic programme (i.e., objective number 1).

- The transfer of responsibility for the national liming operations from NV to SwAM in 2011 seemingly resulted in a shift in the environmental authorities' relationship to IKEU.
- The responsibility for IKEU is now split between two units at SwAM, of which none of them seem to take full ownership of the programme.
- Thereby SwAM and the County Administrations also miss an opportunity to take full advantage of the resources and potential that are embedded in the programme.
- The present format of the basic programme is close to a minimum, and there is already too little funding for data processing and reporting to the main stakeholders.
- IKEU's combination of long-term (>30 yrs.) water chemistry data and whole-ecosystem biological data makes the programme highly suitable to address effects of acidification and liming in combination with other environmental pressures.
- Maintenance and transfer of competences related to liming is extra important today, as many experienced researchers and water managers are approaching retirement.

Recommendations:

- The ownership to IKEU should be clarified in SwAM's organisation.
- The roles and mandates of IKEU's Project Group (where SwAM and NV are represented) and the Reference Group (with representatives from NV the County Administrations) should be clarified and documented.
- The resources and competences within IKEU should be better utilised by the liming community at the national and regional level.
- IKEU still has important tasks to attend to, and the funding should be increased or at least maintained at the current level.
- Should it prove impossible to increase the funding, we suggest an amendment of sub-programme 3 (stations with terminated liming) and that sub-programme 4 (mercury in perch) is removed from IKEU but continued elsewhere in the national monitoring framework.
- All the four objectives of IKEU are still regarded as important and relevant, but we suggest a minor adjustment of project objective 1 and that objective 3 and 4 are merged. However, maintaining objectives 2, 3 and 4 requires that IKEU be provided with financial resources to implement them and that the authorities actually use IKEU to cover their knowledge needs.
- It will not be meaningful to reduce the funding from today's level, which in reality only covers data collection and gives IKEU very little chance to serve as a national competence centre for liming of acidified waters.

5 Overall assessment and recommendations

5.1 Main findings

Long-term monitoring (main objective 1)

IKEU's combination of long-term (>30 yrs.) water chemistry data and whole-ecosystem biological data makes the programme highly suitable to address effects of acidification and liming in combination with other environmental pressures. Such comprehensive, long-term combined water chemical and biological datasets are extremely rare, also in an international context. Data collection in IKEU is done according to well-established methods and the data are of good scientific quality. Except for littoral macroinvertebrates, which follows a separate sampling protocol (M42) and phytoplankton, which is sampled only once per year, IKEU's data are compatible with other national environmental monitoring.

The cut down in the number of stations over the past 10-15 years reduces the value of the dataset in terms of regional representativeness, but the programme still contains enough stations to be able to address long-term effects of acidification and liming on water chemistry and biology. The current number of limed sites and references must be regarded as a minimum, where further reduction will produce little else than anecdotal evidence. However, it is a question whether further monitoring of lakes and streams where liming was terminated more than 15 years ago will provide more knowledge regarding effects of reduced liming. Also, the link between liming and mercury levels in perch appears to be adequately documented. The arguments for sustaining this subprogramme within IKEU is thus less convincing today than 15-20 years ago.

Research and development (main objective 2)

IKEU's time series have been employed in research, both in terms of reports and scientific papers, but not to their full extent and potential. The dissemination activity has decreased over time, mainly due to cuts in funding. According to IKEU's website, only four reports and two scientific papers using IKEU data are published during the past ten years, and no papers are published after termination of focus projects (R&D) since 2017.

In later years, there is a lack of integration across disciplines, i.e., studies that take a whole-ecosystem approach. Chemistry, phytoplankton/diatoms, invertebrates and fish are often treated separately. Also, there are hardly any examples of integrated analyses that connect lime treatment methodology to achievement of chemical and biological goals.

It appears that the IKEU monitoring data from their reference sites may have been used in scientific analyses and reports but that they were not accredited to IKEU. The lack of use is not related to the scientific quality of IKEU's data, which is overall high, but probably rather due to the lack of knowledge of their existence. Moreover, IKEU is often not credited on websites and in reports from the national monitoring programmes where IKEU data are used. This reduces the visibility of the programme within national and regional environment agencies, as well as towards the general public.

Management support and communication (main objectives 3 and 4)

There is still a high demand among water managers for knowledge related to liming of acidified waters. However, IKEU seemed to interact more closely with the environmental authorities regarding

liming questions 10-15 years ago than is the case today. This appears mainly to be caused by the significant budget reductions and a weaker connection to the current leading governmental body (SwAM).

Since IKEU no longer has funds to run R&D projects, the amount of new knowledge that is presented from IKEU is limited. This is an apparent paradox given that more knowledge is needed to reduce liming in accordance with environmental targets, and that the necessary competence for making such assessments actually exists within IKEU.

Major strengths of the IKEU data are the long time series, the high sampling frequencies and that it integrates water chemistry with several biological components. IKEU's non-limed reference stations are often used together with stations in two sub-programmes under SwAM's Monitoring Programme Area "Freshwater" ("Sötvatten") and were also included in the surveys of limed lakes and streams with mitigation targets ("Målsjöundersökningen" and "Målvattendragsundersökningen").

Data from IKEU are generalisable to assess the long-term effects of liming, water quality requirements of different target organisms, and are also to some degree generalisable to give advice related to reduced liming. A continuation of IKEU's data series (limed lakes and streams, including reference sites) can generate new and updated knowledge related to several emerging areas with great relevance both for the liming community and environmental management in general.

Programme organisation and format

IKEU's organisation is potentially suitable to meet all the four main objectives, but due to budget cuts the activity has been limited to just operating the basic programme. The transfer of responsibility for the national liming operations from NV to SwAM in 2011 seemingly resulted in a shift in the environmental authorities' relationship to IKEU. The responsibility for IKEU is now split between two units at SwAM, of which none of them seem to take full ownership of the programme. Thereby SwAM and the County Administrations also miss an opportunity to take full advantage of the resources and potential that are embedded in the programme.

5.2 Recommendations

The basic programme with limed lakes/streams and reference lakes/streams should be continued at today's level to maintain the valuable long-term data records. If liming is terminated at some of the currently limed IKEU sites (which is likely to happen) the monitoring should continue, but then under sub-programme 3 "Terminated liming in lakes and streams". As termination of liming will be an important topic in coming years it is recommended to strengthen IKEU's sub-programme 3 with more sites where liming is planned to stop within the next few years. At the same time, one should consider removing sites where liming was terminated >15 years ago from the sub-programme and instead regard them as new reference sites. Sub-programme 4 "Mercury in perch" is proposed to be taken out from IKEU's basic programme, but as mercury in fish will be a concern for a long time to come, we strongly recommend that the monitoring should continue under a different umbrella. If it is decided to phase out sub-programme 4 from IKEU, it is recommended that funds are allocated for reporting / publishing results for the entire monitoring period.

IKEU's activities must be expanded from pure data collection to include data processing and dissemination of results to a wide audience. Hence, more funds should be allocated to annual reporting of main results and R&D projects that aim for larger integrated syntheses and scientific

publications. The IKEU programme could increase its visibility by more actively publishing information and links to their data repositories on their own website.

The competences within IKEU should be better utilised by national and regional water authorities by providing funds for R&D projects that address pressing knowledge needs within the liming sector. Introducing a simple annual reporting of the programs main findings will also be an efficient way to communicate recent results to SwAM, the County Administrations and the general public. In cases where IKEU's stations are too few to make regional assessments of e.g., the potential for reduced liming, IKEU's competences could still be utilised by combining IKEU data with regional monitoring data from limed lakes and streams.

The ownership to IKEU should be clarified in SwAM's organisation. Moreover, the roles and mandates of IKEU's Project Group (where SwAM and NV are represented) and the Reference Group (with representatives from NV and the County Administrations) should be clarified and documented on SwAM's website. The resources and competences within IKEU should be better utilised by the liming community at the national and regional level. IKEU still has important tasks to attend to, and the funding should be increased or at least maintained at the current level. Should it prove impossible to increase the funding, we suggest an amendment of sub-programme 3 (stations with terminated liming) and that sub-programme 4 (mercury in perch) is removed from IKEU but continued elsewhere within the national monitoring framework.

All the four objectives of IKEU are still regarded as important and relevant, but we suggest a minor adjustment of project objective 1 and that objective 3 and 4 are merged. However, maintaining objectives 2, 3 and 4 requires that IKEU be provided with financial resources to implement them and that the authorities actually use IKEU to cover their knowledge needs.

It will not be meaningful to reduce the funding from today's level, which in reality only covers data collection and gives IKEU very little chance to serve as a national competence centre for liming of acidified waters. Maintenance and transfer of competences related to liming is extra important today, as many experienced researchers and water managers are approaching retirement.

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Appendix A

A1. IKEU's objectives, 2004-2008

Objectives 2004–2008, reviewed by Munthe & Jöborn (2009):

1. To analyse the long-term effects of liming in acidified waters
2. To assess whether the Swedish liming operations restore ecosystems that, in terms of species composition and biological diversity, resemble the situation before acidification
3. To determine whether the liming activity leads to undesirable effects in lakes and streams
4. Provide data for the planning, implementation, follow-up and evaluation of liming by the County Administration or the Water Authorities
5. Provide data for the Swedish Environmental Protection Agency's long-term follow-up of liming and acidification
6. Provide support for the Environmental Protection Agency's advice to the County Administration on liming, termination of liming, acidification assessment, etc.

A2. Stakeholder meetings

Start-up meeting with SwAM and representatives from the IKEU project

Date: 28 October 2022

Participants:

- Michael Pohl, SwAM
- Erik Boström, SwAM
- Ulrika Stensdotter Blomberg, SwAM
- Kerstin Holmgren, SLU
- Marcus Sundbom, SU ACES

Interview meeting with SwAM

Date: 27 January 2023

Participants:

- Michael Pohl, SwAM
- Erik Boström, SwAM
- Ulrika Stensdotter Blomberg, SwAM
- Kristina Samuelsson, SwAM

Interview meeting with IKEU's reference group

Date: 3 March 2023

Participants:

- Stina Ausmeel, NV
- Sandra Woronin, County Administration (Länsstyrelsen)
- Pontus Ekman, County Administration (Länsstyrelsen)

Interview meeting with the IKEU's project group/leader group

Date: 9 March 2023

Participants:

- Stina Drakare, SLU
- Tobias Vrede, SLU
- Kerstin Holmgren, SLU
- Jens Fölster, SLU
- Joacim Näslund, SLU
- Marcus Sundbom, SU ACES

Meeting with the reference group (for our project)

Date: 21 March 2023

Participants:

- Michael Pohl, SwAM
- Erik Boström, SwAM
- Ulrika Stensdotter Blomberg, SwAM
- Kristina Samuelsson, SwAM
- Stina Ausmeel, NV
- Sandra Woronin, County Administration (Länsstyrelsen)
- Tobias Haag, County Administration (Länsstyrelsen)
- Johan Ahlstrom, County Administration (Länsstyrelsen)
- Stina Drakare, SLU
- Kerstin Holmgren, SLU
- Joacim Näslund, SLU
- Marcus Sundbom, SU ACES
- Cecilia Andrén, SU ACES

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