Dispersion of the three-spined stickleback in the Frisian inland

By

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Looking into the dispersion of three-spined sticklebacks (*Gasterosteus aculeatus*) in the Frisian inland near pumping station the Heining using PIT telemetry

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&
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Preface

This report was written for the graduation project of the Applied Biology course at Ares University of Applied Sciences in Almere. I worked on this graduation project from March to July 2021. The product in front of you is the final product of my graduation.

I would like to thank Hendry Vis for offering me this assignment. I would also like to thank him for his help during the research and the feedback on my report. Furthermore, I would like to thank Jan Kemper for allowing me to use data from VisAdvies B.V. for this research. With the help of these data, I was able to conduct my research. Furthermore, I would also like to thank Arno Veenstra for his guidance in visualising the results and organising the data. I would like to thank Annet Pouw for her guidance and constructive feedback.

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I would also like to thank all the other parties involved in my internship for their cooperation.

Finally, I hope that my report will contribute to the solution to the migration problem and the planning of solving this problem in North Fryslân.

Hayco van der Veen,

Ureterp, 4 June 2021

Summary

Worldwide, fish species are the most threatened taxa among freshwater vertebrates and have declined by 76% over the past 40 years. Anthropogenic activities such as the construction of dykes and dams are the main cause of this. These obstacles are very important for contemporary society, but they pose significant problems for the dynamics of aquatic systems. Especially for diadromous fish species such as the three-spined stickleback and eel. In Europe, the population of diadromous fish has declined by 95%. Therefore, the European Union has set up targets to combat fragmentation and to improve the fish population.

In the Netherlands, much is being done to improve or restore fish migration routes. One example is the Heining pumping station, which forms a connection between the Wadden Sea and the Frisian polder. One of the target species at this pumping station is three-spined stickleback. Insight into the dispersal of three-spined sticklebacks is required to implement targeted measures to improve the dispersal routes within the dikes. A multi-year study has been set up to chart this dispersal. This study describes the results of the first year. Utilizing PIT-telemetry the dispersion of three-spined sticklebacks was examined after passing pumping station de Heining. PIT-stations were installed on the routes to the polder and within the storage basin. It was assumed that three-spined sticklebacks would choose the route through the storage basin to reach suitable spawning grounds in the polder.

This turned out to be the case. The majority of the three-spined sticklebacks tagged chose the route through the storage basin. A few individuals chose the route directly into the polder. The results of this study provided good insight into the dispersal of three-spined sticklebacks and have helped in determining a new strategy to further monitor dispersal.

Samenvatting

Wereldwijd zijn vis soorten de meest bedreigde taxa onder zoetwater vertebraten en zijn in de afgelopen 40 jaar met 76% achteruitgegaan. Antropogene activiteiten zoals het aanleggen van dijken en dammen zijn hier de voornaamste oorzaak van. Deze obstakels zijn erg belangrijk voor de hedendaagse maatschappij, maar vormen significante problemen voor de dynamiek van aquatische systemen. Vooral voor diadrome vissoorten zoals de driedoornige stekelbaars en paling. In Europa is de populatie diadrome vissen met 95% achteruit gegaan. Daarom zijn er vanuit de Europese unie doelen opgesteld om versnippering tegen te gaan en de vispopulatie te verbeteren.

In Nederland wordt al veel gedaan om de migratie routes van vissen te verbeteren of te restaureren. Een voorbeeld hier van is gemaal de Heining die een connectie tussen de Waddenzee en de Friese boezem vormt. Een van de doelsoorten bij dit gemaal is driedoornige stekelbaars. Om binnendijks gerichte maatregelen te treven voor het verbeteren van de dispersieroutes is inzicht nodig in de dispersie van driedoornige stekelbaars. Om deze dispersie in kaart te brengen is een meer jarig onderzoek opgezet. Dit onderzoek beschrijft de resultaten van het eerste jaar. In dit onderzoek werd aan de hand van PIT-telemetrie gekeken naar de dispersie van driedoornige stekelbaars na passeren van gemaal de Heining. Hierbij werden de routes naar de polder en binnen de boezem voorzien van PIT-stations. Er werd aangenomen dat driedoornige stekelbaars de route door de boezem zou kiezen om geschikte paaigronden in de polder te bereiken.

Dit bleek ook het geval te zijn. De meerderheid van de getagde driedoornige stekelbaarzen koos voor de route door de boezem. Enkele individuen kozen voor de route naar de polder via de vispassage direct naast gemaal de Heining. De resultaten van dit onderzoek gaven een goed inzicht in de dispersie van driedoornige stekelbaars en hebben geholpen bij het bepalen van een nieuwe strategie om de dispersie verder in beeld te krijgen.

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1. Introduction

Globally, fish species are the most threatened taxa among freshwater vertebrates (He et al., 2019). Overall, fish species suffered a decline of 76% over the past 40 years due to the presence of various obstacles such as dams, dykes, weirs and pumping station sluices (Kemp, 2015; Harris, Kingsford, Peirson, & Baumgartner, 2017). These obstacles are considered to be the major problem for biodiversity and dynamics of aquatic ecosystems (van Puijenbroek, Buijse, Kraak, Verdonschot, 2019). In spite of the detrimental effect of the obstacles, anthropogenic development around aquatic ecosystems are essential to today's society (Heerten & Werth, 2012). For example, dams are important for shipping, green energy in the form of hydropower and for the storage of drinking- and irrigation water (Piper, Rosewarne, Wright & Kemp, 2018; Lehner et al., 2011). Dykes, weirs and sluices on the other hand are important for protecting against flooding, for example, due to climate change (Klijn, Baan & Bruijn de, 2007). These obstacles prevent fish from reaching their feeding, hiding and spawning grounds (Medinas de Campos et al., 2020)

For diadromous fish species in particular, the fragmentation caused by anthropogenic development is substantial, as their habitat becomes fragmented or even inaccessible (Hall, Jordaan & Frisk, 2011). Diadromous species are fish that migrate between salt- and freshwater (Rougier et al., 2014). These fish species can be divided into two groups: catadromous species, which reproduce in saltwater and migrate to freshwater as juveniles, and anadromous species, which migrate from sea to freshwater to reproduce (Jager, 1999). Examples of species that migrate from fresh- to saltwater and *vice versa* are the anadromous American shad (*Alosa sapidissima*) and catadromous European eel (*Anguilla anguilla*) (Atkinson et al., 2020). Adult shads migrate from salt- to freshwater to spawn in the upper reaches of rivers in America and the offspring will migrate back to the Atlantic Ocean (Smith & Hightower, 2012; Stich, Sheehan & Zydlewski, 2019). On the contrary, the adult eels migrate to the Sargasso Sea to spawn (Lennox, Økland, Mitamura, Cooke & Thorstad, 2018). The juveniles then migrate back to Europe and North Africa to grow up in fresh and brackish water (Verhelst et al., 2018). The accessibility of their habitats is therefore crucial not only to sustainably maintain the fish population but also for the survival of diadromous fish species (Limburg & Waldman, 2009; Pompeu, Agostinho & Pelicice, 2012).

Dams, dykes and weirs also form substantial barriers for diadromous fish species in Europe (Merg et al., 2020). To prevent and restore the fragmentation of these habitats, goals have been set by the European Commission. These goals are set in the European Water Framework Directive (WFD) (European Commission, 2000). All Member States have to report to what extent the ecological status of the water meets the WFD standards and which measures are executed to meet these standards (Maia, 2017). To reach the goals for fish mitigating measures, fish ladders, fish-friendly pumping stations and fish migration rivers are being constructed all over Europe (Koschorreck et al., 2020; Pander & Geist, 2013).

In the Netherlands, fragmentation caused by obstacles resulted in several diadromous fish species to seriously decline in number or even to disappear. The exact decline in the Netherlands is unknown, but overall in Europe, this decline lies around 95% (Greene, Zimmerman, Laney, & Thomas-Blate, 2009; De Groot, 2002). Along the northern Dutch coast, near the Wadden Sea, there is only one relatively undisturbed gradient between salt- and freshwater. This is the Ems where fish can still migrate freely up to Herbrum in Germany and back to the Wadden Sea. The other fifty-five transitions from salt- to freshwater and *vice versa* have been disrupted or have disappeared. Most of these transitions from salt- to freshwater are equipped with locks or pumping stations (Jager, 2003). Fish passages are now being constructed at these locks and pumping stations because these blockages along the Wadden Sea constitute a major problem, particularly for diadromous fish species such as three-spined stickleback

(*Gasterosteus aculeatus*), European smelt (*Osmerus eperlanus*), European eel (*Anguilla anguilla*) and European river lamprey (*Lampetra fluviatilis*) (van Booma, 2013). To mitigate these transitions, several projects along the Wadden Sea deal with the migration issues of diadromous fish species (figure 1.1).

Figure1.1: Overview fresh-salt transitions in the Wadden Sea area. These fishes indicate the locations where there are transitions locations. The red fish represent locations where no fish migration is possible, the blue fish represent locations where fish passages are being built, the yellow fish represent locations where plans for improvements are being written and the green fish represent locations where fish migration is possible again. (Source: https://rijkewaddenzee.nl/nieuws/veel-vispassages-aangelegd-en-werkend-in-waddengebied/, 2017)

One of the target species in these projects is the three-spined stickleback. This species is found throughout the Netherlands and is an important food source for numerous bird- and fish species (Wintermans, 1998; Kemper, 1995). Three-spined sticklebacks come in two forms (*leiurus Gasterosteus aculeatus and trachurus Gasterosteus aculeatus)*, of which the anadromous *trachurus Gasterosteus aculeatus* grows up in the sea and reproduces in freshwater and *leiurus Gasterosteus aculeatus* doesn't migrate (Huisman, 2017). The number distribution between the different variants is unknown, although it is expected that *trachuru Gasterosteus aculeatus* will be present in much fewer numbers due to the barriers that lie in its migration route (Winter, Griffioen & Van Keeken, 2014).

A project that supports the migration of three-spined stickleback is "fan swiet nei sâlt", which has ensured a gradual transition from fresh- to saltwater. This project is a collaboration between Wetterskip Fryslân and It Fryske Gea that is carried out in the framework of various laws and regulations, including the WFD, Natura 2000 and the European Eel Plan (van Booma, 2013). Funding for the realisation of this project came from the Waddenfonds and the European Agricultural Fund for Rural Development. In order to prevent flooding and facilitate a connection between the fresh- and saltwater, pumping station 'the Heining' has been constructed. The pumping station is built on a sea dyke, which therefore forms a connection between the Noorderleeg nature reserve outside the dyke, the polder and storage basin (basin or reservoir that collects and drain polder water) inside the dyke (figure 1.2). What is now the storage basin and the polder were still pastures in 2017. These pastures were bought up by Provincie Fryslân and used to create a new polder and storage basin, which formed a connection with the Frisian inland. A channel in the Noorderleeg forms the connection between the Wadden Sea and the pumping station, which in turn has a connection with the freshwater inland (Laansma, van Vliet & Bakker, 2015). This pumping station has a fish passage that attracts fish from the Wadden Sea utilizing a freshwater lure flow. The fish can migrate back to the Wadden Sea via a fish-friendly pump (figure 1.2).

Figure 1.2: The fish-friendly jack screw pumps at De Heining pumping station. The two jack screw pumps form a connection from the storage basin and the polder to the Wadden Sea. (Source: https://www.rijkswaterstaat.nl/water/waterbeheer/waterkwaliteit/maatregelen-waterkwaliteit/ruim-baan-voor-vis/vispassage-de-heining#&gid=1&pid=2)

In order to gain insight into fish migration at the pumping station, VisAvies B.V. has been carrying out research since 2019. A PIT (Passive integrated transponder) telemetry measuring network has been set up to monitor fish migration via the jack screw pumps of the pumping station, the fish passage and the fish sluice between the polder and the storage basin. PIT telemetry is a method in which a tagged fish has to swim through an antenna in order to be detected (Ellis, Linnansaari & Cunjak, 2013). In spring 2019 and 2020, the migration of three-spined stickleback passing the Heining has already been successfully monitored using PIT telemetry (Vis, 2020). After the fish have passed the pumping station, the migration is not yet over, as suitable spawning grounds still have to be found. Also, it is not clear if the three-spined stickleback will use the fish passage next to the Heining to get to the polder. A lot is already known about the three-spined stickleback, but it is not known how the dispersion develops (Arai, Ueno, Kitamura & Goto, 2020) in the Frisian inland after passing the Heining pumping station. One way of gaining an insight into the dispersion of the three-spined stickleback is by applying PIT telemetry. By mapping this dispersion with PIT telemetry, adjustments can be made by Wetterskip Fryslân in the polder- and storage basin to create more suitable spawning grounds. Also, this study is the first year of a multi-year study. Based on the data and conclusions of this research, the network of PIT-stations will be adjusted accordingly.

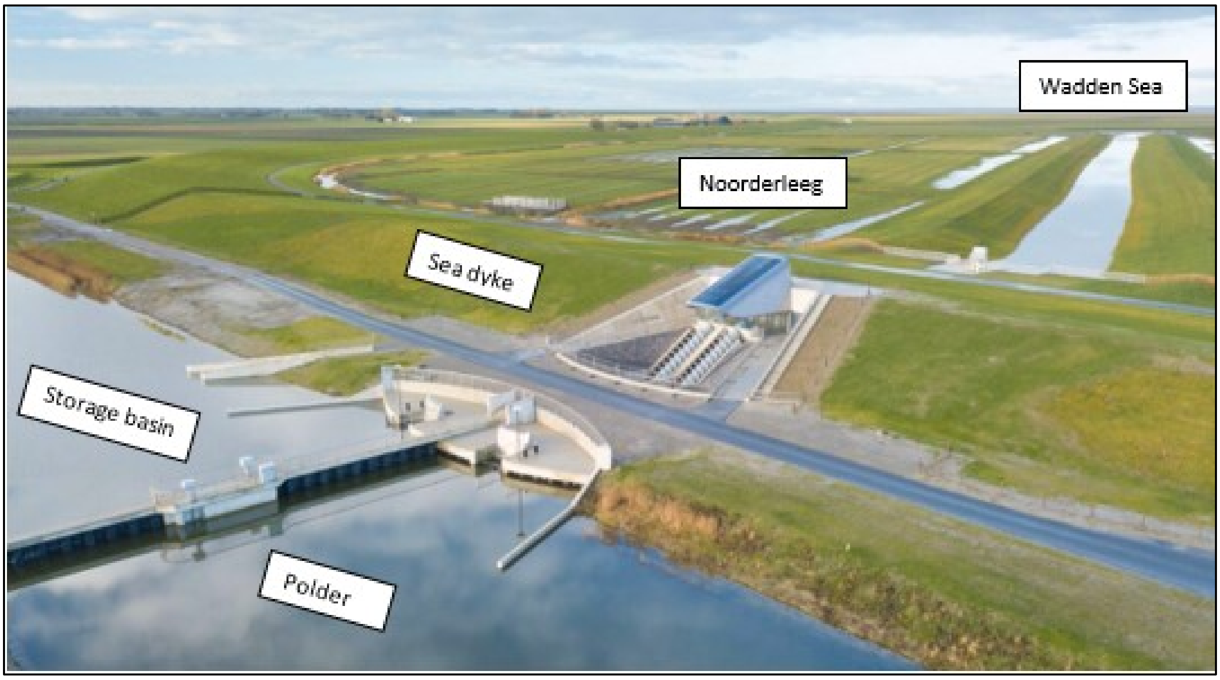

Figure 1.3:Pumping station the Heining was built in the sea dike near Hallum. This pumping station is connected to the Noorderleeg nature reserve and the Wadden Sea. The fish that come from the Wadden Sea can enter the storage basin via a fish passage. From the storage basin, they can use another fish passage to go to the polder, but they can also follow the storage basin inland. The fish can always migrate back via the jack screw pumps, one of which is located in the storage basin and the other in the polder. (Source: Twitter @RWS_NN, 2020)

To gain a better understanding of the dispersion of the three-spined stickleback, the following research question has been formulated:

How does the dispersion of the three-spined stickleback develop in the surrounding Frisian inland after passing the Heining pumping station?

To answer the main question, the following sub-questions have been formulated:

1. Which percentage of the three-spined stickleback follow the route to the polder using the fish passage Loc_5 next to pumping station the Heining and how many remain in the storage basin?

2. What is the dispersion in percentage per PIT-station of the three-spined stickleback, that stay in the storage basin, up to Hallum?
3. What is the dispersion speed in days of the three-spined sticklebacks spread through the Frisian inland?

The hypothesis is that three-spined sticklebacks have to leave the storage basin to find suitable spawning habitat. There are various possibilities, such as the fish passage next to pumping station the Heining. The fish passage is connected to the polder north of Marrum. But given the lack of a lure flow at the fish sluice, it is assumed that three-spined sticklebacks will migrate upstream in the storage basin after passing the pumping station. It is expected that three-spined sticklebacks will either look for a suitable spawning area in the storage basin between the Heining pumping station and the connection to the Dokkumer Ee (figure 2.1). There is also the possibility that they migrate to the Frisian storage basin via the Dokkumer Ee. In the latter case, three-spined sticklebacks can choose all kinds of routes. Therefore, it has been decided to demarcate the research area from pumping station the Heining to Hallum.

reading guide

The underlying report concerns thesis research in which PIT data was analysed of three-spined sticklebacks near pumping station the Heining. By first setting up a network of PIT Antennas, useful data has been collected that helped to answer the mean questions on the dispersion behaviour of three-spined sticklebacks in northern Friesland.

Chapter two describes the research method and the materials used to obtain answers to the research questions. Chapter three describes the planning that is results of this research and chapter four the discussion points. The last chapter, chapter five, describes the conclusions of this research and the recommendations.

2. Material and methods

This chapter describes the material and method used for this study. This research is based on PIT-station data from the 26th of March 2021 until the 7th of May 2021. The underlying chapter first describes the research area. Next, PIT telemetry is described and in chapter 2.2, the execution of the research and the tagging of the fish are described in chapter 2.3 and the data analyses are described in chapter 2.4. The tagging will be carried out by VisAdvies B.V., which has all the necessary permits and exemptions.

2.1 Research area

This section describes the research location, the fish passage near the pumping station and the transition from storage basin to polder.

2.1.1 location pumping station

The Heining was built in the sea dyke near the Frisian towns Hallum and Marrum (Figure 2.1). This is the location where the inland dispersion of three-spined stickleback for this research started. The pumping station has two jack screw pumps, one for the polder and one for the Friesian basin. The jack screw pumps are fish-friendly and pump the freshwater back into the brackish backland connected to the Wadden Sea. The supply of freshwater from the storage basin runs via the Hallumerhoekstervaart and the Hallumervaart, which connects to the Dokkumer Ee at Bartlehiem. Furthermore, there is a fish passage directly next to the pumping station that provides a connection between the storage basin and the polder.

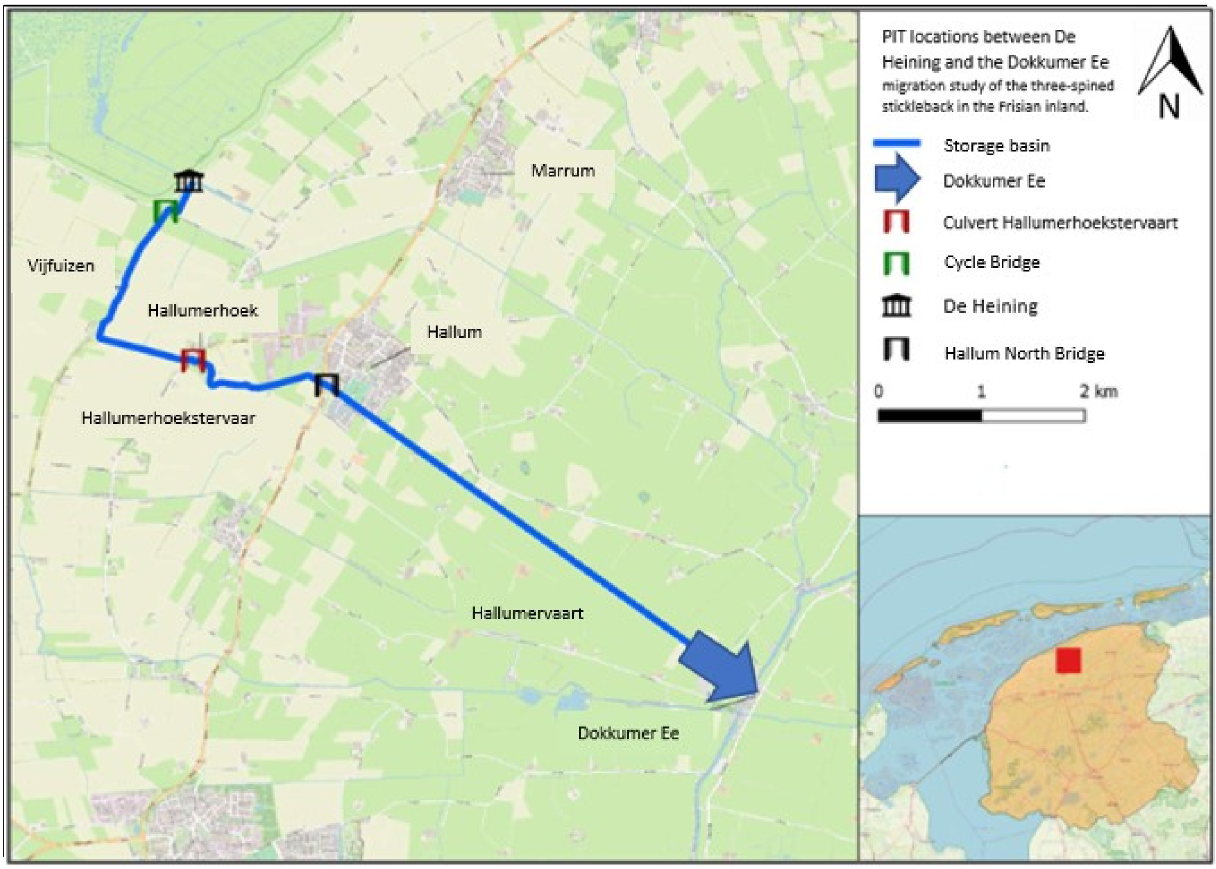

Figure 2.1: The locations of the PIT-stations with in black on the top left the location of the Heining pumping station. The location of the PIT-stations is indicated in colour: In green the cycle bridge near the pumping station, in red the culvert in the Hallumerhoekstervaart and in black the bridge at Hallum Noord. The blue arrow points to the Dokkumer Ee that is connected to the storage basin. Monitoring will be carried out up to Hallum.

2.1.2 Fish passage between storage basin and polder

Figure 2.2 shows a schematic representation of the Heining. The numbers indicate the fish passages in and around the pumping station. Loc_3 and Loc_4 are passages from the polder or the storage basin to the sea. Loc_2 is the connection from the sea to the freshwater storage basin at Loc_1. Loc_1 is the location where the inland dispersion of the three-spined stickleback begins. From this point, the stickleback can leave the storage basin and enter the polder via the fish passage at Loc_5. To check whether this was the case, a PIT-station was placed here. This PIT-station can provide an answer to the question of whether or not the three-spined stickleback disperses into the polder or whether they stay in the storage basin.

Figure 2.2: Schematic illustration of fish passages in the Heining and the fish passage that forms the connection between the polder and the storage basin. Using a lure flow, fish are lured from the sea to a collection tank (Loc_2). There is a waiting room where the fish gather. After a while, the tank closes and the water flows in free fall to the storage basin (Loc_1). Via fish-friendly jack screw pumps, the fish can migrate back to the sea (Loc_3 and Loc_4). Furthermore, there is a fish passage that forms the connection between the storage basin and the polder (Loc_5).

2.1.3 PIT-station from the fish passage to Hallum

Based on an initial reconnaissance by VisAdvies in January 2021, three locations for three separate PIT-stations have been chosen to monitor the dispersion of the three-spined sticklebacks in the storage basin (figure 2.1). Since the dispersion in the Frisian inland near the Heining is relatively unknown, it was decided to place the PIT-stations close to the pumping station for this study (Table 2.1). The description of the PIT-station in the fish passage has already been mentioned above and in this section, the other PIT-stations are described below. The various PIT-stations will help to answer the question of how the dispersion of three-spined sticklebacks develops in the storage basin. The dispersion speed in days of the three-spined stickleback, will be based on the release date and time, the release location and the distance covered at first detection per location.

Table 2.1: The distance that needs to be travelled by three-spined sticklebacks to the four different inland PIT-stations.

Location	Distance in meters to the Heining
Fish passage from storage basin to polder (point 1 to 5)	22
Cycle Bridge (Vijfhuizen)	413
Culvert Hallumerhoekstervaart (Hallumerhoek)	2730
Hallum North Bridge (Hallum)	4236

Cycle Bridge (Vijfhuizen)

Three-spined sticklebacks that were released in the storage basin were expected to disperse further into the storage basin. The cycle bridge is the first measuring point in the storage basin that was used to calculate the percentage of three-spined stickleback that disperse towards Hallum. The cycle bridge at Vijfhuizen was chosen since it was strategically the most suitable location to place a PIT-station. At this point, the storage basin narrowed, making it easier to install a PIT-station. Furthermore, a solar panel and a cabinet with electronics could easily be placed by the cycle bridge. The bridge was equipped with three PIT antennas and nets so that the fish had to swim through the antennas (figure 2.3).

Culvert Hallumerhoekstervaart (Hallumerhoek)

The second PIT-station was located near Hallumerhoek and was attached to a culvert. This location forms the second measuring point in the storage basin in which the percentage of three-spined sticklebacks that disperse to Hallum was calculated. This is also the point where the newly constructed storage basin reaches the Hallumerhoekkanaal.

Hallum North bridge (Hallum)

The last measurement location was in the village of Hallum. Here, a PIT-station was placed under a bridge on the Ljouwerterdyk with three Antennas. The last PIT-station ensured that the dispersal to Hallum could be monitored and an answer could be given on how the dispersal of the tree-spined stickleback developed.

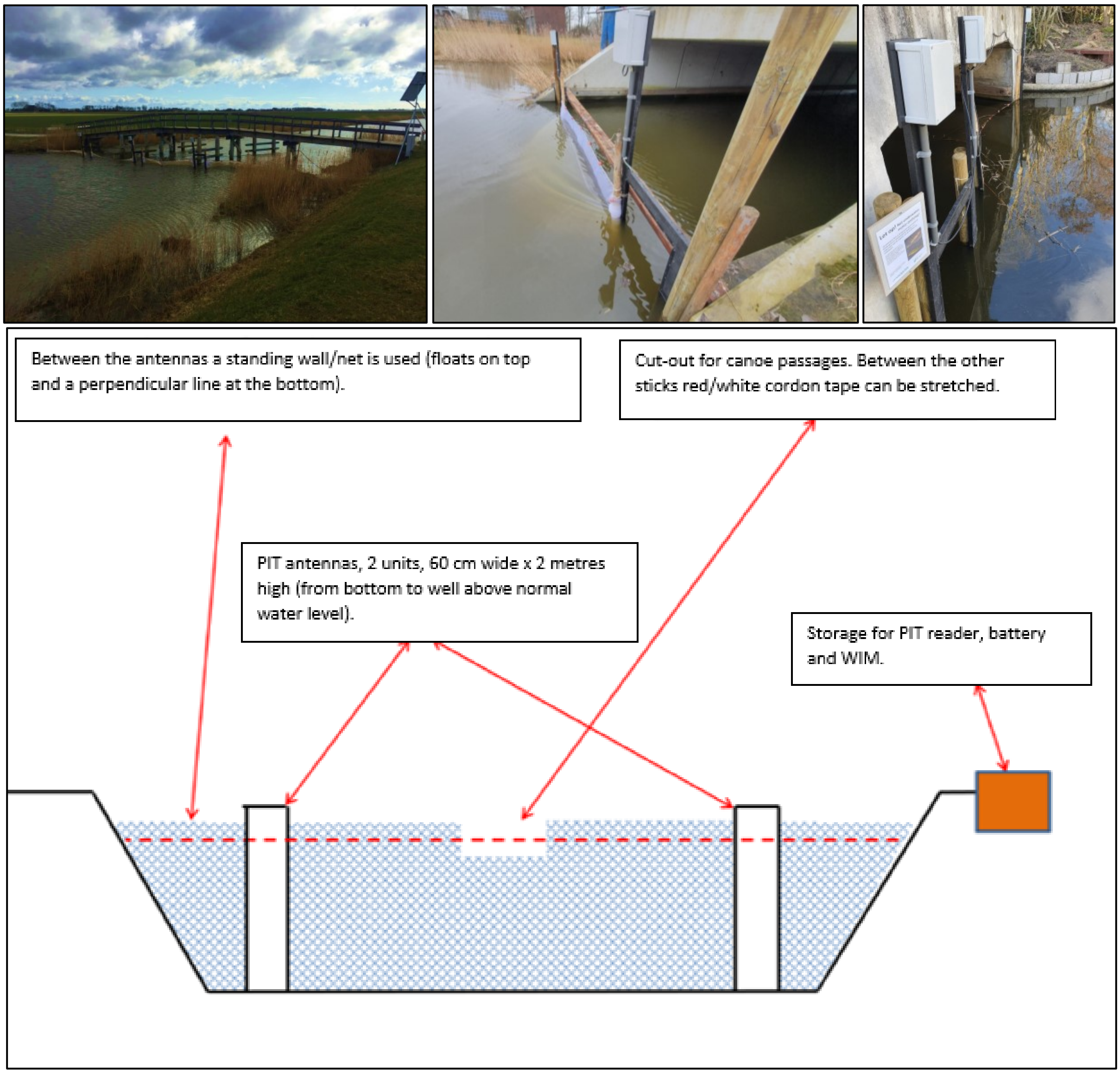

*Figure 2.3: Three PIT-stations were located in the storage basin to map the dispersal. **The left** image is of the PIT-station cycle bridge (vijfhuizen) and is the first PIT-station the tagged three-spined sticklebacks encountered. This location was equipped with three Antennas. The picture in **the middle** is the PIT-station that was placed at the culvert in the Hallumerhoekstervaart. Two antennas were used for this location so that the route for small recreational boats remained free. The last location was the bridge in Hallum north (**right image**). This location was equipped with three Antennas. All sites are equipped with retaining nets, forcing the fish to swim through the Antennas. Solar panels and batteries were used for the power supply. **The bottom** image is a schematic representation of how each location was deposited. (Source: Veenstra, 2021).*

2.2 PIT tag system

Passive integrated transponder (PIT) telemetry is a method using antennas and tags (Ellis et al., 2013). These tags do not have a battery, but a coil and are therefore called passive instead of active (Booth, Flecker & Hairston, 2014). This chapter will explain the further details of PIT telemetry and how it was applied to this research.

2.2.1 PIT tag Reader

A "Passive transponder fish- and wildlife tracking system "TM developed by the American firm Oregon RFID was used for this study. This system is often used to monitor fish migration through fish passages in small brook systems (Vollset et al., 2020). Figure 2.4 shows a diagram of the entire system. The system is based on the fact that fish marked with PIT tags, which pass a detection gate, are detected on the PIT tag reader. Each antenna has a tuner box with which the detection strength can be adjusted. Through Twinax cables, the signal is transferred to the Reader-box which stores the observations. The storage capacity of the system is virtually unlimited, with up to ten million detections being stored in permanent memory.

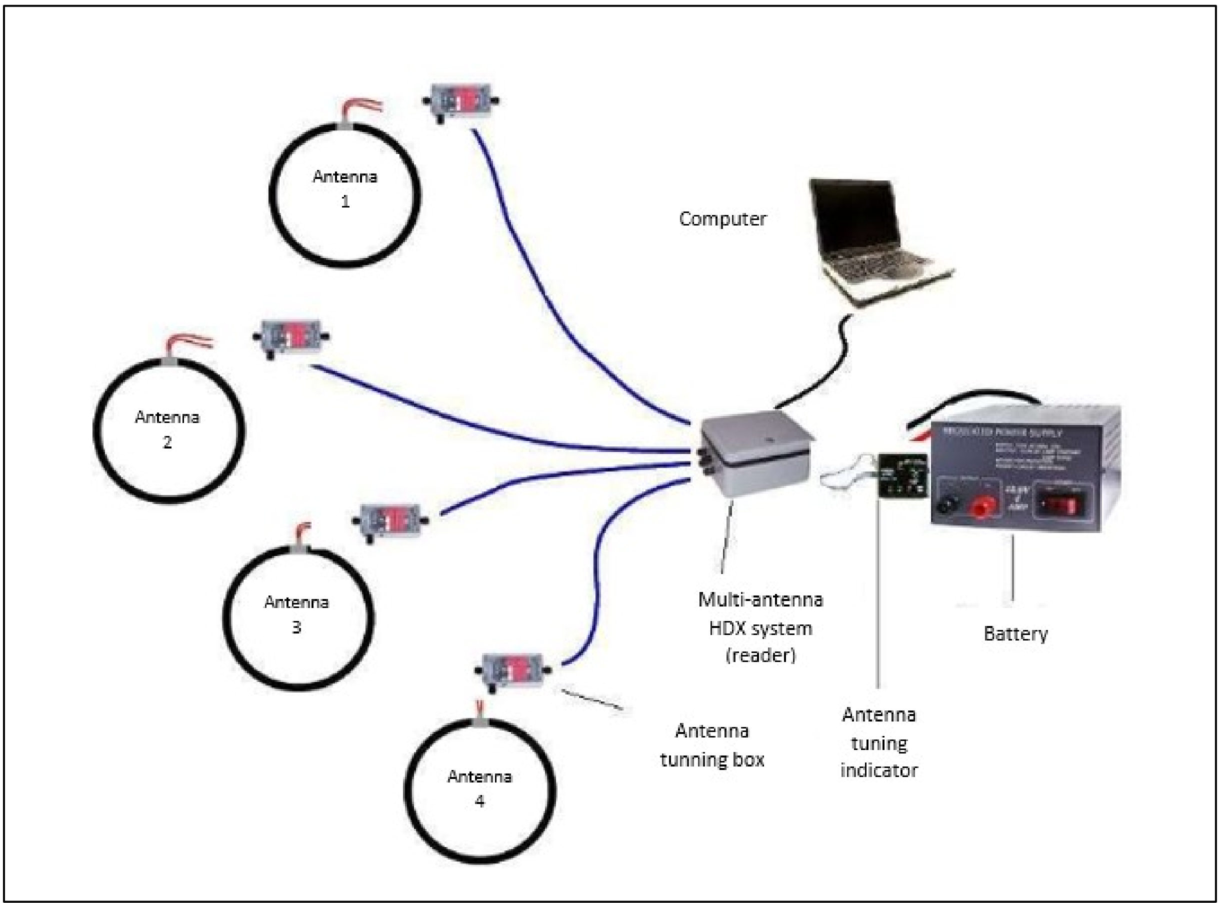

Figure 2.4: A schematic illustration of a PIT-station. The tunning box ensures that the antenna functions optimally for detections. The reader processes the detections and then sends them to the cloud via a WIM (wireless internet module). Via the computer the data can be opened and read out. (Source: Vis, 2020)

A wireless internet module (WIM) ensured that every 24 hours the observations were sent to a cloud for further processing. This way, a malfunction was detected within a day at the most. The data was daily backed up to a different location (Cloud service). Each detection included the unique PIT tag number, the number of the detection antenna and the time/date of detection. The PIT-stations were powered by a mains connection or a solar panel (with a charging unit and two 12V batteries).

2.2.2 Detection gates (Antennas) and PIT tags

The PIT tag Reader can simultaneously monitor the dispersion of tagged fish at four antennas. For this study, a maximum of three antennas was used per PIT-station. The maximum distance between the PIT tag Reader and the detection gates was 20 meters. The detection gates consisted of a durable plastic frame into which an insulated copper wire was inserted. Metal cannot be used for this purpose as it will negatively influence the antenna. The frame was placed in the fish passage so that passing fish has to swim through the detection gate (Figure 2.5). A tag, which comes within range of the detection gate, was charged by the magnetic field of the copper wire. The detection gate then switched to a listening mode. The charged tag sends its unique code, which was received by the detection gate (Vollset et al., 2020). The whole cycle takes place within a fraction of a second. The maximum size depends on the conditions on-site and the type of tag used. Based on the species and especially the size of the fish it was determined which tag can be used. The tags for PIT telemetry range from 32 mm to 12 mm (Thorstad, Rikardsen, Alp & Økland, 2013) and the 12 mm tags were therefore suitable for three-spined stickleback (Lacroix, Knox & McCurdy, 2004).

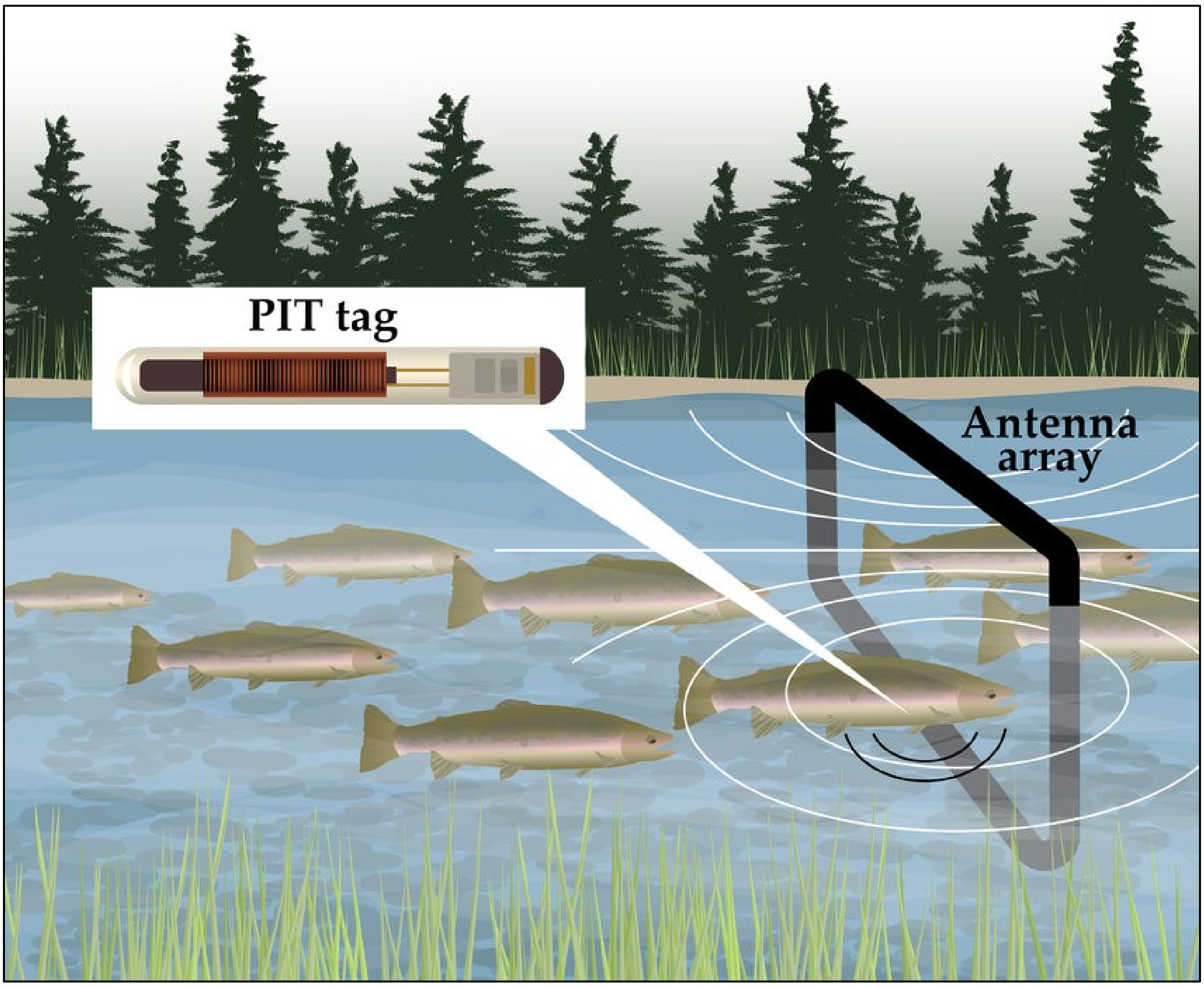

Figure 2.5: An example of how PIT telemetry can be used to detect the dispersion of fish. The antenna produces an electromagnetic field that releases the PIT tag into the fish. The tag in turn sends a unique signal which is then detected by the antenna. By placing a network of antennas, dispersion routes can be monitored. (Source: Keefe et al., 2019)

2.3 Execution dispersion research

Section 2.3 describes how this research was carried out. It discusses the licenses, target species, method of capture, tagging and release location.

2.3.1 Licenses, exemptions and animal experimentation law

Wetterskip Fryslân provided the necessary permits and exemptions for catching the three-spined sticklebacks. According to the Interventions Decree of the Animal Experiments Act, trials on animals are only allowed if there is a positive project authorisation for carrying out this research. The research proposal states that approximately 2000 fish can be marked during three years and several locations. The tagging was carried out by VisAdvies, which holds a WOD license (law on animal experiments).

2.3.2 Target species, numbers and dates

The target species for this study was three-spined stickleback. Three-spined stickleback prefers vegetation-rich environments with clear water. It uses the vegetation to build its nest and it is a sight hunter. Furthermore, the optimum temperature is 15-16°C and the oxygen concentration should be around 7mg/l (van Keeken, Vriese & de Leeuw, 2007; Mehlis & Bakker, 2014). When sexually mature, three-spined sticklebacks migrate to freshwater to reproduce. They migrate between February and May to spawn and between September and October, they return to the sea (Wootton, 1976). The migration of three-spined stickleback is influenced by water transparency, temperature and salinity (Sohel & Lindström, 2015). According to Kitano, Ishikawa, Kume and Mori (2012), three-spined stickleback can migrate quickly and with a short acclimatisation time from salt to fresh water and *vice versa*. The swimming speed lies between 0.2m/s and 0.9m/s (Winter et al., 2014).

From the 26th of March to the 7th of May, 379 sticklebacks over 55 mm in length were tagged with a 12 mm tag (Annex I). Table 2.2 shows the dates and the number of fish that were tagged each day.

Table 2.2: The number of tagged three-spined sticklebacks and their release dates. A total of 379 fish were tagged on three different dates.

Release date	Number of tagged three-spined sticklebacks
26-03-2021	175
09-04-2021	46
16-04-2021	158
Total	**379**

2.3.3 Catching the three-spined stickleback

Due to the low presence of three-spined sticklebacks in the spring of 2021, it was impossible to catch them near pumping station the Heining. The three-spined sticklebacks that were used for this study came from Zwarte Haan and Roptazijl pumping stations, which are located along the Wadden sea coast as well (12 kilometer and 30 kilometer west from the Heining). Both locations had a trap at the end of their fish passage so that all fish that passed through the passage also entered the trap. The traps were emptied on several days and the fish were kept in captivity for up to 72 hours before being tagged. The numbers were counted and damaged and under-sized sticklebacks were released. The remaining sticklebacks were taken to the Heining where they were tagged. The three-spined sticklebacks that were not tagged were released at their place of origin.

2.3.4 Marking and plotting location

The selected three-spined sticklebacks were again checked for external damage so it was certain that the fish to be tagged was in optimal condition. Based on various studies (Acolas, Roussel, Lebel & Baglini`ere, 2007; Baras, Malbrouc, Houbart, Kestemont, & Me´lard, 1999; Bruydoncks, Knaepkens, Meeus, Bervoets & Eens, 2001; Kobler, Humblet, Geudens & Eens 2012; Ridley, Eagle, Ives, Rycroft & Wilkinson, 2003) VisAdvies B.V. has set requirements for a minimum size of 55 mm, the weight of the tag has to be less than 8% of the total bodyweight (Lacroix et al., 2004) and the condition of three-spined sticklebacks should be good. Before tagging, the sticklebacks were anaesthetized by applying a solution of benzocaine (100 ppm). During this process of anaesthesia, the suitability of the fish for tagging was determined by VisAdvies B.V. (general condition, weight criterion; the fish is measured and weighed). Semi-sterile work (sterile cloths, gloves and surgical equipment) was carried out and a PIT tag was inserted into the abdominal cavity. A small incision was made after which the tag was inserted (figure 2.6). The incision was made with a scalpel. This incision was so small that suturing was not necessary. After the operation (total time: approx. 30 seconds) the tagged individuals were transferred to a continuously flowing tank and were observed continuously until the individuals were fully recovered. The following data were recorded: date of capture, location of capture, total length in millimeters (mm), weight in grams (g) and the unique PIT tag number. The tagged three-spined stickleback was released at the outlet of the fish passage. This is where the fish would normally enter if they had come from the sea (figure 2.2 number 1). Every tag day, the number of tagged three-spined stickleback was recorded (table2.2).

*Figure 2.6: (**left**) A small incision was made after the three-spined stickleback was measured and weighed. (**middle**) The PIT tag was inserted into the abdominal cavity of the three-spined stickleback via an incision. (**Right**) The tag was placed and the incision closed by itself because it was a small opening. (Source: Vis, 2021)*

2.4 Analyses and reporting

This section describes the data management and which data was used for this study. The data that could be compared was statistically substantiated. This is explained in section 2.4.2.

2.4.1 data management

From the first day of tagging on the 26th of March until the 7th of May, data was collected from the PIT-stations. This data was transmitted via a WIM to the relational database of VisAdvies as described in section 2.2.1. The collected data from the PIT-stations was merged with the data from each tagged individual in order to match the detected unique PIT code per PIT-station with the characteristics of each individual three-spined stickleback. The merging of the data was done with Postgis in Qgis using Structured Query Language (SQL). The results are displayed in GIS-maps, tables and graphs.

2.4.2 statistics

The geographical dispersion of the three-spined stickleback was analysed using Qgis. The descriptive statistical analyses was performed using Excel. Boxplots were used to describe the dispersion speed

3. Results

A data analysis of the collected detections took place in the spring dispersion from the 26th of March till the 7th of May of the three-spined stickleback. In total 379 individuals were tagged of which 121 of unique individuals were observed on one of the PIT antennas in the area. The tagged individuals were on average 2.47 grams and 64 millimeters (annex II). The detected individuals were on average 2.88 grams and 67 millimeters. In table 3.1 the observations are split up per release date in the columns and per location in the rows. The table also shows the locations of the PIT-stations in the Heining, as these belong to the total detected individuals of this study (figure 3.1). Furthermore, some individuals have been detected at multiple locations.

Table 3.1: Observed Three-spined Sticklebacks per release date and per PIT-station. The column "detected" indicates the number of different individuals detected. Cycle bridge, culvert and Hallum together form the route within the storage basin. Loc_1 to Loc_5 are the PIT-stations around pumping station the Heining as shown in figure 3.1.

Date	Tagged	Detected	Cycle Bridge	Culvert	Hallum	Loc_1	Loc_2	Loc_3	Loc_5
26-mrt	175	95 (54,3%)	78	8	5	15	1	5	3
9-apr	46	6 (13,0%)	x	1	x	1	x	3	2
16-apr	158	18 (11,4%)	2	4	1	4	1	4	8
Total	**379**	**121 (31,9%)**	**80**	**13**	**6**	**20**	**2**	**12**	**13**

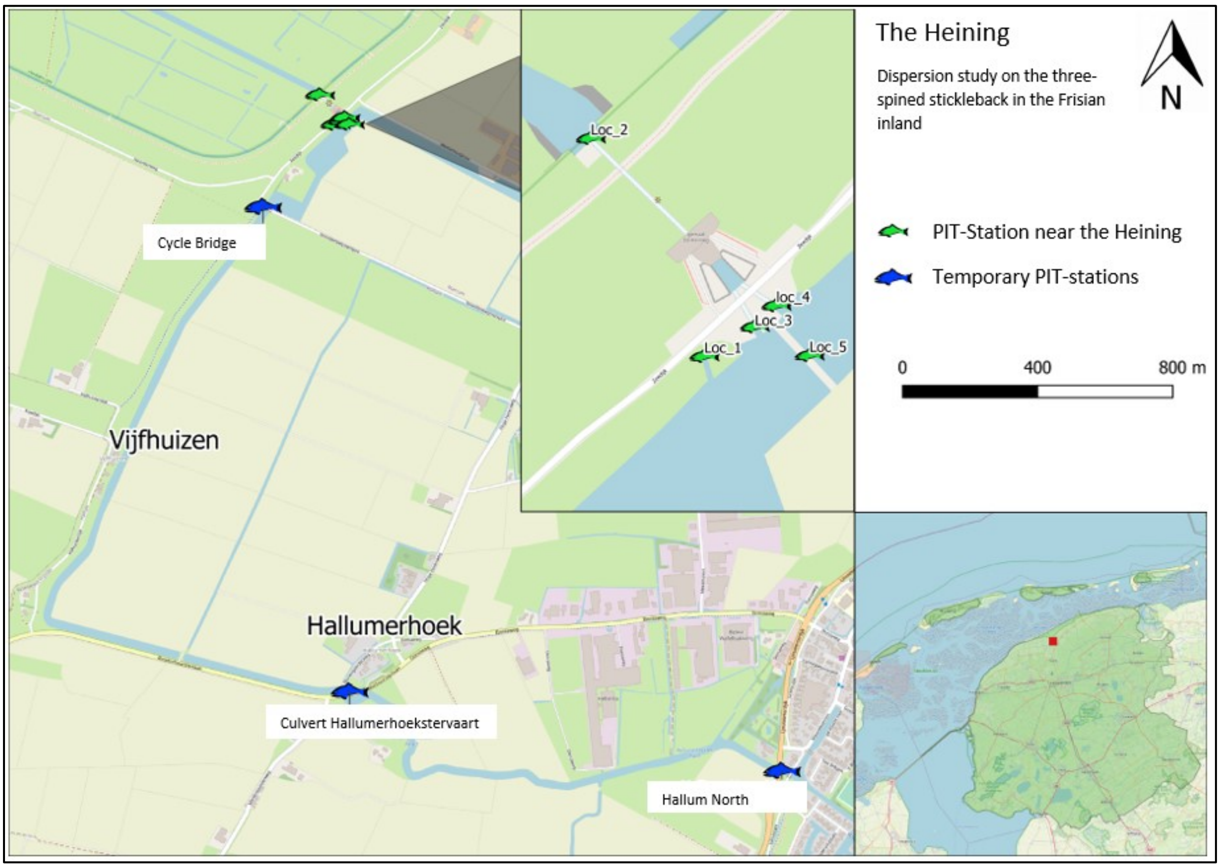

Figure 3.1: All PIT-stations used during the dispersion study of the three-spined stickleback in spring 2021.

3.1 fish passage to the polder

Three-spined sticklebacks were released at Loc_1 on three different dates (26 March, 9 April & 16 April). Loc_1 is the location where fish migrating from salt to freshwater normally enter the storage basin. In total, 121 of the 379 individuals released were detected at one of the PIT-stations. Of these, 100 individuals were detected at Loc_5, the cycle bridge, the culvert or in Hallum. Here, most individuals chose to stay in the storage basin. In total, 87 individuals were detected in the storage basin, which is 23% of the total release and 73.1% of the group that was detected (annex III & annex VIII).

Table 3.2 lists the individuals detected at PIT-station Loc_5. A total of 13 individuals were detected, representing 3.4% of the total release and 10.7% of all detected individuals. Furthermore, the first detection and the last detection are included in the table to confirm that the three-spined sticklebacks chose the route to the polder using the fish passage at Loc_5. It is also noted for Loc_5 the antenna on which they were detected. Loc_5 A1 is located at the polder side of the fish passage and A2 at the storage basin side. From the first release group, three individuals or 1.7% has been detected at Loc_5. This percentage is 3.2% if only the detected individuals are considered. These individuals first swam into the storage basin and then back to the fish passage (Loc_5) that forms the connection with the polder. In the second release on 9 April, two individuals or 4.3% was detected at Loc_5. This percentage is 33.3% if only the detected individuals are considered. In the last release on 16 April, a total of 8 individuals or 5.8% has been detected at Loc_5. This percentage is 34.9% if only the detected individuals are considered. Of the last two groups, the detected individuals at Loc_5 were not detected at other locations. Of the total number of three-spined sticklebacks detected at Loc_5 (N=13), 6 individuals there last detections was at A1 and 7 individuals there last detection was at A2.

Table 3.2: The table below shows the individuals detected at PIT-station Loc_5. The first column shows the number of individuals detected. The second column shows the unique PIT number. Furthermore, the release date, first detection, last detection and the detection locations are shown in the table.

Detections loc_5 (Polder fish passage)						
Number	PIT_ID	Release date	First detections date	Location	Last detection date	Location
1	900_226000310732	26-3	26-3	Cycle bridge	29-3	Loc_5 (A2)
2	900_226000310779	26-3	29-3	Cycle Bridge	1-4	Loc_5 (A1)
3	900_226000310611	26-3	31-3	Cycle bridge	20-4	Loc_5 (A2)
4	900_226000310405	9-4	5-5	Loc_5 (A2)	5-5	Loc_5 (A2)
5	900_226000310433	9-4	18-4	Loc_5 (A2)	18-4	Loc_5 (A1)
6	900_226000310513	16-4	16-4	Loc_5 (A2)	16-4	Loc_5 (A1)
7	900_226000310552	16-4	17-4	Loc_5 (A1)	17-4	Loc_5 (A1)
8	900_226000310507	16-4	19-4	Loc_5 (A1)	19-4	Loc_5 (A1)
9	900_226000310432	16-4	20-4	Loc_5 (A2)	20-4	Loc_5 (A1)
10	900_226000310553	16-4	20-4	Loc_5 (A2)	20-4	Loc_5 (A2)
11	900_226000310539	16-4	20-4	Loc_5 (A2)	20-4	Loc_5 (A2)
12	900_226000310509	16-4	21-4	Loc_3	21-4	Loc_5 (A2)
13	900_226000310523	16-4	4-5	Loc_5 (A2)	4-5	Loc_5 (A2)

3.2 Dispersion percentage in the storage basin

The fish which not entered the polder using the fish passage at Loc_5 or the other passage at Loc_3 to Loc_2 (back to the sea) dispersed upstream in the storage basin (figure 3.2). At the cycle bridge, 80 individuals were detected. This represented a percentage of 21.1% of the total tagged individuals. If only the detected individuals are taken into account, the percentage is 66.1%. From the first release group on 26 March most individuals were detected (N=78) at the cycle bridge. From the other two release days, two individuals were detected near the cycle bridge.

After the cycle bridge, the next PIT-station was located at the culvert in the Hallumerhoekstervaart, which is 2.7 km from the release site. A total of 13 individuals were detected here, which is 3,4% of the total release. This percentage is 10.7% if only the detected individuals are considered.
The last PIT-station was located at 4.2 km from the release site and is situated in Hallum. At this location, a total of 6 individuals or 1.6% of the total release were detected. When comparing to the total of individuals detected, the percentage is 5%. Furthermore in annex VI, the routes of 25 individuals detected at multiple locations are visualized in a table.

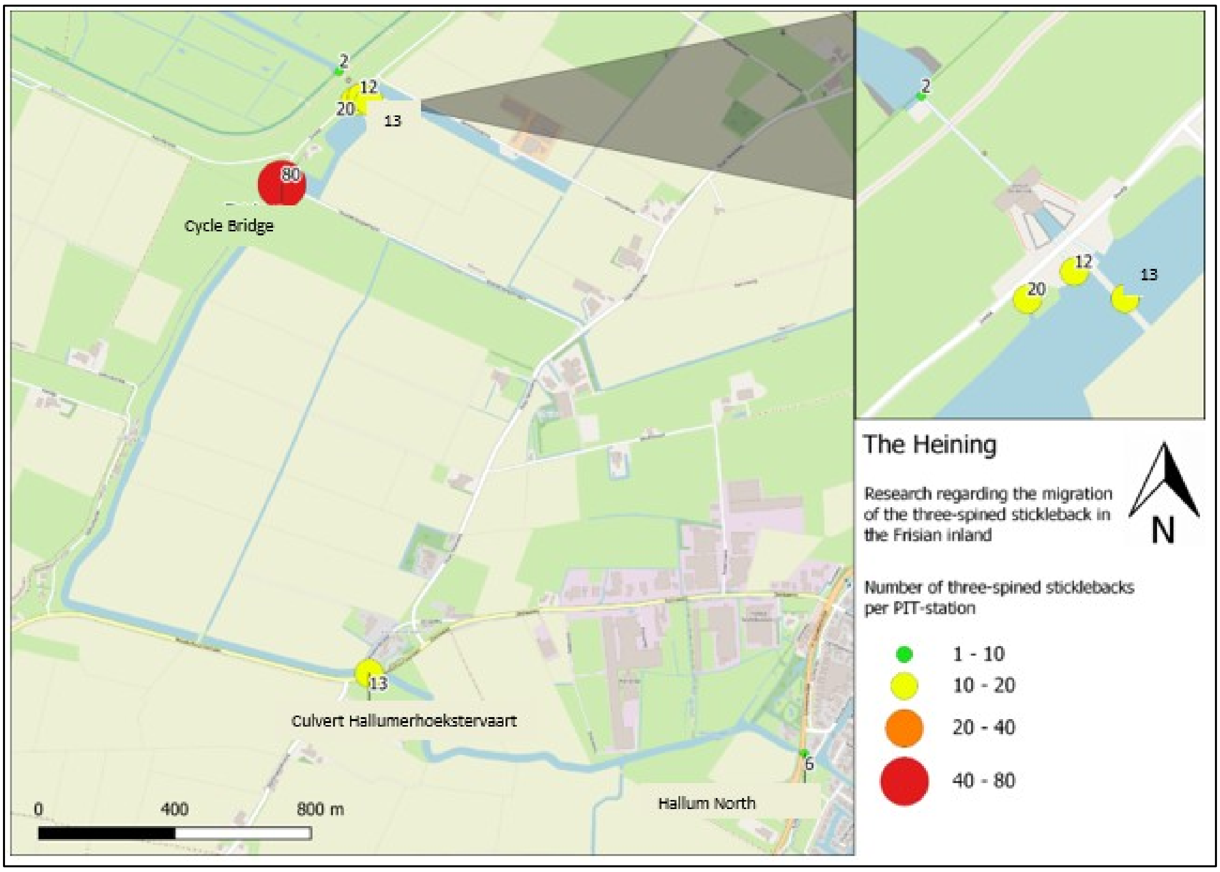

Figure 3.2: The above illustration shows the dispersion of three-spined sticklebacks in the Frisian inland near Hallum. In the upper right corner, the PIT-stations near the Heining are zoomed in. The results of the fish passage to the polder have been described in the previous section. The large image on the left shows the dispersion of three-spined sticklebacks in the storage basin. 80 individuals were detected near the cycle bridge (large red circle). At the culvert at the Hallumerhoekstervaart, a total of 13 individuals were detected (yellow circle) and in Hallum, 6 individuals were detected (green circle).

3.3 Dispersion speed in the Frisian inland

By registering the time of release at pumping station Heining (Loc_1) and the time of detection at one of the inland PIT-stations it was possible to determine the dispersal speed per individual. The dispersion speed in days is based on the first detection at each PIT-station. Figure 3.3 shows the dispersion speed in days of 112 detections. This concerns 100 individuals. Some individuals were detected on more than one PIT-station, which makes the number of detections higher than the number of individuals. So, for example, 900_226000310722 was detected at all three stations in the storage basin. This way the dispersion speed from Loc_1 to the cycle bridge, from Loc_1 to the culvert and from Loc_1 to Hallum could be determined. These individuals are included multiple times in the boxplot. The dispersal speed in days varies strongly with values from 0.1 to 27.2 days. Here 0.1 is a fast dispersion speed and 27.2 a low dispersion speed. The average dispersal speed was 4.4 days till the first detection (annex IV).

The blue box shows 50% of the observations that are around the median and the Whiskers the 25% that are above or below. The outliers are shown as separate dots. The median at Loc_5 was 3.5 days with 50% of the values falling within 3.1 and 13.5 days. For the cycle bridge the median was 2.3 and 50% of the values fell within 1.2 and 4 days. The next location was the culvert where the median was 9.5 and 50% of the values fell between 2.2 and 10.4. The last location was Hallum. Here the median was 8.3 and 50% of the observations were within 5.1 and 25.6.

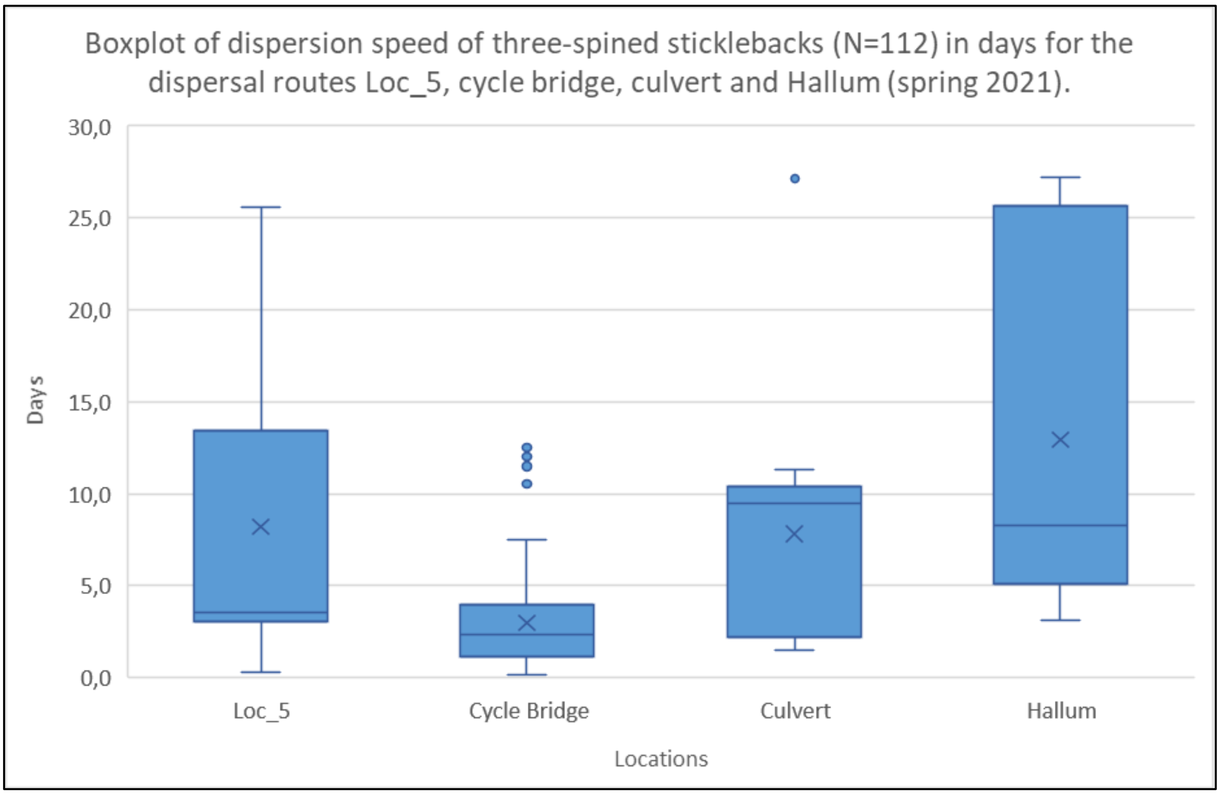

Figure 3.3: Locations after passing pumping station de Heining and the dispersion speed in days. The smallest observation was 0.1 days and the largest observation was 27.2 days. The average is marked with an X. The median is the blue horizontal line in the box. The median is located between the first quartile and the third quartile. The locations Cycle bridge and Culvert have some outliers.

As the PIT stations were located at different distances (table 2.1), the dispersion speed was also calculated in metres per day (figure 3.4). The dispersion speed of each three-spined stickleback was divided by the distance that the three-spined stickleback had to travel so that the dispersal speed per day could be calculated. The dispersal speed in meters per day varies greatly from 0.9 meters per day to 2779.1 meters per day. The dispersion rate in metres per day was lowest at Loc_5 with a median of 6.3 m/day. The median at the cycle bridge was 177.2 m/day, at the culvert 287.5 m/day and at Hallum 551.1 m/day.

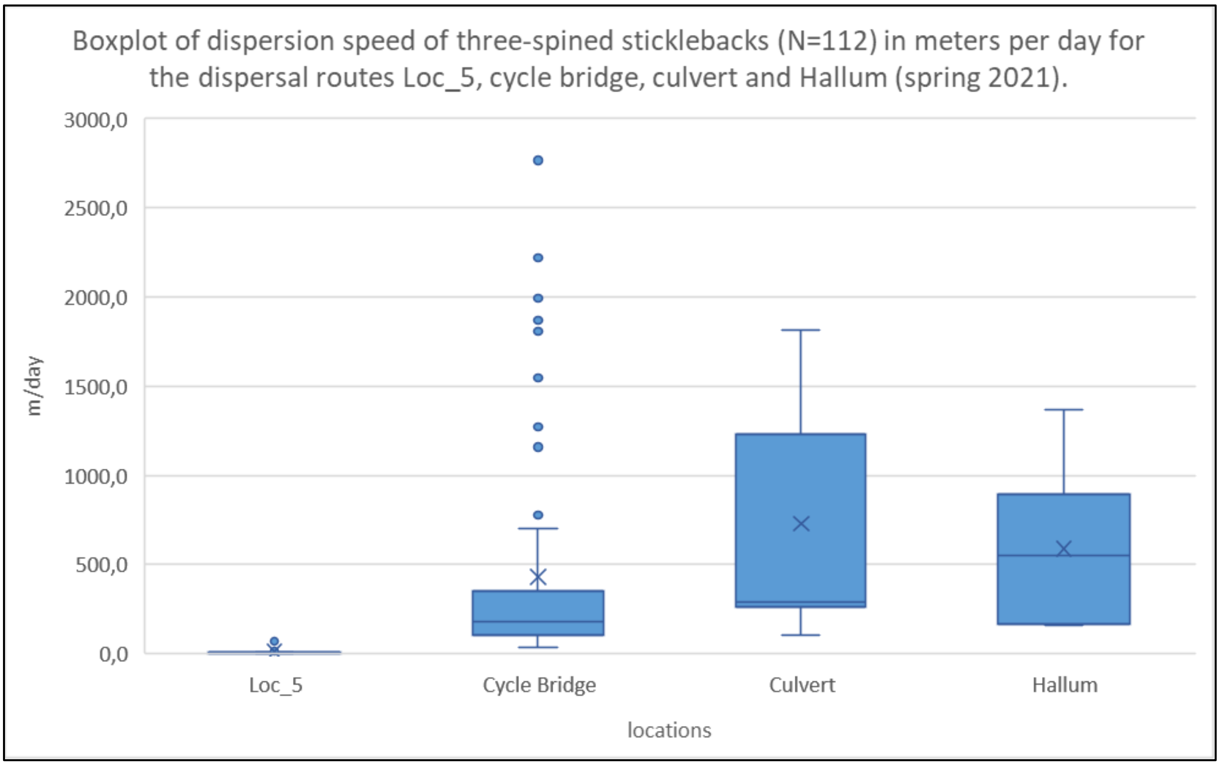

Figure 3.4: : Locations after passing pumping station de Heining and the dispersion speed in meters per day. The smallest observation was 0.9 m/day and the largest observation was 2779.1 m/day. The average is marked with an X. The median is the blue horizontal line in the box. The median is located between the first quartile and the third quartile. The locations Cycle bridge and Loc_5 have some outliers.

4. Discussion

The aim of this first year of a multi-year study was to gain insight into the dispersal of three-spined stickleback in the Frisian inland near Hallum. To this end, 379 three-spined sticklebacks were tagged and PIT-stations were placed at several locations. These individuals had to provide insight into the dispersion and where to monitor next year to get an even better understanding of the dispersion.

The underlying paragraphs discuss the results of the sub-questions and the method used to collect the data and evaluate the results.

4.1 fish passage to the polder

In total 13 individuals or 10.7% of the detected individuals (N=121), were detected at Loc_5 (the fish passage to the polder). Because they were last seen at this location, it was assumed that they entered the polder. The other 366 stayed in the storage basin. Of this total, 87 individuals were detected at one of the PIT-station within the storage basin. Therefore, it can be said with certainty that of the 379 individuals, 87 individuals stayed in the storage basin between the Heining and the cycle bridge, which is 23% of the total release and 71.9% of the group that was detected (N=121).

This partly confirms the hypothesis that the three-spined stickleback will follow the route through the storage basin. Because there was no lure flow, it was assumed that the three-spined sticklebacks could not find the fish passage at Loc_5. Various studies have also described the usefulness of a lure flow and how fish can use it to orientate themselves (Meersschaut, De Charleroy, Verbiest, Wens & Van Slycken, 1998; Faber et al., 2001; Williams, Armstrong, Katopodis, Larinier & Travade, 2012; Silva et al., 2018). Three-spined stickleback also orientates itself to a difference in current and salinity (Sohel & Lindström, 2015; Kitano et al., 2012; Olsson et al., 2019; Ishikawa & Kitano, 2020). Because there was no lure flow at Loc_5, it was likely that the majority of three-spined sticklebacks would choose another route and that only a few would use the fish passage to the polder. Nevertheless, of the total number of detected individuals in the storage basin and at Loc_5 (N=100), 13% used the fish passage at Loc_5 to go to the polder.

How the dispersion develops in the polder is unknown. At the polder side, there is a PIT-station (Loc_4) that monitors the connection with the Wadden sea. This PIT-station was not active during this study, so it could not be ruled out that three-spined stickleback used Loc_4 to return to the sea after passing Loc_5. Therefore, the operating hours of the fish-friendly jack screw pumps were requested from Wetterskip Fryslân (annex VII). This shows that the fish friendly jack screw pumps did not rotate during the dispersion study. It can therefore be ruled out that the three-spined sticklebacks that reached the polder swam back to sea via Loc_4.

There were two active antennas in fish passage Loc_5, which made it possible to establish that the three-spined sticklebacks went into the polder. The antenna A2 was located on the storage basin side and A1 on the polder side. If three-spined sticklebacks were registered on antenna A1, it was assumed that the three-spined stickleback had reached the polder. As can be seen in table 3.2, 6 individuals can be said with certainty to have reached the polder via Loc_5. It is impossible for the fish in the polder to swim back to the storage basin via Loc_5. The other 7 individuals were only detected on antenna A2, which could mean that these individuals did not reach the polder. However, there is a possibility that they reached the polder at Loc_5, because the individuals were not registered at other locations. Furthermore, the antennas of Loc_5 were not very sensitive, so it is possible that individuals have used the fish passage unnoticed. Therefore, it is difficult to estimate how reliable the detections at antenna

A2 at Loc_5 are and whether they can give an answer about reaching the polder. The detections made on antenna A1 can be said with certainty to have reached the polder successfully.

4.2 Dispersion percentage in the storage basin

In line with the hypothesis that most three-spined sticklebacks disperse upstream into the storage basin, the results also show that the gross also spreads in the storage basin. Of the total release (N=379), 87 individuals were observed at one of the PIT-stations in the storage basin. This is 23% of the total release and 71.9% of the group that was detected.

Three stations were placed in the storage basin, so that dispersal could be monitored as far as Hallum. From the pumping station the Heining, the PIT-station at the cycle bridge was the first place where three-spined sticklebacks were detected during their dispersal through the storage basin. A total of 80 individuals were observed here, but three individuals were later observed at Loc_5. Thus, 77 individuals can be said to have stayed near the cycle bridge or to have spread further. This is 88.5% of the three-spined sticklebacks that remained in the storage basin (N=87). The second location was at the culvert in the Hallumerhoekstervaart. A total of 13 individuals were observed here, which is 14.9% of the individuals that remained in the storage basin. The last PIT-station was located in Hallum and ensured that dispersal through the storage basin could be monitored from pumping station the Heining to Hallum. At this location, a total of 6 individuals were detected, which is 6.9% of the individuals detected in the storage basin.

Two of the 87 individuals were detected at all three PIT-stations. In addition, ten individuals were detected at the second and third PIT-stations in the storage basin. These individuals probably also passed the first PIT-station by the cycle bridge, but were not detected at this PIT-station. This may suggest that several individuals passed the PIT-station at the cycle bridge unseen. It is therefore possible that the number of three-spined sticklebacks that pass by the cycle bridge is higher than the number that are detected. Furthermore, there were problems with the reader (collects the data) in the week from 16 April to 23 April, causing valuable information to be lost. Of the group released on 16 April only 11,4% has been observed, of which only 1.3% at the cycle bridge. On 25 March an almost equal number of individuals was released and 54.3% of the group was detected. Most of this group was detected within a week at the cycle bridge (annex IV). The difference in detection percentage between the two release dates is probably due to the fact that the reader was not active for a week. Due to the fact that the reader did not work, many detections were probably missed, as a result of which the number of detections for the cycle bridge in particular was much lower than it would have been if the reader had worked. Also, the detection percentages for the other locations are now higher than they may actually be.

During this study an inlet to the polder between the cycle bridge and the culvert at the Hallumerhoekstervaart appeared to be open. This had not been taken into account. This inlet was not equipped with a PIT-station, so that in theory thee-spined sticklebacks could reach the polder unseen. The number of detected individuals also decreases significantly between the cycle bridge and the culvert (from 77 individuals to 13 individuals). This decrease can be caused by several options. The first one is that three-spined stickleback has found a suitable spawning place in the storage basin between the cycle bridge and the culvert. According to theory, three-spined stickleback prefers a vegetation-rich environment with clear water (Clavero, Pou-Rovira & Zamora, 2009; Candolin, 2004; Taylor et al., 2006; Ajemian, Sohel & Mattila, 2015; Rybkina, Ivanova, Ivanov, Kucheryavyy & Lajus, 2017). There is vegetation in the storage basin, which could mean that three-spined stickleback is already spawning here. Although there is vegetation in the storage basin, it was expected that three-spined stickleback would migrate into the polder. Apart from the fact that three-spined sticklebacks need vegetation, various sources suggest that they find their suitable spawning grounds in the polder (van Keeken et al., 2007; Mehlis & Bakker, 2014; Huisman, 2017). Furthermore, the three-spined stickleback is at risk of predation, which may also reduce the number of detected individuals (Wintermans, 1998; Kemper, 1995; Spence, Wootton, Barber, Przybylski & Smith, 2013). The last possibility is that they did use the inlet to the polder between the cycle bridge and the culvert.

To give a clear answer to where the three-spined stickleback has gone to, follow-up research is needed.

4.3 Dispersion speed in days

To give an indication of how quickly three-spined sticklebacks disperse in the Frisian inland near Hallum, the dispersal speed was calculated in days and meters per day. In total, 112 detections of 100 individuals were used to calculate the dispersal speed. In other studies the swimming speed is often calculated in meters per second (Winter et al., 2014), but that is not possible in this study because this study focused on dispersion speed and not actual swimming speed. Therefore, meters per day and number of days to first detection were chosen. The dispersal speed varied widely from 0.1 days to 27.2 days, in which 0.1 days is a fast dispersal speed. The average dispersal speed per PIT-station also varied widely from 3 to 12.9 days. To get a better idea of the dispersion speed per station, the distance in meters was divided by the number of days until the first detection. For Loc_5 median of the dispersion speed was 6.3 m/day, for the cycle bridge the median was 177.2m/day, for the culvert it was 287.5m/day and for the last location it was 551.1m/day. This information gives an indication of how well three-spined stickleback can orient itself in the storage basin.

As can be seen in Figure 3.3 and 3.4, there were outliers that had a negative effect on the average dispersion speed per PIT-station. The PIT-station at Hallum did not have any outliers, as this was only a small data set of 6 detections. The locations of Loc_5, the cycle bridge and culvert did have some outliers, which means that these values do not seem to fall within the other values. Therefore, it was assumed that these outliers did not belong to the real dispersion speed. The results were therefore discussed using the median. This gave a better picture of the dispersion rate.

The dispersal speed can also be used to determine whether three-spined sticklebacks can easily orientate in the storage basin, as indicated before. A similar advisory report by Schollema (2018) also looked at the dispersion speed. Schollema (2018) determined the dispersion speed in the same way as in this study. He also looked at the first detection per PIT-station and at the distance that three-spined stickleback had to travel to reach a location. In Schollema (2018) his report, the dispersion speed varied from 0.4 m/min to 12.4 m/min (576m/day to 17.9 km/day). The dispersal speed is thus higher in that study than in this study. Also according to Winter et al. (2014) the swimming speed of tree-spined stickleback is between the 0.2 m/sec and 0.9 m/sec. Schollema (2018) links the dispersion speed to the discharge flow rate, which may influence the dispersion speed. He further states that fish tagging, length and weight do not affect dispersal. As mentioned earlier, three-spined sticklebacks need differences in concentration or flow to be able to orientate properly (Kitano et al., 2012). The dispersal speed in Schollema (2018) his study is probably higher because there is more flow discharge than at the storage basin near the Heining. In order to see whether three-spined sticklebacks have difficulty orienting themselves, the routes of individuals detected at several stations have been plotted in a table (annex VI). In this table can be seen that several individuals spread out both upstream and downstream. As this is a small data set, it is difficult to draw conclusions from it. Nevertheless, it does indicate that some individuals are unable to orientate themselves in the storage basin.

The dispersion rate is especially low for Loc_5. This is probably due to the fact that there is no lure flow here and therefore the fish passage is difficult to find as explained in paragraph 4.1.

4.4 Methodology

PIT telemetry is a very suitable method for monitoring the dispersion of fish (Cucherousset et al., 2010). This study also shows how effective the dispersal of three-spined stickleback could be mapped. The deployment of the telemetry network and the process of tagging were carried out by specialists.

This year the supply for three-spined stickleback was very low, so three-spined sticklebacks from other locations were used. Initially, only three-spined sticklebacks caught near the Heining were to be used. Here, almost no individuals were caught. Therefore, individuals from Zwarte Haan and Roptazijl pumping station were used. Zwarte Haan is located 12 kilometres west of the Heining and Roptazijl is located 30 kilometres west of the Heining. It is not known whether this could have had a negative effect on this study, but there are studies that say it does not seem that catching, tagging and displacement really affect the orientation of three-spined sticklebacks (Ivanova et al., 2019; Ward, James, Wilson & Webster, 2013) . Therefore, it is assumed that if individuals from the Heining had been used, the outcome would have been similar.

5. Conclusion and recommendations

The "Fan swiet nei sâlt" project, with the construction of the Heining pumping station, has ensured that three-spined stickleback can again migrate from saltwater to freshwater and vice versa. That three-spined sticklebacks can pass the pumping station was already known, but how they subsequently spread out in search of their spawning grounds is still unknown. With the help of PIT-telemetry this dispersal has been mapped in the spring of 2021. The underlying chapter describes the conclusions that have been drawn based on literature and results. Furthermore, recommendations are given for follow-up research and improvement of the fish passage.

5.1 Conclusion

During this survey, a total of 121 individuals were observed at one of the PIT-stations. This was 31.9% of the total number of individuals that were tagged and released during this study (N=379).

In order to get an idea of the dispersion around pumping station the Heining, it was first examined what percentage remained in the storage basin and what percentage used the fish passage (Loc_5) to the polder. The following sub-question was formulated: *Which percentage of the three-spined stickleback follow the route to the polder using the fish passage Loc_5 next to pumping station the Heining and how many remain in the storage basin?* The percentage was calculated based on the number of detected individuals (N=121). The percentage that follows the route to the polder via the fish passage Loc_5 next to pumping station the Heining amounts to 10.7%. Of the 121 detected individuals 73.6% remain in the storage basin. It can therefore be concluded that the majority of three-spined sticklebacks remain in the storage basin. This confirms the hypothesis that a large part of the three-spined sticklebacks will remain in the storage basin.

The next step was to look at how the dispersion took place in the storage basin. The following sub-question was drawn up for this: *What is the dispersion in percentage per PIT-station of the three-spined stickleback, that stay in the storage basin, up to Hallum?* The results showed that of the 87 individuals that remained in the storage basin, 80 were detected at the PIT-station near the cycle bridge. A total of 80 individuals were observed here, but three individuals were later observed at Loc_5. Thus, 77 individuals can be said to have stayed near the cycle bridge or to have spread further. So 63.7% of the detected individuals have been detected at the cycle bridge. Subsequently, 10.7% of the detected individuals have been detected at the PIT-station near the culvert at the Hallumerhoekstervaart. The last PIT-station was located in Hallum. Here 5% of the detected group has been detected. The percentage of detected three-spined sticklebacks therefore decreases as the distance from the release location increases.

Next, the speed of dispersal was examined. The dispersal speed could say something about how easily three-spined sticklebacks could orient themselves in the storage basin in search of their spawning grounds. The following sub-question was formulated for this purpose: *What is the dispersion speed in days of the three-spined sticklebacks spread through the Frisian inland?* Because this involved a total of 112 detections, the median was calculated per station. This showed that the three-spined sticklebacks that followed the route via Loc_5 to the polder took an 3.5 days. The distance from the release location to Loc_5 is 22 meters. The absence of a lure flow makes it difficult for three-spined sticklebacks to find Loc_5. The three-spined sticklebacks that choose the route through the storage basin took 2.3 days to reach the cycle bridge, 9.5 days to reach the culvert at the Hallumerhoekstervaart and 8.3 days to reach Hallum. This also shows that three-spined sticklebacks find it difficult to orient themselves in the storage basin, which means that the dispersal speed is low.

The three sub-questions helped to answer the main question: ***How does the dispersion of the three-spined stickleback develop in the surrounding Frisian inland after passing the Heining pumping station?*** The dispersion develops both directly into the polder and into the storage basin. Of the total number detected, 10.7% swam in 3.5 days directly to the polder at Loc_5. 71.9% of the three-spined sticklebacks followed the route through the storage basin. According to the median, 63.6% swam a distance of 413 meters in 2.3 days to the cycle bridge. 10.7% continued their trip to the culvert at the Hallumerhoekstervaart. It took the three-spined sticklebacks 9.5 days to cover a distance of 2730 meters to the culvert. The last location in Hallum was reached by 5% of the detected individuals. These individuals took 8.3 days to cover a distance of 4236 meters.

This shows that three-spined sticklebacks disperse through the entire Frisian inland after passing the Heining pumping station and that their dispersion speed is low.

5.2 Recommendations

As mentioned earlier, this study was part of multi-year research. The results of this research also show that follow-up research can help answer new questions. For the first sub-question, it was investigated whether the tagged three-spined sticklebacks chose to remain in the storage basin or whether they immediately entered the polder at Loc_5. The results showed that of the total detected group (N=121) 10.7% chose to go through the fish passage at Loc_5. Therefore it is recommended to monitor the polder side with a PIT-station as well. The results also show that individuals registered on antenna A2 were later detected on antenna A1 as well. Antenna A2 cannot therefore give a clear answer as to whether three-spined sticklebacks actually remain in the polder after entering the polder. This strengthens the advice to place a PIT-station in the polder at Loc_5. This can help to further map the spatial distribution of three-spined sticklebacks. In addition, a lure flow at Loc_5 can increase the success of passing the fish passage.

During the study, it appeared that an inlet to the polder had been opened in the route of the storage basin. This raises the possibility that individuals entered the polder unnoticed. With the help of electro-fishing, it can be checked whether individuals entered the polder unnoticed. It is therefore recommended that this be done, so that the dispersion can be mapped out even better.

The results of the third sub-question show that the dispersal speed is low compared to other studies and reports. This could be due to the discharge flow, as the Heining did not operate during this research. Therefore, it is recommended to check if there is a relation between the discharge rate and the dispersion speed and distance. It is also recommended to look at differences in salt concentration. This could also give an indication as to whether three-spined sticklebacks can orientate themselves on the basis of salt concentration. Since it is unknown whether the use of three-spined sticklebacks from another location has an effect on the result, it is recommended to catch three-spined sticklebacks at the Heining in the future, if possible, and to use them for follow-up research.

The results clearly show that the majority of three-spined sticklebacks spread at least as far as the cycle bridge. This location is therefore a good indication of how many fish swim upstream into the storage basin. It is therefore recommended that this location be equipped with a PIT-station again next year. There is also a chance that three-spined stickleback will spread even further into the storage basin until it reaches the Dokkumer Ee. Therefore, it is also advised to place a PIT-station closer to the Dokkumer Ee. By installing a PIT-station here, an answer can be given to the question of whether three-spined sticklebacks spread further upstream in the storage basin.

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Annex

Annex I: Tag data

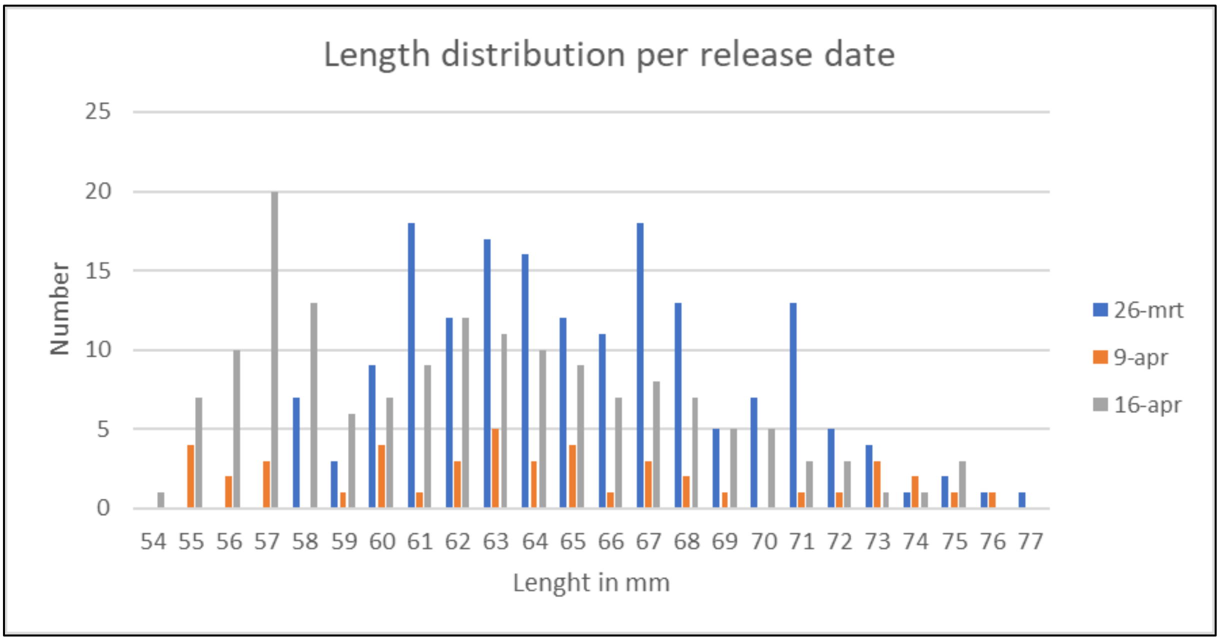
Number	Tag Code	Date	Species	Length_mm	weight_gr	fishing location	Release location	Release time
1	900_226000310789	26-3-2021	G. aculeatus	58	1,66	ZH/RZ	Storage basin (loc_1)	16:00
2	900_226000310707	26-3-2021	G. aculeatus	62	2,28	ZH/RZ	Storage basin (loc_1)	16:00
3	900_226000310703	26-3-2021	G. aculeatus	70	3,38	ZH/RZ	Storage basin (loc_1)	16:00
4	900_226000310729	26-3-2021	G. aculeatus	64	2,64	ZH/RZ	Storage basin (loc_1)	16:00
5	900_226000310796	26-3-2021	G. aculeatus	63	2,11	ZH/RZ	Storage basin (loc_1)	16:00
6	900_226000310700	26-3-2021	G. aculeatus	68	2,66	ZH/RZ	Storage basin (loc_1)	16:00
7	900_226000310783	26-3-2021	G. aculeatus	65	2,19	ZH/RZ	Storage basin (loc_1)	16:00
8	900_226000310795	26-3-2021	G. aculeatus	58	1,53	ZH/RZ	Storage basin (loc_1)	16:00
9	900_226000310745	26-3-2021	G. aculeatus	70	3,24	ZH/RZ	Storage basin (loc_1)	16:00
10	900_226000310717	26-3-2021	G. aculeatus	59	2,03	ZH/RZ	Storage basin (loc_1)	16:00
11	900_226000310738	26-3-2021	G. aculeatus	76	3,84	ZH/RZ	Storage basin (loc_1)	16:00
12	900_226000310753	26-3-2021	G. aculeatus	58	1,91	ZH/RZ	Storage basin (loc_1)	16:00
13	900_226000310759	26-3-2021	G. aculeatus	61	1,95	ZH/RZ	Storage basin (loc_1)	16:00
14	900_226000310770	26-3-2021	G. aculeatus	72	3,66	ZH/RZ	Storage basin (loc_1)	16:00
15	900_226000310786	26-3-2021	G. aculeatus	58	1,98	ZH/RZ	Storage basin (loc_1)	16:00
16	900_226000310726	26-3-2021	G. aculeatus	66	2,4	ZH/RZ	Storage basin (loc_1)	16:00
17	900_226000310704	26-3-2021	G. aculeatus	67	2,72	ZH/RZ	Storage basin (loc_1)	16:00
18	900_226000310762	26-3-2021	G. aculeatus	63	1,97	ZH/RZ	Storage basin (loc_1)	16:00
19	900_226000310752	26-3-2021	G. aculeatus	64	2,5	ZH/RZ	Storage basin (loc_1)	16:00
20	900_226000310797	26-3-2021	G. aculeatus	64	2,46	ZH/RZ	Storage basin (loc_1)	16:00
21	900_226000310774	26-3-2021	G. aculeatus	72	3,25	ZH/RZ	Storage basin (loc_1)	16:00
22	900_226000310775	26-3-2021	G. aculeatus	69	2,57	ZH/RZ	Storage basin (loc_1)	16:00
23	900_226000310734	26-3-2021	G. aculeatus	67	2,55	ZH/RZ	Storage basin (loc_1)	16:00
24	900_226000310754	26-3-2021	G. aculeatus	72	3,16	ZH/RZ	Storage basin (loc_1)	16:00
25	900_226000310722	26-3-2021	G. aculeatus	75	3,59	ZH/RZ	Storage basin (loc_1)	16:00
26	900_226000310740	26-3-2021	G. aculeatus	71	3,04	ZH/RZ	Storage basin (loc_1)	16:00
27	900_226000310768	26-3-2021	G. aculeatus	67	3,03	ZH/RZ	Storage basin (loc_1)	16:00
28	900_226000310771	26-3-2021	G. aculeatus	64	2,48	ZH/RZ	Storage basin (loc_1)	16:00
29	900_226000310725	26-3-2021	G. aculeatus	66	2,39	ZH/RZ	Storage basin (loc_1)	16:00
30	900_226000310723	26-3-2021	G. aculeatus	69	2,96	ZH/RZ	Storage basin (loc_1)	16:00
31	900_226000310728	26-3-2021	G. aculeatus	64	2,16	ZH/RZ	Storage basin (loc_1)	16:00
32	900_226000310718	26-3-2021	G. aculeatus	64	2,71	ZH/RZ	Storage basin (loc_1)	16:00
33	900_226000310727	26-3-2021	G. aculeatus	65	2,56	ZH/RZ	Storage basin (loc_1)	16:00
34	900_226000310743	26-3-2021	G. aculeatus	62	2,21	ZH/RZ	Storage basin (loc_1)	16:00
35	900_226000310799	26-3-2021	G. aculeatus	64	2,44	ZH/RZ	Storage basin (loc_1)	16:00
36	900_226000310777	26-3-2021	G. aculeatus	60	2,8	ZH/RZ	Storage basin (loc_1)	16:00
37	900_226000310733	26-3-2021	G. aculeatus	64	2,29	ZH/RZ	Storage basin (loc_1)	16:00
38	900_226000310750	26-3-2021	G. aculeatus	60	1,83	ZH/RZ	Storage basin (loc_1)	16:00
39	900_226000310741	26-3-2021	G. aculeatus	62	1,96	ZH/RZ	Storage basin (loc_1)	16:00
40	900_226000310782	26-3-2021	G. aculeatus	63	2,31	ZH/RZ	Storage basin (loc_1)	16:00
41	900_226000310746	26-3-2021	G. aculeatus	63	2,12	ZH/RZ	Storage basin (loc_1)	16:00
42	900_226000310701	26-3-2021	G. aculeatus	68	3,56	ZH/RZ	Storage basin (loc_1)	16:00
43	900_226000310773	26-3-2021	G. aculeatus	70	3,5	ZH/RZ	Storage basin (loc_1)	16:00
44	900_226000310764	26-3-2021	G. aculeatus	68	2,85	ZH/RZ	Storage basin (loc_1)	16:00
45	900_226000310784	26-3-2021	G. aculeatus	60	2,07	ZH/RZ	Storage basin (loc_1)	16:00
46	900_226000310716	26-3-2021	G. aculeatus	67	3,02	ZH/RZ	Storage basin (loc_1)	16:00
47	900_226000310705	26-3-2021	G. aculeatus	63	2,13	ZH/RZ	Storage basin (loc_1)	16:00
48	900_226000310790	26-3-2021	G. aculeatus	66	2,83	ZH/RZ	Storage basin (loc_1)	16:00
49	900_226000310781	26-3-2021	G. aculeatus	60	1,61	ZH/RZ	Storage basin (loc_1)	16:00
50	900_226000310769	26-3-2021	G. aculeatus	65	2,02	ZH/RZ	Storage basin (loc_1)	16:00
51	900_226000310779	26-3-2021	G. aculeatus	65	2,15	ZH/RZ	Storage basin (loc_1)	16:00
52	900_226000310711	26-3-2021	G. aculeatus	71	3,33	ZH/RZ	Storage basin (loc_1)	16:00
53	900_226000310756	26-3-2021	G. aculeatus	61	2,26	ZH/RZ	Storage basin (loc_1)	16:00
54	900_226000310748	26-3-2021	G. aculeatus	66	3	ZH/RZ	Storage basin (loc_1)	16:00
55	900_226000310761	26-3-2021	G. aculeatus	68	2,82	ZH/RZ	Storage basin (loc_1)	16:00
56	900_226000310712	26-3-2021	G. aculeatus	68	3,2	ZH/RZ	Storage basin (loc_1)	16:00
57	900_226000310763	26-3-2021	G. aculeatus	71	3,45	ZH/RZ	Storage basin (loc_1)	16:00
58	900_226000310720	26-3-2021	G. aculeatus	67	2,72	ZH/RZ	Storage basin (loc_1)	16:00
59	900_226000310709	26-3-2021	G. aculeatus	72	3,62	ZH/RZ	Storage basin (loc_1)	16:00
60	900_226000310710	26-3-2021	G. aculeatus	68	3,31	ZH/RZ	Storage basin (loc_1)	16:00
61	900_226000310765	26-3-2021	G. aculeatus	74	3,52	ZH/RZ	Storage basin (loc_1)	16:00
62	900_226000310767	26-3-2021	G. aculeatus	61	1,94	ZH/RZ	Storage basin (loc_1)	16:00
63	900_226000310719	26-3-2021	G. aculeatus	62	2,01	ZH/RZ	Storage basin (loc_1)	16:00
64	900_226000310736	26-3-2021	G. aculeatus	67	2,9	ZH/RZ	Storage basin (loc_1)	16:00
65	900_226000310715	26-3-2021	G. aculeatus	68	3,11	ZH/RZ	Storage basin (loc_1)	16:00
66	900_226000310758	26-3-2021	G. aculeatus	67	2,9	ZH/RZ	Storage basin (loc_1)	16:00
67	900_226000310788	26-3-2021	G. aculeatus	62	2,25	ZH/RZ	Storage basin (loc_1)	16:00
68	900_226000310706	26-3-2021	G. aculeatus	67	2,82	ZH/RZ	Storage basin (loc_1)	16:00
69	900_226000310737	26-3-2021	G. aculeatus	64	2,4	ZH/RZ	Storage basin (loc_1)	16:00
70	900_226000310742	26-3-2021	G. aculeatus	60	1,92	ZH/RZ	Storage basin (loc_1)	16:00
71	900_226000310760	26-3-2021	G. aculeatus	66	2,64	ZH/RZ	Storage basin (loc_1)	16:00
72	900_226000310794	26-3-2021	G. aculeatus	71	2,84	ZH/RZ	Storage basin (loc_1)	16:00
73	900_226000310755	26-3-2021	G. aculeatus	68	2,75	ZH/RZ	Storage basin (loc_1)	16:00
74	900_226000310714	26-3-2021	G. aculeatus	63	2,18	ZH/RZ	Storage basin (loc_1)	16:00
75	900_226000310730	26-3-2021	G. aculeatus	70	2,71	ZH/RZ	Storage basin (loc_1)	16:00
76	900_226000310744	26-3-2021	G. aculeatus	63	2,05	ZH/RZ	Storage basin (loc_1)	16:00
77	900_226000310751	26-3-2021	G. aculeatus	68	3,17	ZH/RZ	Storage basin (loc_1)	16:00
78	900_226000310732	26-3-2021	G. aculeatus	71	3,47	ZH/RZ	Storage basin (loc_1)	16:00
79	900_226000310772	26-3-2021	G. aculeatus	66	2,64	ZH/RZ	Storage basin (loc_1)	16:00
80	900_226000310721	26-3-2021	G. aculeatus	58	1,08	ZH/RZ	Storage basin (loc_1)	16:00
81	900_226000310735	26-3-2021	G. aculeatus	60	1,83	ZH/RZ	Storage basin (loc_1)	16:00
82	900_226000310766	26-3-2021	G. aculeatus	67	2,62	ZH/RZ	Storage basin (loc_1)	16:00
83	900_226000310724	26-3-2021	G. aculeatus	60	2,31	ZH/RZ	Storage basin (loc_1)	16:00
84	900_226000310708	26-3-2021	G. aculeatus	59	1,9	ZH/RZ	Storage basin (loc_1)	16:00
85	900_226000310702	26-3-2021	G. aculeatus	73	3,62	ZH/RZ	Storage basin (loc_1)	16:00
86	900_226000310731	26-3-2021	G. aculeatus	60	2,02	ZH/RZ	Storage basin (loc_1)	16:00
87	900_226000310792	26-3-2021	G. aculeatus	59	1,78	ZH/RZ	Storage basin (loc_1)	16:00
88	900_226000310791	26-3-2021	G. aculeatus	71	3,15	ZH/RZ	Storage basin (loc_1)	16:00
89	900_226000310778	26-3-2021	G. aculeatus	65	2,82	ZH/RZ	Storage basin (loc_1)	16:00
90	900_226000310793	26-3-2021	G. aculeatus	67	2,9	ZH/RZ	Storage basin (loc_1)	16:00
91	900_226000310749	26-3-2021	G. aculeatus	61	2,06	ZH/RZ	Storage basin (loc_1)	16:00
92	900_226000310713	26-3-2021	G. aculeatus	68	2,84	ZH/RZ	Storage basin (loc_1)	16:00
93	900_226000310780	26-3-2021	G. aculeatus	73	3,25	ZH/RZ	Storage basin (loc_1)	16:00
94	900_226000310776	26-3-2021	G. aculeatus	75	3,44	ZH/RZ	Storage basin (loc_1)	16:00
95	900_226000310739	26-3-2021	G. aculeatus	65	2,63	ZH/RZ	Storage basin (loc_1)	16:00
96	900_226000310798	26-3-2021	G. aculeatus	73	3,45	ZH/RZ	Storage basin (loc_1)	16:00
97	900_226000310757	26-3-2021	G. aculeatus	62	2,36	ZH/RZ	Storage basin (loc_1)	16:00
98	900_226000311048	26-3-2021	G. aculeatus	64	2,4	ZH/RZ	Storage basin (loc_1)	16:00
99	900_226000310852	26-3-2021	G. aculeatus	64	2,48	ZH/RZ	Storage basin (loc_1)	16:00
100	900_226000310629	26-3-2021	G. aculeatus	66	2,73	ZH/RZ	Storage basin (loc_1)	16:00

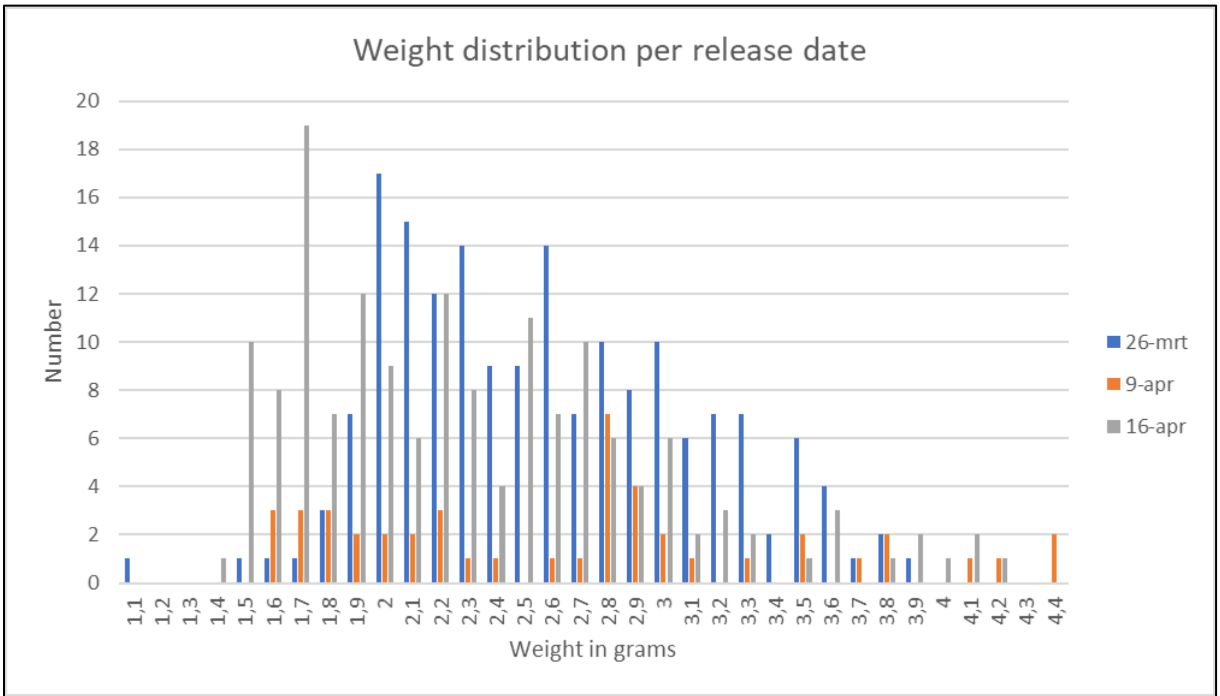
101	900_226000311044	26-3-2021	G. aculeatus	62	2,14	ZH/RZ	Storage basin (loc_1)	16:00
102	900_226000347543	26-3-2021	G. aculeatus	68	3,04	ZH/RZ	Storage basin (loc_1)	16:00
103	900_226000310611	26-3-2021	G. aculeatus	61	1,98	ZH/RZ	Storage basin (loc_1)	16:00
104	900_226000311069	26-3-2021	G. aculeatus	61	1,98	ZH/RZ	Storage basin (loc_1)	16:00
105	900_226000310665	26-3-2021	G. aculeatus	62	2,14	ZH/RZ	Storage basin (loc_1)	16:00
106	900_226000310884	26-3-2021	G. aculeatus	77	3,83	ZH/RZ	Storage basin (loc_1)	16:00
107	900_226000311058	26-3-2021	G. aculeatus	67	2,28	ZH/RZ	Storage basin (loc_1)	16:00
108	900_226000310030	26-3-2021	G. aculeatus	67	3	ZH/RZ	Storage basin (loc_1)	16:00
109	900_226000310617	26-3-2021	G. aculeatus	63	2,11	ZH/RZ	Storage basin (loc_1)	16:00
110	900_226000347568	26-3-2021	G. aculeatus	67	2,59	ZH/RZ	Storage basin (loc_1)	16:00
111	900_226000310677	26-3-2021	G. aculeatus	71	3,3	ZH/RZ	Storage basin (loc_1)	16:00
112	900_226000310655	26-3-2021	G. aculeatus	72	3,54	ZH/RZ	Storage basin (loc_1)	16:00
113	900_226000310685	26-3-2021	G. aculeatus	71	2,8	ZH/RZ	Storage basin (loc_1)	16:00
114	900_226000310643	26-3-2021	G. aculeatus	65	2,23	ZH/RZ	Storage basin (loc_1)	16:00
115	900_226000310633	26-3-2021	G. aculeatus	70	2,98	ZH/RZ	Storage basin (loc_1)	16:00
116	900_226000310694	26-3-2021	G. aculeatus	71	3,91	ZH/RZ	Storage basin (loc_1)	16:00
117	900_226000311025	26-3-2021	G. aculeatus	66	2,2	ZH/RZ	Storage basin (loc_1)	16:00
118	900_226000311089	26-3-2021	G. aculeatus	64	2,46	ZH/RZ	Storage basin (loc_1)	16:00
119	900_226000311036	26-3-2021	G. aculeatus	68	3,26	ZH/RZ	Storage basin (loc_1)	16:00
120	900_226000310674	26-3-2021	G. aculeatus	69	3,27	ZH/RZ	Storage basin (loc_1)	16:00
121	900_226000310600	26-3-2021	G. aculeatus	67	2,46	ZH/RZ	Storage basin (loc_1)	16:00
122	900_226000310806	26-3-2021	G. aculeatus	63	2,64	ZH/RZ	Storage basin (loc_1)	16:00
123	900_226000310607	26-3-2021	G. aculeatus	64	2,43	ZH/RZ	Storage basin (loc_1)	16:00
124	900_226000310650	26-3-2021	G. aculeatus	64	1,99	ZH/RZ	Storage basin (loc_1)	16:00
125	900_226000310624	26-3-2021	G. aculeatus	63	2,34	ZH/RZ	Storage basin (loc_1)	16:00
126	900_226000311077	26-3-2021	G. aculeatus	71	3,2	ZH/RZ	Storage basin (loc_1)	16:00
127	900_226000310684	26-3-2021	G. aculeatus	62	2,25	ZH/RZ	Storage basin (loc_1)	16:00
128	900_226000310642	26-3-2021	G. aculeatus	62	2,25	ZH/RZ	Storage basin (loc_1)	16:00
129	900_226000310676	26-3-2021	G. aculeatus	69	3,03	ZH/RZ	Storage basin (loc_1)	16:00
130	900_226000311062	26-3-2021	G. aculeatus	58	1,99	ZH/RZ	Storage basin (loc_1)	16:00
131	900_226000310601	26-3-2021	G. aculeatus	69	3,06	ZH/RZ	Storage basin (loc_1)	16:00
132	900_226000311064	26-3-2021	G. aculeatus	71	3,13	ZH/RZ	Storage basin (loc_1)	16:00
133	900_226000310850	26-3-2021	G. aculeatus	66	2,75	ZH/RZ	Storage basin (loc_1)	16:00
134	900_226000310636	26-3-2021	G. aculeatus	71	2,92	ZH/RZ	Storage basin (loc_1)	16:00
135	900_226000310612	26-3-2021	G. aculeatus	71	3,1	ZH/RZ	Storage basin (loc_1)	16:00
136	900_226000347559	26-3-2021	G. aculeatus	65	2,58	ZH/RZ	Storage basin (loc_1)	16:00
137	900_226000310672	26-3-2021	G. aculeatus	67	2,45	ZH/RZ	Storage basin (loc_1)	16:00
138	900_226000310862	26-3-2021	G. aculeatus	63	2,25	ZH/RZ	Storage basin (loc_1)	16:00
139	900_226000310873	26-3-2021	G. aculeatus	63	2,13	ZH/RZ	Storage basin (loc_1)	16:00
140	900_226000311087	26-3-2021	G. aculeatus	65	2,47	ZH/RZ	Storage basin (loc_1)	16:00
141	900_226000311019	26-3-2021	G. aculeatus	63	2,28	ZH/RZ	Storage basin (loc_1)	16:00
142	900_226000310824	26-3-2021	G. aculeatus	70	3,22	ZH/RZ	Storage basin (loc_1)	16:00
143	900_226000310620	26-3-2021	G. aculeatus	68	2,6	ZH/RZ	Storage basin (loc_1)	16:00
144	900_226000310641	26-3-2021	G. aculeatus	63	2,21	ZH/RZ	Storage basin (loc_1)	16:00
145	900_226000311090	26-3-2021	G. aculeatus	70	3,04	ZH/RZ	Storage basin (loc_1)	16:00
146	900_226000311094	26-3-2021	G. aculeatus	65	2,59	ZH/RZ	Storage basin (loc_1)	16:00
147	900_226000310804	26-3-2021	G. aculeatus	67	2,92	ZH/RZ	Storage basin (loc_1)	16:00
148	900_226000310683	26-3-2021	G. aculeatus	73	2,87	ZH/RZ	Storage basin (loc_1)	16:00
149	900_226000347542	26-3-2021	G. aculeatus	63	2,36	ZH/RZ	Storage basin (loc_1)	16:00
150	900_226000311007	26-3-2021	G. aculeatus	63	2,17	ZH/RZ	Storage basin (loc_1)	16:00
151	900_226000310678	26-3-2021	G. aculeatus	65	2,23	ZH/RZ	Storage basin (loc_1)	16:00
152	900_226000310667	26-3-2021	G. aculeatus	61	2,1	ZH/RZ	Storage basin (loc_1)	16:00
153	900_226000310646	26-3-2021	G. aculeatus	61	2,28	ZH/RZ	Storage basin (loc_1)	16:00
154	900_226000347519	26-3-2021	G. aculeatus	61	2,09	ZH/RZ	Storage basin (loc_1)	16:00
155	900_226000311073	26-3-2021	G. aculeatus	61	2,01	ZH/RZ	Storage basin (loc_1)	16:00
156	900_226000311010	26-3-2021	G. aculeatus	58	2,02	ZH/RZ	Storage basin (loc_1)	16:00
157	900_226000311033	26-3-2021	G. aculeatus	61	2,17	ZH/RZ	Storage basin (loc_1)	16:00
158	900_226000310686	26-3-2021	G. aculeatus	67	3,14	ZH/RZ	Storage basin (loc_1)	16:00
159	900_226000310619	26-3-2021	G. aculeatus	65	2,35	ZH/RZ	Storage basin (loc_1)	16:00
160	900_226000311043	26-3-2021	G. aculeatus	64	2,61	ZH/RZ	Storage basin (loc_1)	16:00
161	900_226000310907	26-3-2021	G. aculeatus	67	3,06	ZH/RZ	Storage basin (loc_1)	16:00
162	900_226000311067	26-3-2021	G. aculeatus	61	1,99	ZH/RZ	Storage basin (loc_1)	16:00
163	900_226000310698	26-3-2021	G. aculeatus	62	2,1	ZH/RZ	Storage basin (loc_1)	16:00
164	900_226000311016	26-3-2021	G. aculeatus	61	2,11	ZH/RZ	Storage basin (loc_1)	16:00
165	900_226000311075	26-3-2021	G. aculeatus	60	2,03	ZH/RZ	Storage basin (loc_1)	16:00
166	900_226000311071	26-3-2021	G. aculeatus	61	2,34	ZH/RZ	Storage basin (loc_1)	16:00
167	900_226000310820	26-3-2021	G. aculeatus	64	2,86	ZH/RZ	Storage basin (loc_1)	16:00
168	900_226000347574	26-3-2021	G. aculeatus	62	2,15	ZH/RZ	Storage basin (loc_1)	16:00
169	900_226000311072	26-3-2021	G. aculeatus	66	2,71	ZH/RZ	Storage basin (loc_1)	16:00
170	900_226000310658	26-3-2021	G. aculeatus	61	1,86	ZH/RZ	Storage basin (loc_1)	16:00
171	900_226000311028	26-3-2021	G. aculeatus	61	1,91	ZH/RZ	Storage basin (loc_1)	16:00
172	900_226000310621	26-3-2021	G. aculeatus	63	2,14	ZH/RZ	Storage basin (loc_1)	16:00
173	900_226000310622	26-3-2021	G. aculeatus	66	2,48	ZH/RZ	Storage basin (loc_1)	16:00
174	900_226000310639	26-3-2021	G. aculeatus	61	1,94	ZH/RZ	Storage basin (loc_1)	16:00
175	900_226000310899	26-3-2021	G. aculeatus	61	2,01	ZH/RZ	Storage basin (loc_1)	16:00
176	900_226000310680	9-4-2021	G. aculeatus	68	3,1	ZH/RZ	Storage basin (loc_1)	14:00
177	900_226000310618	9-4-2021	G. aculeatus	62	2,1	ZH/RZ	Storage basin (loc_1)	14:00
178	900_226000310875	9-4-2021	G. aculeatus	67	3,3	ZH/RZ	Storage basin (loc_1)	14:00
179	900_226000310798	9-4-2021	G. aculeatus	64	2,8	ZH/RZ	Storage basin (loc_1)	14:00
180	900_226000310638	9-4-2021	G. aculeatus	62	2,2	ZH/RZ	Storage basin (loc_1)	14:00
181	900_226000311048	9-4-2021	G. aculeatus	69	3	ZH/RZ	Storage basin (loc_1)	14:00
182	900_226000311081	9-4-2021	G. aculeatus	61	2	ZH/RZ	Storage basin (loc_1)	14:00
183	900_226000310872	9-4-2021	G. aculeatus	60	2	ZH/RZ	Storage basin (loc_1)	14:00
184	900_226000310785	9-4-2021	G. aculeatus	62	2,2	ZH/RZ	Storage basin (loc_1)	14:00
185	900_226000347558	9-4-2021	G. aculeatus	63	2,3	ZH/RZ	Storage basin (loc_1)	14:00
186	900_226000310681	9-4-2021	G. aculeatus	64	2,4	ZH/RZ	Storage basin (loc_1)	14:00
187	900_226000310747	9-4-2021	G. aculeatus	60	2,1	ZH/RZ	Storage basin (loc_1)	14:00
188	900_226000347732	9-4-2021	G. aculeatus	55	1,7	ZH/RZ	Storage basin (loc_1)	14:00
189	900_226000310602	9-4-2021	G. aculeatus	74	4,2	ZH/RZ	Storage basin (loc_1)	14:00
190	900_226000310644	9-4-2021	G. aculeatus	63	2,8	ZH/RZ	Storage basin (loc_1)	14:00
191	900_226000310640	9-4-2021	G. aculeatus	60	1,9	ZH/RZ	Storage basin (loc_1)	14:00
192	900_226000310405	9-4-2021	G. aculeatus	65	2,8	ZH/RZ	Storage basin (loc_1)	14:00
193	900_226000310479	9-4-2021	G. aculeatus	67	2,9	ZH/RZ	Storage basin (loc_1)	14:00
194	900_226000310446	9-4-2021	G. aculeatus	67	2,9	ZH/RZ	Storage basin (loc_1)	14:00
195	900_226000310400	9-4-2021	G. aculeatus	72	3,5	ZH/RZ	Storage basin (loc_1)	14:00
196	900_226000310433	9-4-2021	G. aculeatus	75	4,4	ZH/RZ	Storage basin (loc_1)	14:00
197	900_226000310484	9-4-2021	G. aculeatus	63	2,8	ZH/RZ	Storage basin (loc_1)	14:00
198	900_226000310480	9-4-2021	G. aculeatus	73	4,1	ZH/RZ	Storage basin (loc_1)	14:00
199	900_226000310431	9-4-2021	G. aculeatus	66	2,7	ZH/RZ	Storage basin (loc_1)	14:00
200	900_226000310458	9-4-2021	G. aculeatus	57	1,7	ZH/RZ	Storage basin (loc_1)	14:00

201	900_226000310477	9-4-2021	G. aculeatus	64	2,6	ZH/RZ	Storage basin (loc_1)	14:00
202	900_226000310452	9-4-2021	G. aculeatus	73	3,8	ZH/RZ	Storage basin (loc_1)	14:00
203	900_226000310435	9-4-2021	G. aculeatus	65	2,9	ZH/RZ	Storage basin (loc_1)	14:00
204	900_226000310428	9-4-2021	G. aculeatus	60	2,2	ZH/RZ	Storage basin (loc_1)	14:00
205	900_226000310475	9-4-2021	G. aculeatus	55	1,6	ZH/RZ	Storage basin (loc_1)	14:00
206	900_226000310430	9-4-2021	G. aculeatus	68	3	ZH/RZ	Storage basin (loc_1)	14:00
207	900_226000310420	9-4-2021	G. aculeatus	63	2,8	ZH/RZ	Storage basin (loc_1)	14:00
208	2048_24761611656	9-4-2021	G. aculeatus	63	2,8	ZH/RZ	Storage basin (loc_1)	14:00
209	900_226000310409	9-4-2021	G. aculeatus	59	1,9	ZH/RZ	Storage basin (loc_1)	14:00
210	900_226000310496	9-4-2021	G. aculeatus	57	1,8	ZH/RZ	Storage basin (loc_1)	14:00
211	900_226000310455	9-4-2021	G. aculeatus	74	3,7	ZH/RZ	Storage basin (loc_1)	14:00
212	900_226000310434	9-4-2021	G. aculeatus	55	1,6	ZH/RZ	Storage basin (loc_1)	14:00
213	900_226000310416	9-4-2021	G. aculeatus	65	2,9	ZH/RZ	Storage basin (loc_1)	14:00
214	900_226000310459	9-4-2021	G. aculeatus	65	2,8	ZH/RZ	Storage basin (loc_1)	14:00
215	900_226000310499	9-4-2021	G. aculeatus	55	1,6	ZH/RZ	Storage basin (loc_1)	14:00
216	900_226000310483	9-4-2021	G. aculeatus	76	4,4	ZH/RZ	Storage basin (loc_1)	14:00
217	900_226000310417	9-4-2021	G. aculeatus	56	1,7	ZH/RZ	Storage basin (loc_1)	14:00
218	900_226000310468	9-4-2021	G. aculeatus	56	1,8	ZH/RZ	Storage basin (loc_1)	14:00
219	900_226000310464	9-4-2021	G. aculeatus	73	3,8	ZH/RZ	Storage basin (loc_1)	14:00
220	900_226000310486	9-4-2021	G. aculeatus	57	1,8	ZH/RZ	Storage basin (loc_1)	14:00
221	900_226000310441	9-4-2021	G. aculeatus	71	3,5	ZH/RZ	Storage basin (loc_1)	14:00
222	900_226000310473	16-4-2021	G. aculeatus	75	4	ZH	Storage basin (loc_1)	15:55
223	900_226000310466	16-4-2021	G. aculeatus	66	2,82	ZH	Storage basin (loc_1)	15:55
224	900_226000310482	16-4-2021	G. aculeatus	67	2,67	ZH	Storage basin (loc_1)	15:55
225	900_226000310481	16-4-2021	G. aculeatus	74	4,13	ZH	Storage basin (loc_1)	15:55
226	900_226000310426	16-4-2021	G. aculeatus	69	3,11	ZH	Storage basin (loc_1)	15:55
227	900_226000310447	16-4-2021	G. aculeatus	75	4,1	ZH	Storage basin (loc_1)	15:55
228	900_226000310442	16-4-2021	G. aculeatus	66	2,61	ZH	Storage basin (loc_1)	15:55
229	900_226000310424	16-4-2021	G. aculeatus	61	2,3	ZH	Storage basin (loc_1)	15:55
230	900_226000310487	16-4-2021	G. aculeatus	66	2,57	ZH	Storage basin (loc_1)	15:55
231	900_226000310471	16-4-2021	G. aculeatus	67	3,01	ZH	Storage basin (loc_1)	15:55
232	900_226000310488	16-4-2021	G. aculeatus	60	2,18	ZH	Storage basin (loc_1)	15:55
233	900_226000310440	16-4-2021	G. aculeatus	57	1,65	ZH	Storage basin (loc_1)	15:55
234	900_226000310411	16-4-2021	G. aculeatus	65	2,8	ZH	Storage basin (loc_1)	15:55
235	900_226000310403	16-4-2021	G. aculeatus	60	2,03	ZH	Storage basin (loc_1)	15:55
236	900_226000310436	16-4-2021	G. aculeatus	68	2,62	ZH	Storage basin (loc_1)	15:55
237	900_226000310489	16-4-2021	G. aculeatus	56	1,64	ZH	Storage basin (loc_1)	15:55
238	900_226000310478	16-4-2021	G. aculeatus	64	2,64	ZH	Storage basin (loc_1)	15:55
239	900_226000310418	16-4-2021	G. aculeatus	57	1,74	ZH	Storage basin (loc_1)	15:55
240	900_226000310437	16-4-2021	G. aculeatus	65	2,37	ZH	Storage basin (loc_1)	15:55
241	900_226000310450	16-4-2021	G. aculeatus	69	2,95	ZH	Storage basin (loc_1)	15:55
242	900_226000310463	16-4-2021	G. aculeatus	75	3,6	ZH	Storage basin (loc_1)	15:55
243	900_226000310453	16-4-2021	G. aculeatus	61	2,23	ZH	Storage basin (loc_1)	15:55
244	900_226000310490	16-4-2021	G. aculeatus	61	1,95	ZH	Storage basin (loc_1)	15:55
245	900_226000310460	16-4-2021	G. aculeatus	64	2,59	ZH	Storage basin (loc_1)	15:55
246	900_226000310422	16-4-2021	G. aculeatus	56	1,51	ZH	Storage basin (loc_1)	15:55
247	900_226000310421	16-4-2021	G. aculeatus	63	2,19	ZH	Storage basin (loc_1)	15:55
248	900_226000310491	16-4-2021	G. aculeatus	61	1,87	ZH	Storage basin (loc_1)	15:55
249	900_226000310406	16-4-2021	G. aculeatus	59	2,19	ZH	Storage basin (loc_1)	15:55
250	900_226000310448	16-4-2021	G. aculeatus	61	2,26	ZH	Storage basin (loc_1)	15:55
251	900_226000310470	16-4-2021	G. aculeatus	59	2,11	ZH	Storage basin (loc_1)	15:55
252	900_226000310476	16-4-2021	G. aculeatus	71	2,99	ZH	Storage basin (loc_1)	15:55
253	900_226000310449	16-4-2021	G. aculeatus	71	3,51	ZH	Storage basin (loc_1)	15:55
254	900_226000310474	16-4-2021	G. aculeatus	65	2,49	ZH	Storage basin (loc_1)	15:55
255	900_226000310415	16-4-2021	G. aculeatus	58	1,74	ZH	Storage basin (loc_1)	15:55
256	900_226000310413	16-4-2021	G. aculeatus	64	2,31	ZH	Storage basin (loc_1)	15:55
257	900_226000310423	16-4-2021	G. aculeatus	59	1,74	ZH	Storage basin (loc_1)	15:55
258	900_226000310429	16-4-2021	G. aculeatus	60	1,78	ZH	Storage basin (loc_1)	15:55
259	900_226000310412	16-4-2021	G. aculeatus	69	2,7	ZH	Storage basin (loc_1)	15:55
260	900_226000310495	16-4-2021	G. aculeatus	57	1,69	ZH	Storage basin (loc_1)	15:55
261	900_226000310465	16-4-2021	G. aculeatus	66	2,68	ZH	Storage basin (loc_1)	15:55
262	900_226000310427	16-4-2021	G. aculeatus	59	2,09	ZH	Storage basin (loc_1)	15:55
263	900_226000310408	16-4-2021	G. aculeatus	58	1,61	ZH	Storage basin (loc_1)	15:55
264	900_226000310407	16-4-2021	G. aculeatus	62	1,97	ZH	Storage basin (loc_1)	15:55
265	900_226000310498	16-4-2021	G. aculeatus	62	2,14	ZH	Storage basin (loc_1)	15:55
266	900_226000310443	16-4-2021	G. aculeatus	58	1,75	ZH	Storage basin (loc_1)	15:55
267	900_226000310469	16-4-2021	G. aculeatus	64	2,28	ZH	Storage basin (loc_1)	15:55
268	900_226000310410	16-4-2021	G. aculeatus	65	2,4	ZH	Storage basin (loc_1)	15:55
269	900_226000310522	16-4-2021	G. aculeatus	58	1,69	ZH	Storage basin (loc_1)	15:55
270	900_226000310501	16-4-2021	G. aculeatus	68	3,04	ZH	Storage basin (loc_1)	15:55
271	900_226000310589	16-4-2021	G. aculeatus	62	1,92	ZH	Storage basin (loc_1)	15:55
272	900_226000310528	16-4-2021	G. aculeatus	68	2,27	ZH	Storage basin (loc_1)	15:55
273	900_226000310523	16-4-2021	G. aculeatus	70	3,07	ZH	Storage basin (loc_1)	15:55
274	900_226000310580	16-4-2021	G. aculeatus	56	1,63	ZH	Storage basin (loc_1)	15:55
275	900_226000310598	16-4-2021	G. aculeatus	58	1,66	ZH	Storage basin (loc_1)	15:55
276	900_226000310547	16-4-2021	G. aculeatus	58	1,63	ZH	Storage basin (loc_1)	15:55
277	900_226000310554	16-4-2021	G. aculeatus	65	2,69	ZH	Storage basin (loc_1)	15:55
278	900_226000310513	16-4-2021	G. aculeatus	64	2,62	ZH	Storage basin (loc_1)	15:55
279	900_226000310587	16-4-2021	G. aculeatus	60	1,7	ZH	Storage basin (loc_1)	15:55
280	900_226000310584	16-4-2021	G. aculeatus	69	2,88	ZH	Storage basin (loc_1)	15:55
281	900_226000310531	16-4-2021	G. aculeatus	67	2,84	ZH	Storage basin (loc_1)	15:55
282	900_226000310551	16-4-2021	G. aculeatus	72	3,58	ZH	Storage basin (loc_1)	15:55
283	900_226000310553	16-4-2021	G. aculeatus	57	1,66	ZH	Storage basin (loc_1)	15:55
284	900_226000310512	16-4-2021	G. aculeatus	62	2,03	ZH	Storage basin (loc_1)	15:55
285	900_226000310404	16-4-2021	G. aculeatus	68	3,21	ZH	Storage basin (loc_1)	15:55
286	900_226000310504	16-4-2021	G. aculeatus	57	1,46	ZH	Storage basin (loc_1)	15:55
287	900_226000310583	16-4-2021	G. aculeatus	55	1,49	ZH	Storage basin (loc_1)	15:55
288	900_226000310505	16-4-2021	G. aculeatus	60	2,19	ZH	Storage basin (loc_1)	15:55
289	900_226000310510	16-4-2021	G. aculeatus	57	1,67	ZH	Storage basin (loc_1)	15:55
290	900_226000310524	16-4-2021	G. aculeatus	57	1,85	ZH	Storage basin (loc_1)	15:55
291	900_226000310561	16-4-2021	G. aculeatus	57	1,74	ZH	Storage basin (loc_1)	15:55
292	900_226000310552	16-4-2021	G. aculeatus	67	2,97	ZH	Storage basin (loc_1)	15:55
293	900_226000310534	16-4-2021	G. aculeatus	57	1,68	ZH	Storage basin (loc_1)	15:55
294	900_226000310568	16-4-2021	G. aculeatus	57	1,94	ZH	Storage basin (loc_1)	15:55
295	900_226000310557	16-4-2021	G. aculeatus	57	1,77	ZH	Storage basin (loc_1)	15:55
296	900_226000310530	16-4-2021	G. aculeatus	63	2,37	ZH	Storage basin (loc_1)	15:55
297	900_226000310597	16-4-2021	G. aculeatus	56	1,44	ZH	Storage basin (loc_1)	15:55
298	900_226000310559	16-4-2021	G. aculeatus	62	2,18	ZH	Storage basin (loc_1)	15:55
299	900_226000310519	16-4-2021	G. aculeatus	58	1,7	ZH	Storage basin (loc_1)	15:55
300	900_226000310590	16-4-2021	G. aculeatus	65	2,82	ZH	Storage basin (loc_1)	15:55

301	900_226000310558	16-4-2021	G. aculeatus	56	1,53	ZH	Storage basin (loc_1)	15:55
302	900_226000310556	16-4-2021	G. aculeatus	63	2,71	ZH	Storage basin (loc_1)	15:55
303	900_226000310550	16-4-2021	G. aculeatus	58	2,01	ZH	Storage basin (loc_1)	15:55
304	900_226000310521	16-4-2021	G. aculeatus	56	1,6	ZH	Storage basin (loc_1)	15:55
305	900_226000310493	16-4-2021	G. aculeatus	57	1,65	ZH	Storage basin (loc_1)	15:55
306	900_226000310485	16-4-2021	G. aculeatus	65	2,28	ZH	Storage basin (loc_1)	15:55
307	900_226000310457	16-4-2021	G. aculeatus	62	2,26	ZH	Storage basin (loc_1)	15:55
308	900_226000310472	16-4-2021	G. aculeatus	65	2,65	RZ	Storage basin (loc_1)	15:55
309	900_226000310511	16-4-2021	G. aculeatus	66	2,76	RZ	Storage basin (loc_1)	15:55
310	900_226000310543	16-4-2021	G. aculeatus	67	2,75	RZ	Storage basin (loc_1)	15:55
311	900_226000310419	16-4-2021	G. aculeatus	69	3,16	RZ	Storage basin (loc_1)	15:55
312	900_226000310577	16-4-2021	G. aculeatus	63	2,36	RZ	Storage basin (loc_1)	15:55
313	900_226000310569	16-4-2021	G. aculeatus	70	3,3	RZ	Storage basin (loc_1)	15:55
314	900_226000310563	16-4-2021	G. aculeatus	60	1,94	RZ	Storage basin (loc_1)	15:55
315	900_226000310508	16-4-2021	G. aculeatus	63	2,71	RZ	Storage basin (loc_1)	15:55
316	900_226000310572	16-4-2021	G. aculeatus	58	1,86	RZ	Storage basin (loc_1)	15:55
317	900_226000310456	16-4-2021	G. aculeatus	66	2,49	RZ	Storage basin (loc_1)	15:55
318	900_226000310462	16-4-2021	G. aculeatus	63	2,45	RZ	Storage basin (loc_1)	15:55
319	900_226000310444	16-4-2021	G. aculeatus	58	1,68	RZ	Storage basin (loc_1)	15:55
320	900_226000310445	16-4-2021	G. aculeatus	68	2,66	RZ	Storage basin (loc_1)	15:55
321	900_226000310497	16-4-2021	G. aculeatus	59	2,02	RZ	Storage basin (loc_1)	15:55
322	900_226000310594	16-4-2021	G. aculeatus	61	2,46	RZ	Storage basin (loc_1)	15:55
323	900_226000310578	16-4-2021	G. aculeatus	64	2,51	RZ	Storage basin (loc_1)	15:55
324	900_226000310575	16-4-2021	G. aculeatus	70	3,63	RZ	Storage basin (loc_1)	15:55
325	900_226000310596	16-4-2021	G. aculeatus	70	2,94	RZ	Storage basin (loc_1)	15:55
326	900_226000310570	16-4-2021	G. aculeatus	67	2,85	RZ	Storage basin (loc_1)	15:55
327	900_226000310560	16-4-2021	G. aculeatus	67	2,67	RZ	Storage basin (loc_1)	15:55
328	900_226000310585	16-4-2021	G. aculeatus	67	2,96	RZ	Storage basin (loc_1)	15:55
329	900_226000310425	16-4-2021	G. aculeatus	72	3,75	RZ	Storage basin (loc_1)	15:55
330	900_226000310401	16-4-2021	G. aculeatus	63	2	RZ	Storage basin (loc_1)	15:55
331	900_226000310539	16-4-2021	G. aculeatus	62	2,51	RZ	Storage basin (loc_1)	15:55
332	900_226000310535	16-4-2021	G. aculeatus	58	1,84	RZ	Storage basin (loc_1)	15:55
333	900_226000310439	16-4-2021	G. aculeatus	62	2,09	RZ	Storage basin (loc_1)	15:55
334	900_226000310451	16-4-2021	G. aculeatus	55	1,59	RZ	Storage basin (loc_1)	15:55
335	900_226000310414	16-4-2021	G. aculeatus	54	1,6	RZ	Storage basin (loc_1)	15:55
336	900_226000310526	16-4-2021	G. aculeatus	63	2,24	RZ	Storage basin (loc_1)	15:55
337	900_226000310555	16-4-2021	G. aculeatus	70	3,26	RZ	Storage basin (loc_1)	15:55
338	900_226000310507	16-4-2021	G. aculeatus	64	2,52	RZ	Storage basin (loc_1)	15:55
339	900_226000310593	16-4-2021	G. aculeatus	63	2,19	RZ	Storage basin (loc_1)	15:55
340	900_226000310432	16-4-2021	G. aculeatus	63	2,49	RZ	Storage basin (loc_1)	15:55
341	900_226000310494	16-4-2021	G. aculeatus	59	1,75	RZ	Storage basin (loc_1)	15:55
342	900_226000310492	16-4-2021	G. aculeatus	62	2,18	RZ	Storage basin (loc_1)	15:55
343	900_226000310541	16-4-2021	G. aculeatus	64	2,5	RZ	Storage basin (loc_1)	15:55
344	900_226000310582	16-4-2021	G. aculeatus	57	1,89	RZ	Storage basin (loc_1)	15:55
345	900_226000310566	16-4-2021	G. aculeatus	71	3,86	RZ	Storage basin (loc_1)	15:55
346	900_226000310579	16-4-2021	G. aculeatus	56	1,49	RZ	Storage basin (loc_1)	15:55
347	900_226000310518	16-4-2021	G. aculeatus	56	1,86	RZ	Storage basin (loc_1)	15:55
348	900_226000310536	16-4-2021	G. aculeatus	57	1,94	RZ	Storage basin (loc_1)	15:55
349	900_226000310573	16-4-2021	G. aculeatus	68	2,88	RZ	Storage basin (loc_1)	15:55
350	900_226000310581	16-4-2021	G. aculeatus	61	1,93	RZ	Storage basin (loc_1)	15:55
351	900_226000310538	16-4-2021	G. aculeatus	64	2,29	RZ	Storage basin (loc_1)	15:55
352	900_226000310517	16-4-2021	G. aculeatus	60	1,95	RZ	Storage basin (loc_1)	15:55
353	900_226000310591	16-4-2021	G. aculeatus	57	1,88	RZ	Storage basin (loc_1)	15:55
354	900_226000310529	16-4-2021	G. aculeatus	66	2,7	RZ	Storage basin (loc_1)	15:55
355	900_226000310515	16-4-2021	G. aculeatus	63	2,22	RZ	Storage basin (loc_1)	15:55
356	900_226000310586	16-4-2021	G. aculeatus	62	2,22	RZ	Storage basin (loc_1)	15:55
357	900_226000310548	16-4-2021	G. aculeatus	55	1,6	RZ	Storage basin (loc_1)	15:55
358	900_226000310527	16-4-2021	G. aculeatus	68	3,23	RZ	Storage basin (loc_1)	15:55
359	900_226000310532	16-4-2021	G. aculeatus	58	2	RZ	Storage basin (loc_1)	15:55
360	900_226000310592	16-4-2021	G. aculeatus	62	2,11	RZ	Storage basin (loc_1)	15:55
361	900_226000310574	16-4-2021	G. aculeatus	73	3,88	RZ	Storage basin (loc_1)	15:55
362	900_226000310514	16-4-2021	G. aculeatus	61	2,48	RZ	Storage basin (loc_1)	15:55
363	900_226000310567	16-4-2021	G. aculeatus	61	2,49	RZ	Storage basin (loc_1)	15:55
364	900_226000310500	16-4-2021	G. aculeatus	62	2,05	RZ	Storage basin (loc_1)	15:55
365	900_226000310564	16-4-2021	G. aculeatus	72	4,22	RZ	Storage basin (loc_1)	15:55
366	900_226000310520	16-4-2021	G. aculeatus	64	2,24	RZ	Storage basin (loc_1)	15:55
367	900_226000310533	16-4-2021	G. aculeatus	58	1,9	RZ	Storage basin (loc_1)	15:55
368	900_226000310540	16-4-2021	G. aculeatus	55	1,47	RZ	Storage basin (loc_1)	15:55
369	900_226000310562	16-4-2021	G. aculeatus	57	1,67	RZ	Storage basin (loc_1)	15:55
370	900_226000310509	16-4-2021	G. aculeatus	57	1,66	RZ	Storage basin (loc_1)	15:55
371	900_226000310502	16-4-2021	G. aculeatus	57	1,83	RZ	Storage basin (loc_1)	15:55
372	900_226000310503	16-4-2021	G. aculeatus	57	1,72	RZ	Storage basin (loc_1)	15:55
373	900_226000310595	16-4-2021	G. aculeatus	56	1,78	RZ	Storage basin (loc_1)	15:55
374	900_226000310545	16-4-2021	G. aculeatus	55	1,45	RZ	Storage basin (loc_1)	15:55
375	900_226000310588	16-4-2021	G. aculeatus	65	2,56	RZ	Storage basin (loc_1)	15:55
376	900_226000310537	16-4-2021	G. aculeatus	56	1,47	RZ	Storage basin (loc_1)	15:55
377	900_226000310525	16-4-2021	G. aculeatus	57	1,74	RZ	Storage basin (loc_1)	15:55
378	900_226000310565	16-4-2021	G. aculeatus	55	1,5	RZ	Storage basin (loc_1)	15:55
379	900_226000310599	16-4-2021	G. aculeatus	55	1,45	RZ	Storage basin (loc_1)	15:55

Annex II: length and weight distribution





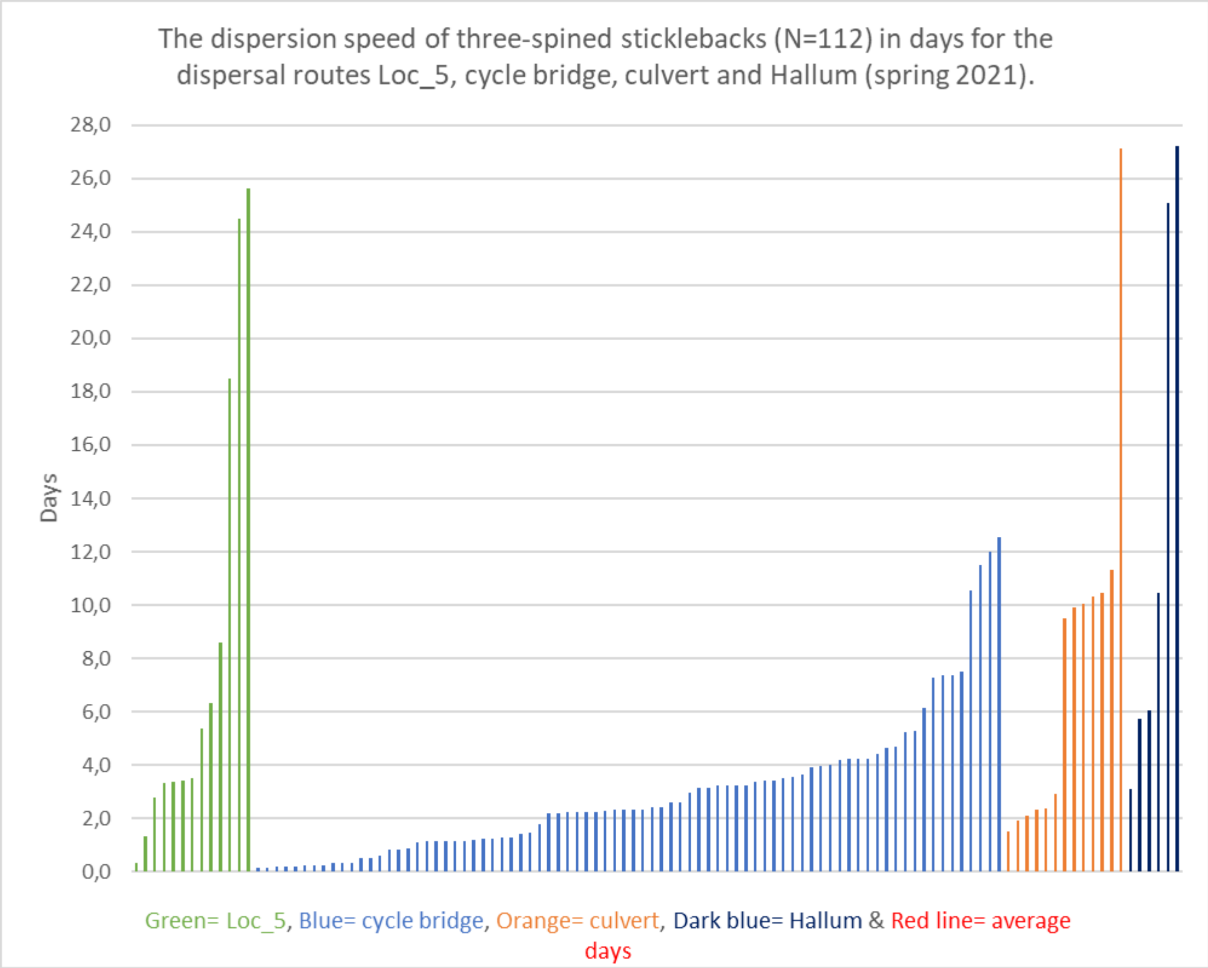
Annex III: Detections per station

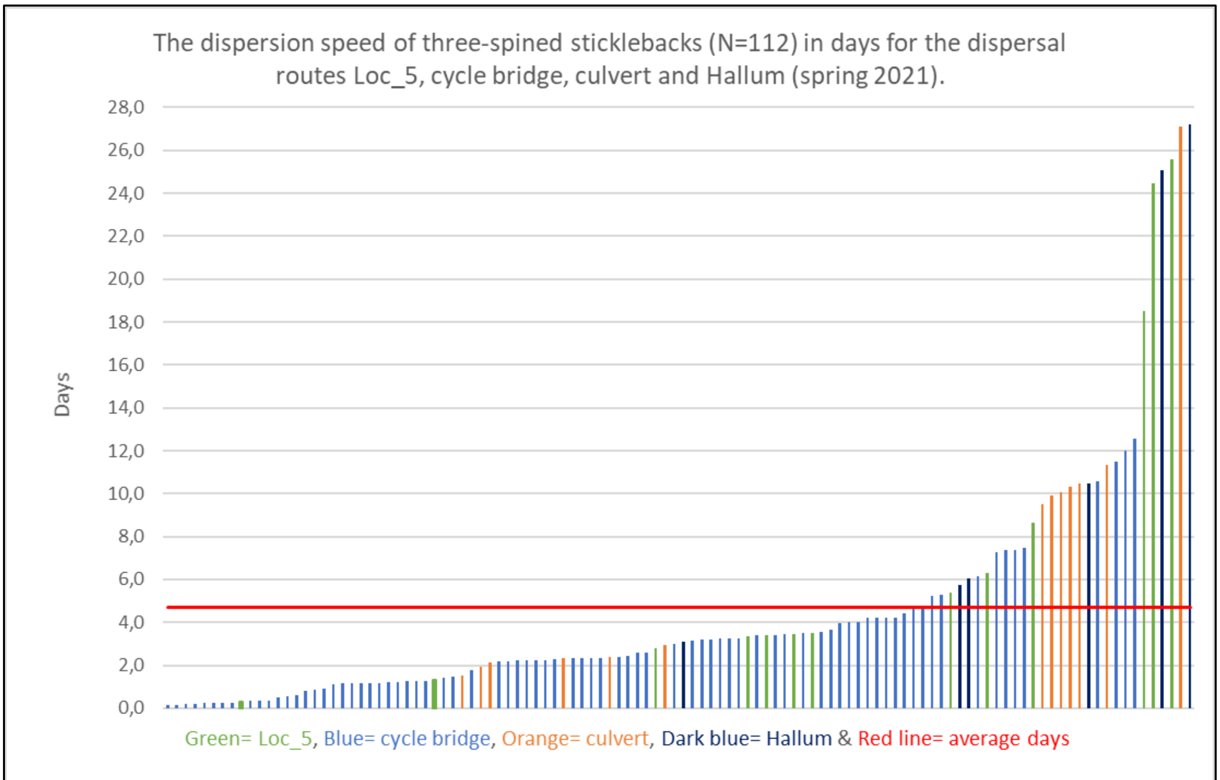
ID	Cycle Bridge	Culvert	Hallum	Loc_01	Loc_02	Loc_03	Loc_05
900_226000310030	1			1			
900_226000310405							1
900_226000310408		1	1				
900_226000310428						1	
900_226000310431		1					
900_226000310432							1
900_226000310433							1
900_226000310436						1	
900_226000310453				1		1	
900_226000310463				1			
900_226000310481	1						
900_226000310507							1
900_226000310509						1	1
900_226000310510				1	1	1	
900_226000310513							1
900_226000310523							1
900_226000310539							1
900_226000310540	1						
900_226000310541		1					
900_226000310552							1
900_226000310553							1
900_226000310564		1					
900_226000310581		1					
900_226000310593				1			
900_226000310611	1						1
900_226000310617	1						
900_226000310629	1						
900_226000310633	1						
900_226000310636	1						
900_226000310638						1	
900_226000310640						1	
900_226000310646	1	1					
900_226000310667				1			
900_226000310676	1						
900_226000310683	1						
900_226000310684	1						
900_226000310686	1						
900_226000310694				1			
900_226000310698	1						
900_226000310700	1						
900_226000310702	1						
900_226000310703	1						
900_226000310704	1						
900_226000310706	1						

900_226000310707	1			1			
900_226000310709	1						
900_226000310710	1						
900_226000310711	1						
900_226000310713	1						
900_226000310714	1						
900_226000310715	1						
900_226000310716	1						
900_226000310718	1						
900_226000310720	1						
900_226000310721	1						
900_226000310722	1	1	1				
900_226000310723	1						
900_226000310726	1						
900_226000310728	1						
900_226000310731		1					
900_226000310732	1						1
900_226000310733	1						
900_226000310734	1					1	
900_226000310736	1						
900_226000310738	1						
900_226000310743	1						
900_226000310745	1						
900_226000310746	1						
900_226000310748		1	1	1			
900_226000310751	1						
900_226000310752	1						
900_226000310753	1						
900_226000310754	1						
900_226000310755				1			
900_226000310756	1						
900_226000310758	1						
900_226000310762	1						
900_226000310763		1		1			
900_226000310765			1				
900_226000310766				1			
900_226000310767	1						
900_226000310768	1						
900_226000310770	1						
900_226000310771						1	
900_226000310773	1						
900_226000310774					1		
900_226000310775	1						
900_226000310776	1						
900_226000310779	1						1
900_226000310780	1						

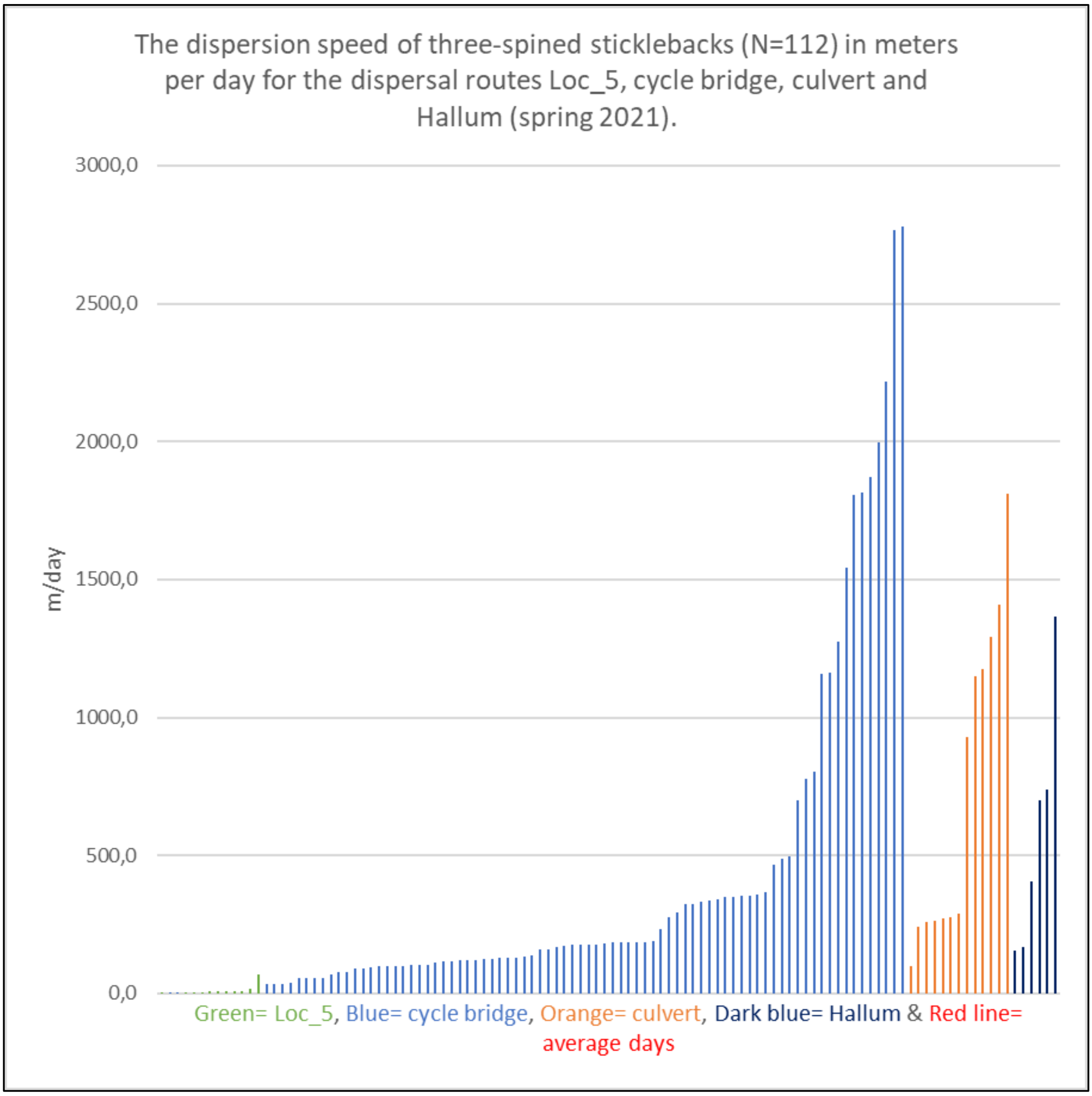
900_226000310781	**1**						
900_226000310788				**1**			
900_226000310790		**1**	**1**				
900_226000310791	**1**	**1**	**1**				
900_226000310792	**1**					**1**	
900_226000310794	**1**						
900_226000310804	**1**						
900_226000310820						**1**	
900_226000310824				**1**			
900_226000310852	**1**						
900_226000310862	**1**						
900_226000310872				**1**			
900_226000310907				**1**		**1**	
900_226000311007	**1**						
900_226000311010	**1**						
900_226000311019	**1**						
900_226000311043	**1**						
900_226000311058	**1**			**1**			
900_226000311062	**1**	**1**					
900_226000311064	**1**			**1**			
900_226000311069	**1**						
900_226000311071	**1**						
900_226000311073	**1**						
900_226000311077				**1**			
900_226000311087	**1**						
900_226000311089				**1**			
900_226000311090	**1**						
900_226000311094	**1**						
900_226000347559	**1**						
900_226000347568	**1**						
900_226000347574	**1**						
121	**80**	**13**	**6**	**20**	**2**	**12**	**13**

Annex IV: Dispersion speed per individual and per location





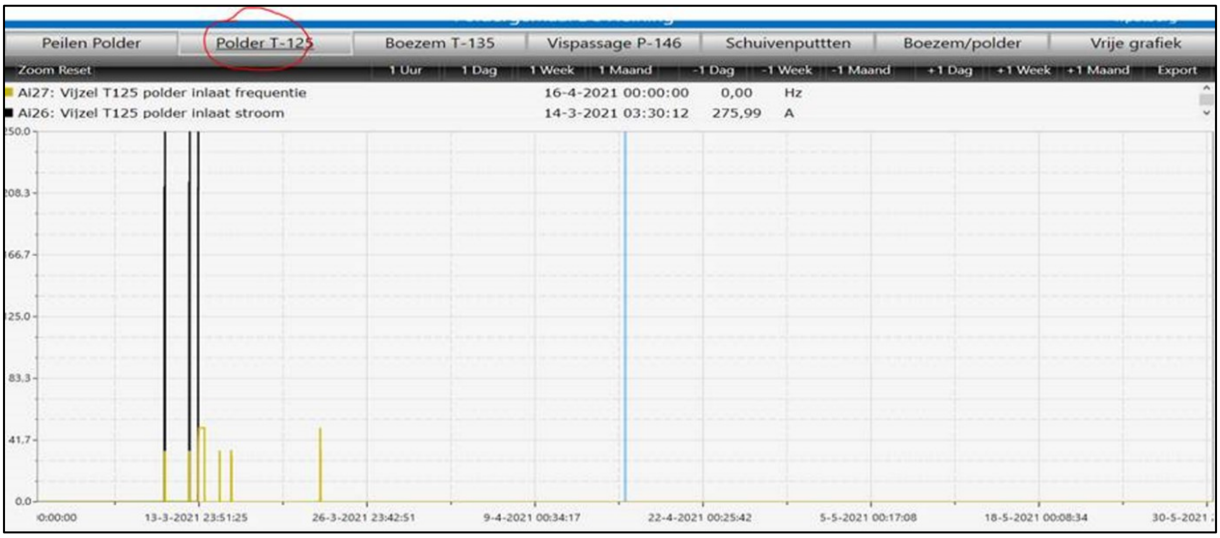
Annex V: dispersion speed per individual in meters per day (m/day)

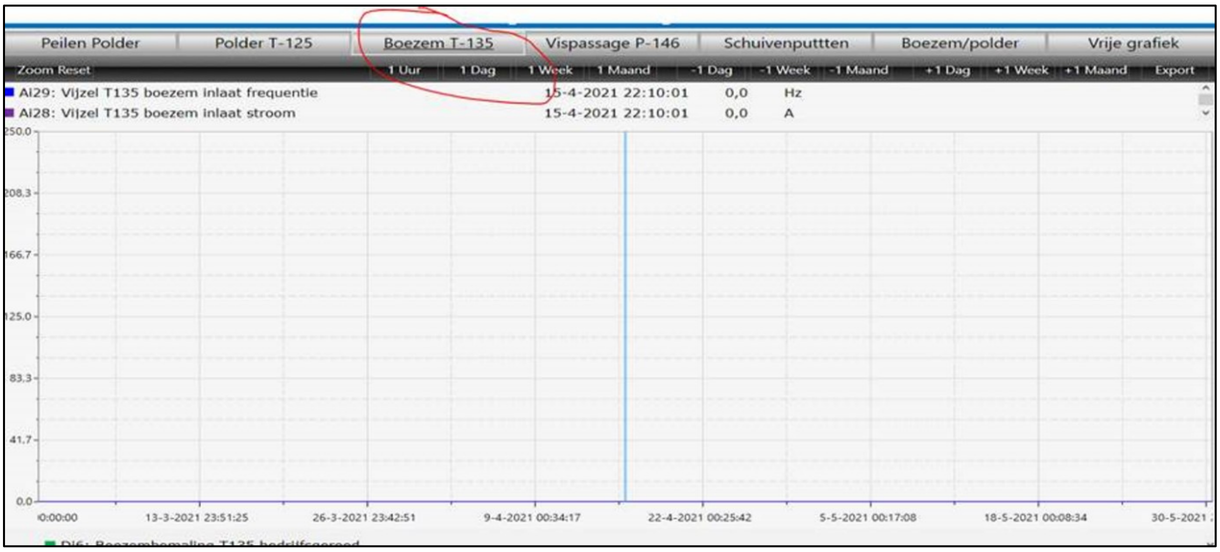


Annex VI: Dispersal routes of individuals detected at several stations. The coloured arrows indicate whether they swim upstream (green) or downstream (red) or whether they stay near the Heining (blue).

Number	PIT_ID	Location	→	Location	→	Location	→	Location	→	Location	→	Location
1	900_226000310030	The Heining (near Loc_1)	→	Loc_01	→	Cycle Bridge						
2	900_226000310408	The Heining (near Loc_1)	→	*Cycle Bridge*	→	Culvert	→	Hallum				
3	900_226000310431	The Heining (near Loc_1)	→	*Cycle Bridge*	→	Culvert						
4	900_226000310541	The Heining (near Loc_1)	→	*Cycle Bridge*	→	Culvert						
5	900_226000310564	The Heining (near Loc_1)	→	*Cycle Bridge*	→	Culvert						
6	900_226000310581	The Heining (near Loc_1)	→	*Cycle Bridge*	→	Culvert						
7	900_226000310611	The Heining (near Loc_1)	→	Cycle Bridge	→	Loc_05						
8	900_226000310646	The Heining (near Loc_1)	→	Cycle Bridge	→	Culvert						
9	900_226000310707	The Heining (near Loc_1)	→	Loc_01	→	Cycle Bridge						
10	900_226000310722	The Heining (near Loc_1)	→	Cycle Bridge	→	Culvert	→	Hallum				
11	900_226000310731	The Heining (near Loc_1)	→	*Cycle Bridge*	→	Culvert						
12	900_226000310732	The Heining (near Loc_1)	→	Cycle Bridge	→	Loc_05						
13	900_226000310734	The Heining (near Loc_1)	→	Loc_03	→	Cycle Bridge	→	Loc_03	→	Cycle Bridge		
14	900_226000310748	The Heining (near Loc_1)	→	Loc_01	→	*Cycle Bridge*	→	Culvert	→	Hallum		
15	900_226000310763	The Heining (near Loc_1)	→	Loc_01	→	*Cycle Bridge*	→	Culvert				
16	900_226000310765	The Heining (near Loc_1)	→	*Cycle Bridge*	→	*Culvert*	→	Hallum				
17	900_226000310779	The Heining (near Loc_1)	→	Cycle Bridge	→	Loc_05						
18	900_226000310790	The Heining (near Loc_1)	→	*Cycle Bridge*	→	Culvert	→	Hallum				
19	900_226000310791	The Heining (near Loc_1)	→	Cycle Bridge	→	Culvert	→	Hallum				
20	900_226000310792	The Heining (near Loc_1)	→	Loc_03	→	Cycle Bridge						
21	900_226000310907	The Heining (near Loc_1)	→	Loc_03	→	Loc_01						
22	900_226000311058	The Heining (near Loc_1)	→	Loc_01	→	Cycle Bridge						
23	900_226000311062	The Heining (near Loc_1)	→	Cycle Bridge	→	Culvert						
24	900_226000311064	The Heining (near Loc_1)	→	Loc_01	→	Cycle Bridge						
26	900_226000310510	The Heining (near Loc_1)	→	Loc_01	→	Loc_03	→	Loc_02	→	Loc_01	→	Loc_02

Annex VII: Operating hours of the jack screw pumps in the polder and storage basin of the Heining pumping station.





Annex VIII: Flowchart