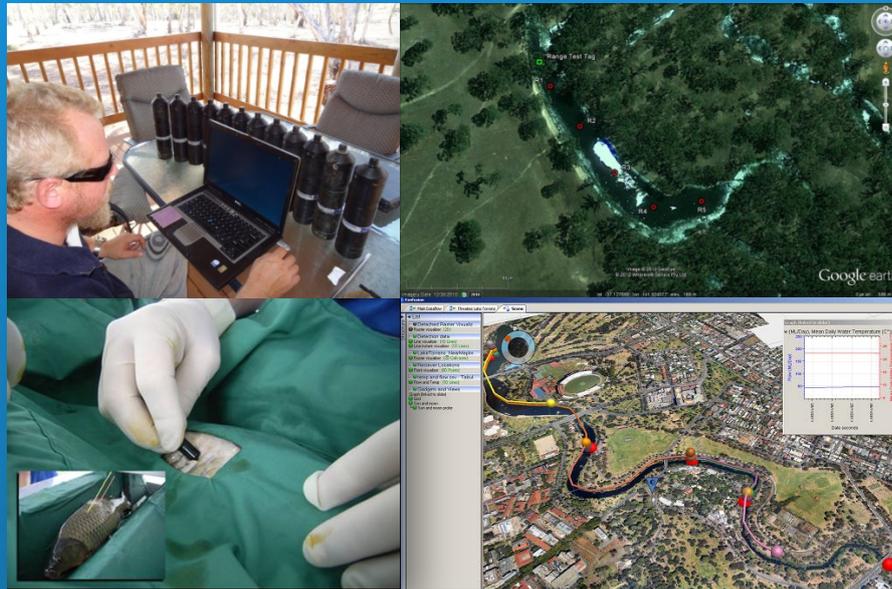


Inland Waters & Catchment Ecology Invasive Species



Glenelg River Acoustic Range Finding Experiment



Dr Leigh Thwaites

**SARDI Publication No. F2012/000122-1
SARDI Research Report Series No. 630**

**SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022**

May 2012

**A Technical Report for the Glenelg Hopkins Catchment Management
Authority**



**Government
of South Australia**

Glenelg River Acoustic Range Finding Experiment

**A Technical Report for the Glenelg Hopkins Catchment
Management Authority**

Dr Leigh Thwaites

**SARDI Publication No. F2012/000122-1
SARDI Research Report Series No. 630**

May 2012

This publication may be cited as:

Thwaites, L. A (2012). Glenelg River Acoustic Range Finding Experiment. A Technical Report for the Glenelg Hopkins Catchment Management Authority. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2012/000122-1. SARDI Research Report Series No. 630. 14pp.

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.sardi.sa.gov.au>

DISCLAIMER

The authors warrant that they have taken all reasonable care in producing this report. The report has been through the SARDI Aquatic Sciences internal review process, and has been formally approved for release by the Research Chief, Aquatic Sciences. Although all reasonable efforts have been made to ensure quality, SARDI Aquatic Sciences does not warrant that the information in this report is free from errors or omissions. SARDI Aquatic Sciences does not accept any liability for the contents of this report or for any consequences arising from its use or any reliance placed upon it.

© 2012 SARDI

This work is copyright. Apart from any use as permitted under the *Copyright Act 1968* (Cth), no part may be reproduced by any process, electronic or otherwise, without the specific written permission of the copyright owner. Neither may information be stored in any form whatsoever without such permission.

Printed in Adelaide: May 2012

SARDI Publication No. F2012/000122-1
SARDI Research Report Series No. 630

Author(s): Dr Leigh Thwaites

Reviewer(s): Rod Ward and Dr Susan Gehrig

Approved by: Dr Qifeng Ye
Science Leader – Inland Waters & Catchment Ecology

Signed: 

Date: 8 May 2012

Distribution: Glenelg Hopkins CMA, SAASC Library, University of Adelaide Library, Parliamentary Library, State Library and National Library

Circulation: Public Domain

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
1. INTRODUCTION	2
1.1. Background	2
1.2. Objectives.....	3
2. METHODS.....	4
2.1. Site Description	4
2.2. Water Quality.....	4
2.3. Acoustic Range Finding Experiment	5
3. RESULTS AND DISCUSSION	7
3.1. Water Quality.....	7
3.2. Acoustic Range Finding Experiment	8
3.3. Acoustic Transmitters	9
3.3.1. VEMCO V16-4L coded acoustic transmitter	10
3.3.2. VEMCO V13-1L coded acoustic transmitter	11
3.3.3. VEMCO V9-2L coded acoustic transmitter	11
3.4. Acoustic Receiver Locations	12
REFERENCES	13

LIST OF FIGURES

Figure 1. Location of the Glenelg River acoustic range finding experiment.	4
Figure 2. Google Earth image of the acoustic range finding experimental set-up.	5
Figure 3. Acoustic range finding experimental set-up including receiver spacing's and depth to receivers and the experimental pools substrate.	6
Figure 4. Temperature ($^{\circ}\text{C}$) and electrical conductivity ($\mu\text{s.cm}^{-1}$) depth profile taken adjacent to receiver R5.	7
Figure 5. V13-1X High/Low acoustic range finding experiment summary.	8
Figure 6. VEMCO V16 coded acoustic transmitter (http://www.vemco.com/pdf/v16coded.pdf). 10	
Figure 7. VEMCO V13 coded acoustic transmitter (http://www.vemco.com/pdf/v13_coded.pdf).	11
Figure 8. VEMCO V9 coded acoustic transmitter (http://www.vemco.com/pdf/v9_coded.pdf). ..	12

LIST OF TABLES

Table 1. VEMCO acoustic transmitter and VR2W receiver identification and location.	6
---	---

ACKNOWLEDGEMENTS

The author would like to thank the staff of the Glenelg Hopkins Catchment Management Authority, in particular Stephen Ryan and Bryce Morden for their assistance during the field experiment. Thanks to Josh Fredberg (SARDI) for assistance in field work preparation and GIS mapping. Also, thanks to Rod Ward, Dr Susan Gehrig and Annie Vainickis (SARDI) for providing constructive comments on earlier versions of this report. Finally, a special thanks to Ian and Kathy Ross for generously providing access to the experimental reach. This work was funded by the Glenelg Hopkins Catchment Management Authority.

EXECUTIVE SUMMARY

The Glenelg River is a high profile, priority river in Victoria containing significant fauna and characterized by many reaches in excellent condition. Carp are a relatively recent arrival to the Glenelg system (*circa* 2001) and the Glenelg Hopkins Catchment Management Authority (Glenelg Hopkins CMA) are keen to slow their spread and manage sites where carp are present to reduce their impact on native fish and overall river health. Key to the development of a cost-effective carp management strategy is to identify carp behavioral patterns and habitat preferences which may be exploited for control purposes. As such, the Glenelg Hopkins CMA is interested in utilizing a VEMCO acoustic tracking array to capture the movements of tagged “Judas” carp throughout the system. An important first step in establishing such an array is to conduct a range finding experiment in order to identify the most suitable acoustic transmitters and to define appropriate acoustic receiver locations. The range finding experiment comprised a VEMCO V13-1X acoustic range finding transmitter and a string of five VEMCO VR2W acoustic receivers which were deployed in a representative location within the Glenelg River on 14th February 2012. Average signal detection during the low power output cycle of the range finding transmitter (147 dB) was maintained at $\approx 72\%$ for 125 m and average signal detection during the high power output cycle (153 dB) was maintained at $\approx 82\%$ to 175 m. A significant drop in detection for both the high and low power cycle was observed at 225 m as a result of the receiver being positioned out of direct “line-of-sight” of the transmitter. The effective detection range will be significantly further in larger straight pools. The less than 100 % signal detection is likely a function of interference associated with vegetation, turbidity, ambient background noise and the presence of a slight thermocline. The observed detection loss will have negligible impact on the utility of acoustic tracking within the Glenelg River. To track the movement patterns and habitat preference of mature and immature carp three VEMCO transmitters are recommended: V16-4L (152 dB; mature carp ≥ 500 mm Total Length (TL), ≥ 1200 g), V13-1L (147 dB; mature carp ≈ 350 -500 mm TL, 550-1200 g) and V9-2L (146 dB; immature carp ≈ 210 -350 mm TL, 235-550 g). To minimize the potential for ping train collisions and to ensure tagged carp are detected as they move past receivers a nominal ping train delay of 120 ± 60 s is recommended. Given this delay, the V16-4L, V13-1L and V9-2L transmitters will last for 10 years, 3 years and 1.4 years, respectively. The Glenelg River has pools at regular intervals which are similar to, or larger than, the experimental pool and therefore suitable for the systematic deployment VEMCO VR2W receivers. As such, the application of acoustic tracking promises to yield exceptional movement and habitat preference data.

1. INTRODUCTION

1.1. Background

Common carp (*Cyprinus carpio* L.) are a successful invader and a declared pest fish in several countries including Australia, New Zealand, Canada and the United States (Koehn 2004). The success of carp stems from their high fecundity (100,000 eggs.kg⁻¹; up to 1 million eggs.y⁻¹), their high level of recruitment (up to 40 % survival), their longevity (28+ years), their ability to occupy a broad range of habitats and their tolerance to extreme environmental conditions (Smith 2005). When in high abundance, carp cause detrimental changes to benthic habitats, water quality and the distribution and abundance of native flora and fauna (Gehrke and Harris 1994; Miller and Crowl 2006; Matsuzaki et al. 2009). These impacts stem largely from carp's bottom-feeding behaviour (Sibbing et al. 1986) and are most commonly reported in shallow off-stream habitats (Parkos et al. 2003) where carp annually aggregate to feed and breed (Smith and Walker 2004; Stuart and Jones 2006).

The Glenelg River is a high profile, priority river in Victoria containing significant fauna and characterized by many reaches in excellent condition. Carp are a relatively recent arrival to the Glenelg River system (*circa* 2001) and the Glenelg Hopkins Catchment Management Authority (Glenelg Hopkins CMA) are keen to slow their spread down the system and manage sites where carp are present to reduce their impact on native fish and overall river health. While the Glenelg Hopkins CMA has already collected considerable background data on the species and are currently applying opportunistic control measures they are now seeking to develop a more strategic approach toward managing carp. In this regard, the Glenelg Hopkins CMA engaged the South Australian Research and Development Institutes (SARDI) Invasive Species Sub-Program in November 2010 to assist in the development of a cost-effective carp management strategy. Key to the development of this strategy is the identification of movement patterns and habitat preferences of carp which may then be exploited for control purposes (i.e. aggregation points, timing of migrations between spawning and overwintering habitats, etc). With this knowledge, the utility of control methods such as carp exclusion screens, carp separation cages or the strategic delivery of environmental water releases to aggregate or disadvantage carp can be critically evaluated. As such, the Glenelg Hopkins CMA is interested in utilizing a VEMCO acoustic tracking array to capture the behavioral patterns of tagged "Judas" carp throughout the

system. This strategy is particularly effective as the behaviour of tagged “Judas” carp mirrors that of untagged carp so that behavioural patterns of schools can be identified and exploited (IFS 2011). An important first step in establishing a tracking array is to conduct an acoustic range finding experiment in order to identify the most suitable acoustic transmitters and to define appropriate acoustic receiver locations.

1.2. Objectives

- Design and conduct an acoustic range finding experiment within a representative reach of the Glenelg River, Victoria.
- Provide a brief technical report detailing the methods utilized, the results of the acoustic range finding experiment and recommendation of the most appropriate acoustic transmitters and acoustic receiver locations for tracking “Judas” carp within the Glenelg River.

2. METHODS

2.1. Site Description

The acoustic range finding experiment was conducted within a reach of the Glenelg River situated on private property approximately 68 km north of the township of Hamilton in south-west Victoria (37.12788°E; 141.92369°N; Figures 1 & 2). This location was chosen as its characteristics are representative of pools encountered at relatively regular intervals along the river. Pools are more suitable for the deployment of acoustic receivers as their depth and length permit greater propagation of signals sent by fish implanted with acoustic transmitters (i.e. the probability of detecting a tagged fish is maximized).

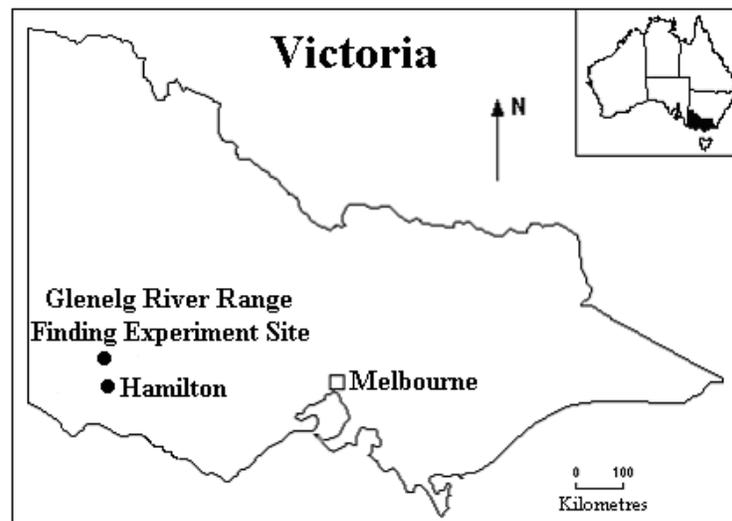


Figure 1. Location of the Glenelg River acoustic range finding experiment.

2.2. Water Quality

An important phenomenon that changes the spherical spreading of transmitted sound in water is refraction that results from spatial variations in sound speed that can be induced by thermoclines and haloclines (Kinsler et al. 2000). These variable conditions create a barrier layer that makes it difficult to detect acoustic transmissions across the cline. As such, a depth profile (0.2 m, 2 m, 3 m and 4 m) of electrical conductivity ($\mu\text{s}\cdot\text{cm}^{-1}$) and temperature ($^{\circ}\text{C}$) was collected from within the deepest section of the experimental pool (adjacent to R5; Figures 2 & 3) using a TPS 90-FLT portable water quality logger (TPS Pty Ltd, Springwood, Brisbane, Australia). Sampling occurred on the first day of the range finding experiment (14th February 2012).

2.3. Acoustic Range Finding Experiment

A VEMCO V13-1X acoustic range finding transmitter with variable programming (see below) and an array of five VEMCO VR2W acoustic receivers (spaced at regular intervals; Table 1, Figures 2 & 3) were deployed in a representative pool within the Glenelg River on 14th February 2012. The transmitter and receivers were moored to Besser blocks and suspended within the water column 2 m below a surface float. A VEMCO VR100 manual tracking receiver was used to confirm the operation of the range finding transmitter prior to the onset of the experiment. The range test was conducted over an eight day period to capture a total of four days for both the high and low output cycles of the range finding transmitter. Receivers were retrieved on 23rd February 2012 and returned to SARDI for download, interpretation and recommendation of the most appropriate acoustic transmitters and receiver locations for the Glenelg River.

V13-1X variable programming:

- Days 1 and 2 - Power Low (147 dB); Fixed Delay: 10 seconds
- Days 3 and 4 - Power High (153 dB); Fixed Delay: 20 seconds
- Days 5 and 6 - Power Low (147 dB); Fixed Delay: 10 seconds
- Days 7 and 8 - Power High (153 dB); Fixed Delay: 20 seconds



Figure 2. Google Earth image of the acoustic range finding experimental set-up.

Table 1. VEMCO acoustic range finding transmitter and VR2W receiver identification and location.

	ID	Latitude	Longitude
Acoustic range finding transmitter	V13-1X	-37.12692°	141.92287°
VR2W Receivers	R1	105968	-37.12713°
	R2	105969	-37.12748°
	R3	105973	-37.12788°
	R4	105974	-37.12818°
	R5	105975	-37.12813°

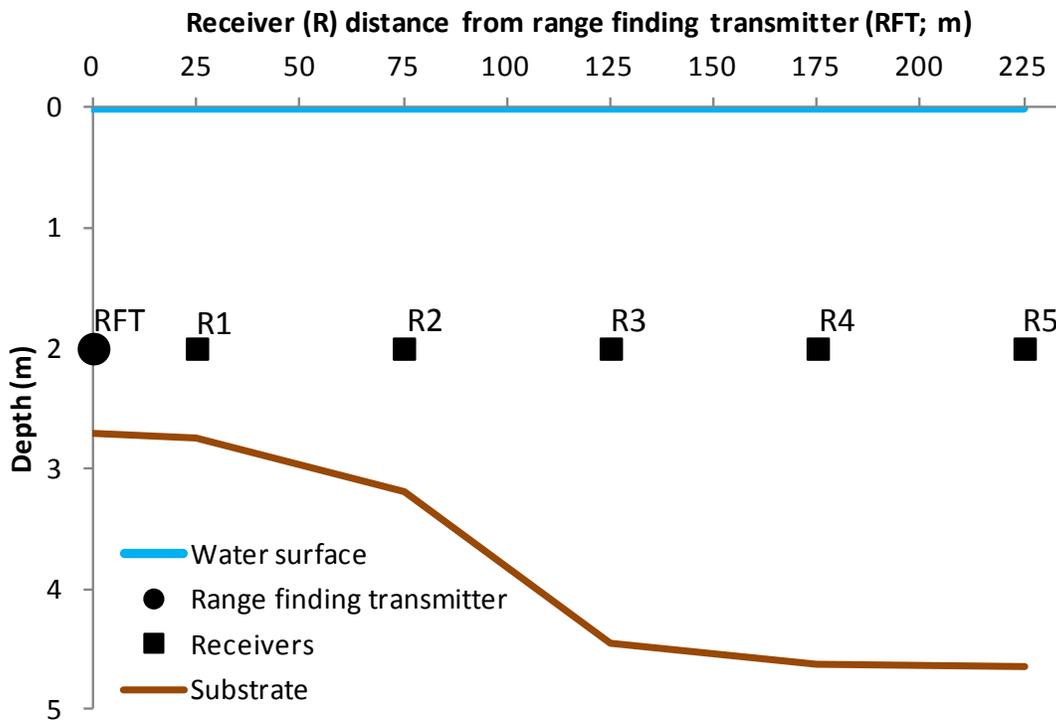


Figure 3. Acoustic range finding experimental set-up including receiver spacing's and depth to receivers and the experimental pools substrate.

3. RESULTS AND DISCUSSION

3.1. Water Quality

The water quality of the experimental site was characterized by a homogenous electrical conductivity profile typical of freshwater rivers ($0\text{-}800\ \mu\text{s.cm}^{-1}$) and a temperature profile indicating the presence of a slight thermocline (surface: 23.7°C ; $2\ \text{m}$ depth: 19.6°C) (Figure 4). While the thermocline may have influenced the acoustic range finding transmitters signal propagation (Kinsler et al 2000), the results of the experiment indicate that the effects were minimal (see section 3.2). In addition, as thermoclines tend to breakdown during flow events and during winter months the results of the range finding experiment are likely to represent the worst case scenario for acoustic tracking within the Glenelg River.

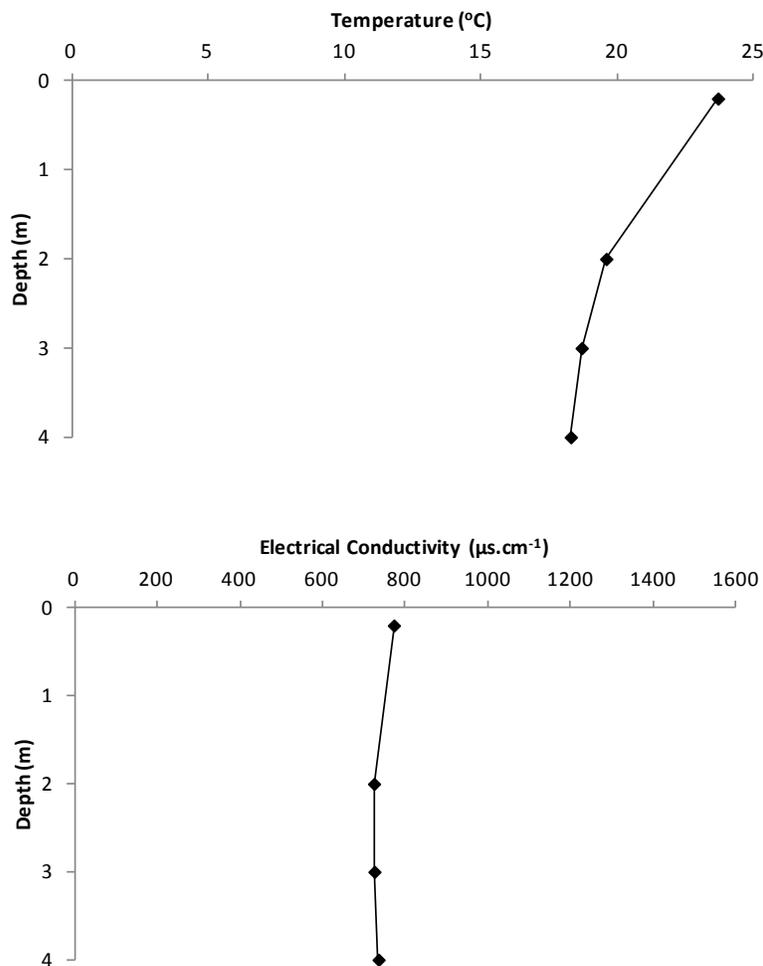


Figure 4. Temperature ($^\circ\text{C}$) and electrical conductivity ($\mu\text{s.cm}^{-1}$) depth profile taken adjacent to receiver R5.

3.2. Acoustic Range Finding Experiment

Average signal detection during the low power output cycle of range finding transmitter (147 dB) was maintained at $\approx 72\%$ for 125 m from the range finding transmitter before declining to $\approx 62\%$ at 175 m and 0 % at 225 m (R5; Figures 2, 3 & 5). Average signal detection during the high power output cycle (153 dB) was maintained at $\approx 82\%$ for 175 m from the transmitter but declined to $\approx 10\%$ at 225 m (R5; Figures 2, 3 & 5). The significant drop off in detection at R5 for both the high and low power cycle is attributed to the receiver being positioned out of direct “line-of-sight” of the transmitter. Given that minimal loss of detection was witnessed over the four receivers in direct “line-of-sight”, the effective detection range should be significantly further in larger straight pools (pers. comm. Jonathan Mulock, VEMCO). It is also important to note that the reported ranges represent the potential range both upstream and downstream of a VR2W receiver in similar or larger pools (i.e. 175 m upstream + 175 m downstream = detection range up to 350 m). Signal detection lower than 100 % is most likely a function of interference associated with vegetation, turbidity, changes in ambient background noise resulting from fluctuations in flow, wind speed, rain events, etc, as well as the presence of a slight thermocline. Although some detection loss is expected as a result of the above factors, this loss will have negligible impact on the utility of acoustic tracking within the Glenelg River.

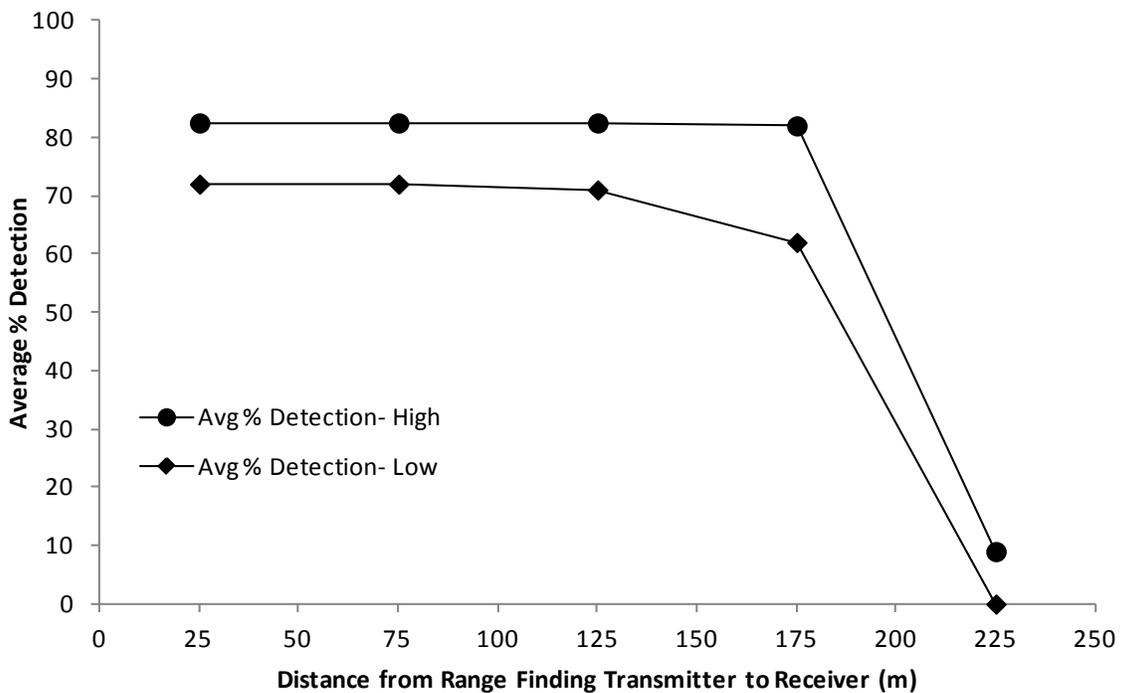


Figure 5. V13-1X High/Low acoustic range finding experiment summary.

3.3. Acoustic Transmitters

Acoustic transmitters are manufactured in a range of sizes and various programming specifications (power output and nominal ping train delay) so that transmitters can be tailored to particular species, life stages (juveniles, adults, sexually mature or immature, etc.) and the specific research objectives of a given study. In this regard, it is important to first develop the research objectives and to identify any potential limitations in order to define the appropriate acoustic transmitters. As such, the transmitter recommendations given below take into account the results of the acoustic range finding study as well as the following considerations (developed through consultation with VEMCO and the Glenelg Hopkins CMA):

- The current experiment represents the first stage of a tracking study which aims to identify movement patterns and habitat preferences of carp over 250-300 km of the Glenelg River that can be exploited for control/eradication purposes.
- The tracking study will be conducted over a three year period to account for behavioral changes resulting from natural and human induced variation between seasons and year's (i.e. flooding, drying, environmental water releases, etc).
- The study will aim to track the behaviour of 100+ carp and will include immature (\approx 210-350 mm Total Length (TL); 235-550 g), small mature (\approx 350-500 mm TL; 550-1200 g) and large mature (\geq 500 mm TL; \geq 1200 g) carp to account for behavioral differences between these size classes (age, length and weight relationships adapted from Smith 2005).
- Carp will be captured and tagged from across the entire study area and tagged carp will be released at their capture locations. This will ensure that tagged carp are widely dispersed at the on-set of the tracking study. However, there is potential that tagged carp will migrate through and aggregate in certain areas during spawning and overwintering times. The actual number of tagged carp that could be expected in any one migration and aggregation is difficult to speculate at this stage.
- In terms of carp behavior, observational evidence suggests that carp are able to swim at burst speeds of approx. $1 \text{ m}\cdot\text{s}^{-1}$, however they rarely swim at this speed and can only maintain it for a short period if they do (SARDI unpublished data).
- Acoustic transmitters cannot exceed 2 % of a tagged carp's total weight (out of water) in order to minimise potential impacts on its behaviour (Winter 1996).
- Transmitter programming will be optimized to minimize the potential for ping train collisions and to ensure that tagged carp will be detected as they pass through the

detection range of a VR2W receiver. Collisions affect a receiver's ability to identify an individual transmitter's unique code and result from multiple tagged fish (20+) being within range of a receiver. The potential for collision can be minimized by increasing the nominal ping train delay but this can also decrease the probability of detection as a carp may pass a receiver between ping trains. A balance between the detection loss resulting from collision or an extended ping train delay is required. Due to extended residency times at aggregations points, the probability of detecting all tagged carp within the aggregation is increased.

- Ideally, transmitters will have a projected battery life of at least 3 years.

3.3.1. VEMCO V16-4L coded acoustic transmitter

V16-4L coded acoustic transmitters (152 dB; Figure 6) with a nominal ping train delay of 120 ± 60 s are recommended for tracking large mature carp ≥ 500 mm TL (≈ 1200 g). With a weight of 24 g, these transmitters are ≤ 2 % body weight of this size class. They offer a power output similar to the high power cycle of the range finding transmitter and should therefore be detected at similar or greater distances (depending on the length of the pool in which the receiver is deployed). The nominal ping train delay will minimize the potential for collisions (pers. comm. Jonathan Mulock, VEMCO) while maximizing the probability of detection as a carp swims past a receiver. For example, using the recommended ping train delay and a carp swimming at a burst speed of approx. $1 \text{ m}\cdot\text{s}^{-1}$, an acoustic receiver should log one to two detections as a tagged carp swims through 200 m of a pool (however the actual number of detections should be higher as carp's normal swim speed is rarely at this maximum). This transmitter's battery size and programming specification will provide 3650 days (10 years) of continuous tracking data.

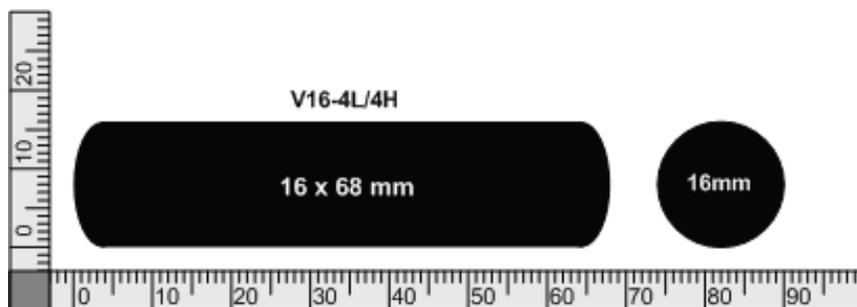


Figure 6. VEMCO V16 coded acoustic transmitter (<http://www.vemco.com/pdf/v16coded.pdf>).

3.3.2. VEMCO V13-1L coded acoustic transmitter

V13-1L coded acoustic transmitters (147 dB; Figure 7) with a nominal ping train delay of 120 ± 60 s are recommended for tracking small mature carp 350-500 mm TL (≈ 550 -1200 g). With a weight of 11 g, these transmitters are a maximum of 2 % body weight of the size class. They offer a power output equivalent to the low power cycle of the range finding transmitter and should therefore be detected at similar or greater distances. Similar to the V16-4L, the ping train delay will minimize the potential for collision while maximizing the probability of detection as receivers should log at least one to two detections as a tagged carp swims through a pool. This transmitter's battery size and programming specification will provide 1092 days (3 years) of continuous tracking data. To ensure this size class is represented for the entire 3 year study it is recommended that carp at the lower end of the size range are tagged at the onset of the study.

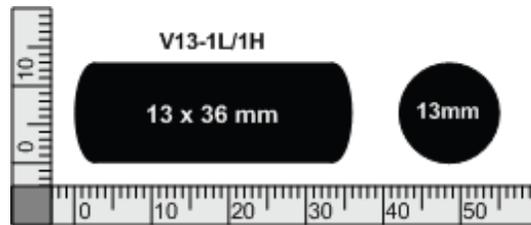


Figure 7. VEMCO V13 coded acoustic transmitter (http://www.vemco.com/pdf/v13_coded.pdf).

3.3.3. VEMCO V9-2L coded acoustic transmitter

V9-2L coded acoustic transmitters (146 dB; Figure 8) with a nominal ping train delay of 120 ± 60 s are recommended for tracking immature carp 210-350 mm TL (≈ 235 -550 g). With a weight of 4.7 g, these transmitters are a maximum of 2 % body weight of the size class. They offer a power output similar to the low power cycle of the range finding transmitter and should therefore be detected at similar or greater distances. While this transmitters performance is similar to the V13-1L, due to its battery size it will only provide 514 days (1.4 years) of continuous tracking data. To ensure this size class of carp is represented for the entire 1.4 years of the transmitter's battery life it is recommended that carp at the lower end of the size range are tagged at the onset of the study. If tracking this size class is to continue for the entire 3 year duration of the study then a second round of surgeries will be required.

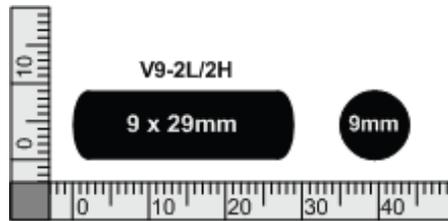


Figure 8. VEMCO V9 coded acoustic transmitter (http://www.vemco.com/pdf/v9_coded.pdf).

3.4. Acoustic Receiver Locations

The Glenelg River is characterized by pools at regular intervals which are similar to, or larger than, the experimental pool and therefore suitable for the systematic deployment of VEMCO VR2W receivers. As such, the application of acoustic tracking promises to yield exceptional movement and habitat preference data. Ideally, receivers should be deployed in large pools every 10-15 km to encompass the current and predicted distribution of carp within the Glenelg River as well as to target known aggregation points such as Clunies Hole (pers. comm. Stephen Ryan, Glenelg Hopkins CMA). It is recommended that the final array design and receiver mooring techniques be undertaken with further consultation between the Glenelg Hopkins Catchment Management Authority and SARDI Aquatic Sciences.

REFERENCES

- Gehrke, P. C., and Harris, J. H. (1994). The role of fish in cyanobacterial blooms in Australia. *Australian Journal of Marine and Freshwater Research* **45**, 905-915.
- IFS (2011) Inland Fisheries Service- IFS Carp Management Program. <http://www.ifs.tas.gov.au/>
- Kinsler, L. E., Frey, A. R., Coppens, A. B. and Sanders, J. S. (2000). *Fundamentals of Acoustics*- 4th Edition. ISBN 978-0-471-84789-2. John Wiley and Sons Inc. America. 548 pp.
- Koehn, J. D. (2004). Carp (*Cyprinus carpio*) as a powerful invader in Australian waterways. *Freshwater Biology* **49**, 882-894.
- Matsuzaki, S. S., Usio, N., Takamura, N., and Washitani, I. (2009). Contrasting impacts of invasive engineers on freshwater ecosystems: an experiment and meta-analysis. *Oecologia* **158**, 673-686.
- Miller, S. A., and Crowl, T. A. (2006). Effects of common carp (*Cyprinus carpio*) on macrophytes and invertebrate communities in a shallow lake. *Freshwater Biology* **51**, 85-94.
- Parkos, J. J., Santucci, V. J., and Wahl, D. H. (2003). Effects of adult common carp (*Cyprinus carpio*) on multiple trophic levels in shallow mesocosms. *Canadian Journal of Fisheries and Aquatic Sciences* **60**, 182-192.
- Sibbing, F. A., Osse, J. W. M., and Terlouw, A. (1986). Food handling in the carp (*Cyprinus carpio*): Its movement patterns, mechanisms and limitations. *Journal of the Zoological Society of London* **210**, 161-203.
- Smith, B. B., and Walker, K. F. (2004). Reproduction of common carp in South Australia, shown by young-of-the-year samples, gonadosomatic index and the histological staging of ovaries. *Transactions of the Royal Society of South Australia*. **128**, 249-257.
- Smith, B. B. (2005). The state of the art: a synopsis of information on common carp (*Cyprinus carpio*) in Australia. Final Technical Report, SARDI Aquatic Sciences Publication No. RD04/0064-2; SARDI Research Report Series No. 77, prepared by the South Australian Research and Development Institute (Aquatic Sciences), Adelaide. 68 pp.

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**, 333-347.

Winter, J.D. (1996). Advances in Underwater biotelemetry. *In* Murphy, B.R. & Willis, D.W. eds., *Fisheries Techniques*, 2nd edition. 555-590 pp. Bethesda, Maryland, American Fisheries Society.