Summary of work activities

Andreas Rohringer

The ECDC Fellowship Programme

Public Health Microbiology path (EUPHEM), 2020 cohort

Background

The ECDC Fellowship Programme is a two-year competency-based training with two paths: the field epidemiology path (EPIET) and the public health microbiology path (EUPHEM). After the two-year training, EPIET and EUPHEM graduates are considered experts in applying epidemiological or microbiological methods to provide evidence to guide public health interventions for communicable disease prevention and control.

Both curriculum paths provide training and practical experience using the 'learning by doing' approach in acknowledged training sites across European Union (EU) and European Economic Area (EEA) Member States.

According to Articles 5 and 9 of ECDC's founding regulation (EC No 851/2004), 'the Centre shall, encourage cooperation between expert and reference laboratories, foster the development of sufficient capacity within the community for the diagnosis, detection, identification and characterisation of infectious agents which may threaten public health' and 'as appropriate, support and coordinate training programmes in order to assist Member States and the Commission to have sufficient numbers of trained specialists, in particular in epidemiological surveillance and field investigations, and to have a capability to define health measures to control disease outbreaks'.

Moreover, Article 47 of the Lisbon Treaty states that 'Member States shall, within the framework of a joint programme, encourage the exchange of young workers.' Therefore, ECDC initiated the two-year EUPHEM training programme in 2008. EUPHEM is closely linked to the European Programme for Intervention Epidemiology Training (EPIET). Both EUPHEM and EPIET are considered 'specialist pathways' of the two-year ECDC fellowship programme for applied disease prevention and control.

This report summarises the work activities undertaken by Andreas Rohringer, cohort 2020 of the European Public Health Microbiology Training Programme (EUPHEM) at the Norwegian Institute of Public Health (NIPH) in Oslo, Norway.

Pre-fellowship short biography

Andreas Rohringer started his academic career studying medical-pharmaceutical biotechnology (IMC Krems, Austria). During thistime, he received placements in Sydney and Edinburgh/Glasgow, working on West Nile virus and tick-borne encephalitis viruses and host immune responses. After graduating, he moved to Australia to complete a PhD looking at highly pathogenic strains of avian influenza (H5 and H7 isolates), and the interaction with the innate immune response at the Australian Centre for Disease Preparedness (formerly known as the Australian Animal Health Laboratory). Andreas began working on Nipah virus countermeasures at the International Centre for Infectiology Research (CIRI) in Lyon.

Stockholm, October 2022

While looking for a more applied way to use the skills gained through his academic career, Andreas was hired as a Senior Scientist of a diagnostic team supporting an outbreak of *Mycoplasma bovis* in New Zealand. In 2020, he returned to Europe to start his EUPHEM fellowship at the Norwegian Institute of Public Health (NIPH) in Oslo.

Methods

This report accompanies a portfolio that demonstrates the competencies acquired during the EUPHEM fellowship by working on various projects, activities and theoretical training modules.

Projects included epidemiological investigations (outbreaks and surveillance); applied public health research; applied public health microbiology and laboratory investigation; biorisk management; quality management; teaching and public health microbiology management; summarising and communicating scientific evidence and activities with a specific microbiological focus.

The outcomes include publications, presentations, posters, reports and teaching materials prepared by the fellow. The portfolio presents a summary of all work activities conducted by the fellow, unless prohibited due to confidentiality regulations.

Results

The objectives of these core competency domains were achieved partly through project or activity work and partly through participation in the training modules. Results are presented in accordance with the EUPHEM core competencies, as set out in the ECDC Fellowship Manual [1].

1. Epidemiological investigations

1.1. Outbreak investigations

1.1.1. Outbreak of Salmonella Enteritidis in Norway, 2021

Supervisors: Heidi Lange, Lin Brandal

The Norwegian National Reference Laboratory (NRL) for enteropathogenic bacteria at the Norwegian Institute of Public Health (NIPH) alerted the Department of Infection Control and Preparedness about a cluster of five cases with *Salmonella* Enteritidis (*S.* Enteritidis) infection belonging to the same whole genome sequencing (WGS) cluster, sequence type (ST) 11 and cluster type (CT) 5784 on 25 February 2021. The outbreak response group at NIPH coordinated the outbreak investigation in close collaboration with relevant municipal doctors, the Norwegian Veterinary Institute (NVI), the Norwegian Food Safety Authority's (NFSA) head office, regional offices, and local departments. In addition, the NFSA assisted the NIPH in conducting trawling interviews of the cases to identify a possible source of the outbreak.

In total, 30 confirmed cases with the *S.* Enteritidis outbreak strain (ST11 and CT5784) have been reported. All cases fell ill. Eight trawling interviews and 11 more targeted interviews revealed that 15/19 (78.9%) cases had consumed minced bovine meat or products containing minced bovine meat, while 8/19 (42.1%) had consumed uncooked minced beef. The NVI was asked for information on meat samples and sequences, and on 9 March 2021 *S.* Enteritidis isolate from bovine meat resulted in a positive match to the human outbreak strain (ST11 and CT5784). Following the positive match, items in storage were seized by the NFSA effective 10 March 2021, and food items were also recalled by the producer effective 11 March 2021. In addition, a Rapid Alert System for Food and Feed (RASFF) notification was issued on 11 March 2021 and linked to the Epidemic Intelligence Information System (EPIS) notification posted on 2 March 2021 (UI-704). This outbreak was linked to two cases in Denmark, three cases in Germany and 16 cases in France.

Role of the fellow: Andreas was involved in this outbreak from the first alert through the microbiological surveillance system, and worked under the supervision of Heidi Lange (Epidemiologist) and Lin Brandal (Public Health Microbiologist). He conducted the WGS analysis of both the sequences from the NRL and collaborating laboratories, with phylogenetic trees, minimum spanning trees, and single nucleotide variance analysis. He also analysed the trawling interviews and supported the investigation by mapping the cases. During the meetings, he took notes, updated the stakeholders on the investigation's progress and results, and wrote the outbreak report.

Training modules related to the assignment/project

EPIET/EUPHEM Introductory Course: The ten steps of outbreak investigation and questionnaire design, data entry/collection/analysis were covered during the course. The basics of study design and result interpretation were taught through lectures and case studies in groups.

Outbreak investigation module: This module gave a step-by-step blueprint for outbreak investigations. Building on the Introductory course, the fellows learned more in-depth concepts of study design, questionnaire design and data analysis (descriptive and univariate/stratified). Practical work included analysis of case studies in R and communication exercises.

[1] European Centre for Disease Prevention and Control. European public health training programme. Stockholm: ECDC; 2022. Available from: https://www.ecdc.europa.eu/en/publications-data/ecdc-fellowship-programme-manual-cohort-2021

Rapid Assessment and Survey Methods (RAS) module: During this module, fellows learned how to assess the risk in an emerging and developing public health emergency and communicate these assessments to the relevant stakeholders. The module also taught the use of mapping during an outbreak and how to interpret geospatial data.

Leadership and Management in Public Health module: The fellows were trained in leadership, communication, and management techniques in the course of this module. Building on the knowledge of the RAS module, the fellows learned how to address different audiences, lead, communicate with all personality types, and manage time and resources effectively.

Educational outcome

The fellow learned the practical aspects of an outbreak investigation following the theoretical education. He applied the knowledge gained through the training modules, from the detection of an outbreak to the outbreak investigation, analysis of the microbiological and epidemiological data, communication with stakeholders, intra-institutional and international collaboration, and management of time, resources and information.

1.2. Surveillance

1.2.1. Aeromonas species in Norway (2014–2018)

Supervisor: Ettore Amato

Aeromonas species are ubiquitous in aquatic habitats and cause many human infections after exposure. A retrospective study analysing demographics, geographical distribution, and hospitalisation of *Aeromonas* cases was conducted during 2014–2018 using laboratory-based surveillance data. Five hundred and three *Aeromonas* cases were identfied over five years with an average incidence of 1.9 cases per 100 000 inhabitants per year. *Aeromonas* was the cause of gastrointestinal infections (GI) in 69.8% of the cases (n=351), wound infections in 8.6% (n=43), and blood infections in 7.4% (n=37). While GI and wound infection cases peaked in the summer, blood infection did not follow a clear seasonal trend. Major isolated species were *A. hydrophila* (15.3%), *A. veronii* (10.7 %), and *A. caviae* (10.7%). Hospitalisation was reported for 81.1% of blood infections (n=30), 51.2% for wound infections (n=22), and 23.1% for GI infections (n=81). Risk factors for hospitalisation with GI infections were: (i) age group >65 years old (adjOR=3.10; 95% CI:1.39-6.93); and (ii) *A. caviae* species (adjOR=3.26; 95% CI:1.3-8.1). This study shows that *Aeromonas* infections are common throughout the year and type of infections suggests a diverse and continuous source of exposure. Future research on the potential environmental source of *Aeromonas* infections is recommended.

Role of the fellow: Under the guidance of the project supervisor Ettore Amato, the fellow organised and combined the data from 16 laboratories, identified and corrected mistakes, unified spelling, and created and assigned variables to facilitate data analysis. While initially, the data cleaning work was conducted in Excel, advanced variables like geocoding and classification of infection types and data analysis were conducted in STATA (descriptive, univariate, and multivariate analysis). The fellow was also responsible for writing the first draft of the manuscript and its consequent revisions.

1.2.2. Establishment of a register-based influenza surveillance system in long-term care facilities in Norway

Supervisors: Trine Hessevik Paulsen, Oliver Kacelnik

Influenza remains a leading cause of infectious death among elderly people. It poses a major challenge for long-term care facilities (LTCF) due to the susceptibility and frailty of the population. LTCF residents are an at-risk group for infections due to shared living quarters, potential exposure from caregivers, and an increased likelihood of serious disease outcomes. The severity of influenza outbreaks in LTCFs has been well documented. The influenza season 2020/21 ended prematurely due to the infection control measures introduced to combat the SARS-CoV-2 pandemic, which made influenza detections in the population rare. The easing of lockdowns and other infection control measures made a resurgence of influenza cases likely. Additionally, co-incidence and co-infections of influenza and SARS-CoV-2 could have led to an even more severe disease outcome as previously seen, and put a strain on the hospital infrastructure. Consequently, influenza surveillance was elevated to a COVID-associated pathogen, enabling the use of the Norwegian pandemic preparedness register, Beredt C19 in conducting enhanced influenza surveillance.

Previously influenza surveillance in LTCFs was monitored through mandatory reporting of outbreaks in healthcare institutions through the Norwegian outbreak report system, Vesuv. In addition, the vaccination status of Norwegian residents is collected in the Norwegian vaccine registry (SYSVAK). However, it is difficult or not possible to use SYSVAK to monitor specific population groups like healthcare workers (HCWs) and LTCF residents.

Firstly, to be able to define the residents of LTCF and staff, multiple databases were linked within the Beredt C19 framework. The Norwegian Surveillance System for Communicable Diseases (MSIS) laboratory database is a newly established registry where laboratories report all infectious disease test results directly to the registry in real time starting on 30 September 2020. Secondly, the NAV databases contain information on payments for residence at care facilities, and Individual-based Statistics for Nursing and Care Services (IPLOS) contains information on the use of municipal health facilities. Thirdly, the SYSVAK database is the Norwegian registry for vaccinations, the State Register of Employers and Employees (Aa-registeret) used for identifying staff working at LTCF, the Norwegian population registry and the Norwegian death registry.

After establishing the new surveillance system, it was trialled in the 2021/22 influenza season and compared to the Vesuv outbreak register. The new surveillance system was able to identify persons involved in all Vesuv-registered outbreaks and additionally detect cases not reported in Vesuv. The new LTCF influenza surveillance system is, therefore, fit for purpose and used to monitor cases in this especially vulnerable population.

Role of the fellow: Under the guidance of his supervisors, the fellow was responsible for the theoretical set-up of the system, definition of the population under surveillance based on available data sources and definition of the stakeholders. Andreas communicated the requirements to the data scientist. Together with the data scientist, Andreas solved problems and refined and maintained the system built in R. He maintained and adapted the surveillance system according to the feedback of all stakeholders. Furthermore, Andreas presented the results from the surveillance system in a weekly influenza meeting and provided data to a weekly influenza surveillance report.

1.2.3. Evaluation of the variable 'underlying disease' for COVID-19 in The Norwegian Surveillance System for Communicable Diseases (MSIS)

Supervisor: Astrid Louise Løvlie

When SARS-CoV-2 was first detected in Wuhan (China) in early 2020 and then later in Europe, it was essential to rapidly obtain comprehensive information on the first reported COVID-19 cases, in order to gain knowledge about the new disease and determine if people with specific underlying diseases were more vulnerable to severe disease and death. To collect this information, the European Centre for Disease Prevention and Control (ECDC) and the WHO Regional Office for Europe developed a standardised form for Member States to report COVID-19 cases to The European Surveillance System (TESSy). The reporting included information on the presence and type of underlying disease.

The Norwegian Institute of Public Health (NIPH) established surveillance for COVID-19 based on the WHO/ECDC reporting protocol. From 30 March 2020 (week 14, 2020), MSIS was used as the official surveillance tool for the number of reported COVID-19 cases in Norway. In addition, to enable monitoring of underlying disease among COVID-19 cases in Norway and reporting to TESSy, a new variable, 'underlying disease' was introduced in MSIS in April 2020. Due to the increased reporting burden from the clinicians, an evaluation of the variable 'underlying disease' in MSIS was needed to assess whether it fulfils the surveillance objectives.

Role of the fellow: The fellow and his colleague Ragnhild Tønnessen analysed the data collected via MSIS and compared it to other gold-standard sources collected through the Norwegian pandemic preparedness register (Beredt C19). Andreas was responsible for the analysis regarding reporting completeness over time and by county. In addition, the fellow produced graphs and contributed to writing the report detailing the findings and outlining recommendations.

1.2.4. Establishment of a registry-based national SARI surveillance system in Norway

Supervisors: Elina Seppälä, Trine Hessevik Paulsen

In October 2021, the control measures against COVID-19 were repealed in Norway. With the ambient temperature falling, non-COVID-19 respiratory infections were expected to rise. Detections of influenza virus and most other respiratory pathogens were markedly absent in Norway, while infection control measures designed to limit the spread of COVID-19 were in effect. A resurgence and the co-occurrence of SARS-CoV-2, influenza and other respiratory infections in hospitals were anticipated to threaten hospital capacity and human life. Therefore, the Norwegian outbreak and response team for COVID-19 was requested to set up a surveillance system for severe acute respiratory infections (SARI) to monitor the situation.

Organisations such as the World Health Organization (WHO) and the European Centre for Disease Prevention and Control (ECDC) provided Member States with guidelines for the surveillance and reporting of SARI cases. The WHO defines a SARI case as; 'an acute respiratory infection with a history of fever or measured fever of ≥ 38°C and cough; with onset within the last ten days and need for hospitalisation'.

The Pan American Health Organization (PAHO) in 2011, in addition to the more traditional case definition, also included recommendations concerning the use of diagnostic codes from the International Classification of Diseases, 10th revision (ICD-10) and guides on how to identify SARI cases based on ICD-10 codes. Recommendations include using J00 to J06 and J09 to J22 for upper and lower respiratory infections, respectively. The guidance document also points out that in addition to the code-based case finding, care should be taken that these cases also match the SARI definition (fever, cough and hospitalisation).

A comprehensive, passive, register-based surveillance system was set up in autumn 2021 using the Norwegian pandemic preparedness register for COVID-19 (Beredt C19). The surveillance system linked the Norwegian Patient Register (NPR), which contains all health-related information about Norwegian residents and the MSIS laboratory database, which contains all test results from Norwegian laboratories. The data from NPR is updated daily. It is case-based and contains a unique identifier per case, which enables data linkage with the MSIS laboratory database, which is updated twice per week once made available in Beredt C19. The data are stored and processed in the Secure Zone at the Norwegian Institute of Public Health (NIPH) and routinely published as part of the weekly COVID-19 report on the NIPH website.

Role of the fellow: Andreas took charge of the literature review for this project, looking both for the background, definitions, and comparable surveillance systems currently in use. He also helped to write the protocol and took part in NIPH and ECDC SARI network meetings.

1.2.5. Laboratory analysis of notifiable diseases during the COVID-19 pandemic

Supervisor: Pawel Stefanoff

In March 2020, in response to the COVID-19 pandemic, Norway implemented strict control measures to limit the spread of infection. Measures, including social distancing, improved hand hygiene, business closures and restrictions on travelling abroad, were maintained to varying degrees between March and September 2020. The long-lasting COVID-19 pandemic and response activities reduced the focus on other public health issues, including surveillance of other infectious diseases. Since April 2020, the Norwegian Institute of Public Health (NIPH) has published periodic reports to monitor the effect of the COVID-19 pandemic on The Norwegian Surveillance System for Communicable Diseases (MSIS) function (www.fhi.no/publ/2020/covid-19-msis/). These reports have shown a significant 50–60% reduction in reports of other communicable diseases to MSIS between March and September 2020, compared to the corresponding period of 2019.

This project aimed to compare the number of referrals for diagnostic testing of selected notifiable pathogens and the proportion that tested positive during the COVID-19 pandemic (March–September 2020) with a normal laboratory function before COVID-19 started (October 2019 – February 2020). To investigate the observed reduction of notifiable disease reporting, NIPH requested 22 medical microbiological laboratories in Norway to send information on referrals for diagnostic testing of 11 pathogens that represent the most frequently diagnosed infectious diseases in Norway. The request included data on the number of referrals, and the number tested positive from the primary and specialist healthcare by pathogen, month of sample collection and age group. The received data were added, cleaned, and analysed to compare testing referrals during the COVID-19 pandemic (March–September 2020) with the reference period (October 2019 – February 2020). After a large reduction in testing referrals for selected infectious diseases in March–April 2020, the referrals were partly restored, indicating that at least some of the problems were resolved. However, our investigation has documented some discrepancies, including changes in laboratory procedures reported by laboratories and abnormal trends for selected pathogens and age groups, which cannot be explained with certainty by changes in infection risk. Our data have several limitations and cannot fully explain the reduction in MSIS reporting. However, we recommend the routine use of test-based indicators to place MSIS reporting in the context of test activity. Based on the new quality assured MSIS laboratory database, we included data on nine pathogens for which data were sufficiently complete to analyse monthly trends.

Role of the fellow: The fellow was involved in the compilation, cleaning, and analysis of the dataset from the laboratories. In addition, Andreas conducted quality control analysis to verify the STATA output and conducted trend analysis over time. He also prepared the graphs for presentation and summarised all the major findings in the final report published on the NIPH webpage.

Training modules related to the assignment/project

EPIET/EUPHEM Introductory Course: This course introduced the fellows to the basics of surveillance systems used in public health, exploring data types, variables, and indicators. It introduced the fellows to descriptive and analytical data interpretation in STATA and R.

Multivariate analysis module: The fellows used R or STATA in advanced statistical data analyses for this module. It also introduced theoretical concepts of regression models and their evaluation.

Educational outcome

The fellow gained first-hand experience with big datasets, how to perform data cleaning and create variables. The fellow also performed descriptive, stratified, uni- and multivariable analysis. Further, these projects improved the fellow's manuscript and report-writing skills.

2. Applied public health research

2.1. Risk factors associated with prolonged convalescent excretion of non-typhoidal Salmonella in humans

Supervisor: Umaer Naseer

Non-typhoidal salmonellae (NT-*Salmonella*) constitute a significant cause of diarrhoea worldwide. *Salmonella* is generally transmitted through the faecal-oral route. Infection occurs through the improper handling of contaminated foods, which usually include raw beef, poultry, eggs, unpasteurised milk, and vegetables. NT-*Salmonella* gastroenteritis is usually self-limited. Fever generally resolves within 48–72 hours and diarrhoea within 4– 10 days. However, asymptomatic excretion of *Salmonella* is common after either symptomatic or asymptomatic NT-*Salmonella* infection. The median duration of excretion following infection is approximately five weeks.

The study aimed to investigate host and pathogen-specific risk factors associated with long-term shedding (LTS) of human non-typhoidal *Salmonella* in post-infection salmonellosis cases in Norway. All salmonellosis cases reported to the national surveillance system in 2019 were invited to the study. Participants submitted a stool sample and a questionnaire five-week post-initial samples. All samples were cultured, and the isolates were whole genome sequenced (WGS) to identify serotype, virulence- and antimicrobial resistance determinants. The data were analysed by descriptive statistics, measures of association and univariable logistic regressions, using two levels of 'length of shedding'; i) long-term shedding, positive sample at ≥ 5 weeks after initial sample, and ≤ 5 allelic differences compared to the initial sample; and ii) short term-shedding (STS), negative sample at ≥ 5 weeks.

Data from 273 study participants were included in this analysis. Of those, 25% (68/273) were categorised as LTS, and 73% (199/273) were categorised as STS and 2% (6/273) were reinfections. Looking at LTS prevalence by serotype, we observed that 45% (10/22) of *Salmonella* Agbeni or Bron isolates were LTS.

In contrast only 19% (5/27) for *Salmonella* Typhimurium or 23% (23/109) for *Salmonella* Enteritidis were classified as LTS. In addition, associations were found between the length of shedding and diarrhoea (p. 0.02) five weeks post-infection. Further associations were found between the age group 18–46 (p. 0.02) as well as lactose-free diet (p. 0.03) and the likelihood of LTS. We found a higher-than-expected proportion of LTS compared to the current literature. However, the small sample size affected our ability to detect other associations. More research is needed to investigate and substantiate the identified associations.

Role of the fellow: Andreas conducted the WGS assembly and analysis, both on MLST and cgMLST of over 300 isolates. The dataset was also used to find any virulence factors common to all long-term shedders. Then, the fellow merged the WGS data to the questionnaire data using the patient ID as a unifying variable. The data analysis then focused on the determining factors for LTS either in the microbiological or patient characteristics. The fellow presented the work at the annual One Health European Joint Project meeting (online) and summarised all the findings in a draft manuscript.

Training modules related to the assignment/project

EPIET/EUPHEM Introductory Course: Apart from the basis of epidemiology, this module also focused on formulating a scientific hypothesis as well as planning and conducting operational research in public health. Furthermore, the module introduced proposal- and report-writing to the fellows.

Multivariate analysis module: The advanced statistical module taught the fellows the theoretical basis and the practical implications of the multivariant analysis. The fellows explored the different regression models and how to choose the suitable model for the data and evaluate model fit to interpret the analysis results in practical case studies.

Educational outcome

Andreas gained experience in WGS assembly, creation of pipeline scripts, and WGS analysis. Further, he used the skills taught in various modules to use STATA for data cleaning, merging, sorting and performing uni- and multivariant analysis. He also gained more experience in the presentation of scientific work as well as writing manuscripts.

3. Applied public health microbiology and laboratory investigations

3.1. Hepatitis Delta Virus Real-time polymerase chain reaction (PCR) evaluation

Supervisors: Rikard Rykkvin, Kathrine Stene-Johansen

Hepatitis D virus (HDV) is a small, enveloped RNA virus that was thought to require Hepatitis B virus (HBV) for replication. However, recent information suggests that other viruses can fill this role too. The actual global burden of HDV is unknown. Global estimates suggest that 62–72 million individuals are currently infected with HDV. The diagnosis of HDV in Norway is also complicated by samples with late HDV gene amplification in the quantitative PCR (qPCR) method currently used at the Norwegian Institute of Public health (NIPH) HDV reference laboratory.

Here we summarise an evaluation of the HDV quantitative PCR (qPCR) method currently used at the HDV reference laboratory of the NIPH. We used data from the qPCR test results and the internal NIPH laboratory database to link information on test results, rulings and repeat tests. We evaluated the performance of the qPCR with a particular focus on late positive, defined as an HDV cycle threshold (CT) value of 30 or more. Overall, the method was well controlled. The histogram of CT values showed the expected normal distribution with a right-leaning tail. We also found a good correlation with CT and international units (IU) values calculated, indicating that the variance between the standard curves is within acceptable limits in the method's quantification range. Of the 746 samples tested, 61 samples (8.2%) showed a late amplification of the HDV gene, making the sample ruling challenging. However, with repeat testing performed, the agreement of two tests is enough to rule the sample positive or negative. For only 3/553 (0.5%) samples ruling could not be established even after repeat testing, showing that the HDV qPCR method could reliably produce repeatable results for 99.5% of tested samples.

As HDV is known for causing low-level chronic infections, it is unsurprising that CT and corresponding IU levels up to the limit of detection were observed, making consistent interpretation of CT/IU values challenging. Therefore, we recommended several improvements in data formatting, a robust guide for scientists for data interpretation, and external gold-standard testing for confirmation of late positive qPCR results.

Role of the fellow: As principal investigator, Andreas formulated the project methodology, and under the guidance of his supervisors, acquired the necessary data. Using STATA, he manually transcribed five years of HDV qPCR testing results into a dataset, and cleaned and linked the data to the HDV testing database. He, then, analysed the test results and corresponding patient IDs for trends in a descriptive manner. Finally, Andreas wrote a report detailing the findings and presented the results at the HDV laboratory team meeting.

Training modules related to the assignment/project

EPIET/EUPHEM Introductory Course: This course introduced the fellows to epidemiology and public health basics. Data analysis and result interpretation skills were taught as well. The course consisted of theoretical lectures and practical case studies where data cleaning and descriptive analysis were explained and practised.

Multivariate analysis module: The advanced statistical module taught the fellows the theoretical basis and the practical implications of the multivariant analysis. The different regression models and how to choose the suitable model for the data were discussed. Techniques were also taught to determine and evaluate model fit to interpret the analysis results.

Biorisk and Quality management module: In this two-day module, the facilitators and trainers taught the fellows the basis for a biological risk assessment and how to quantify and mitigate risk in laboratories. The second day was focused on quality assurance and quality control in laboratory processes with practical examples and experiences from presenters and facilitators, discussing both the theoretical aspects and the practicalities of biological risk assessments and quality management.

Educational outcome

The fellow could build on his previous experience with qPCRs and investigate the real-world performance of an analytical test, deepening his experience with data analysis and interpretation as well as his skill in report writing and giving practical recommendations.

4. Biorisk management

4.1. Biosafety level 3 induction

Supervisor: Tone Johansen

To work in a high containment level 3 laboratory in Norway, passing training and induction to work practices is mandatory. During this training, the fellows were taught about the legal basis for work with high-risk pathogens, the work routinely conducted at the biosafety level (BSL) laboratory at the Norwegian Institute of Public Health (NIPH), and the most common standard operating procedures. Further practical aspects included an exercise on how to identify pathogens and the diagnostic algorithms used to exclude high-threat pathogens. Following the theoretical introduction to the BSL-3 environment, including the personal protective equipment donning and doffing as well as entry/exit procedures, the fellows were scheduled for a practical demonstration and training inside the BSL-3 laboratory under the guidance of the scientists routinely working in this environment. This practical exercise included working in the class III biosafety cabinet, inactivating suspected highly pathogenic samples, RNA extraction, and a quantitative polymerase chain reaction (qPCR).

Role of the fellow: The fellow successfully participated in all the lectures and passed a quiz as well as a practical exercise.

4.2. Biorisk and Quality management module

Supervisor: Aftab Jasir

The objective of this module is to provide training on quality management in biomedical and public health laboratories according to ISO 15189 norm, and Biorisk management in biomedical laboratories. The module taught the fellows about the theoretical background of Biorisk assessments and quality management, and the working of a high containment laboratory with examples and additional literature and guides. The module also addressed practical aspects with case studies and problems as examples, in the form of a Biorisk assessment and an audit to be performed in the laboratories of the training sites.

Role of the fellow: Andreas contributed as a facilitator with the creation, review, and presentation of the lecture, 'Introduction to Biosafety levels, Mitigation and Performance'. He also helped amend and review the Biorisk presentations by Ragnhild Tønnessen. Andreas further participated in the module as a facilitator for the case study leading a group through the exercise. He attended the other lectures as an attendee and completed both homework assignments, the Biorisk assessment and the laboratory audit.

Training modules related to the assignment/project

Biorisk and Quality management module: In this two-day module the facilitators and trainers taught the fellows the basis for a biological risk assessment as well as how to quantify and mitigate risks in laboratories. The second day was focussed on quality assurance and quality control in laboratory processes with practical examples and experiences from presenters and facilitators discussing both the theoretical aspects and the practicalities of biological risk assessments and quality management.

Educational outcome

The fellow could build on his previous experience with Biosafety level 3 laboratories and fill gaps in the Biosafety theoretical and legal basis, and practical aspects of handling highly pathogenic samples. He helped shape the Biosafety and Biorisk lectures with input and feedback, where he gained a deeper understanding of risk assessments and mitigation measures. He gained experience with the organisation and design of the module, management of time and resources, presentation techniques and tools for audience interaction. Andreas also gained more knowledge in Quality management of laboratories and the laboratory audit process.

5. Quality management

5.1. EQA Bordetella Pertussis

Supervisor: Didrik F. Vestrheim

Pertussis (whooping cough) is a highly contagious acute bacterial respiratory infection caused by *Bordetella pertussis*, a gram-negative bacillus. Although the bacteria affect all age groups, it is most severe in infants. The symptoms of this disease include protracted coughs that can last for weeks and the hallmark intense paroxysm ending in an inspiratory 'whoop'.

B. pertussis is one of the leading causes of vaccine-preventable mortality worldwide due to its periodic resurgence, even in countries with high vaccine coverage. At the EU-level, *B. pertussis* infections are classified as a notifiable disease, although there are differences in reporting systems between countries. Therefore, surveillance of pertussis infections remains a critical part of informing notifiable disease strategies, identifying high-risk groups, and detecting and investigating outbreaks.

Suspect *B. pertussis* infections can be notified as clinical suspicion per ECDC and WHO case definitions, although many countries also report laboratory-confirmed diagnosis. These country-to-country variations make it challenging to compare incidence rates across Europe directly. Another complicating factor is the technical limitation of the routine PCR tests used to differentiate *Bordetella* species. In medical diagnostic testing, *B. pertussis*, *B. parapertussis* and *B. holmesii* are closely related species, making it difficult to distinguish due to the cross-reactivity of PCR probes. Further adding to the problem are non-standardised laboratory tests and reporting customs. A Europe-wide survey has highlighted these issues. More information about the Norwegian diagnostic laboratories is needed to evaluate the reporting rate of *B. pertussis* within the Norwegian laboratory network and in other European countries. The Norwegian Institute of Public Health (NIPH), in close cooperation with the Norwegian National Reference Laboratory, performs periodical external quality assessments of various diagnostic tests to ensure high technical compliance and comparability across Norwegian medical diagnostic laboratories.

The purpose of this external quality assessment (EQA) is two-fold – to facilitate the technical comparison of laboratories across the Norwegian public health networks; and to gather information on the technical aspects of testing to understand the notification rates of *B. pertussis* in Norway. All the diagnostic laboratories of Norway, participate in this EQA. The comparison between laboratories is essential for harmonising laboratory and reporting practices.

Role of the fellow: The fellow was responsible for compiling the diagnostic testing results from the EQA in Excel and the questionnaires submitted by the participating laboratories about testing methods and algorithms. Andreas analysed the results after extensive literature research and wrote an EQA report highlighting the most important results and recommendations for future action to harmonise testing across laboratories.

Training modules related to the assignment/project

Biorisk and Quality management module: In this two-day module, the facilitators and trainers taught the fellows the basis for a biological risk assessment and how to quantify and mitigate risk in laboratories. The second day focused on quality assurance and quality control in laboratory processes with practical examples and experiences from presenters and facilitators discussing both theoretical and practical aspects of biological risk assessments and quality management.

Educational outcome

The fellow gained further insights in conducting and analysing a national EQA, furthering his skills in writing reports and summarising a new field of research. He also gained further insights into the working of a national reference laboratory function and how to give advice and recommendations and engage participating laboratories.

6. Teaching and pedagogy

6.1. Nordic Mini Module

Supervisor: Ettore Amato

The Nordic Mini Project Review Module (NMPRM) is organised by the EPIET and EUPHEM fellows at the Public Health Institute of one of the Nordic countries. The module aims to allow the fellows to present and receive feedback on their projects from the Nordic public health network. In 2022, it was the Norwegian Institute of Public Health's (NIPH) turn to host the module. The responsibility was handed over from Sweden in 2021. Four fellows volunteered to organise the module: Ragnhild Tønnessen (EUPHEM, Cohort 2020), Andreas Rohringer (EUPHEM, Cohort 2020), Jeanette Stålcrantz (EPIET, Cohort 2020) and Lea Franconeri (EPIET, Cohort 2021) under the guidance of the training site fellowship coordinator Ettore Amato. The target audience for this Mini Module were EPIET and EUPHEM fellows from the 2020 and 2021 cohorts. In total, 31 persons participated. Thirteen fellows from the cohorts of 2020 and 2021 attended, eight EPIET fellows, five EUPHEM fellows, and 18 supervisors/invited experts facilitated the sessions. Overall, three fellows from Denmark, four fellows from Finland, four fellows from Norway and two fellows from Sweden presented their projects.

Role of the fellow: As a future organiser, Andreas participated in the handover meeting and lessons learned from Sweden in 2020 and, together with the Norwegian fellows, took responsibility for the NMPRM in 2021. Although deployed at the time in the Republic of North Macedonia, he took the opportunity to present his surveillance project (*Aeromonas* in Norway) and attend the NMPRM online. Andreas also prepared, sent out and summarised the feedback from fellows and facilitators via the Kobo toolbox.

6.2. Public Health Microbiology course

Supervisors: Adam Roth

To address the need for a microbiological education for the EPIET fellows, the EUPHEM fellows of Cohort 2020 agreed to create and present a Public Health Microbiology course as a peer-to-peer teaching project. This project aimed to teach the EPIET fellows the value of public health microbiology, recognise the relationship between microbiology and epidemiology, and understand the basic principles used in today's medical microbiology diagnostics.
This online module was designed to consist of eight one-hour lectures running from 28 April to 1 July 2022. The project also included external lecturers from the Robert Koch Institute and the Santé Publique France to cover areas the EUPHEM fellows were not proficient enough to teach. The course was well received with an average attendance of 19 persons, who awarded an average score of 8/10, with 10 being the highest score.

Role of the fellow: Andreas created two lectures, 'The introduction to Public Health Microbiology (PHM)' discusses the origins of epidemiology and microbiology, and presents the main disciplines for PHM. Moreover, a technical presentation on the polymerase chain reaction, discussing the fundamentals of the technique, including small case studies to learn the interpretation of expected results from this technique. Further, he was involved in creating the 'Molecular Biology and Virology' lectures. He reviewed and gave feedback on all the lectures presented in this course.

6.3. Biorisk and Quality management module

Supervisor: Aftab Jasir

The objective of this module is to provide training on quality management in biomedical and public health laboratories according to ISO 15189 norm and Biorisk management in biomedical laboratories. The module taught the fellows about the theoretical background of Biorisk assessments and quality management and the working of a high containment laboratory with examples and additional literature and guides. The module also addressed practical aspects with case studies and problems as examples, in the form of a Biorisk assessment and an audit to be performed in the laboratories of the training sites.

Role of the fellow: Andreas contributed as a facilitator with the creation, review, and presentation of the lecture 'Introduction to Biosafety levels, Mitigation and Performance'. He also helped amend and review the Biorisk presentations presented by Ragnhild Tønnessen. Andreas further participated in the module as a facilitator for the case study leading a group through the exercise. He attended the other lectures as an attendee and completed both homework assignments, the Biorisk assessment and the laboratory audit.

Training modules related to the assignment/project

EPIET/EUPHEM Introductory Course: This course introduced the fellows to epidemiology and public health basics. Data analysis and result interpretation skills were taught as well. The course consisted of theoretical lectures and practical case studies, where data cleaning and descriptive analysis were explained and practised. Part of this course was also a teaching and communication workshop highlighting how to communicate, techniques to be used, and tailoring the message to the audience.

The Management, Leadership and Communication in Public Health: In this module, fellows learn how to communicate effectively to different audiences such as national and supranational leaders in politics and public health, journalists, and public health professionals. Teaching was also a cornerstone of the module. The fellows learned about personality and learning types, preferred media to transport the message and how to construct talking points and take away messages.

Educational outcome

Andreas gained experience in organising, creating, and presenting teaching courses and modules. In addition, the practical didactic knowledge in this course cemented the theoretical principles taught in the Fellowship modules.

7. Public health microbiology management

7.1. Nordic Mini Module

Supervisor: Ettore Amato

The Nordic Mini Project Review Module (NMPRM) is a fellow-organised meeting to allow the EUPHEM and EPIET fellows to network and present their work to enhance collaboration and receive feedback from the Nordic public health network. In 2022, the Norwegian team hosted the module and the 31 participants.

Please see Section 6.1, Nordic Mini Module, for more information.

Role of the fellow: The fellows placed in Norway – Ragnhild Tønnessen (EUPHEM, Cohort 2020), Andreas Rohringer (EUPHEM, Cohort 2020), Jeanette Stålcrantz (EPIET, Cohort 2020), and Lea Franconeri (EPIET, Cohort 2021) – organised all aspects of the meeting in 2022. Andreas received feedback and organisational notes from the organising team in Sweden in 2020. After analysing the information received from Sweden and information from previous NMPRMs organised in Norway, the team scheduled meetings to track the tasks and progress. Andreas reviewed the questionnaires and emails designed to confirm attendance and project titles to help with scheduling. He also proposed a group distribution and timetable. Finally, Andreas organised, prepared, and summarised the feedback from attendees, which was handed over to Denmark for the next NMPRM in 2022.

7.2. Public Health Microbiology course

Supervisor: Adam Roth

The Public Health Microbiology course of Cohort 2020 was a peer-to-peer, fellow-driven teaching project. The aim was to present the basics of microbiological laboratory knowledge to the fellows in the EPIET pathway. It consisted of eight one-hour lectures split into basic microbiological disciplines and special technical lectures by EUPHEM Cohort 2020 fellows and international collaborators. For more information, please see Section 6.2, Public Health Microbiology course.

Role of the fellow: Andreas organised the module in collaboration with his colleague Daniela Michlmayr. He organised weekly meetings to catch up, discuss progress and challenges, made timelines, and communicated with the fellowship office and external presenters. Further, he was responsible for creating, maintaining, and caring for the course homepage on the ECDC internal virtual learning platform (EVA). Andreas was also responsible for the feedback and attendance of each lecture, as well as communication with the attendees.

7.3. WHO deployment in the Republic of North Macedonia

Supervisor: Mark Katz

In response to the COVID-19 pandemic, governments worldwide enacted strict control measures to limit the spread of infection. Although non-pharmaceutical interventions managed to keep the number of infected persons manageable in most countries, true relief was expected from the SARS-CoV-2 vaccine rollout at the end of 2020. To evaluate the real-world vaccine effectiveness post-marketing authorisation for the approved SARS-CoV-2 vaccines, the World Health Organization (WHO) initiated and funded a multi-country study at the beginning of 2021. The High Threat Pathogens (HTP) team at the WHO/Europe office in Denmark asked the ECDC Fellowship office for fellows to volunteer to support the implementation of the study in the participating countries. The fellows' role on deployment was to facilitate the implementation on the ground, help the in-country teams with the workload, and answer or escalate questions to the WHO/Europe team. In the Republic of North Macedonia (RNM), the study was conducted at sentinel hospitals involved in severe acute respiratory infections (SARI) surveillance; the public health institute of RNM led the effort with the support of the WHO.

Role of the fellow: During his time in RNM, Andreas worked with the RNM public health epidemiology team to establish the study, visited the participating laboratories, presented, and supported the team in recruiting the participating doctors and training activities. He also spent two weeks in the Virology Diagnostic Laboratory to oversee the whole genome sequencing workflow and sequence analysis. Further, he participated in the COVID-19 response by analysing risk factors for death in COVID patients and trained the RNM staff in map-making and R.

Training modules related to the assignment/project

EPIET/EUPHEM Introductory Course: This course introduced the fellows to epidemiology and public health basics. Data analysis and result interpretation skills were taught as well. The course consisted of theoretical lectures and practical case studies, where data cleaning and descriptive analysis were explained and practised. Part of this course was also a teaching and communication workshop highlighting how to communicate, techniques to be used, and tailoring the message to the audience.

Rapid Assessment and Survey Methods (RAS) module: During this module, fellows are taught the basis of rapid risk assessments with limited knowledge and risk communication to different audiences. This module highlights ECDC's standard operating procedure in these fast-evolving situations to identify priority areas and effectively communicate necessary information to the stakeholders.

The Management, Leadership and Communication in Public Health module: During this module, fellows learn how to communicate effectively to different audiences such as national and supranational leaders in politics and public health, journalists, and public health professionals. Different personality and management styles are discussed in theory and practised in a controlled environment.

Educational outcome

Andreas learned how to manage projects effectively, communicate, and manage workloads in collaboration with different individuals with unique skills, backgrounds, and expectations. These projects also were a great lesson to use the theoretical knowledge from the modules in communication strategies in practice, primarily focusing on language and specific requirements for each audience group.

8. Communication

Publications

A. Rohringer, H. Syre, S. Hyllestad, E. Amato, A laboratory-based cross-sectional study of *Aeromonas spp.* infections in Norway, 2014–2018, *Manuscript submitted and under peer-review, Journal Water and Health, June 2022*

A. Rohringer, L. Veneti, E. van Boetzelaer, H. M. Lund, Z. Nordeng, E. MacDonald, U. Naseer, Risk factors associated with prolonged convalescent excretion of non-typhoidal *Salmonella* in humans. *Manuscript in preparation*

Reports

Outbreak Report**:** Outbreak of *Salmonella* Enteritidis linked to beef, Norway, January to April 2021
Public Health Management: Rekvisisjoner for laboratorieanalyser av meldingspliktige sykdommer under covid-19 epidemien
EQA: Pertussis Ringtest Report
SUR: Influenza Surveillance in LTCF Protocol
SUR: SARI Surveillance Protocol
SUR: Description and evaluation of the variable 'underlying disease' for COVID-19 in The Norwegian Surveillance System for Communicable Disease (MSIS)

Conference presentations

A. Rohringer, L.T. Brandal, H.M. Lund, A. Wester, P. Katsiouleri, T. M. Berglund, C. Sekse, B. Bergsjø, G. S. Johannessen and H. Lange, Outbreak of *Salmonella* Enteritidis linked to beef, Norway, January to April 2021
Poster Presentation, ESCAIDE 2020, 24–27.11.2020

A. Rohringer, L. Veneti, E. van Boetzelaer, H. M. Lund, Z. Nordeng, E. MacDonald, U. Naseer, Risk factors associated with prolonged convalescent excretion of non-typhoidal *Salmonella* in humans.
Poster Presentation, One Health EJP Conference, 9–11.06.2021

Other presentations

A. Rohringer, L. Veneti, E. van Boetzelaer, H. M. Lund, Z. Nordeng, E. MacDonald, U. Naseer, Risk factors associated with prolonged convalescent excretion of non-typhoidal *Salmonella* in humans.
Oral presentation, MoMir Consortium final meeting, 10–11.05.2021

A. Rohringer, L. Veneti, E. van Boetzelaer, H. M. Lund, Z. Nordeng, E. MacDonald, U. Naseer, Risk factors associated with prolonged convalescent excretion of non-typhoidal *Salmonella* in humans.
Oral presentation Section Meeting (Foodborne Pathogens), 12.05.2021

PHM Lecture series: **A. Rohringer**, Introduction to Public Health Microbiology Lecture, 28.04.2022

A. Rohringer, H**.** Syre, S. Hyllestad, E. Amato**,** A laboratory based cross-sectional study of *Aeromonas spp.* infections in Norway, 2014–2018**,** *Oral presentation* Waterborne pathogens group at NIPH 10.05.2022

PHM Lecture series **A. Rohringer,** Polymerase Chain Reaction, 23.06.2022

Other

N/A

9. EPIET/EUPHEM modules attended

1. EPIET/EUPHEM Digital Introductory course, 28.9.18 – 10.10.18, virtual
2. Operational Research inject day, 09–10.11.2020, virtual
3. Outbreak Investigation Module, 7–11.12.2020, virtual
4. MVA Module, 15–19.02.2021, virtual
5. Intro course part 3, 26.04–07.05.2021, virtual
6. Midterm Review, 24.06.2021, virtual
7. Project Review Module, 23–26.08.2021, virtual
8. BioRisk and Quality Module, 17–18.01.2022, virtual
9. Vaccinology Module, 14–18.02.2022, virtual
10. TSA Module, 04–08.04.2022 Rome, Italy
11. Management and Leadership Module, 13.06.2022, Stockholm, Sweden
12. Project Review Module 2022, 29.08–2.09 2022, Lisbon, Portugal

10. Other training

Nordic Mini Module 2020	23.03–24.03.2021
COVID Think Tank	11.11.2020, 01.02.2021
Webinar on Metagenomics for AMR	24.02.2021
ESWI Webinar: Vaccination in a COVID-19 era	20.09.2021
ESWI Webinar: Childhood Influenza vaccination and treatment in a COVID-19 era	27.09.2021
Royal Society meeting Genomic population structures of microbial pathogens	28.09–30.09.2021
Nordic Mini Module	7.03–8.03.2022
Introduction to Public Health Microbiology Lecture	28.04.2022
Introduction to Parasitology (PHM)	05.05.2022
Presentation of the Aeromonas project to the Waterborne pathogens group at NIPH	10.05.2022
Introduction to Virology	12.05.2022
Introduction to Immunology	19.05.2022
Introduction to Mycology	02.06.2022
Introduction to Molecular Biology	09.06.2022
Polymerase Chain Reaction	23.06.2022
Whole Genome Sequencing	30.06.2022

Discussion

Coordinator's conclusions

One of the main goals of the EUPHEM programme is to expose fellows to diverse and multidisciplinary public health experiences and activities, thus enabling them to work across different disciplines. This report summarises all the activities and projects conducted by Andreas Rohringer during his two-year EUPHEM fellowship (cohort 2020) as an EU-track fellow at the Norwegian Institute of Public Health (NIPH) in Oslo, Norway. The projects described in this portfolio demonstrate the extent of work undertaken by Andreas in field of public health microbiology. Starting his fellowship during the COVID-19 pandemic, Andreas was faced with many challenges both at the professional and human level. He suffered from the challenge but was able to turn the difficulties into opportunities to learn and grow as a public health professional and human being. Andreas contributed intensively to the training site response and resilience evaluation by participating in five different surveillance project/activities. He was also involved in several projects covering a wide spectrum of pathogens from *Salmonella* to *Bordetella Pertussis*, *Aeromonas sp*, influenza and Hepatitis Delta Virus. Andreas got engaged in networking with other fellows quite early. This led to the establishment of the Lecture Series on Public Health Microbiology (with his fellow cohort, Daniela Michlmayr), which was much appreciated by colleagues and scientific coordinators. He was also involved in the Nordic Mini Module organisation and took part as lecturer and facilitator for the BQM module. Andreas revealed sincere enthusiasm and excellent skills in teaching, something that he discovered during the fellowship. The EUPHEM Frontline Coordinator concludes that the fellow has succeeded in performing all his tasks and demonstrated all the core competencies required for graduation. I wish Andreas every success in his future career as a public health microbiologist.

Supervisor's conclusions

Andreas started the EUPHEM fellowship as an experienced scientist with developed skills in virology. He has shown a remarkable capacity to meet the challenges of the COVID-19 pandemic and has displayed eagerness to expand his knowledge and learn new skills. During his fellowship at the Norwegian Institute of Public Health (NIPH), Andreas achieved and demonstrated a thorough understanding of all the major core competencies of the EUPHEM programme, including domains within public health microbiology, epidemiology, outbreak investigation, surveillance, and research. His duties included project design and drafting protocols, descriptive and analytical epidemiological analysis, WGS laboratory work, manuscript and report preparation, and communication with the different stakeholders involved. Andreas has been able to work in parallel across different projects while coping with unexpected situations developing during the pandemic. During his second year of the fellowship, he quickly responded to a WHO European Regional Office request and was deployed for six weeks to the Republic of North Macedonia Public Health Institute, where he supported the High Threat Pathogens team. Andreas is also highly skilled in teaching and training. For instance, he has developed and delivered with great enthusiasm training materials on public health microbiology to his colleagues under the fellowship programme. The outputs of his projects have added to both national and international public health activities. It was a great pleasure to have Andreas as a EUPHEM fellow at NIPH, and we appreciate his contribution and achievements within the fellowship programme. We wish him all the best and every success for the future.

Personal conclusions of fellow

The two-year EUPHEM fellowship was an intense experience that allowed me to work and be part of a national public health institute during a pandemic. From a professional point of view, the fellowship allowed me to further my knowledge in infectious disease microbiology. I also gained broad and deep expertise in epidemiology, rounding off my education. I have no doubts that it will be the steppingstone to a great career in public health.

My Norwegian supervisors and colleagues were fantastic, and it was a pleasure to work with such a motivated and experienced group of people. I do not doubt that Norway is one of the best training sites for the fellowship. The Norwegian Institute of Public Health provided me with all the project opportunities I needed while handling a pandemic. With all the restrictions and measures in place, I could still conduct my fellowship and meet the deadlines, requirements and goals.

On a personal level, this fellowship during the pandemic has been a challenge, one that helped me grow as a person. I could identify the essential things in life for me, and the experience taught me to focus on what is truly important. Although very isolated in the first year, I made great friends and was able to find a permanent position with my colleagues here in Norway.

Acknowledgements of fellow

I want to thank my training site co-supervisor Ettore Amato, who provided stable and patient guidance throughout the stormy parts of the COVID-19 pandemic. It was a pleasure working with you during these two years, and I appreciated your feedback, advice, and calming influence above all things. I would also like to thank Umaer Naseer, my training site supervisor, for making time when there were none, and reviewing my documents through late nights and weekends to meet deadlines. I appreciate the pressure on you and your team during these pandemic years, and it meant a lot to me that you were able to contribute to my fellowship the way you did. I am grateful to my frontline coordinator Loredana Ingrosso for her feedback, for keeping me on track with all the objectives that needed to be fulfilled and for guiding me to a successful end of my fellowship. Also, a big thanks to my colleagues Ragnhild Tønnessen, Jeanette Stålcrantz and Lea Franconeri, and Elburg van Boetzelaer for a fantastic time and for keeping me sane.

Here, I would also like to acknowledge the Influenza group leaders, Trine Paulsen and Elina Seppälä, who adopted me and gave me work and purpose when all the other groups were drowning in COVID-19 work. Of course, I would also like to thank my EPIET and EUPHEM colleagues who came before me, Rob Whittaker, Lin Brandal and Tone Johannsen, for your open ears and helping hands! Finally, I would also like to express my gratitude to all my project supervisors who helped me find my way through the jungle of possible projects, and supported me in finishing on time and meeting the objectives.