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Population monitoring of Great Crested newts in a developmental area – use of ventral side photography and automatic image recognition

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Abstract

1. Amphibian species all over the world are in a decline due to climate change as well as human activities. To mitigate negative impacts on amphibians, especially in urban development areas, it is important to understand how human development impact the populations.

2. The goal of the study was to document the development of the Great Crested newt (*Triturus cristatus*) population in a developmental area with varying degrees of considerations to mitigate negative impacts on newts taken during the construction phase. The main objectives of the study were to assess changes during the last 10 years (2013-2022) in: 1) population size in the ponds based on (a) maximum count per capture session and (b) recaptures of identified individuals and capture-mark-recapture models; 2) average body mass of adults, to assess if there are indications of a decline 3) age structure. Based on identification of individuals from photos of ventral side patterns, I also investigated if there was evidence of movements between ponds, and the relative performance of manual versus automatic methods for individual recognition.

3. The data was collected from two ponds, Kjeller Gård pond (2013-2022) and Lundbydammen (2016-2022) The animals were captured in Ortmann-traps during several trapping sessions each year in each pond and the animals were photographed and weighed. The pictures were sorted manually and by use of the software Zooracle.

Population size for the population Kjeller pond - based on capture-“mark” (i.e., photo)-recapture data of adult females and males - was estimated with Jolly-Seber population models; both closed and open population models.

4. Estimations of the population size in the Kjeller pond showed a decrease in population size from 2013 to 2016, an increase towards 2019 and a decrease from 2019 to 2022. A total decline from 2013 to 2022.

Estimated population size from capture-mark-recapture models were consistently larger than the maximum number of individuals trapped during any trapping night (capture event), irrespective of year. However, the relative difference between maximum number of newts captured and estimated number of individuals was not constant among years. Thus, individual

identification and capture-mark-recapture modelling is required to give reliable estimates of population size.

The average body mass of the animals was shown to decrease from 2016 to 2022, and the females had a larger decline rate than the males.

There was a larger population of recaptures than new animals, but there was no recruitment failure to either of the populations for Kjeller gård pond or Lundbydammen.

There was only one observation of movements between the ponds, and only in this direction from Kjeller gård pond to Lundbydammen.

Manual identification of the animals for recapture mark recapture proved the most effective in this study. Manual recognition identified more than twice as many animals as Zooracle.

5. The population in both ponds seems to have been affected by human activity. The populations had a negative development, and active measures should be taken to prevent further decline in the populations.

Acknowledgments

I would like to thank both my supervisor Katrine Eldegard and project manager Jeroen van der Kooij for all help and support you have given me.

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A large thank you goes to the project manager Jeroen van der Kooij. To start such a project out of interest and continuing collecting data for more than 10 years is impressive to say the least. I am very grateful that I was allowed to be a part of your project and use your data to write my master thesis. The field work, the sorting of data and all that I have learned will follow me for the rest of my life, and I am eternally grateful for this experience.

Lastly, I want to thank my family, my friends, and my colleagues for supporting me, showing interest in my work, and pushing me to do my best during the writing process. A particular thank you to my mother, who has spent multiple hours re-reding my thesis; to make sure that what I wrote was understandable, but also for correcting my typos. Thank you to my sister for always being supporting and telling me to woman up in times I felt like giving up on my schoolwork. I also want to thank my dad and my grandparents for alle the support and encouragement to follow my own interest in academic studies. Lastly, I want to thank my uncle, aunt, and cousins in Kolbotn for letting me stay with you and making the travel route to the field site much more pleasant. Thank you!

Table of content

1. Introduction

The Great Crested newt (*Triturus cristatus*) belongs to the class amphibians (Amphibia). Great Crested newts are semi-aquatic, spending parts of their life in water and parts of their lives on land. The female and male animal have a dark color on their backs, where the male develops a crest during mating season, resulting in the name Great Crested newt. The male is generally smaller than the female. The ventral side is colored in a bright tone of yellow-orange, with dark or black markings. These markings are individual, much like a fingerprint is to humans. The females lay their eggs during spring/summer. The larvae hatch from eggs the same season, first developing gills, which later the same season develop into lungs. The animals then spend their three to four first years on land, before returning to water to reproduce and hunt smaller aquatic animals. They therefore depend on both the breeding pond as well as the surrounding terrestrial habitat to survive and thrive (Dervo, van der Kooij, 2020).

The Great Crested newt, like many other amphibians, are in a decline (Alford & Richards, 1999; Beebee & Griffiths, 2005; Houlahan, et. al, 2000; Houlahan, et al, 2001). Multiple factors contribute to the negative development of population size worldwide. Some of the most important reasons for the decrease in population size is loss of aquatic and terrestrial habitat due to human development projects; overrunning, exposure to fish (predation), contamination, and drought, as well as larger degree of isolation of the ponds (Dervo, et. al, 2021).

Newts, like other amphibians, move slower on land than in water. The reduced ability to move on land therefore makes the newts especially prone to be run over by traffic on roads close to wetlands (Glista, DeValut & DeWoody, 2008). Human development of buildings and infrastructure, especially roads, may result in large consequences for the local newt populations.

Loss of habitat is one of the most important reasons for decline in the newt populations. Since 1980 there has been a decrease in pond habitat locations by around one percent a year, meaning that one in three locations has been lost in the last 30 years (Dervo, van der Kooij, 2020). Many populations live in old fire ponds. In later years these ponds lost their purpose when water became available in pipes underground. In 1957 a law called “Brønneloven» was introduced and stated that all ponds and small waters had to be secured with a fence due to the drowning hazard. This led many landowners to fill the ponds instead of securing with fences, to save money (Dolmen, 2008). The loss of ponds has led to isolations of the remaining waters, and therefore loss of habitat for the newts. “Brønneloven» was abolished in 1997 (Brønneloven, 1997, §1-9).

The Great Crested newt only spends parts of its life submerged in water and is dependent on the surrounding areas to survive. It is especially important that they find areas to hide during the winter months to avoid freezing to death (Langton, Beckett & Jim, 2001). The young newts usually live on land for three to four years before returning to water, and therefore the land habitat is crucial for their survival. It is common to define the habitat to small populations of smooth and Great Crested newt like a circle with a radius of 300 meter around the spawning location. Around 70% of the population will hibernate within a radius of 100 meter surrounding the pond (Dervo & van der Kooij, 2020).

It is not only changes in human land use that affects the newts, but natural causes also play a role. Long drought periods in the summer, changed water level, long and cold winter, late spring and wet or dry spring can affect the population. Temperature and daylength has been found to affect growth and development in the Great Crested newt, where high temperature and increased day length have a positive effect on the larvae in the pond (Dolmen, 1983). The Great Crested newt is also dependent on a moist environment for movement on land, and dry conditions increase the risk of dehydration and thus mortality. A long and cold winter can result in freezing of hibernation areas, thereby killing the animals. Newts cannot survive in temperatures below freezing and is therefore dependent on the hibernation areas to be frost free (Dervo & van de Kooij, 2020).

Another important factor to consider is the depth of the pond. Ponds often have a steady stream of nutrients from the surrounding areas, and if the pond is stationary and have access to direct sunlight there is a risk of overgrowth. The ponds should therefore be greater than 2-2,5 meters deep, and have continuous access to fresh water (Vedum, et. al, 2004). Due to the increasing isolation of ponds, overgrowth is one of the larges threats in loss of water bodies.

The purpose of the study was to monitor and assess any changes in the Great Crested newt population situated in a developmental area by using ventral side photography for individual recognition to study the development of the populations in the area. Two ponds in close proximity to each other were studied, Kjeller gård pond and Lundbydammen in Kjeller (59°58'33.4"N 11°02'15.6"E), Lillestrøm municipality.

Development of new buildings and infrastructure has led to the loss of natural habitats surrounding the ponds, and therefore a loss of potential habitats for the newts. Some mitigation measures have been taken for Kjeller gård pond to protect the animals close to the developmental areas, where a guiding fence has been permanently put up to guide the newts away from the roads that where built. Protective, elevated walking patios has been made to avoid people from accidentally stepping on the newts, as well as a leading pipe to collect water from the surrounding houses. Unfortunately, for Lundbydammen there few or no mitigation measures have been put in place to protect the animals. On the contrary, a manhole (utility hole) has been installed right next to the pond, making it a pitfall trap for the newts and other small animals.

The purpose of the research was to study the development of the populations size, body condition (weight), age structure, movement patterns and performance of manual versus automatic methods for individual recognition. There has been an increase in digital recognition programs to identify animals, but many of these programs are expensive and makes it difficult for everyone to participate in this kind of data collection. I wanted to see if Zooracle, an app available for phones and tablets could be used for these types of data collection in an academic setting.

2. Method

2.1 Species: Great Crested Newt (Triturus cristatus)

The research species in this study is the Great Crested newt. They have been observed in both ponds but were most abundant in Kjeller gård pond. There were other species of amphibians in the ponds, where smooth newts (*Lissotriton vulgaris*), European common frog (*Rana temporaria*) and Moor frog (*Rana arvalis*) were observed yearly. These species will not be assessed in this thesis but was merely mentioned to inform of the presence of competition within the ponds.

2.2 Observation area

2.2.1 The ponds and surrounding areas

Observation of Great Crested newts and the development of the species in the ponds took place in the area surrounding Kjeller school in Lillestrøm. There were two ponds observed;

Kjeller gård pond (59.975999, 11.038084), marked as “1” in Figure 1 and Lundbydammen (59.977556, 11.033921), marked as “2” in Figure 1. Kjeller gård pond was an old fire pond, while Lundbydammen was a new pond created in 2016 as a preserving factor for the newts in the area. The surrounding area was a developmental area for residential building projects. This can be seen visually in Figure 1. Relatively little of the surrounding habitats were left in 2021 compared to 1950.

*Figure 1. Pictures of the study area of Kjeller gård pond (*59.975999, 11.038084), marked as “1” *from the year 1956 and 2010 (top), and both Kjeller gård pond and Lundbydammen* (59.977556, 11.033921), marked as “2” *from 2016 and 2021 (bottom). The pictures show the change in the development of the surrounding areas. (Kart, u.å.)*

2.2.2 Development

The area was relatively undeveloped up until 2010, with little change from 1956. Most of the development happened from 2010 to 2022, where the surrounding area changed considerably as seen in Figure 1.

Roads was built a few meters from the ponds, and a manhole (utility hole) was placed next to Lundbydammen pond with no consideration for the fall hazard risk. No guide fence was placed to shelter the animals from the road either, see Figure 2. The only protective measure the developers made was to put up a fence around the pond. This fence did nothing to stop the animals from walking directly into the road and building site. Jeroen van der Kooij put up a guiding fence made from plastic to guide the animals away from the roads and residential areas.

Figure 2. Picture from 2021. Lundbydammen is to the upper right in the picture. The developers placed a man hole a few meters from the pond which as of 2023 is leveled with the ground making it a pit fall trap for the animals. The only “protective measure” the developers did to protect the animals from the building site was to put up the fence as shown here. Picture by Jeroen van der Kooij.

For Kjeller gård pond consideration was taken, where permanent guide fences made from metal were put up to protect the animals from the nearby road that was built to the surrounding residences. A “newt-bridge” was built to guide the animals away from the road, see Figure 3. Residents in the area that I spoke with confirmed that the animals did use this bridge. A raised platform made as walking patio doubled as “roof” for the newts, so that the residents could walk to and from the buildings without the risk of stepping on animals on the way (not seen in the photographs).

Figure 3. The left picture is Kjeller dam gård during development from 2013 to 2016, plastic guiding fences have been put up to guide the animals along a safe path to and from the pond. The right picture is the back of the building facing Kjeller gård pond, the pond is straight ahead. The metal is the guiding fences for the animals, and the wooden path along the building is the newt bridge, which lead the animals away from the road to the left.
Pictures were taken by Jeroen van der Kooij.

To protect the pond from drought, one roof of the closest building had their roof gutter connected to the pond so that the rain was collected and transported to the pond. There have been discussions about connecting more roofs to the ponds, due to the increased drought periods early in the summers. A new part of the storehouse was connected to the water system during the summer of 2022.

Figure 4. Left: Kjeller gård pond with satisfactory levels of water. Right: The same pond in 2022, very low levels of water. Pictures taken by Jeroen van der Kooij

Figure 3 shows Kjeller gård pond, the first picture was from when the pond had a satisfactory amount of water. The pole seen in the right picture was placed there to be used as a measure of water height. This could not be used any capture day of 2022 due to too low levels of water.

2.3 Events of importance

The first mapping of the area was done the spring of 2013 before the development started (van der Kooij, 2013). The development of the area begun in the autumn of 2013 and continued to 2016. The development affected the terrestrial habitat to the newts and other amphibia in the area.

Excavations of 2/3 of Kjeller gård pond were carried out in 2018 as a preventative measure due to overgrowth. This was repeated in April of 2023 before the breeding season due to new overgrowth from the previous year. Some trees close to the pond were also trimmed. Removal of the trees has been discussed, due to the large water loss through transpiration.

Lundbydammen was excavated in 2015 due to overgrowth.

2.3 Capture

2.3.1 Background for data collection

The project was started by Jeroen var der Kooij as a collaboration with Kjeller school. The data was collected from 2014 to 2022 with the help of 6th grade students. The students were divided into groups of four to five and helped collect the data. The children gave the different animals names, and the same names were used in the data processing for this thesis. Some of the names were given by me, due to lack of names for some of the animals. Every individual animal that was photographed got a name where no name was the same. Names are therefore be used to refer to the individual animal. The data collection was also used to teach the children about the animals near their school. The children were very respectful towards the animals where no animals were hurt during the data collection. The children learned a lot about the animals before participating in the project and took part in the “dugnad” to remove overgrowth of the ponds.

2.3.2 Quantitative capture method of 2013

In 2013 a quantitative capture of the animals was done to estimate the population size in the pond before major development of the area. Guiding fence bucket traps was used to get a quantitative estimate of the population before the use of Ortmann traps for data collection.

The report made by Jeroen van der Kooij in 2013 gives an accurate explanation with pictures on the method (van der Kooij, 2013). The animals were captured using bucket traps along guiding fences towards the pond. It started early spring, where the animals were guided towards the multiple traps spread along the guiding fences. The animals were counted and released on the other side of the guiding fence, and thus avoiding multiple captures of the same animals. The total amount of animals could then be counted and gave a minimum estimation of the population in the pond in 2013.

2.3.3 Capture method from 2014 to 2022

The method used for observing the animals was capture by Ortmann traps as illustrated by me in figure 5 and was made by Alex Sattarvandi, Keith Redford and Jeroen van de Kooij. The traps were placed in the ponds the evening before observation. Ortmann traps are common in data collection regarding newts and have given good results in other studies (Nergaard, 2020; Dervo, et. al, 2014; Schulpmann & Kupfer, 2009; Skei et al, 2010). There were ten traps in Kjeller gård pond, and five in Lundbydammen, all numbered 1-10 and 1-5 respectively. The traps were placed evenly along the edge of the ponds, the same trap was placed in the same location every time it was used. There were also placed a piece of floating material for the animals to rest upon to prevent drowning. The traps were placed two days in a row weekly in Kjeller gård pond, and once a week for Lundbydammen. Which days of the week varied some, but mostly Tuesday and Wednesday was used for observation. The year of 2022 where I attended the fieldwork the data collection time lasted from 20th of April to 3rd of June. For the years from 2014 to 2021 there was variation in the number of days and weeks of observation (Appendix I, Figure17). The year of 2020 the animals where not individually photographed, but data on number of animals captured was collected. The data collection in the years of 2020 and 2021 were affected due to the Corona virus pandemic.
*All data used for this thesis belongs to Jeroen van der Kooij.

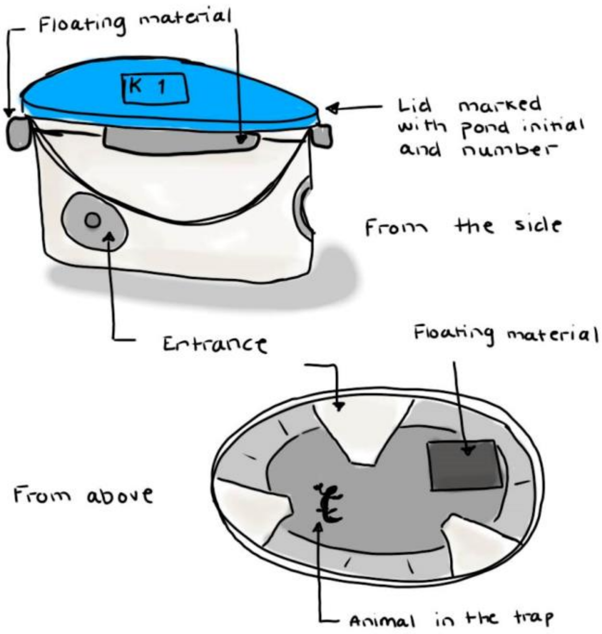


Figure 5. Illustration of the Ortmann traps used. The traps were handmade and consisted of an 15L bucket with multiple bottle neck entrances for the animals to pass through. The top illustration is the trap from a front profile, while the bottom illustration is the trap seen from above. The traps had floating material tied around the top part to avoid sinking, where the traps were made to be ¾ submerged in water.

2.4 Variables and data

The animals were counted, and sex was determined at the trap site for each of the animals in a manner displayed in Figure 6. This was done for both Great Crested newts and smooth newts. The number of animals were written down on a data sheet. The animals were collected into a medium sized container to be weighted after the collection from all traps. The weight was measured with a digital pocket weight, Aweight KS series Precision pocket scale. The animals were categorized as female, male and juvenile. The sex, weight and the name given to the animals by the school children was written into a different data sheet than for the counting per trap. Both data sheets were later written into an Excel file. The animals were written down into the Excel file randomly to the different traps, so the animal was not necessarily captured in the designated trap.

Figure 6. Me (Emily Thorbjørnsen) teaching the group of children that accompanied us on our data collection days. The animals were counted, and sex was determined for each animal before placed in a see-through container. Picture taken by Jeroen van der Kooij.

2.5 Photography and sorting

2.5.1 Photography and naming

For the observation of the animals a sieve was used to transfer the animals from the trap. From the sieve the smooth newts and the Great Crested newts was separated in to different medium sized, see-through containers.

For the data analysis the Great Crested newts were placed individually in a see-through box filled with water from the pond. The box had a white background for picture taking. A Nikon SLR camera was used to take pictures of the ventral side. Jeroen van der Kooij was the photographer of the pictures, I did not take on this task during field work. I took a few of the pictures in the absence of Jeroen on one occasion, but for the most part he continued to take the pictures to avoid unnecessary variables in the digital sorting. The animals were pictured with their heads to the right. The entire animal was photographed, but the focus was the patterned area from the chin to the cloaca. There was minimum one picture per animal, and if multiple pictures were taken, the best picture was chosen, and the rest deleted before photographing the next animal to avoid confusion during input into dropbox. This way the names and pictures would come in the same order, and sorting later was therefore not necessary.

The animals where designated gender, pond, date, and number for their observation name. Kjeller had the initial “K”, while Lundby had “L”. The year was written fully, the month was written first, then date. The last part of the name was the order of photography. The order number started at the beginning for each gender. E.g. FK20220521_01. This means that the animal was female (F), captured in Kjeller gård pond (K) in 2022, the 21st of May and was the first female to be photographed that day (_01). These names were placed under the pictures taken of the animals, see figure 14 for an example.

2.5.2 Manual sorting

The sorting was done manually by using an Excel file. The pictures were collected from Dropbox, where the picture of the animals with the observation name was printed. I used Paint to cut out the pictures separately and placed them in an Excel spread sheet. I sorted the spread sheet in name and number of the animals on top. Under in the next rows I sorted after year. The years were color coded to make sorting and comparisons easier. The first year all the animals from the first capture day were new, so I placed them next to each other. After that, all other pictures/animals had to be compared to the previous pictures. I always started by comparing the new picture to all the previous pictures, and if there was a recapture, I placed it under the year it was captured. This way all recaptures was placed in the same column. For the animals that were new, I placed them to the right, and a step down under the designated year and color row. This created a stair formation in the Excel sheet, see Figure 7. The names were placed on the top row. This was convenient if some pictures were left out, if the observation name was typed incorrectly into the data Excel sheet, or if some observations names were missing from the data Excel sheet. The observation names were written down into a Word document. This data was then used to sort the “recapture” data in the data spreadsheet.

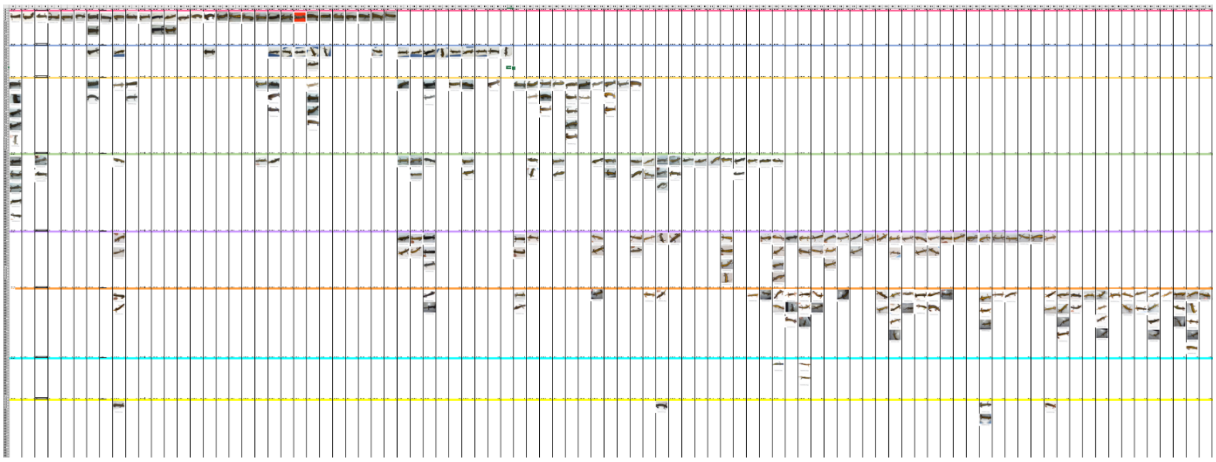


Figure 7. Example from the sorting of the females in Kjeller gård pond. The different colors symbolize different years, starting with magenta – 2014, lavender– 2015, yellow-2016, green-2017, purple-2018, orange-2019, turquoise-2021 and neon yellow-2022.

2.5.3 Digital sorting

Digital sorting was done by using a Samsung Galaxy S7 FE 5G tablet, and the app ZOORACLE. The pictures were retrieved from Dropbox and downloaded to the app individually. The app used a black and white pattern for comparison. When entering the picture of the animal into the app, there was options of color. I choose orange, and the entire orange spectrum from red to yellow, see Figure 8. This gave the most similar result to the colored picture, particularly for blurry patterns. If the entire spectrum was not selected, parts of the pattern would look different than the original. In some pictures the hands and feet of the animals would be in the picture and impossible to cut out. These limbs were orange and would become a part of the pattern. Fortunately, this did not seem to affect the comparison, where the app found the same animal with and without the limb pattern.

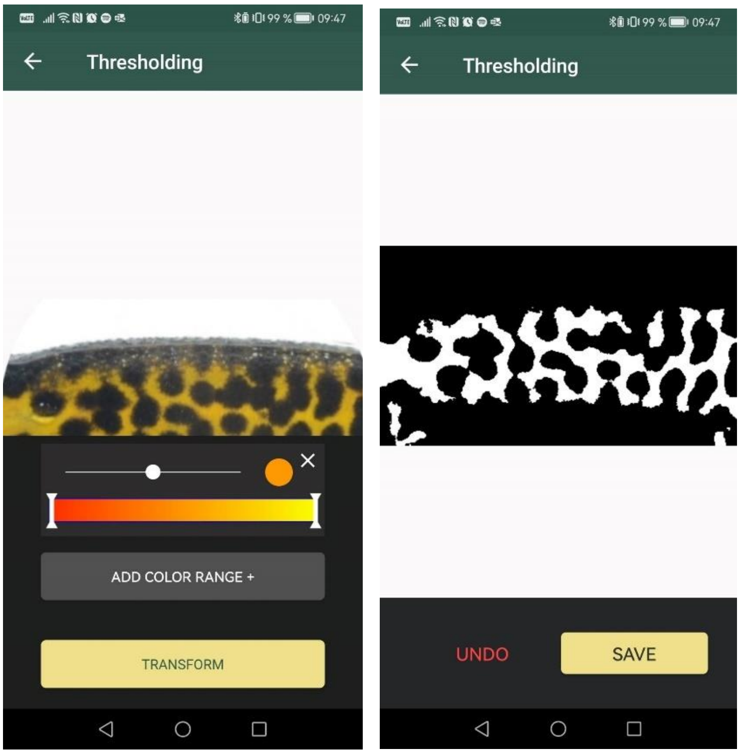


Figure 8. Here are two pictures of the app when selecting color. I choose orange, and then the entire spectrum of orange. This was done to alle pictures. The transformation led to the second picture, left, of a black and white version of the pattern. This was used to compare the patterns.

Screenshots from the Zooracle app (2023)

The app then had a comment section, which I used to write the observation name. The app named the inputs as “Individual001” and so forth that could not be altered, see Figure 9. This made the inputs inconvenient to read later, due to all the males, females, and juveniles for each date only show as numbers. The males were entered first, receiving the same number as for their observation name, but the females and juveniles received different numbers, and to find the different individuals I had to calculate which of the next number would be the animal of interest. The reason this was necessary was to be able to look at recaptures.

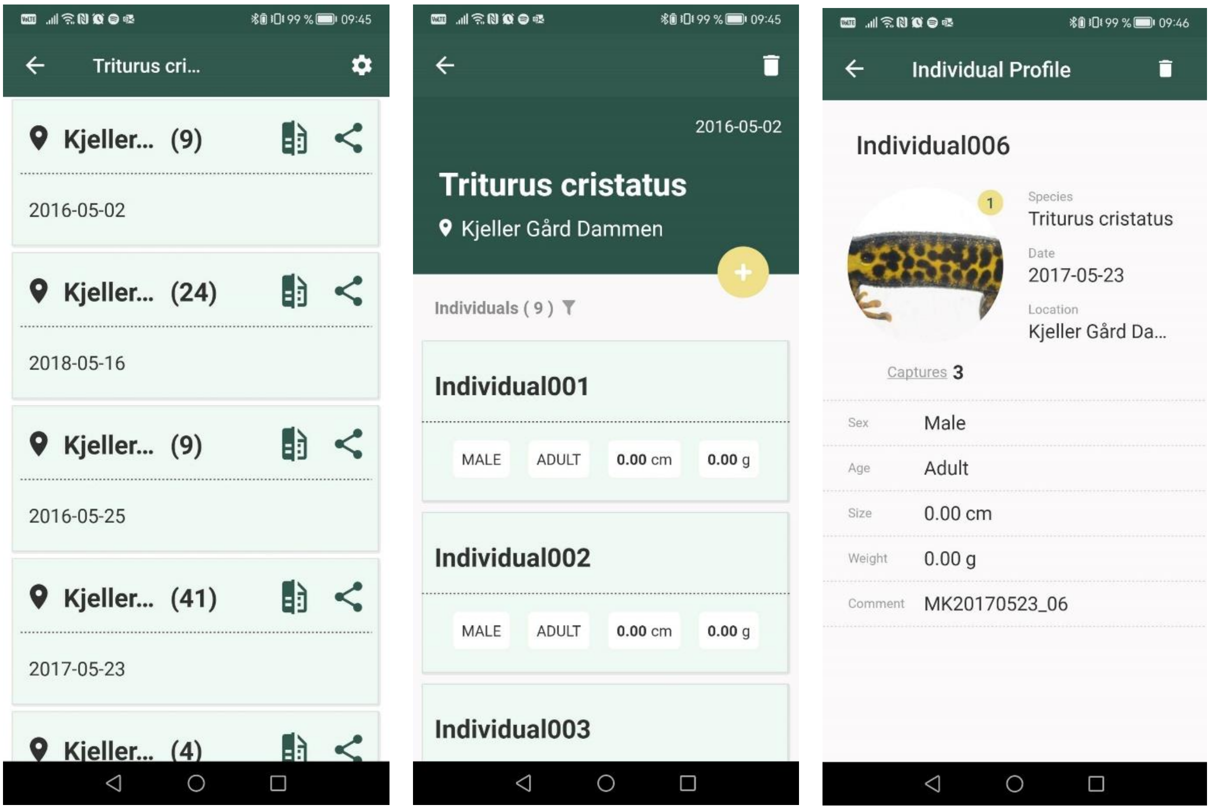


Figure 9. Here are three pictures of the app. The first picture(left) is a list of dates that I had made for each capture day. If you click one of the days, you get a list of the individuals you have entered (middle). Here is the list of the different inputs. I started with the males, then females and last juveniles. To see the names of the animals, the observation names, you click on an individual (right). Here you can see recaptures as "Captures X" and observation name in the comments. Screenshots from the Zooracle app (2023)

The Zooracle app compared the individual input to the database, producing five different options to select. At the beginning, multiple, options for the same picture due to lack of data to compare with, but after more than five inputs, the app always gave five different pictures. If one of the options was the same pattern as the individual, you could "match" the animals. The app had a sorting function, where the animals that was matched with each other showed as "recaptures "NUMBER"" for the individual animals. To find this information later after input of all the animals for a specific date, I had to look at each input individually. To find the animal of interest, I had to use the names given by the app, which did not coincide with the observation name, so the sorting done by the app was difficult to use.

To make the sorting easier, I wrote down the two identification names for each match, and later compared the names in a word document instead of going back to each individual input to check for matches. I sorted all the identification names that had a connection with each other in groups. An as example, if I had three individuals, and the first and the second was matched, then later the second and third was matched, I put these three in a group even though the first and third did not match directly. Some of the animals was sorted in multiple recapture groups, even though it was the same animal found by manual sorting because no connection was made with either one in each group by the app.

2.4 Statistical analysis

RStudio was used to carry out statistical analyses (version 4.2.3). Population size for the population Kjeller pond - based on capture-mark-recapture data of adult females and males - was estimated with a Jolly-Seber open population model, using the R package Rmark (Laake 2013). In contrast to closed population models, open population models allow for individuals entering the population from the "superpopulation" (via births and immigration). The R code for the population estimate followed the example in Paterson (2020). Difference on average body mass of females and males was analyzed with ANOVA F-test. Within-season trends in body mass was analyzed with linear regression, using body mass as response variable and sex, date, and the sex × date interaction as explanatory terms. Among-season trends in body mass was analyzed with linear regression, using body mass as response variable and sex, year, and the sex × year interaction as explanatory terms. Age structure, movements between ponds, and comparison between manual and automatic methods for species identification was done by visual inspection of the data and graphical displays of the data.

3. Results

3.1 Population size estimates

In 2013 there was a capture of animals captured by using guided fences with bucket traps. This method showed a minimum population of 153 animals this year. This was the highest minimum estimation for any of the yeas in the study. For the years 2014 to 2022 the animals were captured with Ortmann traps. Maximum number of individual captures per trapping season, not necessarily the same day each year, was used to find a minimum population estimate and compared to the minimum estimation by capture-mark-recapture individual recognition.

3.1.1 Maximum number of individuals captured per trapping session (night)

The highest maximum number of newts (pooled across sex and age) captured per trapping session (night) was observed in 2019 in the Kjeller pond and in 2020 in the Lundbydammen pond (Figure 10). For the Kjeller pond, I will compare these maximum captures per year with population estimates from capture-mark-recapture models in the next section.

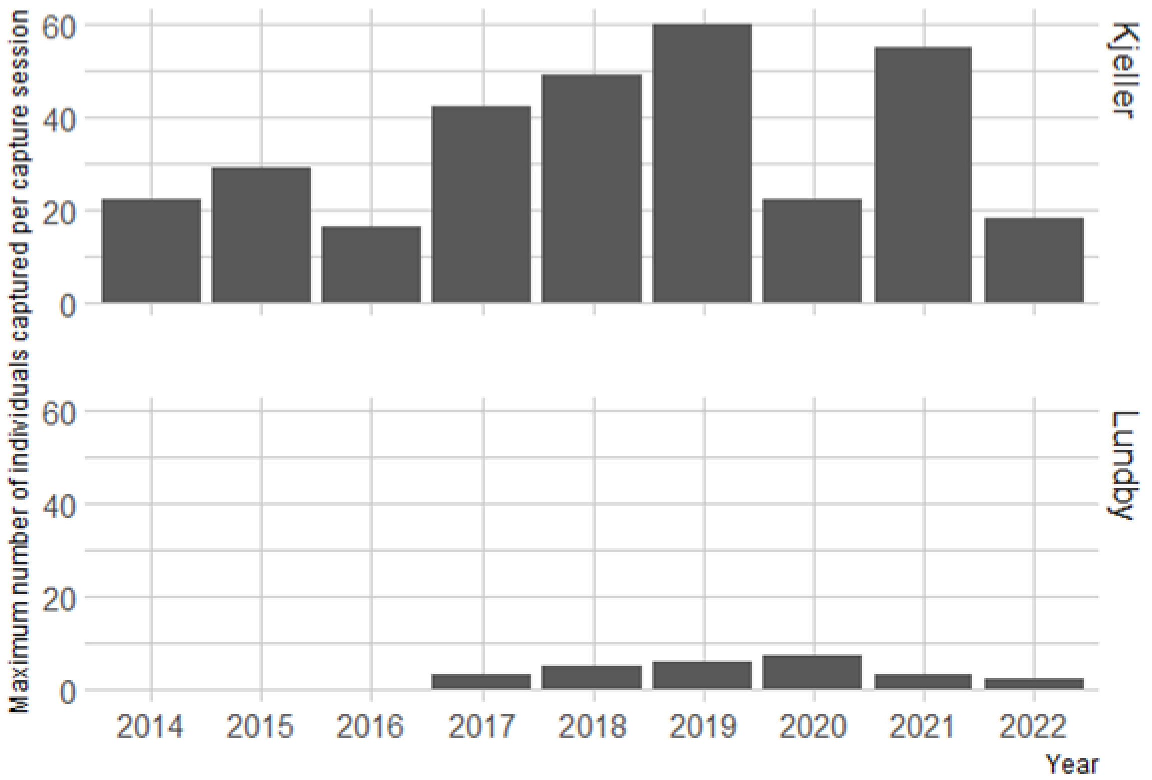
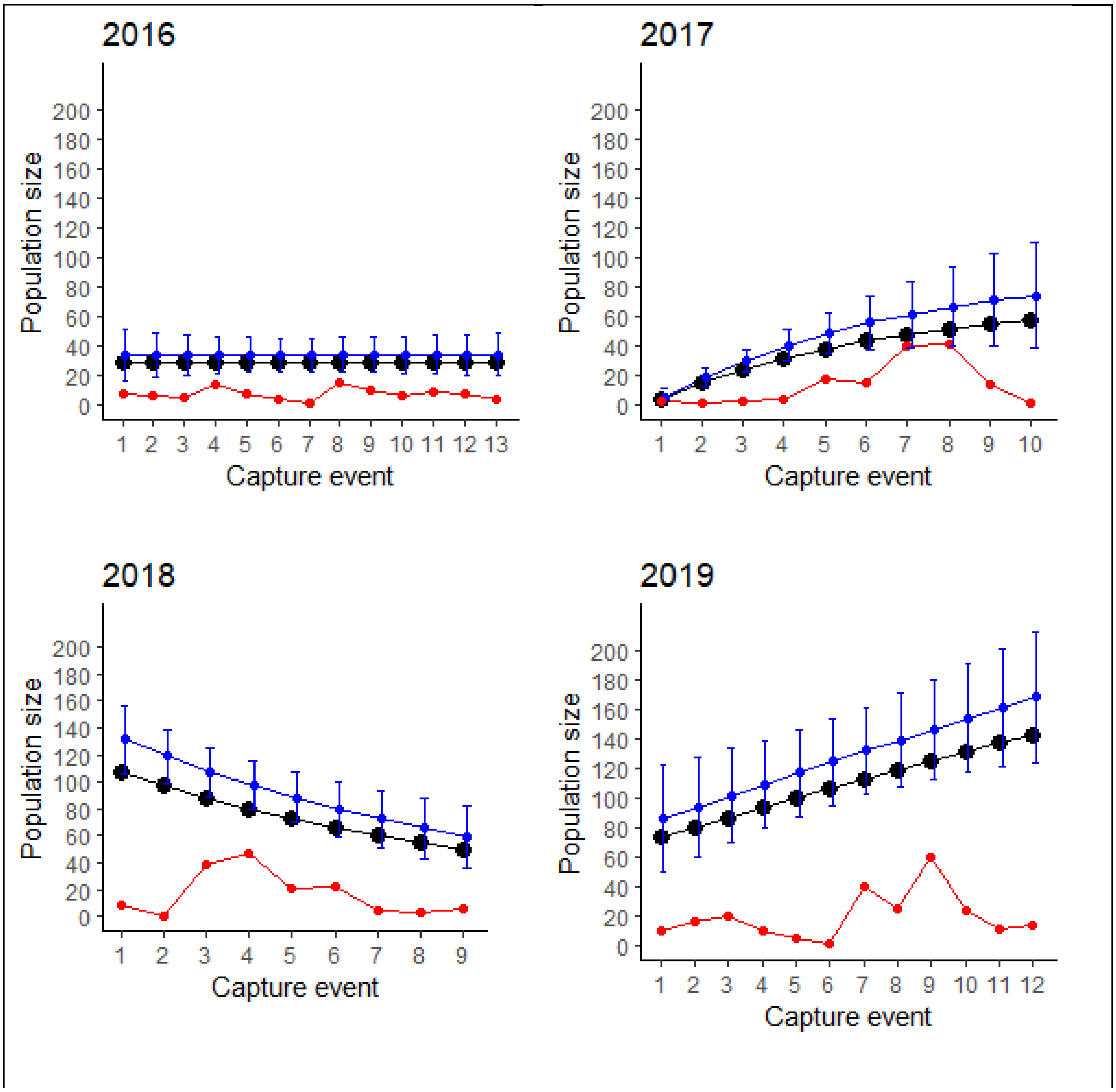


Figure 10. The distribution of maximum number of newts (pooled across sex and age) captured in a Ortmann trap per capture event (night) per year and location. The lateral axis shows the maximum number of individual captures, while the horizontal axis shows the year of capture. Number of capture days varied significantly, see Appendix I, Figure 17 for capture days per year.

3.1.2 Population size estimated from capture-mark-recapture models

Estimated population size from capture-mark-recapture models were consistently larger than the maximum number of individuals trapped during any trapping night (capture event), irrespective of year (Figure 11). Estimated population size was consistently lower for closed populations models than for open population models (Figure 11).



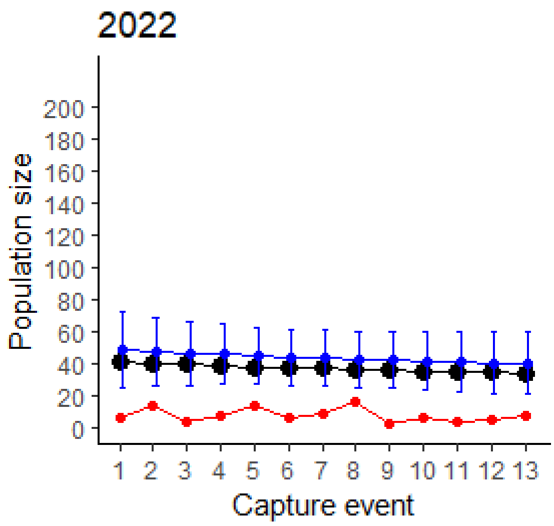


Figure 11. Blue points and error bars: Estimated population size (number of individuals) and 95 confidence intervals, estimated with a Jolly-Seber open population model for each year separately. Black points are population size estimated with a Jolly-Seber closed population model. Red points are number of observed crested newts with a unique individual ID. Estimated and observed values are based on data from Kjeller pond; i.e., pooled data for adult males and females captured in Ortmann traps. Within each year, capture events represent individual capture nights; see Appendix I, Figure 17 for distribution of capture nights within years. Data from 2014, 2015, 2020, and 2021 were not included because of few or no captures where individual IDs were recorded.

.

Within-year variation in estimated population size appeared to reflect within-season variation in number of trapped individuals per capture event; low within-season variation in number of individuals captured per capture event gave rise to relatively stable population size estimate; whereas relatively higher number of individuals captured early in the season led to an estimated decline in population size over the season, and vice versa (Figure 11).

Notably, the relative difference between observed number of newts captured and estimated number of individuals varied quite a lot, both among and within years (Figure 11).

3.2 Within and among season trends

To measure the body condition of the individuals, body mass was measured during the season for each year from 2014 to 2022. It is important to note that the years of 2014, 2015, 2020 and 2021 the amount of capture days were fewer than for the other years, resulting in low sample size.

3.2.1 Within-season variation in body mass

On average, body mass of adult females was larger than body mass of adult males: Estimated mean body weight (95% confidence interval) was 9.26 [7.87-10.64] for females and 7.50 [6.13-8.87] for males (Analysis of Variance). These estimated body weights were based on data from Kjeller in the years 2016-2020 and 2022. Data from 2014-2015 and 2021 were not included due to low sample size and missing data.

Average body weight declined as the season progressed for males, but not for females (Table 1, Figure 12). This means that the weight did not significantly change over the season for the "average" female. It is important to note that weight development during the season for the individual animal may differ from this population average.

Table 1. Influence of sex and date (number of days after March 30th) on average body mass of crested newts in the Kjeller pond in the years 2016-2020 and 2022. Data from 2014-2015 and 2021 were not included due to low sample size and missing data. Results from linear regression model.

Variable	df	F	p
Intercept	1,694	277.3	<.0001
Sex	1,694	148.6	<0.0001
Date	1,694	5.6	0.0186
Sex × Date	1,694	4.2	0.0405

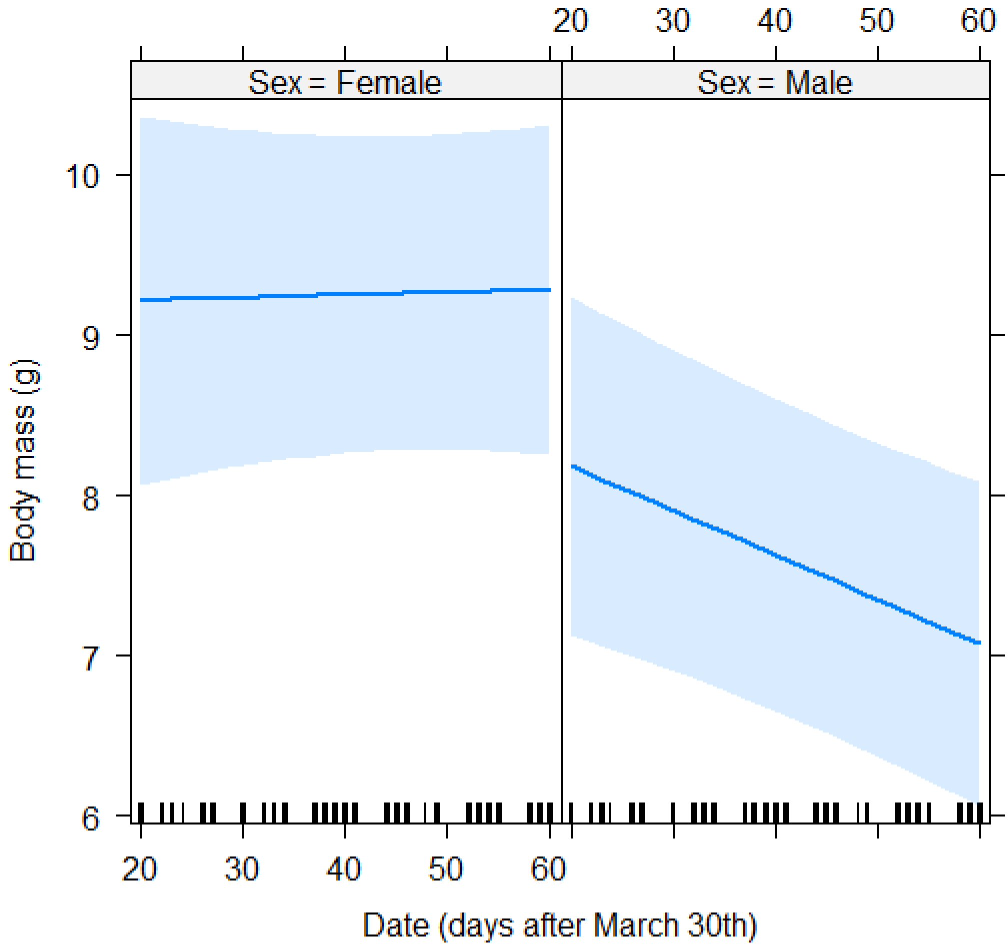


Figure 12. Relationship between estimated body mass and date for adult male and female crested newts in the Kjeller pond. Estimated values (solid blue lines) are based on the ANOVA model in Table 1. The light blue polygons show 95% confidence limits.

The sample size of body mass measurements from Lundbydammen was too small to allow for a formal statistical test of any differences between the Kjeller and Lundby ponds. Yet, when comparing observed body weights from the same year, sex, and time-of-year, I found that body mass of individuals from the Lundbydammen pond were slightly higher or about the same as for individuals from the Kjeller pond (Appendix I, Figure 19).

3.2.2 Among-years changes in body mass

In the Kjeller population, average body mass of adult females and males varied significantly among years and there appeared to be a declining trend over time for both sexes, but the decline was steeper for females (Table 2, Figure 13).

Table 2. Influence of sex and year on body mass of crested newts in the Kjeller pond in the years 2016-2020 and 2022. Data from 2014-2015 and 2021 were not included due to low sample size and missing data. Results from linear regression analysis (ANOVA).

Variable	df	Sum Sq	Mean Sq	F	p
Sex	1	516.1	516.1	162.1	<0.0001
Year	4	611.5	152.9	48.0	<0.0001
Sex × Year	4	99.1	24.8	7.8	<0.0001

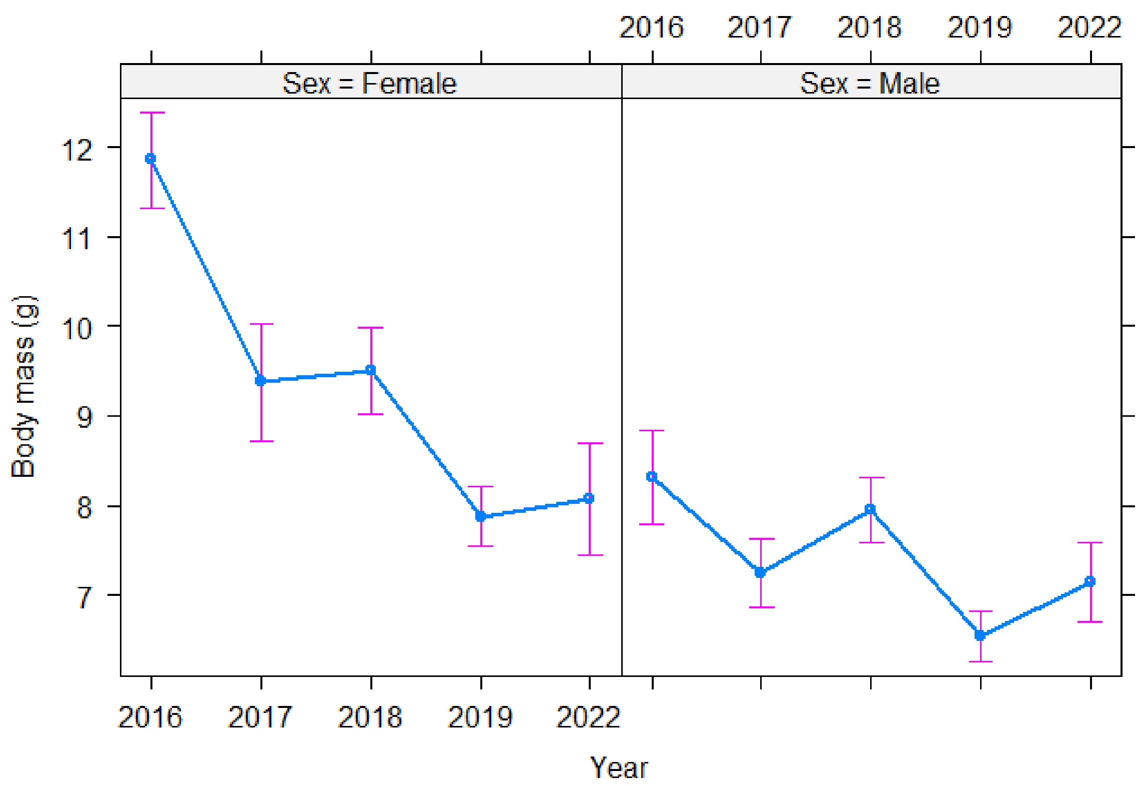


Figure 13. Estimated body mass and associated 95% confidence limits for adult male and female crested newts in the Kjeller pond. Estimated values are based on the ANOVA model in Table 4. The years 2014, 2015 and 2020 and 2021 were not included due to insufficient amount of data.

3.3 Population age structure

The age of the individual was assessed by estimating the age of the animals caught in 2022, as well as by looking at the new captures, compared to the recaptures. Captures of juvenile animals also indicates an influx of new, young animals to the ponds.

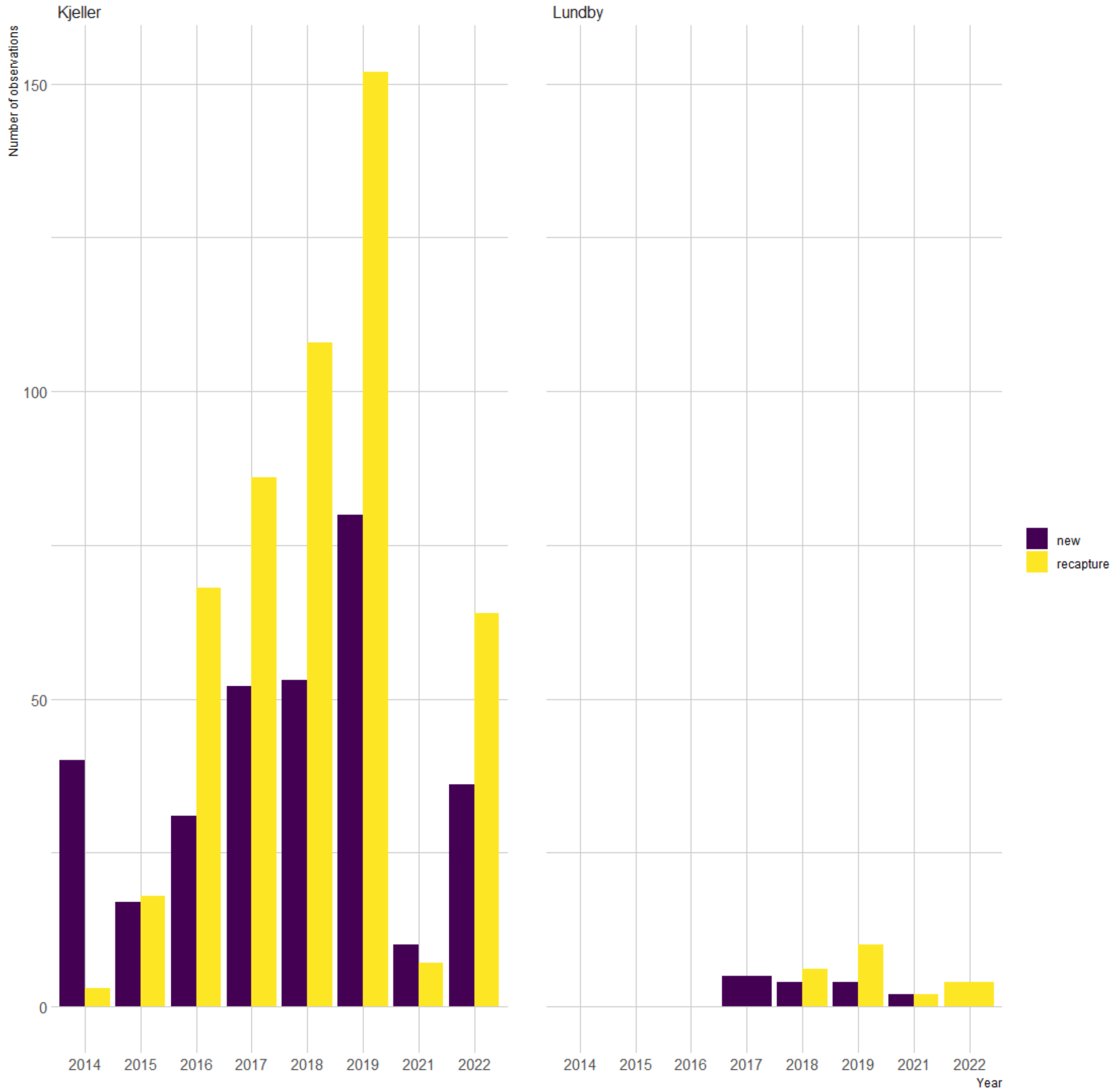


Figure 15. Numbers of observations each year (age and sex are pooled) for Kjeller gård pond and Lundbydammen respectively. The graph shows the new animals observed (purple) and recaptures (yellow). Only photographed animals were used, were 2020 er excluded due to lack of pictures taken this year.

Kjeller gård pond had the largest amount of data. For 2016 to 2019 and 2022 the number of recaptures seems to be close to twice as many as for the new animals captures. The years of 2014 and 2015 were the first years of captures and cannot be taken in consideration but created the basis for the comparison from 2016 and onward. 2021 had considerably less capture days than 2016 to 2022, which is visible in the low numbers shown in Figure 15.

Lundbydammen pond had considerably less data, and therefore it is difficult to determine a trend. For 2019 there seems to be a similar pattern to Kjeller gård pond, where the recaptures are twice as many as the new animals. For the other years the ratio of recaptures and new animals vary from only new animals in 2017, first year of capture, to only recaptures in 2022 (Figure 15).

Kjeller gård pond seems to consist of mostly recaptures, were most of the animals captured are adult animals. There are multiple older animals in the pond, some reaching the high age of more than 12 years of age.

Figure 14. A compilation of pictures taken of Barbie; the oldest animal observed in the pond. Pictures taken by Jeroen van der Kooij.

Barbie was the oldest animal observed (Figure 14). She was first captured in 2014, and observed over multiple years, as well as in 2022. This made her at least 12 years old, if not older.

There is a lack of data from Lundbydammen, making an estimation of age of the population difficult due to few captures, few capture days and few years of data collection compared to Kjeller gård pond. In 2022 there were only recaptures, indicating that the majority of the newts in the pond were adults.

Juveniles have been captured in both ponds, as well as observation of eggs. This indicates that the population in the ponds does not have recruitment failure, and that the populations are renewing themselves for both Kjeller gård pond and Lundbydammen.

3.4 Movements of individuals between ponds

After the making of the new pond in 2016, Lundbydammen, animals did show up the year after. Kitty was the only recaptured animal that was captured in both ponds. She was first captured in Kjeller gård pond in 2014 and captured again twice in 2016. She was captured the last time in Lundbydammen in 2018. Thus, there is evidence for movement from Kjeller gård pond to Lundbydammen, but not vice versa. It is important to note that the pattern on juvenile animals is difficult to use for recognition, due to unfinished pattern development. Therefore, only adult animals were possible to use for determining whether movements between ponds occur.

3.5 Comparison of manual and digital sorting methods

The figure 16 shows recaptures found by the Zooracle application (Z) and by manual recognition (M) done by me. The manual sorting found much more recaptures than the app did. For M,Z both me and the app made the same recapture identification, while M was all the recapture identification I made that the app did not. The app found one recapture that I did not in the manual sorting (yellow pole). The manual sorting did a better job at identifying multiple observations as the same individual, where the app sorted multiple animals as different individuals (did not recognize individual patterns).

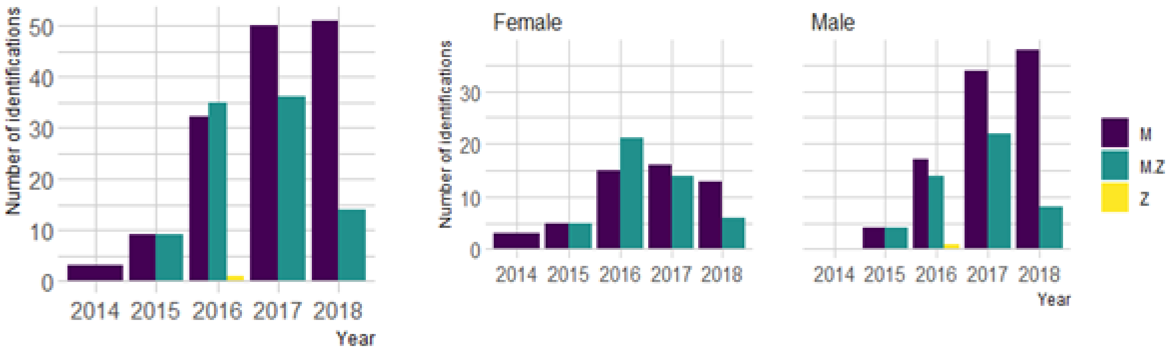


Figure 16. The graph shows number of manual recapture identifications (M), recapture identification by both manual and Zooracle app (M,Z) and recapture identification by the Zooracle app alone (Z). The graphs contain data from 2014 to 2018. 2019 to 2022 was not included due to incomplete inputs because of malfunctions in the app. Only recapture data from animals that were pictured was used for comparison. There were no recaptures identified for juveniles. For the first graph the male and female data were pooled. The second graph shows the number of females, and the third graph shows the number of males identified.

The app stopped working in the middle of the input process. The pictures dated from 9th of May 2018 to 2022 were therefore not possible to include in the comparison. Only pictures from 2014 to 2018 were compared. The date 4th of May 2018 was not included either in the data used for Figure 16 due to an overlook in the inputs.

4. Discussion

As expected, I found that population estimate based on capture-'mark'-recapture of identified individuals was consistently higher than maximum number of individuals captures per capture session each year. However, the relative difference between maximum number of newts captured each trapping session and estimated number of individuals by capture-mark-recapture was not constant among years.

I found that body mass of the animals within season did not change for females but did decline for males. I also found a decreasing trend in average body mass for both sexes during the study period (2016-2022) but the females had a steeper decline than the males.

Captures and recaptures of identified individuals showed that the population did not have recruitment failure, but the population seems to consist of multiple older animals, where the oldest individual was a female with a minimum age of 12 years.

I detected movement between ponds where one animal, Kitty, moved from Kjeller gård pond to Lundbydammen from 2017 to 2018. She was the only recapture, which confirmed movement between the two ponds.

The manual method for identification outperformed the automatic method and found twice the number of recaptures. The automatic method (Zooracle app) found only one animal that the manual sorting did not.

4.1 Population size estimate

The population estimates were done using two methods; maximum number of individuals captured per capture session and population estimates by capture-mark-recapture. Both methods were compared to the fence bucket trap method used at the beginning of the project in 2013. Firstly, I will comment on the development of the population and comment on what might lead to this result. Secondly, I will compare the methods, and comment on which method that worked best for these populations.

4.1.1 Population development and effects

In 2013 a guided fence was used to capture animals and give a quantitative measure of the population. This method is practical for population estimates, due to the lack of recapture. In 2013 153 animals were caught using the guiding fence and fall bucket method. This is the highest minimum estimation for the population. The larger part of the development of the area started right after the mapping in 2013. The population estimates from this year may therefore be used to compare the general trend. Due to the change in capture method, the change in population estimates and captures may therefore seem steeper than they would be if the same capture method was used for all years. This should be taken in consideration when comparing numbers from the other capture years.

Great Crested newts spend three to four years in terrestrial habitat before returning to the pond (Dervo; van der Kooij, 2020). Therefore, an impact on the population size will be visible three to four years after an event such as development or drought. The studied area was under heavy development from late 2013 to 2016, when the development slowed down. A negative trend in the population was to be expected, due to increased difficulty of movement to and from the pond (Hamer, 2016, Hels & Buchwald, 2001). The animals were more exposed to predators such as birds and cats, and traffic was an imminent danger for the animals around the pond as can be seen in the left picture in Figure 2. As a result of the development there was expected a decrease in captures during the developmental period from 2014 to 2016. From 2016 the development slowed down, and much of the areas around the pond was finished, making the path to and from much safer for the animals. This new safety was expected to result in new animals hatched in 2016, giving a new wave of young animals to come back to the pond in 2019 after maturing in the surrounding terrestrial habitat. This new generation were then expected to generate another new wave of young animals due in 2021/2022.

This development did correlate to some degree with the result. Figure 10 and figure 11 both show similar changes in minimum population size estimates. There was a decrease in population from 2013 to 2016, with a particular drop in 2016. This coincides with the heavy development from 2013. It is also interesting to note that for 2014 and 2015 there were fewer capture days than for 2016, and yet the numbers for 2016 stand out in the graph in figure 10. The figure then shows an increase from 2016 to 2019, which coincides with the slowing down of the development and protective measures made locally. Due to the drought in 2018, the decline in population found in 2022 was not surprising. The drought of 2018 had a large impact on the pond, where the water level was particularly low, large growth of plants creating very little space for the animals. Movement between the terrestrial habitat and ponds were also an important factor, where death by dehydration were more likely to occur during migration and emigration (Dervo & van de Kooij, 2020)

Loss of habitat due to human activity as well as overgrowth is an increasing risk and is one of the major reasons for loss of breeding sites for newts (Dervo & Bærum, 2016). Multiple studies have shown how human effect on the habitat and habitat loss has had a negative impact on amphibians (Arntzen, 2017; Erős, 2020; Mushet, 2014). During development the animals were exposed to cleared, open areas. These types of areas have been shown to have a negative impact on the population, where the animals prefer terrestrial habitat for migration, but especially emigration to foraging and wintering areas (Todd, et al, 2009). Human land use close to the habitat has shown to have a negative impact on the population (Mushet, et. al, 2014; Lehtinen, et. al, 1999; Gallant, et. al, 2007). The ponds lay close to both grazing areas for animals, as well as developmental areas and residential areas. All of which therefore may impact the population negatively.

Drought and overgrowth were a growing concern, where Lundbydammen were built as a preventative measure to habitat loss. Loss of ponds in the area had made Kjeller gård pond a secluded pond, with few alternative breeding places. Studies have shown that creation of new ponds have positive effects on the population, particularly in areas were wetlands dry up in spring and summer (Denton & Richter, 2013; Cushman, 2006; Lambert, et. al, 2021, Gallant, 2007). Connectivity to the surrounding habitats also play an important role in the population (Cushman, 2006). Lundbydammen was placed between wooded landscape and Kjeller gård pond, creating a closer connection between the terrestrial habitat and the pond habitats.

It is evident that human development, as well as natural events, had a direct effect on the new population. Preventative measures, and protection of habitat is therefore important to avoid further decline in population size.

4.1.2 Population size estimated from maximum number of individuals captured per trapping session and capture-mark-recapture models

I studied the difference between the population size estimates done by maximum number of individuals captured per trapping session, and by individual recognition with capture-mark-recapture estimation. The capture-mark-recapture model used to compare with maximum capture model, was a Jolly-Seber open population model. This model takes movement in and out of the pond into account. Therefore, the open population model will give a constant higher estimate than for closed population models. A capture-mark-recapture model based the estimates on the number of individual captures made during the season, where maximum captures per trapping session only counts for the highest observation day. The day of most observations will not include animals that have left the pond, avoided the trap due to previous capture or animals that have yet to migrate to the pond. It is not only the estimation number itself that is of interest, but the difference between the methods. If the relative difference between the two methods were equal each year, then maximum number of captures per trapping session would be an adequate data collection method for population size estimate.

As expected, there was a relatively large difference between the minimum population by using the maximum number of individuals captures per capture session data and the capture-mark-recapture data. The individual recognition showed that the population were larger than the maximum number of individuals captures per capture session estimate each year. By comparing the estimates in Figure 10 and 11 the ratio between recapture estimates and maximum estimates, the relative difference between the two methods varied between 1.5 to more than 2.5. Therefore, a maximum number of individuals captures per trapping session may not be adequate to make reliable population size estimates. Capture-mark-recapture method is necessary for studying the population size in these ponds.

A difference in the minimum population estimates by the two methods were expected. I wanted to see if the difference were equal every year. If so, the maximum captures per trapping session could be multiplied with the ratio and used for minimum population estimations. This did not apply to the population in Kjeller gård pond, were the ratio varied yearly. One explanation may be due to the decrease in captures when the traps are used regularly (Skei et al, 2010). The newts have shown to learn to avoid the traps. Therefore, the animals that have been captured may avoid being captured later, and new animals fall for the traps. Then the maximum number of animals captured per session could be relatively low but capture many different animals during the season adding to the recapture minimum population estimates but not the maximum number per session. The results, with the majority of population being recurring adults, may be significantly impacted by this trend. Some animals were, on the other hand, captured many times per season. PartyBella and FazeRacin was two of the "most unlucky" animals and were some of the animals that were captured the most times. These animals would add to the maximum number, but these animals were not the majority, so it is less likely to have any major effect on the results. Due to random placement of animals and trap number, it is not possible to determine if the animals did learn to avoid the same area where the traps were placed, and simply fell for many different traps, or if they fell for the same trap multiple times and where just "not that smart". The last few years ten traps for Kjeller were used, and five traps for Lundby. If the animals were to avoid the area of the traps they initially were captured, there is still a possibility for capture in the remaining traps. Capture-mark-recapture were the best method for Kjeller gård pond.

For Lundbydammen there was a smaller amount of data collection. There did not seem to be a big difference between the maximum number of individuals captures per capture session and the capture-mark-recapture method in this pond. This is most likely due to the small number of animals captured, and few capture days. More data is needed to determine which method work best for this pond.

For Kjeller gård pond capture-mark-recapture method were the most accurate method for population size estimate, were the relative difference between maximum captures per trapping session versus individual recognition varied significantly yearly. For Lundbydammen there did not seem to be a difference between the two, but this is most likely due to the minimal amount of data. Further data collection will be necessary to establish any trend for this population.

4.2 Body mass of adults – within and among season trends

4.2.1 Body condition of individuals

The animals health can be indirectly measured by body mass in adults. By studying the weight development, it is possible to see whether the development of the area affects the animals in other ways than population size. Firstly, I will look at the within-season variation and what might lead to this result. Secondly, I will look at the among-years changes in body conditions, and what might lead to this trend.

4.2.2 Within-season variation in body mass

The results showed that there was no significant change in weight during the season for females, but there was a decline in weight for the males in the population of Kjeller gård pond (Table 1, Figure 12).

There was a decline in weight during the season for the average male. This means that either 1) the individual animal loose weight during the season and add to the average weight loss of the population, 2) the smaller animals get captured later in the season and the bigger animals in the beginning of the season making it seem as though the weight declines during the season, or 3) a combination of the two. Few animals were captured many times per season, but one animal that did was FaceRazin. This male did lose weight during the season but had regained the weight back the next year. This indicates that the decline in weight may also include the weight of the individual animals adding to the average. Males use a large amount of energy during the breeding season. Both sexes change their skin for the aquatic season, where the males produce the crest. The males also spend much time in the water, looking for a female to mate with preforming the mating dance/game. Males therefore spend less time looking for food, and more time in activity. Most of the males tend to remain in the pond for a longer amount of time compared to the females, which leave the pond after laying their eggs, even though it is still early in the season (Ruud, et. al, 1949). I did not look at the weight of all the individual animals. This could have given an indication of the weight of the animals first arriving to the pond, and the animals that remained later in the season. If the animals first captures were all heavier, and new animals captured later were lighter, that could indicate that the weight development was based on the size of the animals in the pond at a given time of the season and not necessarily the weight loss of the individual animals. This could be a subject for further study but was not assessed here.

Females lose weight during the season because of egg laying. The development could potentially have been a decline in average weight during the capture days. This did not occur. One explanation is that female animals leave the pond after laying eggs (Ruud, et. al, 1949), or there being an equilibrium of females with and without eggs captured, making the weight seem equal through the season. Females that still have eggs and arrive at different times to the pond during the season will add to the average weight in the data collection. This may be the reason why the weight does not seem to change for the average animal in the pond. If we look at the individual animal such as PartyBella as an example. In 2016 her weight dropped from 13.3 to 9.8 from 3rd of May to 25th of May. The next season, she had gained back much of the weight and went through the same weight loss again. Most animals, on the other hand, did not get captured multiple times, and therefore adding to the general weight data. The animals may vary greatly in weight on an individual scale, but not collectively.

The results showed a significant difference between the weight based on sex. The females weighted 1.67 g more than the males. Female Great Crested newts have been found to be larger than the males (Shine, 1979; Shine 1988; Duellman & Trueb , 1986; Malmgren & Thollesson, 1999). The weight difference may be due to general dimorphism in the newts, but also likely due to the weight of the carried eggs. Therefore, the results fit the expectations for the population.

4.2.3 Among-years changes in body mass

The results showed that the average weight of the animals decreased over the years for both sexes (Figure 13). The females weight declined at a faster rate than for the males. A negative trend in population size and body condition has been found for some populations (Unglaub, et. al, 2018). Less intraspecific competition could result in better body condition for the remaining animals, but this connection did not seem to apply to the population. The decline in weight continued through years simultaneously with decreased population size. There may be multiple reasons for the declining rates. Disease, development of the habitat, overgrowth and drought are causes than could have affected the populations.

Illness and pesticides were not examined in this study but have been a focus in many studies done in newt populations due to an increase in disease in populations word wide (Kilpatrick, et al, 2010; Bates, et. al, 2019). Few of the animals had any indication of disease, and most of the observations made in changed appearance often seemed to stem from altercations with other animals or other types of accidents that could cause small wounds. Since disease is a growing issue, this could be an interesting subject for further study of the population.

The females had a larger decline than the males. This can possibly be due to decline in egg production. Is has been found that stress can affect the amount and quality off the eggs in amphibians (Narayan & Hero, 2015). Lower body condition may lead to reduced fecundity in amphibians (Reading & Clark, 1995). This may be the cause of the larger decline than for the males.

The ponds were close to a developmental area, and the surrounding areas were being built upon. This was one of the most likely explanations to the decline in weight. During the development from 2013 to 2016, the area was stripped from vegetation around the pond, making the movement a greater cost than for more vegetated habitat (Todd, et. al, 2019). The terrestrial area for the newts is small, with only a little wooded area in proximity. Data from 2016 to 2022 (Figure 13) show that the weight keeps declining even after the development has slowed down. The alterations made to the habitat surrounding the pond were therefore likely to still affect the animals negatively. During the period of data collection, there were also two especially dry seasons, one in 2018 and the second in 2022. The water stand was low, and the growth of plants in the pond were in abundance. This may have been an influencing factor in the negative weight development.

The weight of both males and females in the pond was shown to decline, where the female population had a steeper decline than the males. Further study is required to establish the reason for the continued decline, even after the finishing of the developmental projects and the considerations taken.

4.3 Population age structure

The population did not seem to be suffering recruitment failure. New animals were captured yearly, as well as juveniles and visual observation of eggs. The proportion of new individuals in the captures seemed to be about half of the number of recaptures (see figure 15).

Many of the new animals were adults. The label "new" does not necessarily indicate a new animal to the population, only new observation. The years 2014 and 2015 were the first years of capture. This means that almost all animals captured would be new animals, due to the lack of previous data. The captured animals for these years would become the recaptures for the next years of observation. Therefore, 2016 or 2017 will be the first adequate representation of recaptures versus new animals. From 2016 to 2019 the recaptures seemed to be twice as large as the number of new animals each year. The year 2021 differs from the rest in figure 15 and is due to lack of capture days. Both 2020 and 2021 were affected by the pandemic, which led to less data collection with photographs. This explains the difference in ratio compared to the other years. 2022 had less observations but maintained a similar ratio as for 2016 to 2019.

The reasons for the large number of recaptures compared to new animals may be explained by survival probability due to age. Young animals are more likely to die on the trip to and from the pond because of small body size, predation, slow movement, drought, and similar effects. Lack of food in the surrounding areas due to development may also cause death by starvation during the autumn and winter periods (Rothermel, 2004). Juveniles return to the pond before they reach reproductive age to feed and will thus travel despite the evident threats (Schön, et. al, 2011) Larger animals have better conditions for survival, so the remaining population is more likely to be adults from previous years, and therefore recaptures from the year before. Most of the recaptures were from the previous year, or two years back, were only a few animals were captured over more than three years.

Most of the recaptures in 2022 was from 2018 and 2019, with only a very few from 2014 to 2017. Generally, the recapture was greatest from the first year to the second. Learning to avoid the traps, moving to a different pond or die are all explanations for the trend. Newts can reach the high age of 22 years and older (Ruud, et. al, 1949), but normally they age between 16-18 years old in the wild (Dervo; van der Kooij, 2020). Only one animal from 2014 was captured again in 2022, Barbie. This makes her at least 12 years old, since she was captured first time as an adult. This means that she would have had to be at least 4 years of age by the first capture (Dervo; van der Kooij, 2020).

There did not seem to be recruitment failure in either pond. Both populations seemed to consist of twice as many recaptures as new captures, where most new captures were adult animals, but juveniles were also captured yearly.

4.4 Movements of individuals between ponds

Movement may occur for multiple reasons. Some reasons for movement may be due to random walking by juveniles or insufficient habitat driving the animals to migrate (Gustafson, et. al, 2009). To study the movement pattern individual recognition was used.

There was only one animal that moved between the ponds, and this was Kitty. She moved from Kjeller gård pond to Lundbydammen. She was captured multiple times at Kjeller gård pond, and once in Lundbydammen. Lundbydammen was smaller than Kjeller gård pond and contained fewer animals and less water. Other adults showed in Lundbydammen the year after it was made, and therefore a movement from Kjeller gård pond, the closest pond in the area, is the most likely occurrence. Due to lack of data, more captures over the next years are essential to be able to determine a cause for movement, and if movement happens in both directions.

As stated, the most likely movement is by young animals, as adults tend to return to the same pond. Juveniles emigrates from the pond, walking at random due to no previous knowledge of the surrounding areas (Sinsch & Kirst, 2016; Sinsch, 2007; Pittman, et. al, 2014; Petrovan & Schmidt, 2019). The first years the animals stay in their terrestrial habitat, randomly walking to find pond habitat to feed and reproduce in. This random walking is a game of chance, which may result in exhaustion and potentially death, but those that survive would benefit greatly for their further survival if resulting in a new pond (Pittmann, et.al, 2014). There is only one wooded area in close proximity to the ponds, see Figure 1, which is close to Lundbydammen. If the animals spent wintertime in the wooded area, the chances of walking to the new pond are high for random walkers such as juveniles. Juveniles, as well as adults, have shown to prefer wooded terrestrial areas and avoid cleared areas (Pittman, et. al, 2014; Jehle & Arntzen, 2000). Breeding pond fidelity is common in adult animals, but ponds in close proximity to the terrestrial habitat may lead to some adults utilizing new ponds for breeding (Joly & Miaud, 1989). Such as the case for Kitty, and adult animal using a new pond.

Another reason for movement, which is of interest for further study of the area, are pond quality. Adults did show in the new pond the year after it was built. Adults tend to migrate to the same pond year after year (Pittman, et. al, 2014; Matos, et. al, 2019). If the breeding habitat would become less suitable, the animals might migrate to different areas in hopes of finding new habitats with better conditions such as more sunlight, greater depth, less shrub, and less nutrients in the water (Gustafson, et. al, 2009). Lundbydammen was smaller, shallower, and more had more shade than Kjeller gård pond. The reason for movement might therefore be different than expected, and could be a subject for further study.

The patterns on the juveniles were extremely difficult to compare due to the little development of the pattern at a young age. Movement of juveniles or adults captured last as juveniles, therefore are extremely difficult to determine by pattern recognition, and may require other forms of identification such as DNA recognition or other non-invasive markings.

Movement was happening between the ponds in one direction, from Kjeller gård pond to Lundbydammen. Movement pattern and reason for movement is impossible to determine with so little data and will require further study and data collection.

4.5 Comparison of manual and digital sorting methods

The manual sorting was the best method for individual recognition in this study. The results show that there was a significant difference in manual and digital sorting (Figure 16). The manual sorting found more recaptures than the app did.

Visual identification has become a preferred method of recognition. Methods such as toe clipping, tattooing, tagging, skin dying, passive integrated transponder (PIT) tagging, etc (Matthé, 2017; May, 2004; Bailey, 2004; Guimarães, et. al, 2014; Winandy & Denoël, 2011) have shown to have a negative impact on the animals (Bailey, 2004). A more humane, non-invasive method to differentiate the animals is by ventral side photography. Pattern photography can be sorted manually (Dunbar, et. al, 2014; Gore, et. al, 2016), but due to the large data sets of recent years, a need for digital program is imminent. Individual recognition by digital programs have been used more frequently (particularly a software called AMPHIDENT, which is a relatively expensive program) (Unglaub, et al, 2021; Neergard, 2020; Grini, 2017; Drechsler, 2015; Matthé, 2017). In my study, I did not compare different digital programs for sorting such as Matthé (2017), but the difference between manual sorting and digital. The digital sorting program I used was a newly developed app, Zooracle, which could be utilized from a phone or a tablet. This makes real-time identification in the field possible with minimal equipment.

The sorting time was different for the two methods. For the manual sorting, I used approximately fifteen seconds to print screen from Dropbox, copy to “Paint” and cut out the pictures and put them into Excel for the sorting to start. The sorting done manually depended on the number of animals to compare with. The setup for Excel took more than an hour in total to make it look neat and easy to read. The more animals to compare with, the more time it took for comparing as well as an increased probability for making mistakes such as skipping an animal. Due to this, double-checks done by additional comparison rounds were more frequent towards the end.

For each input in the app, I would use approximately one minute, and about three minutes to set up the date groups (Figure 9). Input time same during the entire process and did not depend on the number of prior inputs. The app needed 24 hours between inputs, because the database had to be updated to compare animals. Therefore, I could only work a day at the time. This made the time frame a lot longer than the manual sorting, but total amount of work hours less than for manual sorting. This is not a problem with real time inputs during fieldwork, but for comparison of an already collected data base it is inconvenient.

I did many interesting observations by using Zooracle. The app was mostly user friendly and intuitive (Figure 8 and 9). It did a splendid job at sorting animals that I had trouble with, such as animals with small patterns. It was quicker in the comparison and gave options to choose from five different previous inputs, so that there was an element of manual sorting as well. The app did not do well with patterns that where the dark marks were blurry and/or big. Many of which the app where not able to match. This may be due to the color selection, where I chose the whole spectrum of yellow to orange. This may have affected the size of the blurry pattern differently for different light exposures in the photographs, and therefor make comparison more difficult for the algorithm. The app only matched two-and-two animals. Therefore, there was a need for sorting after the input process, making the app less user friendly that it could be. The app only grouped animals that were directly or indirectly matched with each other. This resulted in multiple groupings of the same animal. As an example, I found one individual animal named “FaceRazin”. The app sorted this individual as four different individuals of recaptures.

The app found one (1) match that the manual sorting overlooked. R2D2 and Lynet was sorted as two individual animals, while the app made the connection. These animals did not have additional recaptures; therefore, this made the animals more prone to be overlooked in the manual sorting than others with many recaptures.

The comparison of the juveniles was extremely difficult, and both the manual and digital sorting failed to find recaptures.

Using a digital program such as an app can be advantageous, but it is important to consider the significant lack of recaptures done by the app. This can result in larger estimations of "new" animals in the pond, and a larger estimation of population size than by using manual sorting. On the other hand, the app also grouped the same animal in different groups, and without an additional manual comparison may lead to the impression of multiple recaptures of different animals. This can give an impression of a larger recapture and indicate less "new" animals if looking at quantitative data. This relatively "random" variation in sorting makes it difficult to trust the results of the app. Manual sorting therefore were the best of the two methods for sorting in this project.

5. Conclusion

My findings indicate that there has been a decline in population size in the Kjeller pond over the years. I also found evidence of a decline in average body mass in both sexes, but a steeper decline in females. This may indicate a reduction in body condition of both males and females, and maybe also reduced fecundity in females. Although causal relationships cannot be determined from this study, the apparent negative development of the population status has occurred simultaneously with human development projects in the areas surrounding the ponds. Thus, it seems plausible that human land use change is the driver behind the negative trend in the population size and condition in this study system. Capture-mark-recapture method for population estimation where the most accurate method for estimation and should therefore be continued for these populations. Due to the increasing data collection, a digital sorting program is of interest for further studies. Even though preventative measures were utilized for Kjeller gård pond, the population is still declining. Further protection seems to be essential for the prevailing of the species in the area and is in need of human action.

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7. Appendix I

Table 3. New females, males, and juveniles found for each year from 2014 to 2022 by manual recognition, 2020 was not included due to lack of photographs. "New" indicates never-before-observed animals. Total captures mean the number of different animals captured that year, an may include previously captured animals from previous years.

Year	New females K	New females L	New males K	New males L	New juveniles K	New juveniles L	Total captured females	Total captured males	Total captured juveniles	Total captures	
2014	30	0	10	0	0	0	30	10	0	40	
2015	9	0	9	0	1	0	18	13	1	32	
2016	10	0	15	0	10	0	22	25	10	57	
2017	11	0	39	4	5	1	25	58	6	89	
2018	21	3	22	5	9	0	38	57	9	104	
2019	35	1	44	3	1	0	59	75	1	135	
2021	6	2	5	0	0	0	11	8	0	19	
2022	11	0	14	0	7	0	18	28	7	53	

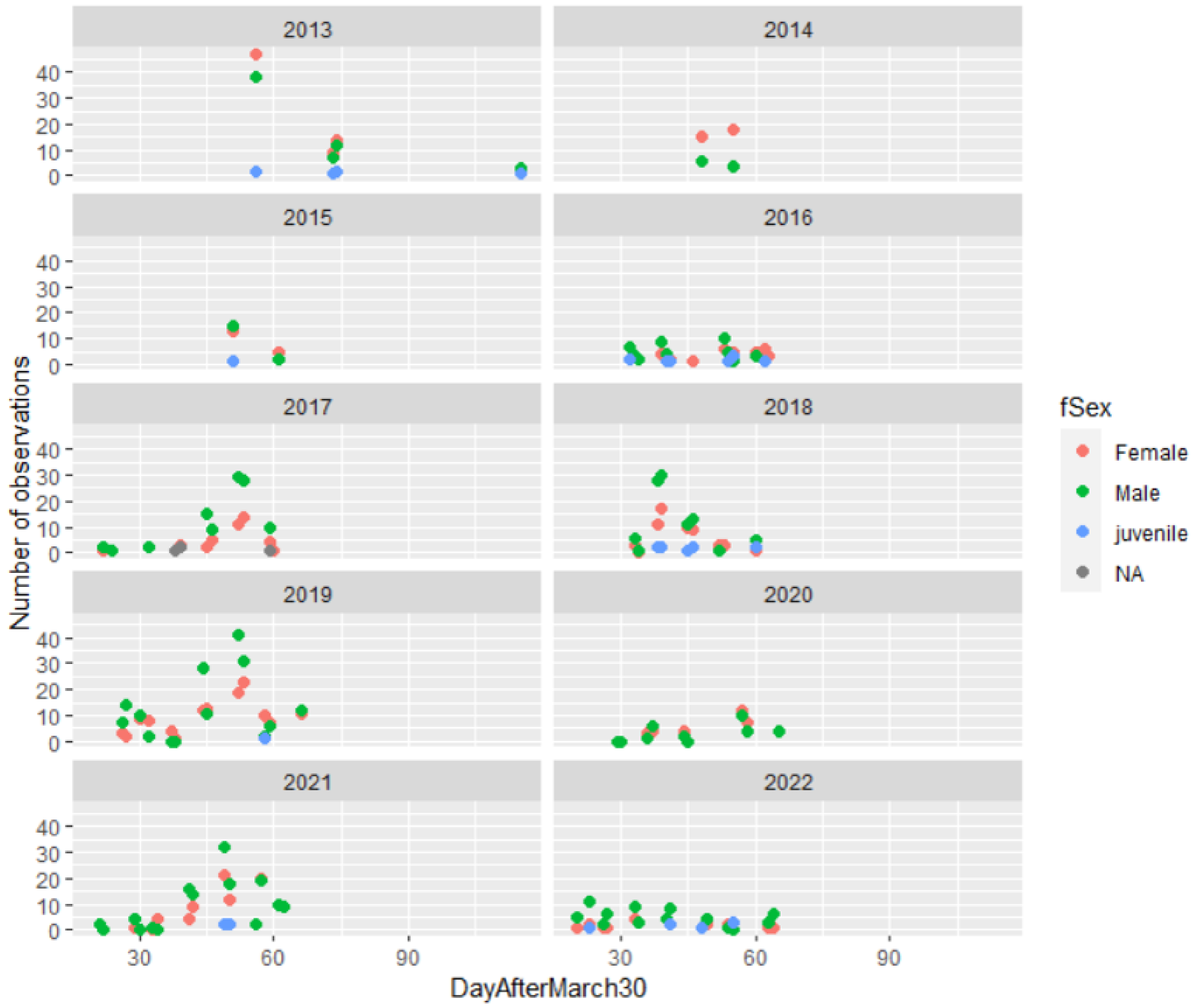

Figure 17. Shows the numbers of observations of female (red), male (green), juvenile (blue) or not specified (NA) on each capture day per year. Note that guiding fence and bucket method was used in 2013, and Orthmann traps were used for 2014 to 2022. Capture dates is indicated as "Days after March 30th".

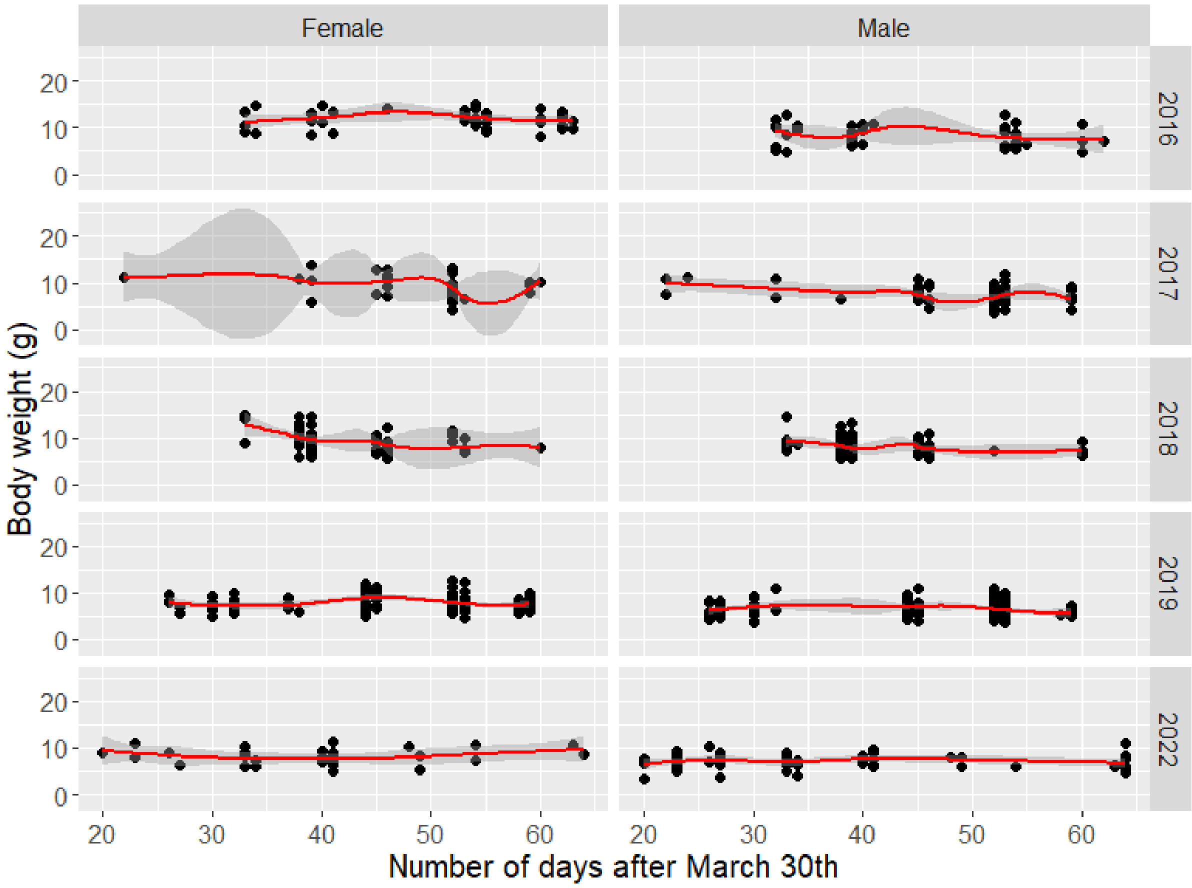

Figure 18. Average bodyweight of adult animals chategorized in female (left) and male (right) on each capture day measured in days after March 30th from 2016 to 2022. 2014, 2015 and 2020 was not included due to insufficient data and few capturing dates (Appendix I, Figure 17).

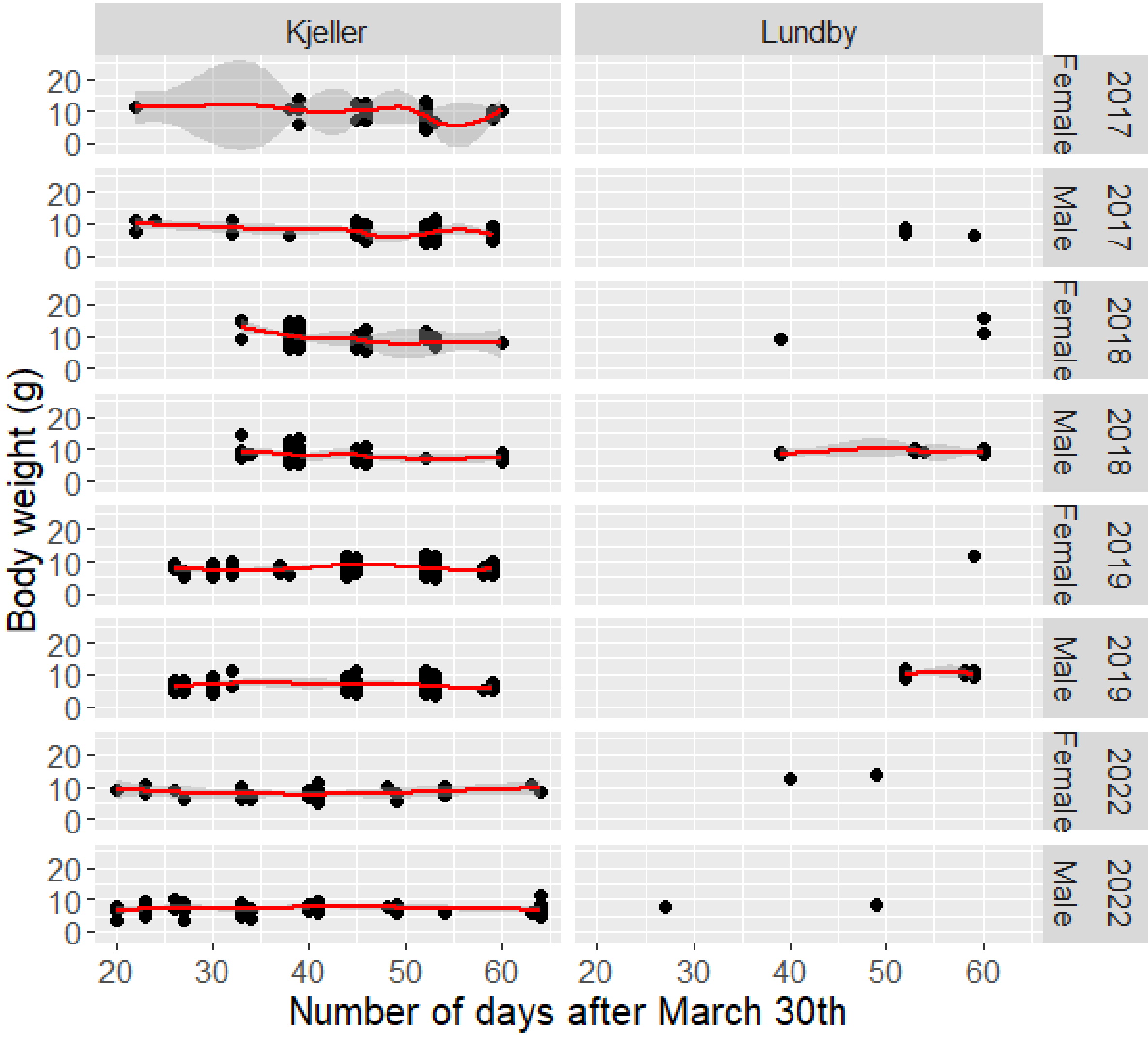

Figure 19. Average bodyweight of adult animals for Kjeller gård pond (left) and Lundbydammen (right) on each capture day measured in days after March 30th from 2017 to 2022. 2014 to 2016 and 2020 was not included due to insufficient data and few capturing dates (Appendix I, Figure 17).

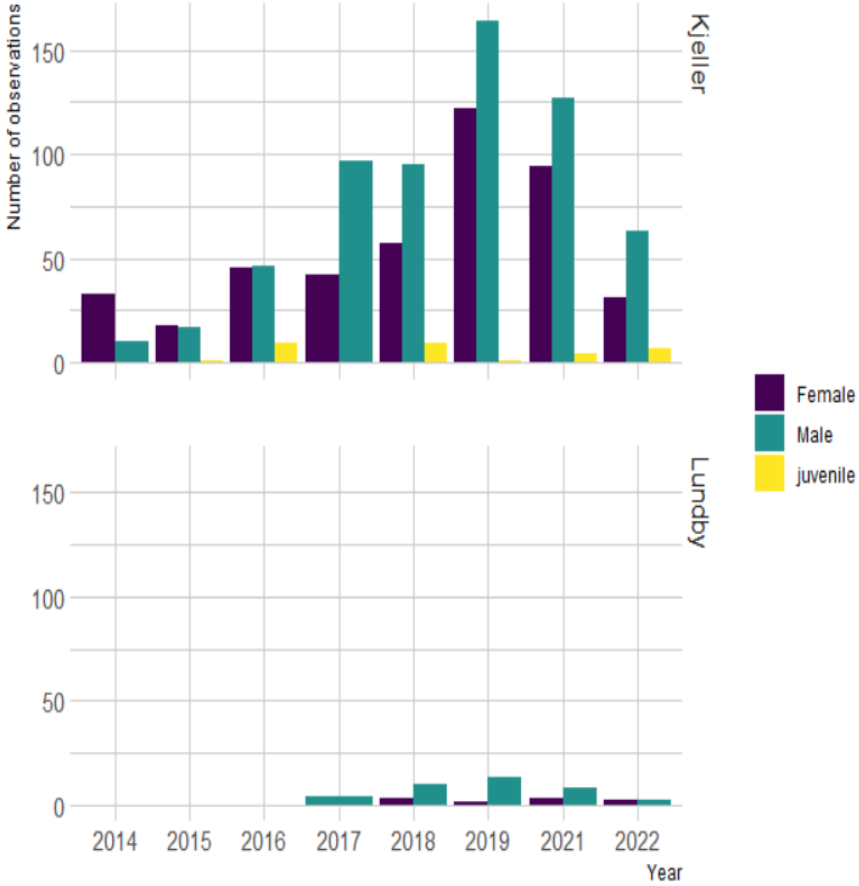

Figure 20. This figure shows the number of observations of crested newts (adult female; adult males; and juveniles) each year, in the Kjeller (top graph) and Lundby ponds (bottom graph). The graphs are based on observation data from 2014 to 2022. The year 2020 was excluded due to lack of data collection this year.

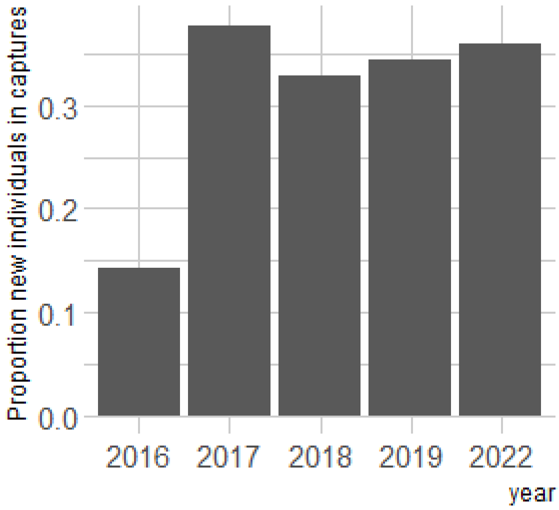

Figure 21. Proportion of new individuals in the captures, relative to total number of individuals captured. New individual in this context means that the individual has not been observed previously in any year (since 2014). The figure is based on data from Kjeller pond. Data from 2014, 2015, 2020, and 2021 were exclude due to few or no capture events where individual ID was recorded (see Appendix 1, figure 17). Number of capture events per year was: 2016 (13); 2017 (10); 2018 (9); 2019 (12); and 2022 (13).

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