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A pilot trial to evaluate novel carp monitoring techniques at wetland carp exclusion screens

Leigh Thwaites and David Cheshire

SARDI Publication No. F2016/000323-1
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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

July 2016

A technical report to the Department of Environment, Water and Natural Resources

PREMIUM FOOD AND WINE FROM OUR CLEAN ENVIRONMENT

Government of South Australia
Department of Environment, Water and Natural Resources

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South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024
Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.pir.sa.gov.au/research

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Author(s): Leigh Thwaites and David Cheshire

Reviewer(s): Qifeng Ye (SARDI) and Karl Hillyard (DEWNR)

Approved by: Assoc. Prof. Qifeng Ye
Science Leader – Inland Waters & Catchment Ecology

Signed:

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EXECUTIVE SUMMARY

Carp exclusion screens (CES) are physical mesh barriers that are installed at wetland inlets and outlets to exclude carp from entering preferred breeding grounds. However, without careful management screens may have significant impacts on other fish and fauna that use wetlands or may actually concentrate carp and large bodied native species within wetlands. As such, the Department of Environment, Water and Natural Resources (DEWNR) is currently developing a project to evaluate the effect of CES on wetland fauna (native and invasive fish, turtles) and to inform ongoing management of CES. As a part of this study, it is proposed to monitor the frequency, timing and duration of carp aggregations at several screened wetlands using remote cameras and monitor carp exiting screened wetlands via a one-way exit gate using finger movement sensors. While a finger movement sensor has been trialed at Lake Waikere in New Zealand with varying levels of success, its utility is yet to be evaluated at wetland inlets/outlets, and although "trail" cameras are regularly used to monitor terrestrial species, their ability to capture the presence of carp has not been assessed. As such, a pilot trial was conducted at Banrock Station wetland outlet (South Australia) during 28–29 April 2016 with the aim of:

- Evaluating the potential for one-way gate finger movement sensors to log the numbers and timing of carp exiting a wetland, and
- Testing the utility of remote "trail" cameras to capture the presence, timing and duration of carp aggregations at wetland inlets/outlets.

To evaluate the one-way gate finger movement sensors, a prototype one-way gate was installed on the concrete apron ~1.8 m from the outlet culvert. Heavy gauge fencing panels were used to enclose the 4.96 m^2 area between the gate and culverts carp screen. A prototype finger movement sensor comprising a trigger switch, switch activation mechanism and electronic counter was fitted to the one-way gate. A total of 81 carp were captured in the River Murray adjacent to Banrock Station using a boat mounted electrofisher. Captured carp were transported to the outlet regulator and released into an enclosure directly downstream of the one-way gate. Of the 81 carp introduced above the one-way gate, 46 pushed through resulting in the sensor logging a total of 48 counts. This disparity was due to two factors: 1) on several occasions more than one carp (usually two) was observed to pass through the gate at the same time and, 2) carp were observed triggering the counter by nudging a finger but not passing through the gate. Notwithstanding, the prototype system provided proof of concept and, although it may not log

exact numbers, when further refined and used in conjunction with a time and date logger it will capture the timing and duration of carp exiting a wetland via a one-way gate system.

The utility of remote “trail” cameras (with standard and polarised lenses) to capture the presence of carp aggregations was evaluated under ambient (secchi depth >40 cm), turbid (mean secchi depth ~7 cm) and turbulent water conditions during three distinct light phases: overcast, night and sunlit. A total of four cameras were tested: a 3G enabled camera, two standard cameras (one set to motion sensor mode and one to time interval mode) and a standard camera fitted with a polarised lens. Cameras were installed in a pole mounted weather proof enclosure ~4.7 m above culvert water level. Images were taken of a 4.96 m^2 caged area immediately downstream of Banrock Station outlet culvert that contained a total of 81 carp which had been moved into this area at the completion of the one-way gate trial. Cameras fitted with a standard lens set to capture images at regular intervals proved to be the most effective, particularly in low turbidity (secchi depth >40 cm) with ~80% of carp detected during sunlit conditions and ~20% and ~14% detected under night and overcast conditions, respectively. These results support the use of remote “trail” cameras to monitor carp at wetland inlets. However, monitoring will require careful planning and an understanding of site specific variables (i.e. water quality, culvert design, 3G network coverage, public access) to ensure consistent and representative data are captured at each monitored wetland.

1. INTRODUCTION

Carp exclusion screens (CES) are physical mesh barriers that are installed at wetland inlets/outlets to exclude carp from entering preferred breeding grounds (Meredith et al. 2006). While this may be beneficial in terms of population control and minimising within wetland impacts (i.e. decrease water quality; Vilizzi et al. 2014), without careful management screens may have significant impacts on other fish and fauna that use wetlands or may actually concentrate carp and large bodied native species within wetlands (Nichols and Gilligan 2003; Hillyard et al. 2010).

Historically, screens have been fabricated from various forms of metal mesh and although largely effective at restricting access of large carp to wetlands, their designs gave little consideration to broader wetland fish and fauna assemblages. Recently, Hillyard et al. (2010) proposed two “optimised” screen designs: jail bars with 31 mm apertures and grid mesh with 44 mm across each axis of the mesh. Although these screens are designed to restrict the passage of carp ≥250 mm TL, while allowing the passage of small-bodied native fishes, juveniles of large-bodied native fishes (e.g. golden perch) and >95% of bony herring (the most abundant large-bodied native fish in wetlands), they still exclude native fauna with body dimensions similar to carp (e.g. adult golden perch and turtles).

In conducting small scale surveys of carp screens, Nichols and Gilligan (2003) reported that carp occurred in similar abundance and biomass in adjacent wetlands with and without carp screens. The authors suggest that either large carp were entering wetlands despite the use of screens or juvenile carp were passing the screen and growing to adult size. While regularly drying screened wetlands (1–2 years) may eradicate stranded carp and help maintain a low biomass during subsequent wetted periods, this strategy is not always practical (i.e. inappropriate infrastructure, desiccate stranded native fish). Other strategies which seek to manage/reduce the biomass of carp in screened wetlands by exploiting natural behaviours need to be evaluated.

Carp generally occupy two broad habitats: shallow wetland habitats during spring through autumn and deep water habitats during winter. The shallow habitat enables feeding, spawning and the replenishment of populations via recruitment (Smith and Walker 2004; Stuart and Jones 2006). The deep habitat maintains warmer stable temperatures in comparison with surface waters (Johnsen and Hasler 1977; Inland Fisheries Service 2008; Penne and Pierce 2008). Migrations between these two habitats occur annually (Penne and Pierce 2008). Conallin et al. (2012) reported that adult carp movements into wetlands commenced during August in response to increasing water temperatures, peaked in mid-September before spawning, then declined and were close to zero by December. This suggests that carp screens could be managed to block wetland entry for the first half of the spawning season (August-December) before being opened to allow trapped fish to exit the wetland. This strategy would also permit unrestricted access for large bodied native species once screens are opened. Given the potential to manage carp biomass in wetlands with relatively simple manipulations of existing infrastructure, this strategy warrants further investigation, particularly in terminal wetlands which represent the vast majority of wetlands within the South Australian section of the River Murray.

An additional management strategy that may aid in maintaining a low carp biomass within screened wetlands is the application of a CES fitted with a one-way push gate (Figure 1) (Smith et al. 2009; Thwaites et al. 2010). The screen and one-way push trap element ‘fingers’ prevent the entry of carp to the wetland, but the push trap element allows the exit of large carp (and potentially native fish) from the wetland back into the river. This could be applied at seasonal/ephemeral or permanent wetlands, particularly where site access or on-ground management resources may be limited or where full wetland drying is not proposed in a wetland management plan. This option could also be combined with a rotating CES to permit greater movement of fish and other fauna out of the wetland during winter.

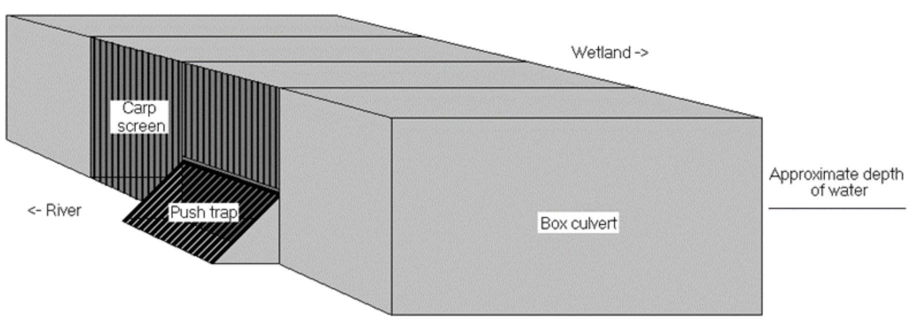

Figure 1. Schematic of a box culvert with two chambers; the left chamber is fitted with a CES only, whilst the right is fitted with a CES + one-way push trap element/gate.

While both these strategies may aid in controlling wetland carp abundance, they need to be evaluated against non-screened wetlands in order to determine their impact on fish assemblages. For CES (with and without one-way gates) to be considered effective they should maintain wetland carp abundance below that of comparable non-screened wetlands while having minimal impact on native species.

The Department of Environment, Water and Natural Resources (DEWNR) is currently developing a project to evaluate the effect of CES on wetland fauna (native and invasive fish, turtles) and inform ongoing management of these screens. As a part of this study, it is proposed to monitor the frequency, timing and duration of carp aggregations at several screened wetlands using remote cameras and to monitor carp exiting screened wetlands via a one-way gate using finger movement sensors. While a finger movement sensor has been trialed at Lake Waikere in New Zealand with varying levels of success (David 2015), its utility is yet to be evaluated at wetland inlets/outlets, and although "trail" cameras are regularly used to monitor terrestrial species, their ability to capture the presence of carp has not been assessed. As such, the aim of this project was to design and conduct a pilot trial to:

- Evaluate the potential for one-way gate finger movement sensors to log the numbers and timing of carp exiting a wetland, and

- Test the utility of remote "trail" cameras to capture the presence, timing and duration of carp aggregations at wetland inlets/outlets.

2. METHODS

Experimental system

The experimental system was designed to test the feasibility of remote "trail" cameras and evaluate the finger style one-way gate during the same experimental period (Figures 2 and 3). The system was installed in the channel immediately below the Banrock Station wetland outlet regulator (South Australia; Figure 4) during 28–29 April 2016. This location was selected as the culvert design is representative of those currently being installed at managed wetlands, it has a relatively uniform channel morphology, water depth can be manipulated by a stop-log weir situated ~10 m below the culvert, flow rate can be varied or de-watered by manipulating the outlet regulator sluice gate, and the site is not accessible to the public. To contain carp within the experimental system a security mesh CES was fitted to the downstream end of the culvert and a barrier fence was installed ~5 m from the culvert. The weir and outlet flow was initially set to maintain a water level of ~40 cm in the culvert.

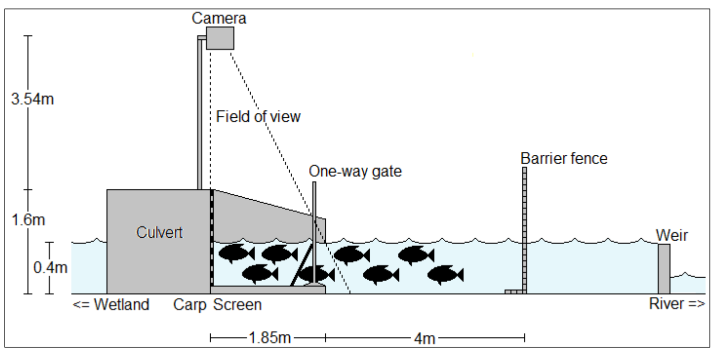

Figure 2. Schematic of the pilot trial experimental system (not to scale)

Cameras were installed in a pole mounted weather proof enclosure ~4.7 m above culvert water level. Camera angle was set to capture images of the 4.96 m^2 area of the culvert between the one-way gate and carp screen before the system was secured to the culverts safety rail (Figures 2 and 3). The mounting pole consisted of two steel sections with the upper section telescoping inside the lower section. This design enabled height adjustment by sliding the upper section and repositioning a locating pin. It also permitted easy access to the cameras by either removing or lowering the upper section. A total of four cameras were evaluated: a 3G enabled camera (8 GB internal storage with images also sent to email and phone), two standard cameras (8 GB internal storage, one set to motion sensor mode and one to time interval mode) and a standard camera fitted with a polarised lens (Figure 3). All cameras were fitted with a "no glow" flash.

Figure 3. Banrock Station outlet regulator and pilot trial experimental system. Inset: "trail" cameras mounted in weather proof enclosure (left to right: standard camera set to motion sensor, standard camera fitted with polarised lens, 3G enabled camera, standard camera set to time interval mode)

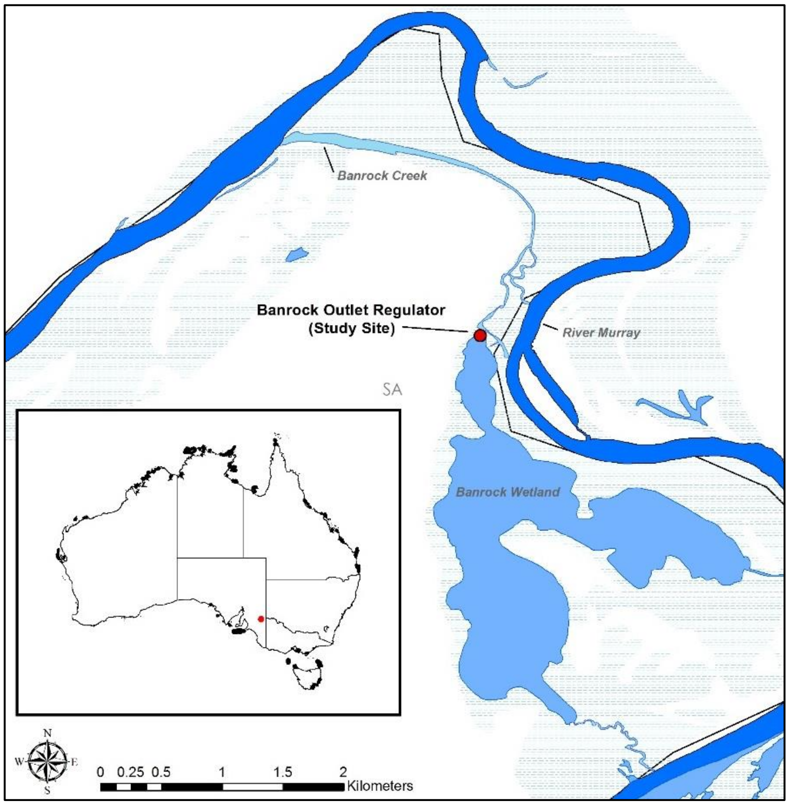

Figure 4. Map showing the location of Banrock Station outlet regulator, South Australia.

A prototype one-way gate was installed on the concrete apron ~1.8 m from the culvert (Figures 2, 3 and 5). The gate was fixed in position by attaching it to heavy gauge fencing panels which were bolted to the sides of the culvert. The fencing panels and one-gate system prevented escape of carp that had passed through the gate. A prototype finger movement sensor comprising a trigger switch, switch activation mechanism and electronic counter was fitted to the one-way gate. As a carp pushed through the gate, the lifted finger activated the switching mechanism by lifting a hinged stainless steel rod which was fitted across all the fingers. As this rod lifted it moved an extension arm off the trigger switch and the passage was logged by the electronic counter (Figure 5). The design and function of the sensor was based on the system trialed by David (2015)

A. B.

Figure 5. A) One-way push gate fitted with finger movement sensors, B) finger sensor mechanism being activated, note the finger lifting the hinged stainless steel rod.

One-way gate sensor proof of concept trial

A total of 81 carp (mean total length (TL) ± S.E. = 564 ± 13 mm; mean weight (g) ± S.E. = 2308 ± 140 g; Figure 6) were captured in the River Murray adjacent to Banrock Station using a vessel mounted Smith-Root GPP 5.0 kW portable electrofisher over a two day period (2–3 May 2016). On each occasion the on-board fish-wells reached capacity, captured carp were transported to the outlet regulator and released into the experimental system between the barrier fence and one-way gate (Figure 2). The aim was to seed a known quantity of carp within this section and allow them to push through the one-way gate. If carp had not pushed through by the end of the second day's electrofishing they were "encouraged" to move through by slowly compressing them toward the gate using a block net. After six attempts to "encourage" carp to move through the gate, a Smith-Root LR24 backpack electrofishing unit (Smith-Root Inc., Vancouver, Washington, USA) was used to capture and count the numbers of carp that pushed through or that remained outside the gate. The total numbers of carp that pushed through were compared to the sensor count. At the completion of this trial all carp were moved into the area between the push gate and carp screen in preparation for the camera trials.

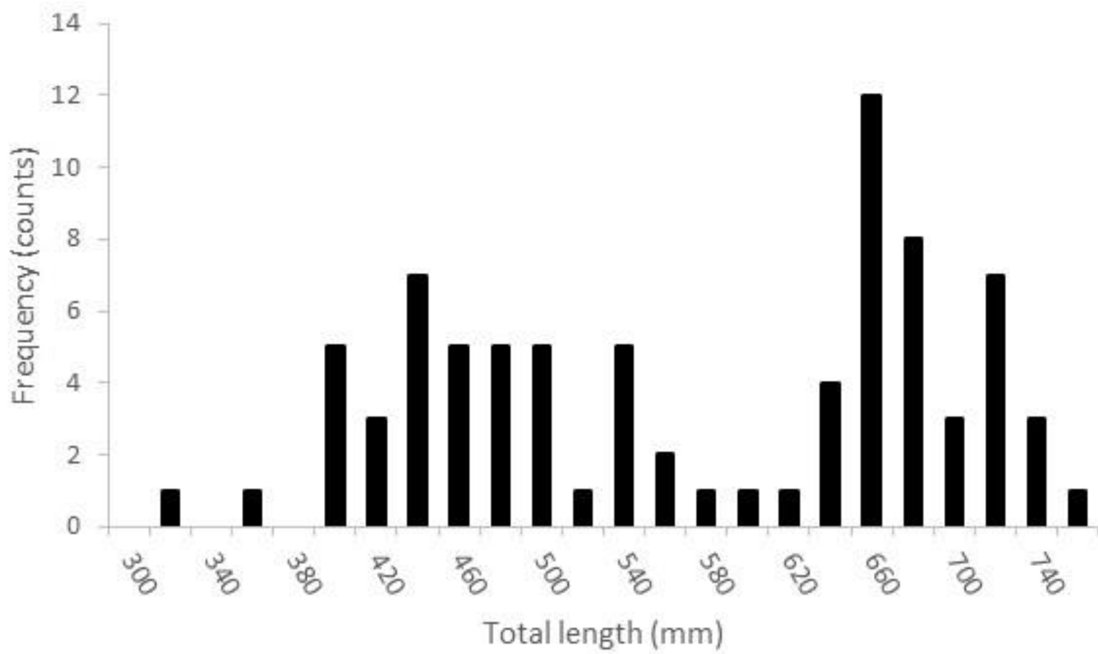

Figure 6. Length frequency distribution for carp captured for the pilot trial (*n*=81).

Camera evaluation

The utility of remote “trail” cameras to capture the presence of carp aggregations at wetland inlets/outlets was evaluated at Banrock Station outlet under ambient (secchi depth >40 cm), turbid (mean secchi depth ~7 cm) and turbulent water conditions during three distinct light phases: overcast (4 May 2016), night (4 May 2016) and sunlit (5 May 2016).

During ambient conditions, three cameras were set to time lapse mode and programed to capture 8 MP images at 5 min intervals during the day and 30 min intervals at night while the fourth camera was set to capture 8 MP images in motion sensor mode. The outlet flow was set to ensure minimal turbulence while balancing weir leakage loss and maintaining water levels of ~40 cm within the culvert. Secchi depth within the culvert was >40 cm which was representative of turbidities in the River Murray at the time of the trials (Secchi depth ~70 cm). A total of 81 carp (total of 186.92 kg) were within the 4.96 m^2 culvert area between the push gate and the carp screen representing a relative carp density of ~94 kg/m^3. At the completion of each trial, carp numbers were estimated using three subsets of six consecutive photographs taken during periods of differing ambient lighting, these comprised sunlit, overcast and night conditions. Carp were counted within each of the six photographs and only fish that could be clearly identified as individual carp were included in the estimate. The average number of carp observed under each lighting condition was then tallied, providing accurate estimates with a calculated standard error.

To evaluate the utility of cameras to capture the presence of carp under a “worst case” scenario, turbidity trials were conducted during each light phase. At the onset of each trial, the outlet sluice gate was closed and a 10 litre bucket of fine clay and sediment was added to the water. Given that low densities of carp may be difficult to detect in highly turbid water, the relative density of carp in the culvert (kg/m^3) was increased during each 1 hour trial by allowing the system to slowly drain via weir leakage. A relative carp density of ~94 kg/m^3 was within the experimental area at the onset of each trial. By the completion of each trial the relative density increased to ~290 kg/m^3 for the overcast and sunlit trial and ~300 kg/m^3 for the night trial. Secchi depth (cm) and water depth (cm) were measured at ~5 min intervals and cameras remained in the programming specifications outlined above (Figures 7, 8 and 9). At the completion of these trials, photographs were visually analysed to determine the lowest relative density at which carp could be detected.

The effect of turbulence on the ability of cameras to detect carp was evaluated during each light phase. For this evaluation, the flow rate within the culvert was increased until turbulence was created by water passing through the culverts carp screen. Camera programing and carp densities were the same as the ambient conditions trial. Photos were analysed to determine if carp could be visually detected.

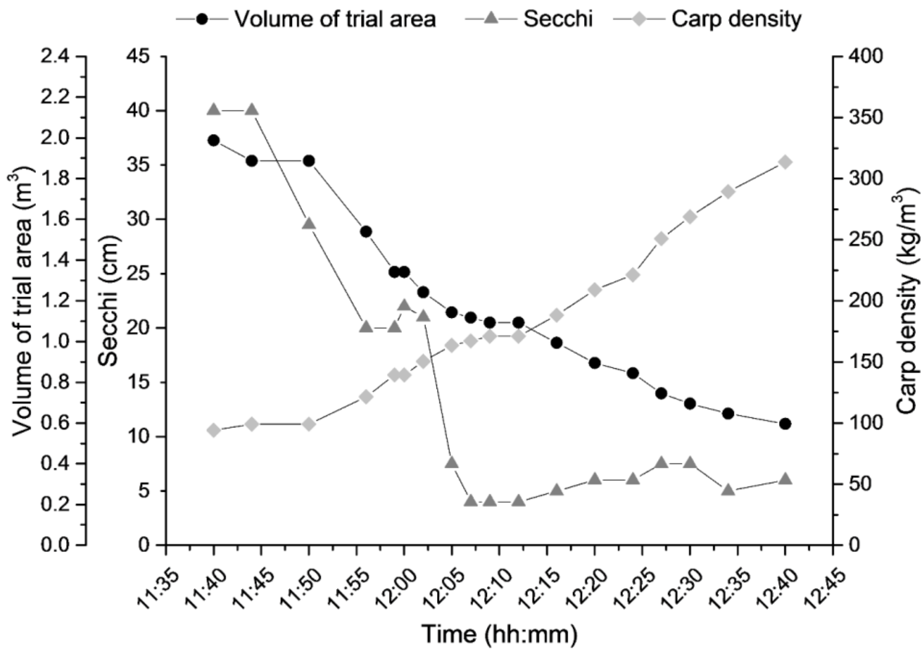

Figure 7. Volume of trial area (m³), secchi depth (cm) and relative density of carp (kg/m³) for the duration of the overcast turbidity trial.

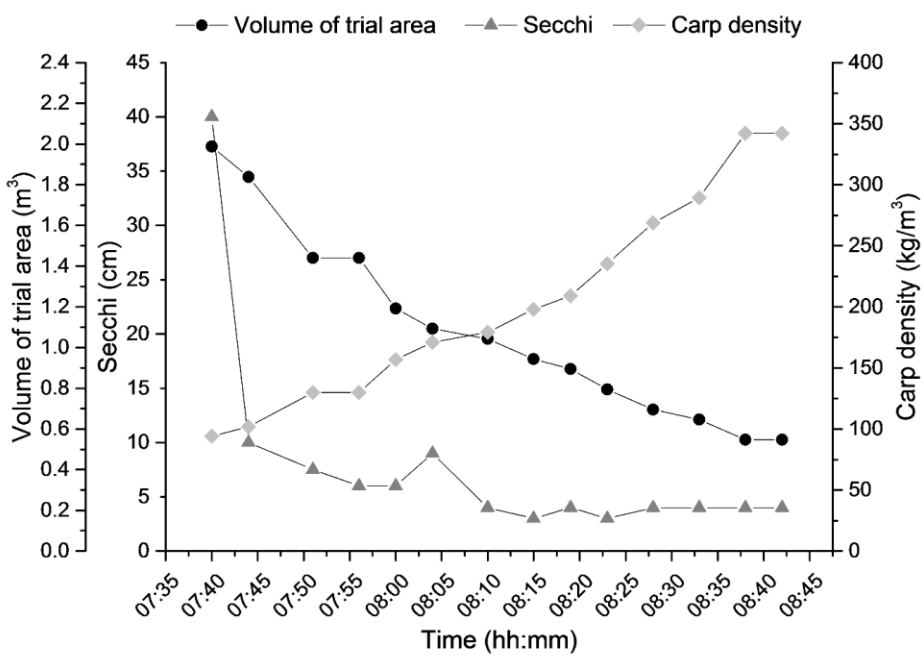

Figure 8. Volume of trial area (m³), secchi depth (cm) and relative density of carp (kg/m³) for the duration of the night turbidity trial.

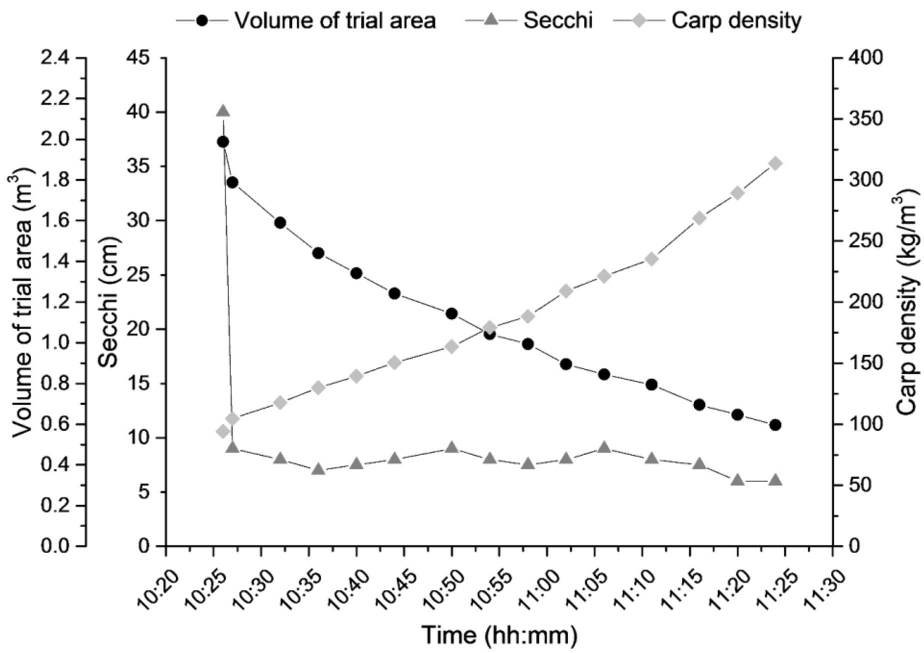

Figure 9. Volume of trial area (m^3), secchi depth (cm) and relative density of carp (kg/m^3) for the duration of the sunlit turbidity trial.

3. RESULTS AND DISCUSSION

One-way gate sensor proof of concept trial

A total of 81 carp were introduced into the experimental system over the two day electrofishing period. On two occasions during this period three carp were observed pushing through the one-way gate. However, due to a technical issue associated with excessive current draw resulting in the counter having <4 hour battery life, these passages were not effectively logged. As this issue was not resolved in the field the block net was employed to conduct a “proof of concept” trial within a 2 hour period. Of the 81 carp introduced above the one-way gate, 46 pushed through resulting in the counter logging a total of 48 counts (Figure 10). This disparity was due to two factors: 1) on several occasions more than one carp (usually two) was observed to pass through the gate at the same time, and 2) carp were observed triggering the sensor mechanism by nudging a finger but not passing through the gate. Notwithstanding, the prototype system provided proof of concept, and although it may not log exact numbers, when further refined and used in conjunction with a time and date logger (see recommendations below) it will capture the timing and duration of carp exiting a wetland via a one-way gate system.

Figure 10. Image of the prototype one-way gate sensor counter at the completion of the “proof of concept” trial.

Camera evaluation

The ability of remote “trail” cameras to capture the presence of carp aggregations at wetland inlets/outlets varied in relation to the camera lens (standard vs. polarised), ambient conditions, water quality and carp density. The standard lens proved the most effective in low turbidity (secchi depth >40 cm) with ~80% of carp detected during sunlit conditions and ~20% and ~14% detected under night and overcast conditions, respectively. The polarised lens provided no additional “penetration” at low turbidities and actually decreased the detectability of carp across all light conditions (Table 1, Figure 11). As such, the remainder of this analysis will focus on the capabilities of cameras fitted with the standard lens.

Table 1. Mean percentage of carp detected in photos captured by the standard and polarised lens under various light conditions in low turbidity (secchi depth >40 cm; relative carp density ~94 kg/m^3).

Conditions	Standard lens (mean % carp detected ± S.E.)	Polarised lens (mean % carp detected ± S.E.)
Sunlit	80.04 ± 1.29	73.66 ± 1.52
Overcast	14.61 ± 3.92	6.17 ± 0.64
Night	20.37 ± 2.53	10.08 ± 2.67

High turbidity levels (mean secchi depth ± S.E. = 7.8 ± 0.7 cm) reduced the visibility of carp with <5% detected across all light conditions at relative densities between 94 and 150 kg/m^3. However, for both sunlit and overcast conditions, once densities exceeded ~170 kg/m^3 the percentage of carp detected steadily increased with increasing density until ~63% of carp were detected at the maximum density of ~290 kg/m^3 (Figures 12 and 13). Under night conditions, <4% of carp were detected until densities exceeded ~200 kg/m^3. While the percentage detected continued to increase beyond this point it only reached ~30% at the maximum relative density of ~300 kg/m^3. The higher percent of carp detected with increasing densities is due to the dorsal region of larger carp becoming exposed as water levels dropped. Notwithstanding, the images are considered representative of what is likely to be captured by cameras when high densities of carp aggregate at screened wetlands. Aggregating carp are known to regularly breach the water’s surface, particularly when in high densities and when “fighting” other carp to gain access to screened breeding grounds and river fishways (Stuart et al. 2006).

A.


B.

C.


D.

E.


F.

Figure 11. Images captured of carp (81 individuals, ~94 kg/m^3) within Banrock Stations outlet culvert using: 1) the standard lens under sunlit (A), night (C) and overcast (E) conditions and, 2) the polarised lens under sunlit (B), night (D) and overcast (F) conditions. Secchi depth during all photos was >40 cm.

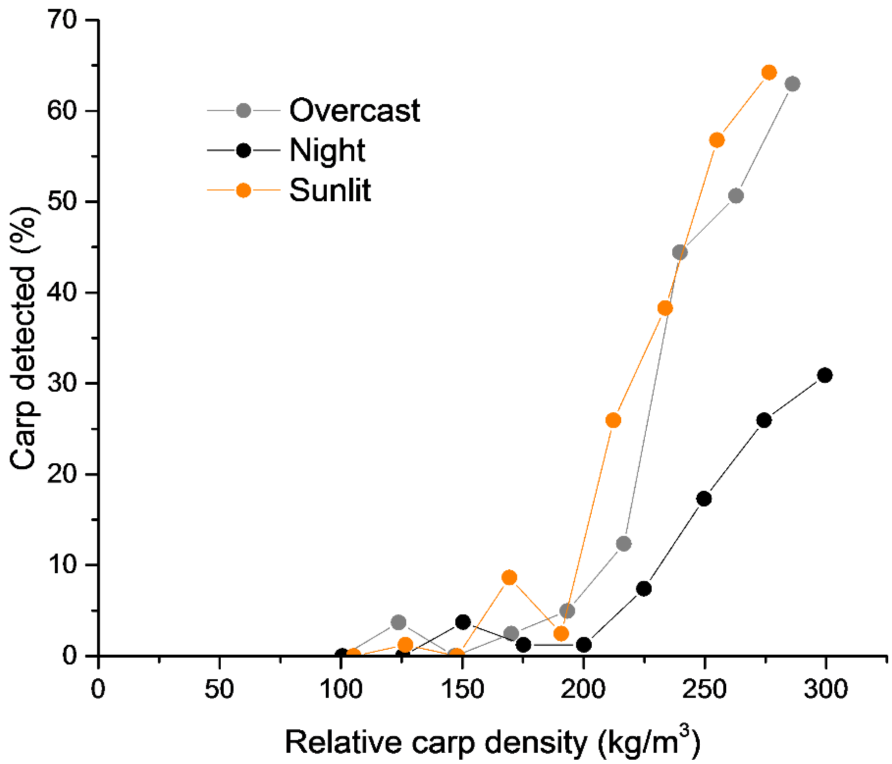

Figure 12. The percentage of carp detected with increasing relative density (kg/m^3) during turbidity trials conducted at the Banrock Station outlet culvert during sunlit, overcast and night conditions.

Moderate levels of turbulence at low turbidities reduced visibility, with no carp detected during overcast and night conditions and <5% of carp detected during sunlit conditions (Figure 14 - A, B and C). Given that very few South Australian wetlands experience even moderate levels of flow and turbulence this should not pose an issue to detecting carp with cameras at screened wetlands. Finally, cameras will need to be set to time lapse mode as the presence of carp under all conditions failed to trigger the camera set to motion sensor mode (Figure 14 - D).

A. Relative carp density ~ 160 kg/m^3

B. Relative carp density ~ 290 kg/m^3

C. Relative carp density ~ 165 kg/m^3

D. Relative carp density ~ 290 kg/m^3

E. Relative carp density ~ 235 kg/m^3

F. Relative carp density ~ 300 kg/m^3

Figure 13. Images captured of carp during turbidity trials within Banrock Stations outlet culvert using the standard lens under sunlit (A, B), overcast (C, D) and night (E, F) conditions. Mean secchi depth ± S.E. = 7.8 ± 0.7 cm.

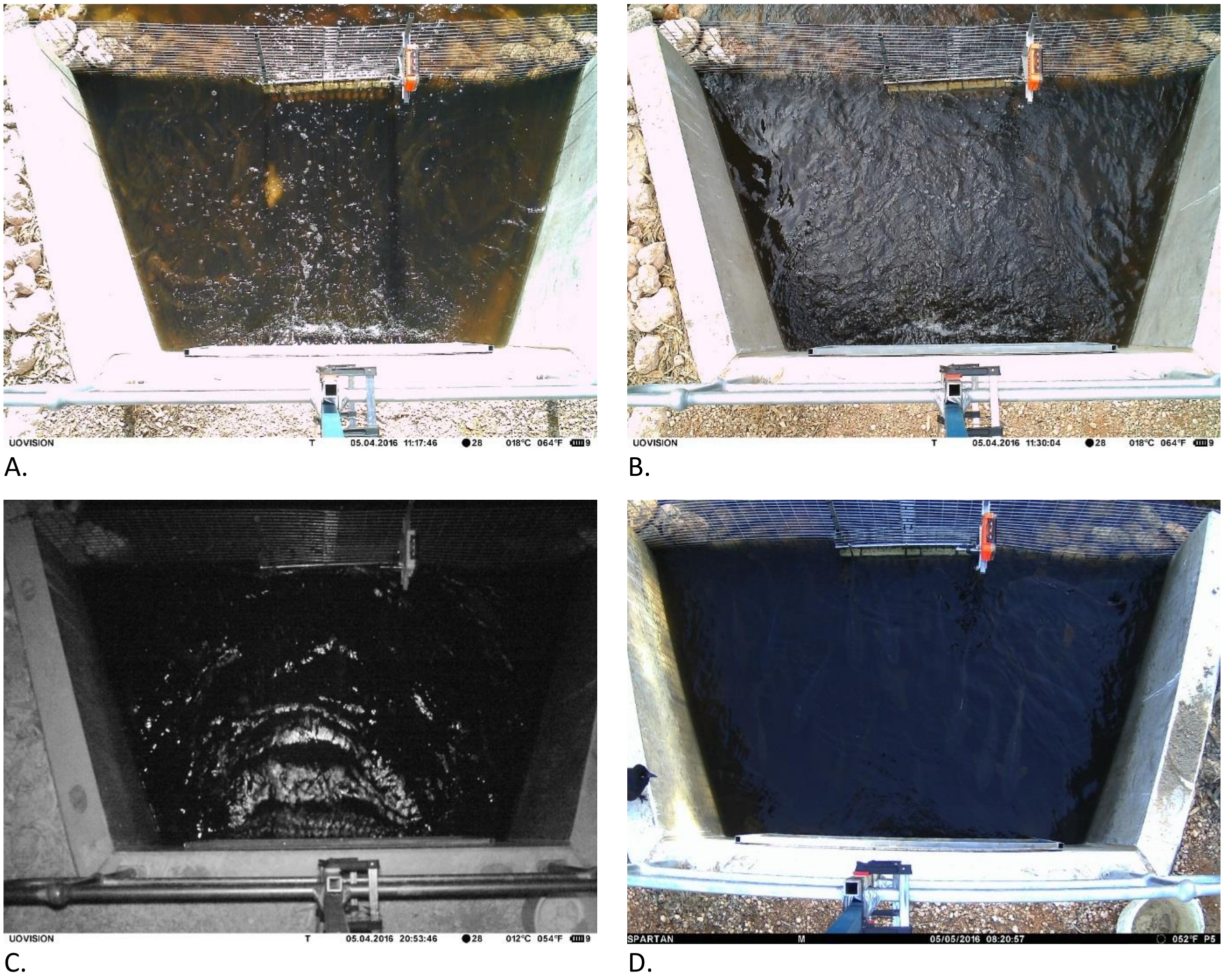

Figure 14. Images captured of carp during turbulence trials within Banrock Stations outlet culvert using the standard lens under sunlit (A), overcast (B) and night conditions (C) and an image triggered by the presence of a crow while a camera was set to motion sensor mode (D).

4. RECOMMENDATIONS

One-way gate sensor

The results of this pilot trial support the use of finger movement sensors to monitor carp exiting screened wetlands via a one-way gate. However, to more reliably log the passage of carp and withstand extended periods in the field the system will need to be improved. Future versions of the one-way gate sensor would benefit from a water proof magnetic reed switch set to trigger only once fingers are lifted beyond a preset angle. One-way gate finger apertures are 31 mm to restrict passage of carp ≥250 mm TL, a size class that is required to lift a finger ~14° before it can pass through (Thwaites et al. 2010). Setting the switch to trigger at this angle would minimise logging nudges (or false passages) and therefore provide a more reliable indication of when and how many carp are moving from the wetland. The use of a water proof reed switch will also enable simplification of the sensor activation mechanism. As the prototype switch was not water proof, it was mounted within a water proof container approximately 50 cm above the water surface which required an extension arm to trigger the mechanism (Figure 5). A water proof magnetic switch would eliminate this requirement as it could be mounted adjacent to the hinged stainless steel rod fitted across the fingers. The date and time of each passage can be logged via water-proof cable and a culvert mounted data logger such as a Raspberry Pi or an Arduino. These small portable data logging devices have programmable applications that can actively log and store data for any custom defined purpose.

It will be difficult to quantify the percentage of detections where more than one carp passed the gate at the same time. However, an estimate could be established by utilising a dual frequency identification Sonar (DIDSON) to capture under water video of carp pushing through the one-way gate. In addition, a large fyke net or steel mesh cage set to block the entire channel outside the gate could be utilised to compare catches to sensor counts. Both techniques could be trialled at experimental wetlands fitting with one-way gates during the carp breeding season. If an estimate can be established then sensor counts can adjusted accordingly.

Cameras

The pilot trial demonstrated the utility of “trail” cameras to capture the frequency, timing and duration of carp aggregations at wetland inlets/outlets. A camera fitted with a standard lens set to capture images at regular intervals proved to be the most effective under all conditions tested. However, the application of “trail” cameras will require careful planning and an understanding of site specific variables (i.e. water quality, culvert design, 3G network coverage, public access) in order to ensure consistent and representative data are captured at each monitored wetland.

Data storage

Although cameras were set to capture images at 8MP resolution, image size on disk varied between ~1000-3000 KB. At the larger image size, a camera fitted with a 32 GB SD card is capable of storing ~10,000 images, the equivalent of capturing one image every 30 minutes over a six month period. While this is sufficient storage to capture images for an entire carp breeding season, to minimise any risk of data loss (i.e. malfunction, theft) cameras should be downloaded on a regular basis (i.e. once a month). In addition, the 3G camera reliably sent images to mobile phones and e-mail accounts for the duration of the pilot study. If mobile coverage is available at experimental wetlands then 3G cameras should be used as data can be collected, sent and stored on a continual basis.

Power options

The pilot trial did not provide sufficient time to determine the longevity of each camera's batteries. However, battery life is dependent on the style of battery (i.e. lithium vs alkaline), number of images captured, standby current draw, connectivity to the 3G network, use of the flash and even ambient temperature. As such, battery life may vary between weeks to months. To avoid the risk of data loss associated with battery failure it is recommended that cameras are fitted with an external power supply that incorporates rechargeable batteries and a solar recharge system (Figure 15).

A.

B.

Figure 15. External power supply for "trail" cameras, A) solar charger with built-in rechargeable battery and, B) high output solar panel and battery kit (http://www.spartancamera.com.au/external-power-options)

Camera programing

The ability of remote “trail” cameras to capture the presence of carp aggregations at wetland inlets/outlets varies in relation to ambient conditions, water quality and carp density. To increase the probability of capturing images of aggregating carp, cameras should be programmed to take images at 30 min intervals for the duration of the study (48 images per day per camera). While this will generate a significant amount of images over the duration of the carp breeding season, if 3G cameras are utilised images can be sent and analysed daily to filter out the image that captures the most carp per wetland.

Image analysis

Photos should be evaluated to identify the image that captured the most carp at each location per day. Due to the depth of each culvert, water clarity, ambient conditions and limitations associated with the focal range of each camera (~5 m^2), it will be difficult to accurately determine the actual numbers or density of carp within each image. As such, a ranking system should be used to classify each image (e.g. 0 = no carp present, 10 = dense coverage of carp within the cameras focal range). This system should be refined at the completion of the breeding season by locating the images with the least and most amount of carp and ranking all other images accordingly. If these image are not captured under the same conditions then a conversion factor derived from the results of the pilot trial could be applied (see Table1).

Camera mounting

The mounting system used for the pilot was sufficient but a more secure theft resistant system is required if cameras are to be deployed for extended periods. The design for this system may need to be customised for each site to account for culvert design (i.e. height, safety railing, orientation) and the level of public access. As such, a scoping study will be required prior to construction of each mounting system. This study should also be used to determine the utility of 3G cameras at each site.

5. CONCLUSION

The results of the pilot trial demonstrate the utility of remote cameras and one-way gate sensors to monitor the behavior of carp at screened wetlands. With further development, careful planning and an understanding of site specific variables (i.e. water quality, culvert design, 3G network coverage, public access) these novel monitoring techniques will allow cost effective data collection to generate new knowledge to inform the ongoing management CES.

REFERENCES

David, B. (2015). Tools for Drafting, Counting and Trapping Invasive Fish. Section 4.2 in Collier KJ & Grainger NPJ eds. New Zealand Invasive Fish Management Handbook. Lake Ecosystem Restoration New Zealand (LERNZ; The University of Waikato) and Department of Conservation, Hamilton, New Zealand. Pp 60–66.

Conallin, A., Smith, B., Thwaites, L. Walker, K. and Gillanders, B. (2012). Environmental water allocations in regulated lowland rivers may encourage offstream movements and spawning by common carp, *Cyprinus carpio*: implications for wetland rehabilitation. *Marine and Freshwater Research* 63, 865-877.

Johnsen, P. B., and Hasler, A. D. (1977). Winter aggregations of carp (*Cyprinus carpio*) as revealed by ultrasonic tracking. *Transactions of the American Fisheries Society* 106, 556-59.

Hillyard, K. A., Smith, B. B., Conallin, A. J., and Gillanders, B. M. (2010). Optimising exclusion screens to control exotic carp in an Australian lowland river. Marine and Freshwater Research, 61 (4), 418-429.

Inland Fisheries Service (2008). Carp management program annual report for 2007 / 2008. Inland Fisheries Service, New Norfolk, Tasmania.

Meredith, S. N., Zukowski, S., and Conallin, A. (2006). A case study approach to managing ephemeral wetlands for native fish: linking fish ecology to regulatory structure design and operation. In 'Native Fish and Wetlands in the Murray–Darling Basin: Action Plan, Knowledge Gaps and Supporting Papers'. (Ed. B. Phillips.) pp. 29–44. (Murray–Darling Basin Commission: Canberra.).

Nichols, S., and Gilligan, D. (2003). What about the fish? – Improving fish passage through wetland flow control structures in the lower River Murray. Australian Landscape Trust, Renmark.

Penne, C. R., and Pierce, C. L. (2008). Seasonal distribution, aggregation, and habitat selection of common carp in Clear Lake, Iowa. *Transactions of the American Fisheries Society* 137, 1050-62.

Smith, B. B., and Walker, K. F. (2004). Spawning dynamics of common carp in the River Murray, South Australia, shown by macroscopic and histological staging of gonads. *Journal of Fish Biology* 64, 336-54.

Smith, B., Thwaites, L. and Conallin, A. (2009) Guidelines to inform the selection and implementation of carp management options at wetland inlets: a test case for South Australia. Prepared by the South Australian Research and Development Institute (Aquatic Sciences) for the Invasive Animals Cooperative Research Centre, Canberra.

Stuart, I. G. and Jones, M. (2006). Large, regulated forest floodplain is an ideal recruitment zone for non-native common carp (*Cyprinus carpio* L.). *Marine and Freshwater Research* 57, 333-47.

Stuart, I. G., Williams, A., Mackenzie, J. and Holt, T. (2006) Managing a migratory pest species: a selective trap for common carp. *North American Journal of Fisheries Management* 26(4), 888-893.

Thwaites, L. A., Smith, B. B., Decelis, M., Fleer, D., and Conallin, A. (2010). A novel push trap element to manage carp (*Cyprinus carpio* L.): a laboratory trial. *Marine and Freshwater Research*, 61, 42-48.

Vilizzi, L., Thwaites, L., Smith, B., Nicol, J. and Madden, C. (2014) Ecological effects of common carp (*Cyprinus carpio*) in a semi-arid floodplain wetlands. *Marine and Freshwater Research*, 65, 802-817.