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Procambarus clarkii

Species description

The red swamp crayfish (*Procambarus clarkii*) is a freshwater crustacean native to North America. Introduced to Europe in the 20th century through the aquarium trade and the food industry, its first recorded presence in the Belgian environment dates back to the 1980s. Intentional releases of live specimens are probably at the origin of its presence in the natural environment. Today, the species represents a problematic aquatic invasive species in numerous countries worldwide and is now listed as IAS of Union concern under the EU Regulation No 1143/2014. The red swamp crayfish is gradually extending its range throughout the Belgian territory.

Fig 1. *Procambarus clarkii*. Photo: Xavier Vermeersch

Guide de gestion complet en version française

Volledige beheergids in Nederlandse versie

Photo: Jérémie Guyon

Procambarus clarkii

Procambarus clarkii can colonise a wide range of aquatic environments, including ponds, streams, marshes, and irrigation systems. Its robust and resilient nature allows it to inhabit polluted and poorly oxygenated waters, seasonally flooded wetlands as well as saline environments like estuaries. The species can reach impressively high population densities in the absence of controlling factors, and can exert various and important pressures on ecosystems. Its presence in water systems has been associated with a decline in native macrophytes and in macroinvertebrate diversity, a modification of food web composition and habitat structure, increased water turbidity, and bank erosion. Furthermore, the red swamp crayfish is also a potential carrier of *Aphanomyces astaci*, also known as the crayfish plague, to which it seems to display high resistance. This pathogen is, however, lethal to all indigenous European crayfish species, such as the threatened noble crayfish (*Astacus astacus*). Beyond ecological impacts, economic consequences involve management-related costs and significant damage to irrigation systems and water control structures.

Biological characteristics, reproduction and spread

This invasive species exhibits intensive burrowing behaviour for reproductive purposes or to seek refuge in adverse conditions or from predators. After mating, females excavate 1 to 2-meter-deep simple sub-vertical burrows. Crayfish at various life stages are capable of digging burrows with the dimensions and depths influenced by the size of the resident crayfish. Typically, a burrow houses no more than one individual, although pairs (a male and a female) can sometimes be observed. The red swamp crayfish seems to display preference for low light intensity and demonstrates greater activity at night. The species' lifespan is believed to be around 4 to 5 years. While showing preference for water temperatures ranging between 22 and 27°C, the species displays high tolerance to temperature extremes and can survive conditions as low as 2°C. Persistent *Procambarus clarkii* populations are also found to endure, even in regions where frequent freezing occurs. Indeed, when winter temperatures threaten their survival, some crayfish species are known to burrow into underground tunnels to withstand freezing. Like other crayfish species, the red swamp crayfish exhibits reduced activity in colder temperatures, typically below 10°C.

Fig 2. *Procambarus clarkii*. Photo: Arnaud Monty

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The red swamp crayfish exhibits form alternation in males. This cyclical dimorphism involves an alternation between form I (sexually active) and form II (sexually inactive). Within its native range, this species reproduces throughout the year, with peaks in summer, early winter, and spring. However, in parts of its introduced range such as Germany, the red swamp crayfish seems to display a single breeding period and peak occurring between autumn and winter. Females have the ability to store the sperm, and may either lay eggs (around 600) shortly after mating or up to 6 months later. The species possesses an incredible capacity to colonise both connected and non-connected water systems. Natural overland dispersal is possible, covering substantial distances (3 to 4 km/night) thanks to its high resistance to desiccation. Nonetheless, dispersal via aquatic systems remains the primary mechanism of spread and transport, occurring at rates of approximately 7.7 km and 4.6 km per year for downstream and upstream colonisation, respectively. Those high reproductive, adaptive, and dispersal abilities highlight the critical need for effective management measures against this species.

Fig 3. *Procambarus clarkii.* Photo: Jérémie Guyon

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General considerations about management

Eradicating and controlling red swamp crayfish populations poses a considerable challenge, especially once well-established. While several efficient management techniques exist for controlling this species, successful implementation often necessitates a combination of methods over multiple years to achieve satisfactory outcomes and potential eradication.

Given the similarity between the different crayfish species, 5 efficient methods are applicable for all alien invasive crayfish species. Occasionally, species-specific information must be taken into account to allow a better application of the methods. In the case of *P. clarkii*, known for excavating deep burrows, some techniques such as reinforcing predator populations might be less effective. This emphasises the importance of predator selection (e.g. favouring eels). In addition, given its high resistance to desiccation, the implementation of water drawdown as a management method must be prolonged over a sufficiently long period of time. The feasibility of eradicating red swamp crayfish populations should be evaluated on a case-by-case basis, accounting for site-specific factors and thorough discussion within the management team.

"Given the similarity between the different crayfish species, 5 efficient methods are applicable for all exotic invasive crayfish species. Occasionally, species-specific information must be taken into account to allow a better application of the methods".

Due to the species' ability to move on terrestrial and in aquatic environments between and within different water systems, precautionary measures must be implemented prior to management to prevent the dispersion of individuals to other water systems. Managed areas are, therefore, isolated by physical barriers. This precaution is especially important when the environment is disrupted by the ongoing management measures, as such disturbances may heighten the likelihood of individuals seeking new favorable sites. This is particularly noteworthy for this species, as it has been observed to escape, rather than dig burrows, when disturbed by management actions. During and after management, rigorous biosecurity measures are essential to prevent the potential spread of the crayfish plague. This entails systematically disinfecting all equipment that has come into contact with crayfish and the invaded site, using a disinfectant with fungicidal action. Subsequently, thorough drying of all equipment is conducted. Having multiple sets of equipment (boots, waders, gloves, buckets, etc.) is advisable, especially when surveying several sites in a condensed timeframe. Items potentially contaminated are meticulously kept separate from other equipment to ensure comprehensive biosecurity.

Managed and surrounding sites must remain under enhanced surveillance for at least 3 years after the implementation of the last treatment, and recurrent trapping implemented if necessary.

Trapping

v This method is applicable in most situations

v Trapping has limited impact on the ecosystem

v The method enables the monitoring of the population size (CPUE)

x There is a risk of bycatch

x There is a risk of exclusively capturing large males

x The method is time consuming

x Control can be obtained through this method. Eradication is highly unlikely

x The real effectiveness of the method is difficult to predict

Method description

Trapping consists in placing crayfish traps in the water and collecting them at regular intervals, spanning one or several days. Ethical methods are employed to euthanise captured crayfish, minimising unnecessary suffering. The effectiveness of trapping depends on factors such as bait selection, seasonality, and weather conditions. Trapping is ususally conducted in the warmer months when crayfish are most active, maximising the chances of successful captures.

This approach enables the reduction of crayfish populations, is relatively straightforward to implement, and enables the monitoring of population density through CPUE (Catch Per Unit Effort). By consistently employing the same traps and lifting them at regular intervals, the average number of captures per trap serves as an indicator of crayfish density changes over time. While trapping is a commonly employed method, accurately predicting its effectiveness poses challenges, particularly because capturing the youngest and least mobile individuals, such as ovigerous females, is complicated

Fig 4. *Procambarus clarkii* caught in a trap. Photo: Marie Patinet

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To increase the chances of success, it is necessary to combine different trap designs and maintain an important capture pressure over several years. This method is time-consuming and labour-intensive, making it more suitable for small water bodies and situations where crayfish populations are still relatively limited.

When carrying out a trapping operation, it's crucial to ensure an adequate quantity of traps. Traps are available in various sizes and shapes, including cylindrical, rectangular, conical, etc. The materials commonly used are wire mesh or polyethylene netting, known for its resistance to damage caused by claws. Additionally, there are both foldable and non-foldable models.

The selected model(s) should exhibit good efficiency while minimising the risk of bycatch (such as fish, amphibians, etc.), especially in sites where these species hold high conservation value. Consistent and frequent trap collection helps mitigate mortality among unintentionally captured individuals. It's essential to disinfect and thoroughly dry traps if they are moved to a different site.

Holdich, D. M., Gydemo, R. and Rogers, W. D. (2017). *A review of possible methods for controlling nuisance populations of alien crayfish.* In: Crayfish in Europe as alien species, pp. 245-270.

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• Baited traps

Nets baited with fish, dog food, or other meat products, are commonly employed in both water bodies and slow-moving rivers. They are placed on the water bottom at a depth of at least 30-40 cm and secured to a support on the bank. It is crucial that these nets do not exclusively capture large male individuals, as this would limit or negate the impact on the population. The presence of such large individuals in a trap tends to discourage smaller ones from entering. The use of larger traps can mitigate this effect, as can restricting the size of openings: traps with larger openings (> 4 cm) predominantly capture large crayfish, whereas smaller openings (< 4 cm or even < 2 cm) facilitate the capture of smaller individuals. Additionally, the screen mesh size must be fine enough to prevent the escape of small individuals.

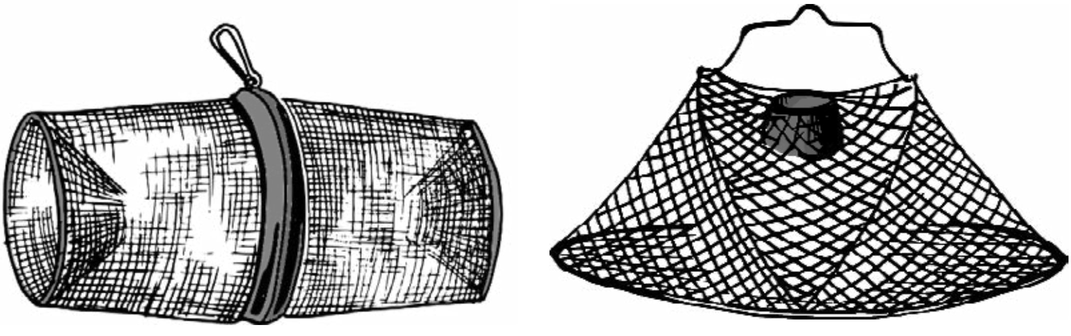

Fig 5. Example of baited traps. Drawing : Arnaud Monty

• Fyke net

A fyke net is a very long, more or less conical net mounted on a rigid frame. It is usually equipped with side wings that guide the crayfish towards the trap entrance. Setting up a fyke net is more challenging compared to a regular net, as it needs to be anchored to the bottom with stakes, and aquatic vegetation may impede the process. In river settings, the opening is typically oriented downstream. The fyke net may be baited or left unbaited. While it has the advantage of capturing a large number of individuals and is less selective regarding crayfish size, the installation is complex, and there is a genuine risk of unintentional catches, with significant mortality.

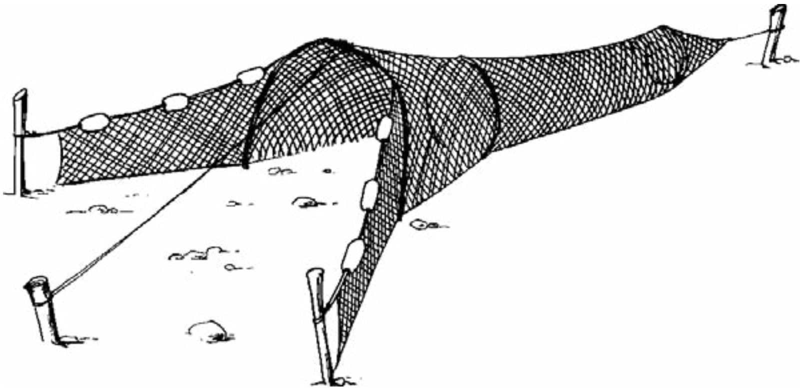

Fig 6. Example of fyke net.
Drawing : Arnaud Monty

• Unbaited traps

Unbaited traps serve as artificial refuges, which mimic natural shelters used by crayfish such as galleries and cavities. Various structures, including PVC tubes attached to a support or bricks with holes, can be employed. The strategy involves leaving the traps in place for an extended period, typically a few days, allowing crayfish to seek refuge in the cavities before removing the traps. For optimal placement, it is recommended to place the cavities horizontally on the water body's bottom, perpendicular to the current, and secure them with stones if necessary. These traps offer the advantage of not selecting individuals based on sex or size, require no bait, and minimise risk of bycatch. Additionally, they can be used for extended periods (from April to November). However, their effectiveness, which has not been proven yet for all species, depends on the environment. While demonstrated to be effective for *Pacifastacus leniusculus* in running waters, efficacy on *Procambarus clarkii* in ponds is very low. The presence of numerous natural shelters likely diminishes their effectiveness.

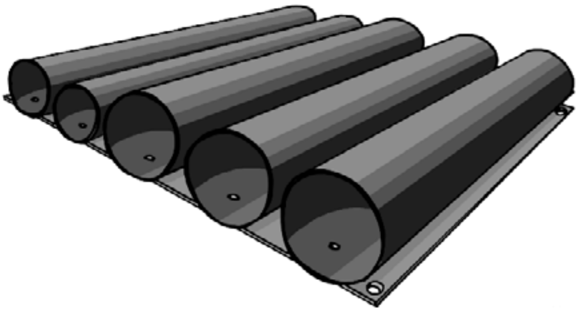

Fig 7. An example of an artificial refuge trap, consisting in pieces of PVC pipe riveted onto a metal plate and blocked on one side. It may be necessary to weight this type of trap with a stone, for example

Seine fishing

Method description

v The method enables balanced catches of different sizes and sexes

x The method demands expertise and a qualified staff for proper execution

x The movement of operators poses potential impacts on the ecosystem.

x While the method allows for control, achieving eradication is highly unlikely.

x The real effectiveness of the method is difficult to predict

The seine is a large net employed by operators, typically two individuals walking in the water, that is dragged along the water's bottom during daylight hours for crayfish capture. In river settings, additional operators may flip stones and disrupt upstream vegetation to coax crayfish out of their hiding spots. Net fishing proves most effective in small, shallow water bodies that can be crossed on foot, especially those with relatively clear water.

This method facilitates the capture of juvenile crayfish and ovigerous females, offering a distinct advantage. It serves as a valuable complement to trapping, proving especially useful for harvesting significant quantities of crayfish during periods of increased activity and important population density, notably in the summer season.

However, this method does not enable local eradication and is relatively labour-intensive. The movement of operators and the overturning of obstacles constitute a non-negligible disturbance to the aquatic environment. Although the risk of bycatch is high, operators have the possibility to release individuals of non-target species.

Fig 8. Seine fishing

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DID YOU KNOW?

Catching crayfish

Fishing for invasive alien crayfish is feasible using equipment known as "crayfish ring nets." These circular nets, equipped with ledges and attached to strings, are strategically placed on the water body's bottom. They are periodically lifted to capture crayfish. The nets are baited with pieces of fish or any other baits crayfish find palatable. String catching is another possible technique to capture crayfish.

Catching crayfish in public waters requires a permit. It is important to adhere to the specific regional regulations and designated opening periods. On private properties, the owner's authorisation is required. Although catching crayfish can be a recreational activity which may present a culinary interest, its contribution to the regulation of invasive alien crayfish is limited. On the contrary, transporting living individuals poses an increased risk of dispersal.

It is crucial to highlight that the transport of EU-listed species is strictly prohibited, with an exception allowing transportation for eradication measures. Furthermore, consuming crayfish is not recommended, as they have the potential to accumulate heavy metals or other toxic substances from polluted waters. Importantly, using invasive alien crayfish as bait for fishing is strictly forbidden.

Fig 9. Crayfish ring net. Photo: Hari Seldon

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Holdich, D. M., Gydemo, R. and Rogers, W. D. (2017). A review of possible methods for controlling nuisance populations of alien crayfish. In: Crayfish in Europe as alien species, pp. 245-270.

Drainage

Method description

v This method has the potential to achieve local eradication.

v This action can be integrated in the regular management of the water body (reduction of siltation)

x This method can have significant impacts on the ecosystem and aquatic species

x Drainage can be an expensive method

x The success of this approach depends on the drainage possibilities of the water body

This method involves the complete drainage of a water body to make the habitat inhospitable to crayfish, while inducing maximum mortality through additional actions. Sustained drainage over several years creates conditions that result in crayfish mortality due to desiccation or predation. A recommended duration is a 3-year drainage, spanning at least 2 winters, as crayfish exhibit resilience to both desiccation and frost.

Crayfish must be effectively contained within the desiccated area; thus, the placement of physical barriers, both on land and in the water, is essential. In the case of pumping, the discharged water must undergo filtration (using a plankton filter with a mesh size of 1 millimeter) to prevent the downstream dispersion of juveniles. Following the drainage, manual harvesting can be implemented in the subsequent days to eliminate a significant number of individuals and minimize the risk of accidental dispersion by predators. Subsequently, the application of slaked lime (calcium hydroxide) in the remaining wet areas and at the entrance of the galleries will help eliminate surviving individuals. Ideally, the drainage process should be leveraged to clean the pond's bottom and/or embank the shores, effectively destroying remaining galleries where individuals may persist. Consideration may be given to occasional concreting in high-risk areas, such as rockfill locations where individuals persist.

References

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If properly done, this method can enable the local eradication of a crayfish population. This has been demonstrated across various species, including *Procambarus clarkii*, which is known to be difficult to eradicate. It is crucial to emphasise that the mere implementation of routine maintenance dredging does not yield the same outcomes, and that no method can guarantee absolute eradication success.

This method has strong impacts on the aquatic environment, particularly in the medium term (over a few years). The potential transfer of non-target species to alternative sites poses risks, potentially leading to the dispersal of juvenile crayfish. Moreover, the method is associated with substantial costs and proves burdensome for users of the water body.

The method is particularly relevant for drainable water bodies of relatively modest size, where emerging populations are likely to rapidly colonize other sites.

Fig 10. Example of pond drawdown. Achieving a thorough drainage of a water body can be challenging, potentially impacting the effectiveness of the management measure. To address this challenge, various techniques can be employed, such as liming remaining water puddles or manually removing crayfish. Upper photo: Marie Patinet, lower photo: jacki-dee.

Reinforcing predator populations

Method description

- v Method that can be implemented in many situations
- v Limited impact on the ecosystem
- v Limited costs
- v Method that is easy to combine with other methods
- x Difficulty in supplying some predatory species
- x Method that enables control. Eradication is highly unlikely
- x The real effectiveness of the method is difficult to predict

Eel (*Anguilla anguilla*), burbot (*Lota lota*), perch (*Perca fluviatilis*), and pike (*Esox lucius*) represent four native species that regularly prey on crayfish if present in the environment. Additionally, other exotic carnivorous fish, such as pike-perch (*Sander lucioperca*) or wels catfish (*Silurus glanis*), also include crayfish in their diet. Juveniles may be consumed by various species, including omnivorous fish like carp (*Cyprinus carpio*) or tench (*Tinca tinca*). Increasing predator density not only reduces crayfish populations but also limits their activity, and therefore their impact. This is a cost-effective and sustainable method. It is recommended to introduce individuals of indigenous species already present in the environment, or to encourage the growth of their populations by adjustments (water purification, spawning grounds, renaturation of banks) or regulations (protection of species, fishing restriction).

The eel is considered the most effective species in controlling crayfish populations, particularly due to its ability to consume young individuals, detect crayfish by smell, and access galleries. However, challenges in managing its reproduction and its critically endangered status present significant constraints for its use. The introduction of eels into an environment should primarily be part of a conservation plan for the safeguard of this species. If strong measures were to be taken in the future to conserve this species and restore its populations, this would probably have a positive impact on the control of alien crayfish populations.

The perch is a commonly found, sometimes abundant, small predator. Its potential impact on the youngest crayfish is particularly noteworthy, especially when combined with trapping. Although non-native, pike-perch can have a similar effect. Pike, being important consumers of crayfish, exhibit a size-dependent prey preference. Young pike feed on crayfish from their early stages, while adult individuals tend to select larger prey.

References

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Various insects, such as dragonfly larvae and dytids, contribute to crayfish predation, along with birds and mammals. Beyond the occasional introduction of fish, the conservation of aquatic environments fosters a diverse predatory fauna, enhancing its ability to curb the demographic expansion of invasive alien crayfish.

Fig 11. Perch (*Perca fluviatilis*). Photo: Christa Rohrbach

Fig 12. Pike (*Esox lucius*). Photo: Gilles San Martin

Fig 13. Burbot (*Lota lota*). Photo: paul_sk11

Fig 14. Eel (*Anguilla anguilla*). Photo: Frederic-andre

Ecosystem modifications

Method description

v This approach can have positive impact on the ecosystem

v It is a long term approach

x The method requires a good knowledge of the species being managed

x The method enables control. Eradication is however highly unlikely

One of the factors contributing to the rapid formation of large populations of invasive alien crayfish is the simplification of aquatic ecosystems. Aquatic systems are increasingly becoming artificial, with features such as loose, vertical, or steep banks known to favor the construction of galleries (e.g. red swamp crayfish). These galleries, crucial for their life cycle, enable them to withstand adverse conditions like drought or frost, posing challenges for effective management. Moreover, the lack of vegetation along the banks can facilitate the dispersal of individuals and the colonisation of new water bodies. The decrease in natural predators is another element that make degraded aquatic environments particularly susceptible to invasion.

These diverse findings strongly indicate that restoring natural and diverse aquatic environments is a promising strategy for long-term control of invasions by alien crayfish. Implementing measures to restrict the construction of galleries, such as restoring gently sloping banks with abundant vegetation or introducing stony substrates, constitutes tangible elements that can be integrated into the development plan for a water body.

Fig 15. Natural banks are less likely to be invaded by crayfish species Photo: Arnaud Monty

References

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The impact of management actions on ecosystem services

While the adverse effects of IAS are well-known and provide strong incentives for implementing management actions, the impacts of these management actions on ecosystems and the services they provide are less considered. The matrices are the result of expert assessments of the evolution of relevant ecosystem services (ES) from a highly invaded situation towards a managed situation. ES evolution is considered over 2 given periods of time: 1 year and 5 years after the initiation of management.

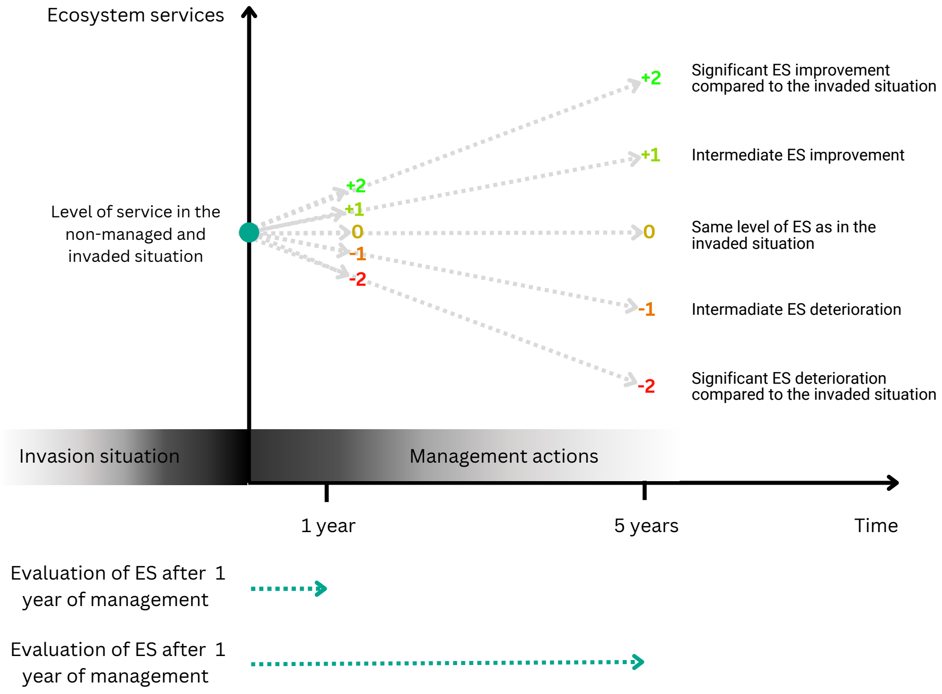

Fig 16. Representation of the survey process

Each matrix displays the average impact scores of management methods on ecosystem services. These scores have been associated to colours to facilitate the visualization of the impacts of every method on every relevant ecosystem service. Green indicates a significant improvement in the ecosystem services (ES) due to management, orange represents no or minimal effect, and red signifies a negative impact of the method on the ES.

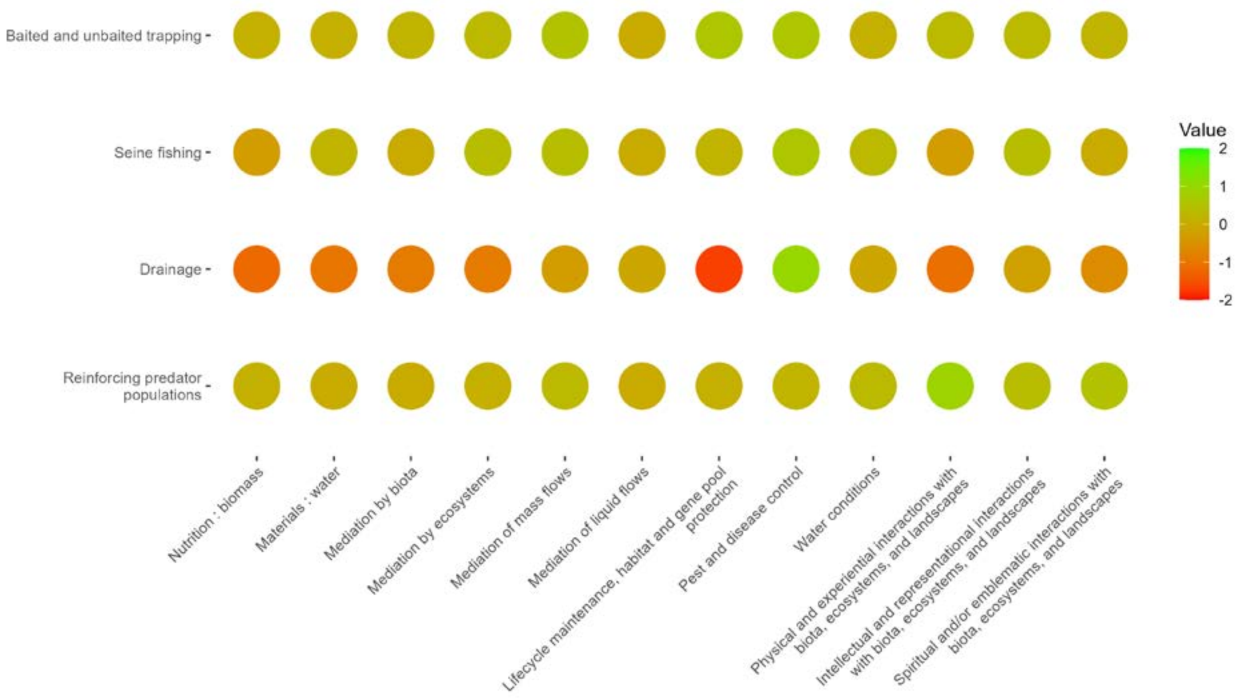

Fig 17. Matrix displaying the impact of management methods for crayfish species on ecosystem services after 1 year

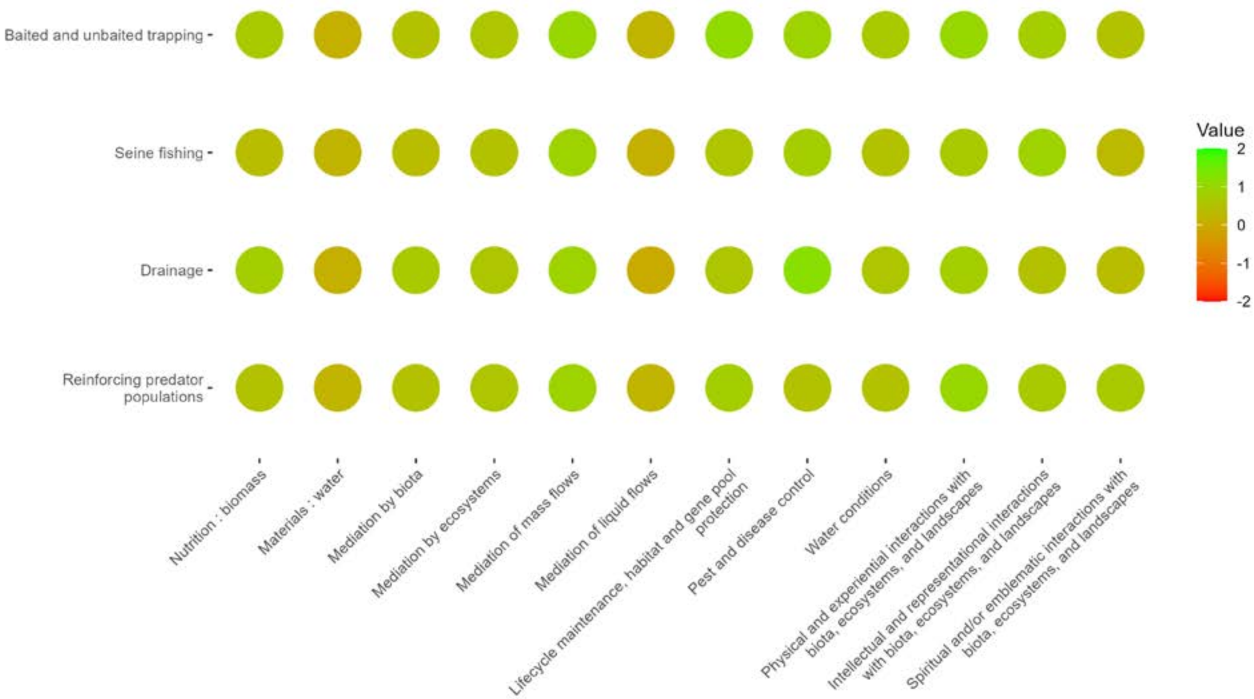

Fig 18. Matrix displaying the impact of management methods for crayfish species on ecosystem services after 5 years

LIFE RIPARIAS

Reaching Integrated and Prompt Action in Response to Invasive Alien Species

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www.riparias.be

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