Aquaculture, Fish and Fisheries

WILEY

AQUACULTURE, FISH and FISHERIES Open Access

UNDERWATER NOTES OPEN ACCESS

A Self-Reproducing Population of Common Carp *Cyprinus carpio* at 59°16’N in Sweden

Joacim Näslund | Mikael Andersson

Department of Aquatic Resources, Institute of Freshwater Research, Swedish University of Agricultural Sciences, Stångholmsvägen 2, Drottningholm, Sweden

Correspondence: Joacim Näslund (joacim.naslund@slu.se)

Received: 19 November 2024 | **Revised:** 24 February 2025 | **Accepted:** 25 February 2025

Funding: The data were collected within a project funded through the County Administrative Board in Stockholm.

Keywords: invasive species | non-native species | pond | reproduction | species introduction

ABSTRACT

In this brief report, we report on the occurrence of young-of-the-year common carp, as well as older juveniles, in a golf course irrigation pond in Stockholm County, Sweden (59°16′40.4″N 18°28′0.6″E). This documents a case of natural reproduction of the regularly stocked non-native carp in Swedish waters, near the northern limit for the stocking operations. Stocking of common carp in Sweden is generally conducted under assumptions that reproduction is not possible due to low spring-time water temperatures not meeting the reproductive requirements of common carp. Our observation suggests that risks for ecological impacts through the establishment of self-reproducing populations of common carp can be higher than previously assumed. We recommend that this observation is considered when deciding on permits for future carp stocking in Sweden.

1 | Introduction

The common carp *Cyprinus carpio* L. (henceforth ‘carp’) is one of the most cultured, domesticated and translocated fish species in the world (Welcomme 1988; Balon 2004; Chen et al. 2024). According to the literature, it was likely first introduced to Sweden in the 1500s (Stuxberg 1895), and regular stocking and restocking occur to the present date; in recent times, mainly as either an ornamental pond fish or as a target species for angling. Sometimes the stocking is conducted illegally, by moving carp from one area to another by private citizens (e.g., Borg 2018). Due to its early introduction, prior to the year 1800, the carp was not officially considered a foreign species in Sweden (Strand et al. 2018). Nevertheless, it is still clearly a non-native species from a historical biogeographic and ecological point-of-view and is classified in the highest possible risk category in terms of both invasion potential and ecological effects (Strand et al. 2018). Hence, if the carp begins to spread to waters where it is not intentionally stocked, the most reasonable approach is to treat it as a high-risk invasive species.

In Sweden, carp typically occur as a stocked species in ponds south of *Limes Norrlandicus*, the biogeographical limit separating the northern and southern ecosystems in Sweden (Figure 1B). The natural reproduction of carp in Swedish waters is anecdotally known, also from areas close to the location of the present report, but there is no scientific documentation. However, pond-based production of carp in southern Sweden, including a shallow-pond culture research station in Aneboda (constructed in 1906), is well documented (Nordqvist 1922). For pond production, shallow spawning ponds (depth: 20–30 cm) were used to ascertain appropriate spawning conditions and to control the stocking densities in the growth ponds, to which the produced juveniles were later transferred (Nordqvist 1922). The Swedish Species Information Centre (SLU Artdatabanken) notes that reproduction is only expected in Scania (Swedish: Skåne), the southern-most county

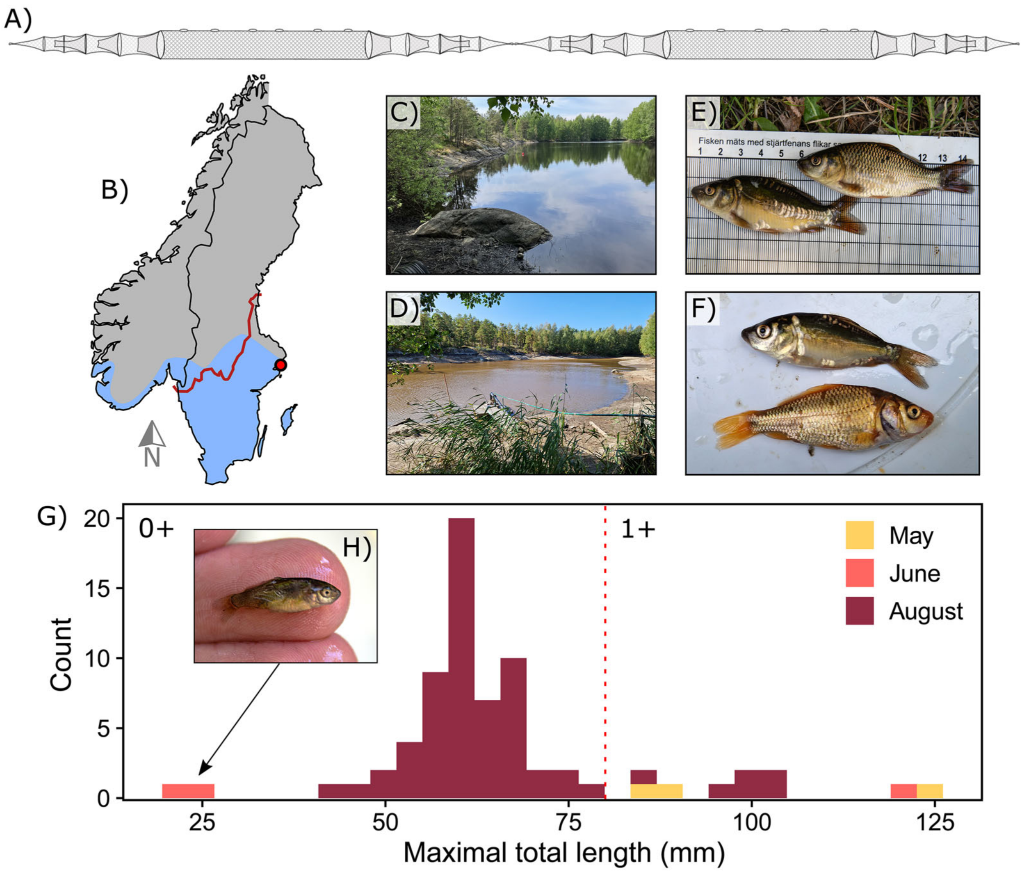

FIGURE 1 | (A) Illustration of the pair-coupled fyke net used in the survey. (B) General distribution of common carp (including stocked and non-reproducing populations) on the Scandinavian Peninsula (*Limes Norrlandicus* drawn as a red line); survey site location marked with a red dot. (C and D) The surveyed pond in early summer (C) and late summer (D). (E) Two carps captured in May, estimated to belong to the Age 1+ cohort (left: 'mirror' variety [total length: 87 mm]; right: 'common' variety [total length: 88 mm]). (F) Two carps captured in August, estimated to belong to the Age 0+ cohort (top: 'mirror' variety [total length: 54 mm]; bottom: 'gold' variety [total length: 60 mm]). (G) Length distribution of captured common carp juveniles. (H) Photograph of one of the Age 0+ carps captured during electrofishing, lying on a fingertip (fingertip width ca. 17 mm). *Source:* (B) GBIF (2023).

of Sweden; the basis for this expectation is that carp is assumed to only reproduce at temperatures approaching 20°C in spring or early summer (SLU Artdatabanken: https://artfakta.se/taxa/206124). Temperatures in the region of 20°C are indeed considered optimal for carp reproduction (Horváth 1986), but laboratory studies show that carp eggs develop viably already at 16°C, although development and growth rates are slowed compared to higher temperature incubation (Réalis-Doyelle et al. 2018). In the Northern United States (Lake St. Lawrence), reproduction was not observed below 17°C (Swee and McCrimmon 1966).

Here, we document the presence of young-of-the-year carp in a Swedish pond located in the northern region of the species' Swedish distribution range (59°16′40.4″N 18°28′0.6″E; Figure 1C,D).

2 | Methods

The investigated pond is an artificial waterbody (7330 m^2), constructed by excavation of a peat bog in the 1990s, located on the Ingarö island in the Stockholm archipelago. The pond is located at the edge of a golf course and functions as a water storage basin for irrigation. The maximal depth of the pond is approximately 4 m, but the water level is drastically lowered over summer due to irrigation. The bottom of the pond largely consists of a layer of mud and clay above bedrock; some outcrops of bare- or soil-covered bedrock are found along the pond margins. Fish surveys were conducted in May (27–29), June (17–19) and August (26–28), 2024, as part of a survey for invasive fish species. Fyke nets were set overnight (in different locations each night) twice on each sampling occasion. Three pair-coupled fyke nets (Figure 1A) per night were set in May and June, and four pair-coupled fyke nets were set each night in August. Each individual fyke net was 9 m long, consisting of two netting bags (2 m in length and a mesh size of 10 mm) and a leader (5 m in length and a mesh size of 20 mm). In June, we also made a small effort with backpack electrofishing gear (Smith-Root LR-24; Smith-Root, Inc., Vancouver, WA, USA) in the only wadable part of the pond (ca. 15 m^2). Similar efforts were made simultaneously in two other ponds in the area, without any catches of carp being recorded. The presence of large carp in the irrigation pond was known prior to the survey. Age assessment of captured carp was based on a length and frequency diagram (Figure 1G).

TABLE 1 | Summary of the catches of juvenile common carp in the irrigation pond.

Date (2024)	Temperature	Catch (per variety)			Capture method
		'Common'	'Mirror'	'Gold'	
May 27–29	19.4–20.0°C	2 (1+)	1 (1+)	0	Fyke nets
June 17–19	19.0–19.5°C	1 (1+)	0	0	Fyke nets
June 17	19.0°C	2 (0+)	0	0	Electrofishing
August 26–28	17.0°C	43 (0+), 5 (1+)	15 (0+), 1 (1+)	1 (0+)	Fyke nets

Note: '0+' indicates individuals assessed to belong to the young-of-the-year cohort; '1+' indicates individuals assessed to belong to the previous year's cohort (separation set at 80 mm based on a length frequency histogram).

3 | Results and Discussion

In total, 71 juvenile carp were caught (Figure 1E–H; Table 1). No carp with an assessed age of 2 years or older were captured, but several adult carp were observed from the shore. Body length was recorded as maximal total length (from the tip of the upper jaw to the end of the folded caudal fins). In May, three individuals were caught in fyke nets in a shallow bay in the pond, interpreted to belong to a cohort hatched in 2023 ('1+'; range: 87–125 mm; mean ± SD: 100 ± 22 mm). In June, a single individual (1+; size: 122 mm) was caught in a fyke net, and two young-of-the-year ('0+'; range: 22–26 mm; Figure 1G,H) were captured using electrofishing. In August, when the pond was substantially drained, 65 individuals were caught in fyke nets across the whole pond (0+: 59 [range: 44–78 mm; mean ± SD: 61 ± 6 mm]; 1+: 6 [range: 86–103 mm; mean ± SD: 97 ± 6 mm]). At least two, possibly three, varieties of carp were found among the juvenile individuals (Table 1). The normally scaled 'common' variety was most common (75%), and the partially scaled 'mirror' variety was less common, although not rare (24%). In addition, a single individual of a golden-coloured variety was also caught.

The strongest direct evidence for successful reproduction in 2024 is the observation of two <30 mm individuals caught by electrofishing in June. In light of this observation and the presence of >80 mm individuals in May, we conclude that at least the fish <80 mm caught in August also belong to the 2024 cohort.

Other northern extremes for the reproduction of carp include Lake Manitoba in North America (50°11′N 98°12′W) (Weber et al. 2015), and three populations in Norway. These Norwegian populations (Mildevatnet [60°14′57″N 5°15′21″E), Mosvolltjønn [58°05′39″N 6°46′18″E] and Tønsberg [approx. 59°17′N 10°24′E]) were considered to have been self-maintaining for 100–150 years when information was summarized in the mid-1990s (Kålås and Johansen 1995). The Norwegian populations are located within the coastal climate region of southern Norway, which tends to have a similar temperature climate as the area of Sweden where reproduction is now documented (Römgens 2024).

Although carp are not among the main angling target species in Sweden, carp angling (mainly catch-and-release angling) is a large-enough hobby to create a demand for carp stocking. Hence, the Swedish County Administrative Boards, which decide on permits for fish stocking, handle carp stocking permits regularly (at least in the southern counties). Given that carp is considered to be one of the most invasive fish species in the world (Lowe et al. 2000) and that it can contribute to ecosystem change with associated biodiversity loss, for example, through predation, competition, macrophyte destruction and bioturbation (Cahn 1929; Weber and Brown 2009; Kloskowski 2011), there is a need to consider potential risks of reproduction before allowing stocking. This recommendation is further substantiated when considering increasing water temperatures in spring as a consequence of climatic change (Woolway et al. 2020), which is expected to improve conditions for carp in Central and Northern Europe (Souza et al. 2022).

This report shows that the reproduction of carp can occur in Swedish freshwaters, further north than what is noted in the literature guiding stocking decisions. Given the potential ecosystem impacts of this non-native species, future stocking of carp should be carefully considered; especially, when the waterbodies where stocking is planned are connected to natural lakes and rivers, allowing carp fry to disperse. For instance, spring and early summer temperatures may have to be monitored prior to stocking decisions being made. Both natural connections through brooks, rivers or occasionally flooded land areas (including areas flooded during intense rainfall) and artificial connections in the form of pipes or ditches need to be considered potential dispersal routes for juveniles into unintended distribution areas. In natural waterbodies, the presence of carp may potentially lead to a deviation from the original reference ecosystem state. In artificial waterbodies, like ornamental or angling ponds, reproduction, of carp may lead to larger populations than aimed for in the stocking plan. This may cause, for example, increased water turbidity (Weber and Brown 2009), reduced growth of the stocked carp (Linfield 1982) and eventually stunted populations of low interest for anglers.

Given the relatively widespread stocking of carp in southern Sweden, we call for a systematic survey and thereafter continuous monitoring of feral carp reproduction across the stocked range. Investigations into the lower temperature limits of carp reproduction, as well as spawning timing, in Sweden are also recommended. From the information gathered, a risk assessment is required, taking waterbody connectivity, current-day spring-time water temperatures, and climate change effects on future water temperatures into account.

Author Contributions

Joacim Näslund: conceptualization, investigation, resources, methodology, data curation, visualization, formal analysis, validation, writing–original draft. **Mikael Andersson**: conceptualization, funding acquisition, project administration, investigation, resources, methodology, data curation, visualization, formal analysis, writing–review and editing.

Acknowledgements

We thank the County Administrative Board in Stockholm County for financing the survey that led to the reported observations, and Jennie Barthel Svedén and Martin Olgemar at the County Administrative Board in Stockholm for support in the field. Josefin Sundin, Caroline Ek and Eirik Åsheim are thanked for motivating us to write this brief note.

Ethics Statement

Data were collected during invasive species monitoring under the supervision of the County Administrative Board in Stockholm County. All necessary permits for fishing were obtained prior to the fieldwork.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data are openly available from the Figshare repository: https://doi.org/10.6084/m9.figshare.28477385.

Peer Review

The peer review history for this article is available at https://publons.com/publon/10.1002/aff2.70056.

References

Balon, E. K. 2004. "About the Oldest Domesticates Among Fishes." *Journal of Fish Biology* 65, no. s1: 1–27. https://doi.org/10.1111/j.0022-1112.2004.00563.x.

Borg, A. 2018. *Stora illegala fiskar upptäckta i Nybro*. Barometern OT. https://www.barometern.se/artikel/stora-illegala-fiskar-upptackta-i-nybro/.

Cahn, A. R. 1929. "The Effect of Carp on a Small Lake: The Carp as a Dominant." *Ecology* 10: 271–274.

Chen, X., T. G. Evans, J. M. Jeschke, S. C. Jähnig, and F. He. 2024. "Global Introductions and Environmental Impacts of Freshwater Megafish." *Global Change Biology* 30: e17289. https://doi.org/10.1111/gcb.17289.

GBIF. 2023. *Cyprinus carpio Linnaeus, 1758 in GBIF Secretariat. GBIF Backbone Taxonomy. Checklist Dataset*. GBIF. https://doi.org/10.15468/39omei.

Horváth, L. 1986. "Egg Development (Oogenesis) in the Common Carp (*Cyprinus carpio* L.)." In *Recent Advances in Aquaculture*, edited by J. Muir and R. Roberts, 31–77. Routledge. https://doi.org/10.4324/9780429303937.

Kålås, S., and R. Johansen. 1995. "The Common Carp (*Cyprinus carpio* L.) in Norway." *Fauna Norvegica Series A* 16: 19–28.

Kloskowski, J. 2011. "Impact of Common Carp *Cyprinus carpio* on Aquatic Communities: Direct Trophic Effects Versus Habitat Deterioration." *Fundamental and Applied Limnology* 178: 245–255.

Linfield, R. S. J. 1982. "Studies on the Growth of Common Carp *Cyprinus carpio* L., in a Lake Fishery." *Fisheries Management* 13: 45–88. https://doi.org/10.1111/j.1365-2109.1982.tb00031.x.

Lowe, S., M. Browne, S. Boudjelas, and M. De Poorter. 2000. 100 of the World's Worst Invasive Alien Species: A Selection From the Global Invasive Species Database. The Invasive Species Specialist Group.

Nordqvist, H. 1922. "Karp- och sutarodling i dammar." In *Sötvattensfiske Och fiskodling*, edited by O. Nordqvist, 587–659. Albert Bonniers Förlag.

Réalis-Doyelle, E., A. Pasquet, P. Fontaine, and F. Teletchea. 2018. "How Climate Change May Affect the Early Life Stages of One of the Most Common Freshwater Fish Species Worldwide: The Common Carp (*Cyprinus carpio*)." *Hydrobiologia* 805: 365–375. https://doi.org/10.1007/s10750-017-3324-y.

Römgens, B. 2024. *Climatemaps [Visualised IPCC Temperature Data 1961–1990]*. Climatemaps. https://climatemaps.romgens.com.

Souza, A. T., C. Argillier, P. Blabolil, et al. 2022. "Empirical Evidence on the Effects of Climate on the Viability of Common Carp (*Cyprinus carpio*) Populations in European Lakes." *Biological Invasions* 24: 1–15. https://doi.org/10.1007/s10530-021-02710-5.

Strand, M., M. Aronsson, and M. Svensson. 2018. *Klassificering av Främmande Arters Effekter på Biologisk mångfald Sverige—ArtDatabankens risklista*. ArtDatabanken Rapporterar. ArtDatabanken SLU.

Stuxberg, A. 1895. Sveriges Och Norges fiskar. Wettergren & Kerber.

Swee, U. B., and H. R. McCrimmon. 1966. "Reproductive Biology of the Carp, *Cyprinus carpio* L., in Lake St. Lawrence, Ontario." *Transactions of the American Fisheries Society* 95: 372–380. https://doi.org/10.1577/1548-8659(1966)95[372:RBOTCC]2.0.CO;2.

Weber, M. J., and M. L. Brown. 2009. "Effects of Common Carp on Aquatic Ecosystems 80 Years After "Carp as a Dominant": Ecological Insights for Fisheries Management." *Reviews in Fisheries Science* 17: 524–537. https://doi.org/10.1080/10641260903189243.

Weber, M. J., M. L. Brown, D. H. Wahl, and D. E. Shoup. 2015. "Metabolic Theory Explains Latitudinal Variation in Common Carp Populations and Predicts Responses to Climate Change." *Ecosphere* 6: 1–16. https://doi.org/10.1890/ES14-00435.1.

Welcomme, R. L. 1988. *International Introductions of Inland Aquatic Species*. FAO Fisheries Technical Paper. FAO.

Woolway, R. I., B. M. Kraemer, J. D. Lenters, C. J. Merchant, C. M. O'Reilly, and S. Sharma. 2020. "Global Lake Responses to Climate Change." *Nature Reviews Earth & Environment* 1: 388–403.