Scottish Public Petitions Committee: Petition PE1558

ANNEX 1

SNH and SEPA response to issues raised by the Committee on 26 May 2015

During the meeting, the Committee asked SNH and SEPA to provide further joint written evidence on the following issues:

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Additional information relevant to this response is included in the following Annexes

Annex 2 North American Signal Crayfish (NASC) frequently asked questions

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Annex 4 Fish, fisheries & angler survey in Loch Ken – project summary

Annex 5 River Annan Check Clean Dry campaign

Annex 6 Examples where biocides have been used

1 A list of local work on American Signal Crayfish as an INNS

The Dumfries & Galloway Invasive Non Native Species Working Group (D&G INNS Working Group) was convened in early 2010. The group meets biannually to work in partnership to prevent the spread of Signal Crayfish and other non-native species. Sixteen organisations are represented, including SNH (Chair), SEPA (Secretary), Local Biodiversity Action Plan Officer, Police Scotland, Galloway, Nith Catchment and Annan Fishery Trusts, Annan and Nith District Salmon Fishery Boards, Forestry Commission Scotland, Dumfries & Galloway Council Ranger Services, Dumfries and Galloway council Infrastructure, National Farmers Union Scotland and RSPB.

Much of the work described in Section 1 has been delivered or planned with the Working Group's support and all have been co-ordinated by SEPA, unless otherwise stated.

1.1 Signal Crayfish – action specific to Loch Ken

Public meeting on 13th March 2012 at the Cross Keys Hotel, New Galloway (Loch Ken). Scottish Government, SNH and SEPA attended a public meeting, organised by the community council, to discuss the reasons why a licence for trapping Signal Crayfish had been refused. The meeting was attended by the Petitioner, local stakeholders and business interests, Alex Fergusson MSP and a commercial crayfisherman from England.

Meeting with the Petitioner on 4th March 2013 at the SNH Office in Clydebank. SNH met with the Petitioner to discuss his licence application for trapping Signal Crayfish. In their response to the Petitioner, SNH stated that it would not licence commercial trapping of Signal Crayfish,but it could licence a non-commercial project with a clear management aim and which was supported by a clear scientific methodology. Such an application would require a sound monitoring and evaluation element, and would need to be fully biosecure.

Publication of a 'Signal Crayfish Frequently Asked Questions' document in August 2014 to help answer questions regularly asked about the legality of Signal Crayfish trapping and reasons for not permitting commercial trapping. This was distributed throughout the Glenkens/Loch Ken area and to all working group members. See Annex 2.

A 'drop-in' session on 5th July 2014 at the Cross Keys Hotels, New Galloway (Loch Ken). SNH, SEPA, Police Scotland, Galloway Fisheries Trust and Dumfries & Galloway Council Ranger for Loch Ken were available to answer questions about issues surrounding Signal Crayfish. The event was attended by many local residents, including the Petitioner, along with several visiting anglers and other non-locals. It was advertised in local press, including a dedicated article in the Glenkens Gazette (Loch Ken community newsletter).

Scottish Environment Minister's meeting on 31st July 2014 at the Catstrand in New Galloway (Loch Ken). The event was chaired by Paul Wheelhouse MSP and was attended by 42 individuals from a number of organisations and interests, including the Petitioner and Alex Fergusson MSP. See Annex 3 for a full list of attendees. Three key actions were agreed at the meeting:

1) Use Dalbeattie as a test case for rapid response. Needs urgent action but could also learn quite a lot from it.
2) Survey to assess the status of freshwater fish in Loch Ken and ascertain the viability of the loch as a fishery.
3) SG officials to speak to tourism colleagues and VisitScotland about support for the area.

Progress on the first two of these actions, which required input from SEPA and SNH, is given in section 1.2

1.2 Signal Crayfish – action across Dumfries and Galloway

Buittle Reservoir, Dalbeattie (Minister's meeting Action 1): SEPA is working closely with Scottish Water to find feasible options for the potential eradication/control of a Signal Crayfish population at Buittle Reservoir, Dalbeattie (River Urr catchment). An action plan has been completed, with key actions to prevent spread being undertaken in August 2015; net fencing will be installed to encircle the spillway; the scour outlet will be altered and tested to determine if it will allow the reservoir to be managed at a lower level; and trapping will continue to monitor the population. Longer-term options for eradication are under consideration, (including the use of biocide), with a contract for initial bathymetry and hydrology surveys out to tender.

Fish, Fisheries & Angler Survey in Loch Ken (Minister's meeting Action 2): this project proposal is being prepared by SNH (in conjunction with SEPA) to undertake a three year coarse fish survey. SEPA and SNH have secured funding for the first year of the project, to start in September 2015. The project summary is given in Annex 4.

Angler biosecurity stations: Galloway Fisheries Trust has purchased and positioned two angler biosecurity stations within the Urr catchment (Dalbeattie Loch, where Signal Crayfish are present, and Loch Roan). They are promoting the importance of biosecurity to help regular anglers prevent spreading Signal Crayfish from one loch to the other.

Police Scotland: Fears over potential exploitation of Signal Crayfish in the region have led SEPA and SNH to work closely with Police Scotland to translate Signal Crayfish information posters into a number of languages to ensure all local resident and visitors are aware of the legal position in Scotland. Posters are due to be published in July 2015 and distributed throughout the summer and autumn.

1.3 Check Clean Dry biosecurity across Dumfries and Galloway

Launch of Check Clean Dry (CCD) in spring/summer 2014. This took place across Dumfries & Galloway, including erection of CCD signage across the region's waters, leaflets distributed and local press publicity. D&G INNS Working Group members and key water stakeholders across the region were involved in promotion of the campaign, with strategies put in place to target appropriate audiences and locate signage.

On Loch Ken, the CCD promotion was undertaken by the Council Ranger Service:

- Three fixed CCD signs were erected on the loch. The Loch Ken Management Committee agreed that it was important to encourage biosecurity but without creating a message that the loch was 'closed for business' which would discourage visitors to the area. The public boat launch site and the two main fishing laybys were judged to reach the greatest number of the target audiences.
- Approximately thirty laminated CCD posters for anglers and boaters were placed on information boards around the loch and offered to other locations such as local angling shops and other businesses, as appropriate.
- CCD leaflets were distributed to dozens of local businesses around the loch, including the water sports centre, caravan parks, hoteliers, shops and other businesses. 2500 leaflets and identification guides have been distributed since Easter 2014 in this part of the region alone.

- Information about Signal Crayfish and the importance of CCD was included in the loch's boat registration booklet which targets both boating and fishing interests.
- Face to face contact by the Ranger and Fishery Trusts has been greatly influential in encouraging biosecurity by Loch Ken anglers, boaters residents and visitors. It is estimated this has accounted for several hundred contacts to promote CCD with individuals. Feedback to the Ranger has been very positive with most people keen to know more and to help prevent spread of NNS in general, not just Signal Crayfish.
- Information about CCD has been put on the Council's website.
- ITV Border filmed a local news article on the banks of Loch Ken with the Ranger, Police Scotland and Galloway Fisheries Trust to demonstrate washing of boats and fishing equipment, and encourage responsible behaviour.

Elsewhere in the region CCD promotion was undertaken by Galloway Fisheries Trust, River Annan Trust and Nith Catchment Fishery Trust, Forestry Commission Scotland, and Solway Firth Partnership in order to cover marine and freshwaters across the whole region. The River Annan's CCD signage plan is given in Annex 5 as an example of the plans put in place.

Additional activities continue to be undertaken by organisations across the region to support the initial CCD campaign launch, this includes:

- Talks and presentations to fishing clubs, rotary clubs etc.;
- Promotion of CCD and biosecurity at local shows and events;
- Promotion through websites and social media;
- CCD signage placed at other 'at risk' sites across the region such as coarse fishing lochs.

Water Event Biosecurity Support Scotland Pack has been produced by SEPA, with input from water user groups such as the Scottish Canoe Association, Royal Yachting Association and several Fishery Trusts to help water event organisers understand how to implement biosecurity measures to prevent spread of INNS at their events. The pack is planned for launch at the first available event in the Loch Ken area.

1.4 Other INNS action across Dumfries and Galloway

River catchment INNS control projects started in 2010 with Fishery Trusts across the Dumfries and Galloway region mapping and undertaking control of invasive non-native plant species on rivers and lochs. Funding came from a number of sources including SEPA's Water Environment Fund. These projects are ongoing in 2015.

Dumfries and Galloway INNS Workshop Seminar Events were held in October 2011 and November 2013. Both aimed to raise awareness about the issues surrounding INNS in the region and across Scotland, and included sharing of good practice through, for example, workshops to consider practical management issues, and case studies such as the Freshwater Invasive Non-Native Species Project (FINNS) Cumbria which promotes biosecurity in the Lake District, including lessons learnt from their launch of the Check Clean Dry campaign. Attendance rose from 47 delegates from 24 organisations in 2011 to 73 from 33 organisations in 2013. Very positive feedback confirmed events were worthwhile, with many interested to attend any future events.

Collation of INNS data: D&G INNS Working Group is running a project with the D&G Environmental Resource Centre with the objective of sharing INNS data across organisations to help them collectively target/manage them at a local level. This includes a citizen science aspect, encouraging local people to send in records.

Prioritising INNS in Dumfries and Galloway: D&G INNS Working Group are undertaking a prioritisation process on species present in the region, using Scottish guidelines, to identify the key species for which management action should be taken. A guidance note on prioritisation of actions for partner organisations will also be produced. This work is coordinated by the D&G Council Biodiversity Officer.

Marine INNS identification guide: in January 2014 the Solway Firth Partnership published a marine INNS identification guide for distribution to key audiences such as marinas, to promote awareness of marine INNS species.

1.5 Other relevant actions

Glenkens Landscape Partnership Bid. Dumfries and Galloway Council is currently developing bid to the Heritage Lottery Fund to undertake a multi-million pound landscape scale project in the Glenkens Area (including Loch Ken). The bid is still at a very early stage, and many aspects are still to be finalised, however if the bid is successful the project would start in 2017. SEPA and SNH have been working closely with D&G Council and other partners to identify aspects of the project that could help to support the actions identified at the Minister's meeting in July 2014. These include:

1) A Sustainable Fisheries Management Plan (including a survey of the population extent of Signal Crayfish);
2) Updating of the current Loch Ken Management Plan to help address a number of issues on Loch Ken, such as promoting sustainable development and promotion of tourism events in the area, including angling;
3) Provision for funding for years two and three of the 'Fish, Fisheries and Angler Survey in Loch Ken' project detailed in section 1.2.

Signal Crayfish impact on flooding: following recent suggestions that Signal Crayfish have had a role in exacerbating flooding, SEPA has consulted with its Flood Risk Specialist who advised that a number of flood studies have been undertaken in the Dumfries and Galloway area and none at this time have identified Crayfish as a significant source of flooding. We are aware that there is a potential link between Signal Crayfish and bank erosion, however bank erosion does not necessarily lead to flooding and is part of a natural process within an active river system.

Signal Crayfish impact on power generation: recent suggestions that Scottish Power hydropower generation has been affected by the impact of Signal Crayfish on flooding have been investigated. The Plant Manager of Scottish Power's Glenlee hydropower station has indicated that, 'regarding the issue of Scottish Power ceasing generation to alleviate flooding due to flood bank failures, this is not the case; the water will come down the system whether power stations generate or not. Glenlee and Drumjohn power stations are "restricted off" during times of flooding to mitigate flooding impact but this is independent of flood banks failing.'

2 The proposed work by local colleagues to monitor the effectiveness of the Check, Clean, Dry Campaign

The Check Clean Dry was launched across the UK in 2011, with the then Minister for the Environment and Climate Change, Stewart Stevenson, launching it in Scotland in October that year. It has been promoted by many partner organisations across Dumfries and Galloway, and across Scotland and the UK, since then. It is not a legal requirement in itself but instead promotes good practice to prevent the spreading of non-native species. For most organisations the promotion of the CCD campaign is not considered to be a 'one off' event, but as an ongoing message that is advertised at events and shows, and included in presentations and talks throughout the year. Social media has proved to be a good way to circulate information to create discussion and feedback amongst relevant user groups, and many partners feature CCD on their websites.

The Check Clean Dry message was adapted by the GB Non-Native Species Media and Communications Working Group from a freshwater biosecurity campaign in New Zealand. The effectiveness of this campaign is due to be evaluated at a GB-level, starting next year. The following work will feed into the planned review.

A recent study[1] undertook an online questionnaire with 960 anglers and 599 canoeists, to investigate their locations of activity, equipment used, and how frequently equipment was cleaned and/or dried after use. Anglers were also asked about their use and disposal of live bait. The findings of this study will help to provide a baseline against which to evaluate the effectiveness of the campaign in future and help to identify groups to target with biosecurity information.

In New Zealand, where biosecurity campaigns have been running for over 10 years, a recent review[2] of their efficacy noted that regional biosecurity campaigns have led to high public awareness of biosecurity (71%) with signs at boat ramps being the most cost-effective communication channel, costing NZD $0.06 for every water user reached. Watersports events and angling tournaments were identified as a key biosecurity risk, highlighting the importance of close liaison with event organisers, effective biosecurity briefings and decontamination stations at events.

Following the arrival of the Killer Shrimp in the Norfolk Broads, the Broads Authority appointed a Biosecurity Officer to promote biosecurity and CCD. After a year in post, his annual report[3] noted that a targeted promotional campaign across many platforms can affect a behavioural change amongst the public. High uptake of messages across all users in each group requires several communication methods and formats, combined with the need for regular and repetitive sightings of information.

As a result of these reports, SEPA is proposing to monitor uptake of the Water Event Biosecurity Support Scotland Pack by water user groups to aid prioritisation of efforts to reach those who are not adopting good biosecurity.

The 'Fish, Fisheries & Angler Survey in Loch Ken project' intends to promote best practice bio-security measures at all events and in general contacts with anglers as part of this study. This will include monitoring angler responses and uptake of biosecurity practices over the course of the project, which will help to determine any change in awareness and/or biosecurity actions by those involved over a three year period.

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[1] Anderson LG, White PCL, Stebbing PD, Stentiford GD, Dunn AM (2014) Biosecurity and Vector Behaviour: Evaluating the Potential Threat Posed by Anglers and Canoeists as Pathways for the Spread of Invasive Non-Native Species and Pathogens. PLoS ONE 9(4)

[2] Anderson, L, Rocliffe, S, Stebbing, PD and Dunn, AM (2014) Aquatic biosecurity best practice: lessons learned from New Zealand

[3] Burchnall, W (2013) Wetland Biosecurity Officer Project Report. Broads Authority

3 Work being done in England/Wales to tackle deliberate spreading

There are three main statutes governing the keeping and introduction of Signal Crayfish in England and Wales.

3.1 Prohibition of Keeping of Live Fish (Crayfish) Order 1996

The 'Crayfish Order' was made under the Import of Live Fish Act 1980. It bans the keeping of live Signal Crayfish in England and Wales, except in postcode areas where Signal Crayfish are widespread, shown in pink on the map below.

Map 1 Postcode map of areas where keeping live Signal Crayfish is permitted

The Crayfish Order divides England and Wales into 'go' and 'no-go' areas for trapping of Signal Crayfish in the wild.

- Individuals who wish to trap Signal Crayfish in the 'go' area must to apply to the Environment Agency or Natural Resources Wales for permission to use traps on a particular water body. The trap licensing scheme is operated through the 2004 Crayfish Byelaws, created under the Water Resources Act 1991. Approved traps must be individually marked with plastic tags and licensed trappers must follow a code of practice to stop the spread of alien crayfish and crayfish plague.
- The rest of England and Wales is designated as a 'no-go' area for trapping Signal Crayfish for human consumption. There is a presumption against trapping within these areas. The objective is to prevent further introduction and spread of Signal Crayfish within the 'no go' areas to protect uninvaded water bodies and vulnerable populations of native White-clawed Crayfish.

A general licence under the Import of Live Fish Act 1980 authorises fish markets, hotels, restaurants and suppliers to keep live Signal Crayfish for direct human consumption. This licence covers the whole of England and Wales but does not include Scotland or Northern Ireland. Despite the fact that a regulatory regime is in place, this has not prevented the deliberate movement of Signal Crayfish to new areas

3.2 The Wildlife and Countryside Act 1981

Section 14 of the Act makes it an offence to release Signal Crayfish into the wild, anywhere in England and Wales (the wording slightly is different in Scotland but the effect is the same).

In 2013, a strategic assessment by the National Wildlife Crime Units noted that "*criminality is suspected to be high with deliberate release*" in relation to Signal Crayfish [4]. Although the environmental impacts associated with this crime are potentially very high, it has proved very difficult to prosecute offenders, and it is not currently a wildlife crime priority.

It is difficult to prove that someone has released Signal Crayfish into the wild, unless they are caught in the act. It is almost impossible to detect low numbers of Signal Crayfish in a water body for several years after they have been introduced. People caught in possession of live Signal Crayfish in the 'no-go' area have the defence that they were for intended human consumption, which is permitted under the general licence.

The problem of illegal release is exacerbated by the trade in live Signal Crayfish for human consumption. It provides a steady flow of live Signal Crayfish into the 'no-go' area with the inevitable consequence that some are bought and released into ponds, lakes and rivers. People found to have ponds illegally stocked with Signal Crayfish have claimed that the suppliers specifically told them that there were no restrictions on keeping them in ponds.

3.3 Alien and Locally Absent Species in Aquaculture Regulations 2011

The Regulation covers the keeping of Signal Crayfish in aquaculture. It adopts the same policy standards that were previously in place under the Crayfish Order. Effectively there has been a prohibition on new Signal Crayfish farms since 2006, unless strict biosecurity requirements are met.

3.4 Recommendations for review of crayfish legislation

There are plans for a review of the legislation on Signal Crayfish in 2016[5]. This follows an early day motion in the House of Commons in 2013, which called on the UK Government to give urgent consideration to emulating Scottish biosecurity control measures in England and Wales, to review the 2004 Crayfish Byelaws and to ban the live transport and sale of all alien crayfish species in England and Wales.

A report to Defra in 2012,[6] recommended two options for tightening the controls on transport and sale of live Signal Crayfish in England and Wales:

- **Regulating the sale of live Signal Crayfish.** This could be achieved by amending the Crayfish Order or introducing a ban on sale of non-native crayfish under Section 14 of the Wildlife and Countryside Act. This would mean that crayfish suppliers would need to be licensed, and could have their licence revoked for misdemeanours.
- **Revoking the general licence**. This would introduce a presumption against the keeping and transport of live non-native crayfish for human consumption, bringing England and Wales into line with Scotland and Northern Ireland. Imports of live crayfish have decreased significantly since the Crayfish Order was introduced in 2006. The catering industry has adapted to using processed crayfish tails and, the report argues, it would not be adversely impacted by such a ban.

[4] National Wildlife Crime Unit Strategic Assessment 2013

[5] Invasive Species Action Plan on Non-Native Crayfish

[6] Stebbing P.D., Longshaw M., Taylor N., Norman R., Lintott R., Pearce F. & Scott A. (2012) Review of methods for the control of invasive crayfish in Great Britain. CEFAS. Contract C5471 final report.

4 The amount being spent on scientific research in Scotland

The table below itemises the amount spent on scientific research on Signal Crayfish in Scotland since 2000. This assessment does not include the costs of relevant work being carried out by Academia and Government Agencies elsewhere in Great Britain.

Table 1. Amount spent on research on Signal Crayfish in Scotland

Amount spent (£1,000s)	Cash	In kind	Total
4.1 Initial research			
Long-term manual removal of Crayfish from the River Clyde	95	40	135
Biocide trials at North Esk ponds[7]	104		104
Biocide trials at Ballintuim[7]	70		70
Biocide trial at Ballachullish[7]	73		73
4.2 Species Action Framework			
Training fisheries biologists to trap and monitor Crayfish	3		3
Fine scale mapping of the Signal Crayfish in Scotland	25	25	50
Prospects for the biological control of Crayfish in Scotland	25		25
Review of Crayfish control and cost implications	10		10
Two Signal Crayfish awareness courses for key staff	10		10
Signal Crayfish awareness posters and leaflets	6		6
Signal Crayfish barrier installation in the Upper Clyde[7]	60	35	95
Zara Gladman's PhD on Signal Crayfish in Scotland	58	24	82
4.3 Relevant additional work			
Assessing the potential of intensive trapping in Loch Ken	100		100
Reducing the risks of spread during transportation of live fish	50	6	56
4.4 PhD and Masters projects			
Other PhDs (Harper, Houghton) and Masters (O'Reilly)	170		170
4.5 Other ongoing work			
Environmental DNA Workshop[8]	2		2
Fisheries monitoring in Loch Ken project	5		5
Total	**866**	**130**	**996**

[7] Costs do not include ongoing monitoring of each treatment site to evaluate success
[8] Does not include the costs of any potential follow-up work

5 An itemised list of the scientific research underway in Scotland

The control of Signal Crayfish is a UK (and international) issue, and research in this area is being conducted by a range of agencies in a number of countries. Within the UK, an overview of research effort is co-ordinated by the Non Native Species Secretariat's Crayfish ISAP (Invasive Species Action Plan).

5.1 Initial research

Since Signal Crayfish were first identified in Scotland in 1995, a number of projects were commissioned to examine ways in which these animals could be removed from, or controlled within, Scottish waters. Given our initial lack of knowledge of this species, much of our earliest work focussed on the use of traps to remove Signal Crayfish. Attempts were also made to develop other removal methods. Examples of these earliest projects include:

Sinclair, C. & Ribbens, J. (1999). *Survey of American Signal Crayfish, Pacifastacus leniusculus, distribution in the Kirkcudbrightshire Dee, Dumfries and Galloway, and assessment of the use of electrofishing as an eradication technique for Crayfish populations*. Scottish Natural Heritage.

Ribbens J.C.H. & Graham J.L. (2004). *Strategy for the containment and possible eradication of American Signal Crayfish (Pacifastacus leniusculus) in the River Dee catchment and Skyre Burn catchment, Dumfries and Galloway*. SNH Commissioned Report No. 014.

Reeve, I D (2004). *The removal of the North American Signal Crayfish (Pacifastacus leniusculus) from the River Clyde*. SNH Commissioned Report No. 020

Peay, S. & Hiley, P. (2006). *Biocide trial to eradicate Signal Crayfish in the North Esk catchment*. SNH Commissioned Report No. 122

5.2 The Species Action Framework 2007-2012

North American Signal Crayfish was included with the SNH Species Action Framework 2007-2012 as an invasive species which required management action. This work aimed to establish a baseline understanding of the distribution and spread of this species in Scotland, to improve our knowledge of control and eradication techniques and prevent further spread. The key objectives of the North American Signal Crayfish project were:

- To ensure that future monitoring provides a better understanding of the current scale of the Signal Crayfish issue and to quickly identify new populations.
- To collaborate with partners to achieve containment or eradication of known populations.
- To increase understanding of the ecology of the Signal Crayfish and its impact on Scottish aquatic biodiversity.

Works carried out as part of the Species Action Framework included:

- Delivery of a Signal Crayfish monitoring course (18 Dec 2008) and purchase of traps for Signal Crayfish monitoring by Trust biologists.
- Fine scale mapping of the Signal Crayfish in Scotland.
- Prospects for the biological control of Signal Crayfish in Scotland.
- Review of Signal Crayfish control and cost implications.

  - Delivery of two Signal Crayfish awareness courses for Fishery Trusts, DSFB biologists, Police, Local Authority, SNH and SEPA staff at the University of Stirling.
  - Development and publication of Signal Crayfish awareness posters and leaflets.
  - Signal Crayfish barrier installation in the Upper Clyde. (in-kind contributions from South Lanarkshire Council, Clyde River Foundation and the Annan Fishery Trust)
- Funding towards Zara Gladman's PhD on *Crayfish in Scotland*.

The following scientific publications arose from SAF work:

Gladman, Z., Adams, C., Bean, C., Sinclair, C. & Yeomans, W. (2009) Assessing the status of Signal Crayfish in Scotland. Brickland J, Holdich D.M. and Imhoff E.M. (eds) *Crayfish conservation in the British Isles.* Proceedings of a conference held on 25th March 2009 in Leeds, UK. pp. 43-48.

Freeman, M. A., Turnbull, J. F., Yeomans, W. E. & Bean, C. W. (2010) Prospects for management strategies of invasive crayfish populations with an emphasis on biological control. *Aquatic Conservation: Marine and Freshwater Ecosystems* **20**, 211-223.

Gladman, Z., Yeomans, W. E., Adams, C.E., Bean, C.W., McColl, D. Olszewska, J., McGillivray, C. & McCluskey, R. (2010) Detecting North American Signal Crayfish (*Pacifastacus leniusculus*) in rivers. *Aquatic Conservation: Marine & Freshwater Ecosystems* **20**, 588-594.

Gladman, Z.F., Adams, C.E., Bean, C.W., Long, J. & Yeomans, W.E. (2012) Investigating the threat of non-native North American Signal Crayfish (*Pacifastacus leniusculus*) to salmonid redds. *Aquatic Conservation: Marine & Freshwater Ecosystems* **22**, 134-137.

During this period, the Scottish Government funded a £100k project to assess the potential for an intensive trapping in Loch Ken to control or eradicate Signal Crayfish there. The project took place over five months in 2009. An independent review[9] of the project concluded that:

- The benefits are uncertain, but likely to be small.
- The cost is high, ongoing and very quickly unsustainable when the population spreads (as it definitely will do).
- The research benefits could be achieved elsewhere, without the need to carry out an intensive trapping programme.
- There are other project options that offer greater and potentially more long-lasting benefits than this programme.
- There is a significant risk that allowing a control programme of this kind may, indirectly, increase the risks of further introductions rather than decrease them.
- The Scottish Government and its agencies should strongly resist the start of trapping programmes in Scotland. In particular, a Signal Crayfish enterprise should not be permitted at Loch Ken, nor anywhere else in Scotland. It would be counter to the conservation goals of the Species Action Framework.

5.3 Relevant additional work – Academia and Government Agencies

[9] Peay, S. (2010). Review of the Loch Ken (Kirkcudbrightshire Dee) American Signal Crayfish, Trapping Project, 2009. Scottish Government Commissioned Report

Other work carried out during this time included research funded by bodies such as the Scottish Aquaculture Research Forum and academia. One such project, carried out by the Institute of Aquaculture at the University of Stirling, examined the potential for Signal Crayfish spread with consignments of freshwater fish used for stocking purposes and put forward proposals for mitigation. The report details, and those of the Masters thesis which supported it, are provided below.

Turnbull, J.F. (2009) *Developing practical strategies for reducing the spread of harmful organisms during the transportation of live fish.* Project SARF 041.

Bunker, K. (2008) *Trout transportation in the UK; methods and changes in water quality*. M.Sc thesis.

Research has also been carried out by other academic institutions within Scotland and by bodies such as Marine Scotland Science. For example:

Crawford, L., Yeomans, W.E. & Adams, C.E. (2006) The impact of introduced Signal Crayfish *Pacifastacus leniusculus* on stream invertebrate communities. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **16**, 611-621. (work carried out in the upper Clyde)

Griffiths, S.W., Collen, P., Armstrong, J.D. (2004) Competition for shelter among over-wintering Signal Crayfish and juvenile Atlantic salmon. *Journal of Fish Biology* **65**, 436–447. (work carried out in the Marine Scotland Science fluvarium, Almondbank)

Peay, S., Dunn, A.M. Kunin, W.E., McKimm, R. & Harrod, C. (in press) A method test of the use of electric shock treatment to control invasive Signal Crayfish in streams 2014 (originally trialled in Dumfries & Galloway and again in North Yorkshire - published in *Aquatic Conservation: Marine and Freshwater Ecosystems* in press - DOI: 10.1002/aqc.2541)

5.4 PhD and Masters projects

PhD and masters research programmes offer the potential to carry out intensive scientific work over a period of 1-3 years. They also help to develop capacity within the scientific sector. A number of Signal Crayfish-related doctoral and masters research projects have been, or are currently being, undertaken in the UK. Details are provided below. SNH staff have been involved in the supervision or development of all of these and SEPA contributed directly to the work of Zara Gladman.

- *PhD - Gladman, Z. - Crayfish in Scotland, University of Glasgow 2008-2012*

  This project developed a standard methodology for the assessment of Signal Crayfish presence in river habitats in Scotland. It also examined the potential impact of Signal Crayfish on aquatic species of high conservation value, such as Atlantic salmon, freshwater pearl mussel and lamprey. Additional work was carried out (using data collected from the Scottish Government-funded Signal Crayfish trapping trial in Loch Ken), and in separate marking and radio-tracking experiments to determine the scale of movement within aquatic ecosystems.

- *PhD - Harper K. - Trophic niche and detection of the invasive Signal Crayfish (Pacifastacus leniusculus) in Scotland. University of Stirling 2011- 2015 (expected)*

  This project uses a number of novel approaches to examine the impact of Signal Crayfish on aquatic communities. It has used lab-based approaches to determine which factors are important in determining the directional movement of Signal Crayfish and includes the use of stable isotope techniques to examine the invasive potential and ecological role of non-native Signal Crayfish in Loch Ken. Recent work has included the

development of genetic barcodes for the identification of Signal Crayfish using an environmental DNA approach.

- *PhD - Houghton, R. - Barriers to acting now to protect the future: The American Signal Crayfish invasion of Scotland as a paradigm. University of Aberdeen 2013-2016 (expected)*

  This project will combine collecting empirical evidence on the effectiveness of novel NASC control techniques through laboratory and field trials. It will also explore how exposure to new techniques and evidence of their efficacy modifies willingness by the public to support practical action.

- *Masters by Research – Sinead O-Reilly. - Assessing the toxicity of biocides on the North American Signal Crayfish (Pacifastacus leniusculus) to aid eradication in Scotland. University of Glasgow 2014-2015*

  This detailed ecotoxological research focussed on the concentration of the pyrethroid biocide (Pyblast) required to induce mortality in Signal Crayfish. This work found significant differences in Pyblast susceptibility within Signal Crayfish size classes, between sexes and between families. Additional ecotoxological work was carried out using other potential biocides - Deltamethrin and Azamethiphos. This work will greatly inform future biocide treatments within Scotland and elsewhere.

5.4 Other ongoing work

In addition to the research activity detailed above, other relevant areas of research or monitoring activity include:

- Environmental DNA

  Environmental DNA (also known as eDNA) is at the cutting edge of aquatic science, where it is seen as a revolutionary advance in our ability to monitor the presence or absence of plants and animals in freshwater habitats. From a Crayfish perspective, this tool offers the possibility to survey a large number of freshwater habitats quickly and cheaply – offering the potential to identify new populations before they have the chance to establish and put in place measure to contain, or if possible, eradicate, them.

  SNH ran an eDNA Workshop to help develop our thinking on the development of rapid identification techniques for assessing the presence of aquatic species (including Crayfish) in aquatic habitats in Scotland on 28-28 April 2015. Contributors to this workshop came from a variety of academic, Government institutions from around the UK. We are currently considering how we can develop this technique to help with our work on Signal Crayfish and other invasive non-native species.

- Fisheries monitoring in Loch Ken

  The main objective of this project is to provide an assessment of the current condition of the fish community within Loch Ken, and the status of Loch Ken as an angling venue. The contract will also provide recommendations for the future management of Loch Ken as a coarse fishery, with particular reference to the pike fishery, and as a venue for specialist pike anglers. The project will entail trialling of methodology within the first year of the project for both data collection using data available direct from anglers and angler interviews and questionnaires along with trials of the trapping survey methods. This will be used to inform a proposed further two years of survey.

Work being carried out by the Centre for Environment, Fisheries and Aquaculture Science in England, which is also relevant to Scotland includes:

- Review of methods for the control of invasive Crayfish in Great Britain

Review of control/management methods, including existing and potential. The work also included the development of a population model to evaluate the relative effectiveness of some of the control methods reviewed.

- Laboratory trials of male sterilisation methods

  Testing pleopod removal as means of sterilisation, effects of the treatment moult rate, aggression and mating.

- Review of trapping as a means of controlling Signal Crayfish in enclosed water bodies

  The overall aim of the work is to produce guidance on populations control/management using traps which can be applied to enclosed bodies of water by members of the public. The project is testing the effects of trapping at different densities on Signal Crayfish populations. The work is being conducted by citizen scientists with the data used to inform the population model previously developed and the model informing the trapping programme in an iterative process. The project is also looking at increasing trap efficiency through various modifications. The population model is also being used to further test the effects of multi-disciplined control/eradication attempts.

- *Towards the realisation of chemical control agents for aquatic invasive arthropods*

  Testing of pesticide spiked baits deployed in feeding stations to reduce the potential impact of water column based biocide treatments.

- PhD- The effects of male sterilisation on wild Signal Crayfish populations.

  This work is being conducted in the River Exe in Devon. The student is registered at Bournemouth University.

6 A list of examples where biocide treatments have been used

A list of examples where biocide treatments have been used to control Signal Crayfish is included in Annex 6.

Many biocides, including organophosphate and pyrethroid insecticides, are capable of killing Signal Crayfish. However, there is no biocide available that is selective for Signal Crayfish only. This means that any attempted eradication using a biocide treatment is expected to kill some, or all, of the non-target fauna in the area being treated.

Only the natural pyrethrum, Pyblast, has been used in the biocide treatments in Britain. Case studies are given in Box 1 in Annex 6. The results have been mixed but it appears that eradication has been achieved in at least some cases – at a gravel pit near Edzell, Barmbyfield Reservoir, Pocklington and quarry ponds at Ballachuilish Quarry. There have been no Signal Crayfish detected in monitoring surveys at these sites for a number of years.

Other biocides have been used to control Crayfish in the USA and other parts of Europe. Case studies are given in Box 2 in Annex 6. The early trials in France and the USA used organophosphate insecticides which are now banned in Europe. The later trials in Norway and Sweden have learned from Scottish experience, but have used cheaper synthetic pyrethroid insecticides.

Synthetic pyrethroids are commonly used in agriculture. Compounds such as cypermethrin and deltamethrin were developed for use as agricultural insecticides and veterinary products because of their much greater stability and higher toxicity to invertebrates than natural pyrethrum. Case studies of accidental episodes of insecticide pollution, where sheep-dip (a synthetic pyrethroid called cypermethrin) was introduced into river systems, have shown that there can be a severe impact on the invertebrate community over timescales of 1–2 years.

Synthetic pyrethroids are also toxic to fish. The Veterinary Medicines Directorate temporarily suspended the marketing authorisation of the cypermethrin sheep dip products in 2006 because of pollution concerns raised by the Environment Agency, and the manufacturers voluntarily withdrew their marketing authorisations in 2010.

The Water Framework Directive has the overall objective of reaching good status for all waterbodies. The presence of Signal Crayfish will limit the status to 'moderate'; however the use of synthetic pyrethroids would not be expected to eradicate Signal Crayfish, but would remove most other invertebrates, leading to a status of 'poor' or even 'bad'. Therefore the deliberate use of such chemicals to attempt Signal Crayfish eradication in river systems would not at present be sanctioned by the Scottish Environment Protection Agency.

North American Signal Crayfish (NASC)

FREQUENTLY ASKED QUESTIONS

What are North American signal crayfish, and where are they found?

North American Signal crayfish are a very aggressive and highly adaptable freshwater species which can be easily identified by their lobster like appearance, and can be 2-15cm in length.

Signal crayfish are not native to Scotland. They were introduced to Britain in the 1970s and are now commonly found in waterways throughout England and parts of Wales. They were first formally recorded in Scotland during 1995 and have since been recorded from Galloway in the south, to Inverness-shire in the north at a variety of locations including running and standing waters.

Why are they a problem?

Signal crayfish are one of many non-native freshwater species in Scotland which have found their way here by human intervention. A large proportion of non-native species are not currently known to be 'invasive', but once established some, such as signal crayfish, can cause problems for recreational users and others who rely on our rivers and lochs for their livelihoods.

Signal crayfish can have a significant adverse impact on our native freshwater plants and animals in any river, loch or pond they inhabit. In running waters extensive burrows can destabilise banks, causing erosion, and bank collapse. They also prey on young fish and their eggs, and compete for food and habitat which further impacts on the populations of native fish.

Signal crayfish are already causing a significant problem in some areas of Scotland, so why are trapping licences not permitted to reduce their numbers?

Trapping trials have concluded that although numbers may be reduced during the short-term, traps may favour the capture of larger individuals. An unintended consequence of selective harvesting is the increased growth and earlier maturation of juvenile crayfish, which can cause the population to increase. It is not, therefore a sustainable long-term solution.

It is illegal to trap for signal crayfish for personal consumption or for onward sale, due to the significant and unacceptable risk of introduction to other waters, which are presently unaffected by crayfish. **Any trapping for scientific purposes, or to limit numbers, requires a licence.**

What is being done to find a solution to the signal crayfish problem and to protect the rivers and lochs of Scotland?

SEPA is the lead organisation for non-native species issues in freshwaters in Scotland. SEPA (www.sepa.org.uk) oversees efforts to prevent signal crayfish from becoming established across all the waters of Scotland, working closely with partners such as Scottish Natural Heritage (www.snh.gov.uk), Police Scotland and the Rivers and Fisheries Trusts of Scotland, (RAFTS).

Unfortunately no long-term solution has yet been found to eradicate signal crayfish once they are established.

Research continues to try to find suitable control techniques and to prevent the movement of signal crayfish within rivers and between catchments. In some situations where the crayfish are in small enclosed ponds eradication by poisoning has been possible, but in larger lochs such techniques are unsuitable.

To stop migration of crayfish from one river headwater in South Lanarkshire, into another nearby watershed in Dumfries and Galloway, a large barrier was constructed recently, but it will not be known for some time how successful this has been at stopping the crayfish. Many water users, businesses and associated organisations across the region and further afield are hugely concerned that other water bodies could also become infested with signal crayfish.

Until a long-term solution can be found the only way of protecting unaffected water bodies is to prevent the movement of any crayfish or their eggs, which could find their way to new locations….

This includes:

- Encouraging good bio-security practice by everyone who uses or works in or around water (including fishermen, boaters and contractors), to prevent the transfer of animals or eggs between waters, by promoting the 'Check Clean Dry' message. This advice relates to preventing the spread of all non-native species but in and out of water.
- Working to prevent the illegal trapping and movement of signal crayfish, to reduce the risk of transfer to other waters (intentionally or unintentionally).
- Supporting research into sustainable techniques to control or prevent movement of crayfish within rivers and between catchments.

What can I do to help?

Please help to prevent the spread of **ALL** invasive non-native species by **Checking, Cleaning and Drying** all equipment that is used in water, before using it elsewhere (particularly in other river catchments), and raise awareness with others. For more information on the Check Clean Dry campaign, visit www.nonnativespecies.org/checkcleandry. This advice relates to both recreational and commercial activities in or near water.

If you see a signal crayfish: please take the time to inform the Scottish Environment Protection Agency (SEPA) by contacting **Scotland's Environmental and Rural Services (SEARS) 24/7 Customer Service Helpline on08452 302050,** or email info@sears.scotland.gsi.uk. Tell us where (a grid reference if possible), when and how many. Take a photograph if you can, showing its size. All this will help to confirm identification and age.

If you come across a crayfish trap:
Please do not handle it or remove it from the water. Please report it to **Police Scotland** by telephoning: **'101'** or call **Crimestoppers** on: **0800 555 111.**

If you take one from the water (accidentally or otherwise): **Do not take it away**, as female crayfish may be carrying eggs which could be spread to other waters.

To humanely dispose of a signal crayfish, SSPCA accepted guidance advises to crush crayfish with a single blow from a heavy or hard object, followed by burying the remains close to where it was found.

Can signal crayfish live out of fresh water?

Signal crayfish do not often come out of the water but they can migrate short distances over land, usually on a wet night when they won't dry out too quickly and they're less vulnerable to predators.

It's very unlikely that they would choose to be out of the water during the day. Signal crayfish can survive out of water for a number of days, particularly if they are in moist conditions.
They can also survive in salt water for a short time.

Aren't crayfish useful for coarse fishing? (e.g. bait/fattening fish etc.)

In the short term, juvenile signal crayfish may provide food for some fish species. However, they breed rapidly and can soon prey on fish eggs, fry and small fish. They can also have a significant impact on the habitats used by fish. For these reasons, the introduction of signal crayfish cannot be seen as being of benefit to an existing fishery, and in fact, their presence can lead to significant, and irreversible, damage.

Want to know more?

For further information about signal crayfish, other non-native species and good biosecurity measures, please visit:

www.nonnativespecies.org
www.sepa.org.uk
www.snh.gov.uk

What does the law say?

The law is clear.
Because signal crayfish are so destructive to native freshwater life,
it is illegal to:

- **Be in possession of a live crayfish or have them under your control without a license.**
- **Release, or allow to escape from captivity, any animal to a place out-with its native range. (This includes returning to the wild any signal crayfish that you may have accidentally caught)*.**
- **Set a crayfish trap in Scotland without a license.**

THIS DOCUMENT HAS BEEN PUT TOGETHER BY DUMFRIES & GALLOWAY NORTH AMERICAN SIGNAL CRAYFISH ACTION GROUP & IS SUPPORTED BY THE FOLLOWING ORGANISATIONS:-

Dumfries & Galloway Council

SEPA Scottish Environment Protection Agency

Scottish Natural Heritage

Police Scotland Keeping people safe

The Scottish Government

Forestry Commission Scotland
Coimisean na Coilltearachd Alba

River Annan Trust

Galloway Fisheries Trust

Nith Catchment Fishery Trust

Attendee list – 31st July 2014, CatStrand Auditorium

Bellemy	Richard	Dalbeattie reservoir
Blunsum	Andrew	D&G Council Rangers Service
Carson	Finlay	Councillor
Collins	Brian	Councillor
Connick	Anne	SEPA
Davidson	Stuart	Police Scotland
Dignon	Hugh	Scottish Government
Ewing	Tim	Dee District Salmon Fisheries Board
Fergusson	Alex	MSP
Fieldhouse	Simon	D&G Council
Gordon	Graeme	Kenmure Fisheries Ltd
Gourlay	George	UrrDSFB, Chair
Graham	Jackie	Galloway Fisheries Trust
Green	Ewan	D&G Council
Greenhill	Steven	Scottish Water
Henderson	Jim	Nith Catchment Fishery Trust
Hill	Ros	Loch Ken Management Committee
Ingall	Anne	Dee DSFB, Clerk
Irvine	Kenny	Castle Douglas Angling Association, Chair
Long	Jo	SEPA
Marshall	Will	Dalbeattie Angling Association, Chair
Mavin	Andy	Police Scotland
McCallum	David	Police Scotland
McClelland	Jim	The Thistle Inn, Crossmichael
Monk	Geoff	Loch Ken Management Committee
Morley	Karen	D&G Council Rangers Service
Munday	Karl	NTS Threave
Murdoch	Catherine	Scottish Government
Oakley	Steve	Dumfries and Galloway Angling Association, Secretary
Park	Debbie	Nith Catchment Fishery Trust
Prentice	George	Councillor
Ribbens	Jamie	Galloway Fisheries Trust
Stones	Chris	The River Annan Trust
Thom	John	Community Councillor
Warren	Jon	SNH
Whitaker	Stan	SNH
Woods	Ron	Scottish Federation for Coarse Angling

ANNEX 4: Fish, Fisheries & Angler Survey in Loch Ken Project summary

Fish, Fisheries & Angler Survey in Loch Ken

Project Summary

Objectives:
1) To provide an assessment of the condition of the fish community within Loch ken as an angling venue.
2) Provide recommendations for the future management of Loch Ken as a coarse fishery, and as a venue for specialist pike anglers

Methodology:
Conventional fish surveys, using standard methods (such as gill netting, seine netting and hydro-acoustics), are likely to be ineffective in Loch Ken. This assessment is based on the physical characteristics of the site and, paradoxically, the presence of signal crayfish (which damage nets and rapidly consume any fish trapped in them).

Various alternative survey methods are being considered and are still to be confirmed, but will include a Citizen Science based approach for data collation.

Outputs:
a) Establish a citizen science recording scheme for anglers on Loch Ken to report details of their catches;
b) Establish a creel-based fish population assessment methodology for Loch Ken, and develop a strategy for routine and event-based data collection;
c) Trial techniques and approaches in a pilot project Summer/ Autumn 2015 (Phase 1 of the project);
d) Use resulting approved methodology to collect key fish and fisheries data from anglers over the period June 2016 – October 2016. (Phase 2 of the project);
e) Refine the methodology to collect key fish and fisheries data from anglers over the period June 2017 – October 2017. (Phase 3 of the project);
f) Evaluate all of the data collected to provide an overall assessment of the potential for Loch Ken to operate as a coarse fishery in the short, medium and long-term. The report will contain information on the fish species exploited by anglers; their growth, recruitment and condition;
g) Assess the level and quality of angling activity within Loch Ken in relation to that experienced in alternative coarse angling venues within the Galloway area;
h) Provide recommendations for the future management of Loch Ken as a fishery, and as a venue for specialist pike anglers.
i) Promote best practise bio-security measures such as Check Clean Dry at the bio-security tool kit at all events and in general contacts with anglers as part of this study.
j) Circulate a standard questionnaire to anglers using Loch Ken to assess levels of awareness and compliance with Check Clean Dry.

Funding for a year 1 (possibly as a pilot) has been confirmed by SNH & SEPA, and it is the intention to start the project in the Summer/Autumn of 2015. Funding for years 2 and 3 has been included as part of a Heritage Lottery Fund bid for the 'Glenkens Landscape Partnership Project' (see page 4/5).

Yearly progress reports will be produced by the contractor, along with a final report in December 2017.

River Annan – Check Clean Dry Campaign

Location of Signs

The River Annan Trust has put up 14 Check Clean Dry (CCD) signs in high profile parts of the River Annan catchment (fig 1) while the Annandale sailing club have erected a sign at Castle Loch. Each site was specifically chosen to target either anglers, boat users or both depending on the types of activity carried out in that location. Angling is the predominant activity on the river and the type of CCD signs used reflect this The signs cover all the busiest parts of the catchment and its still waters and are highly visible.

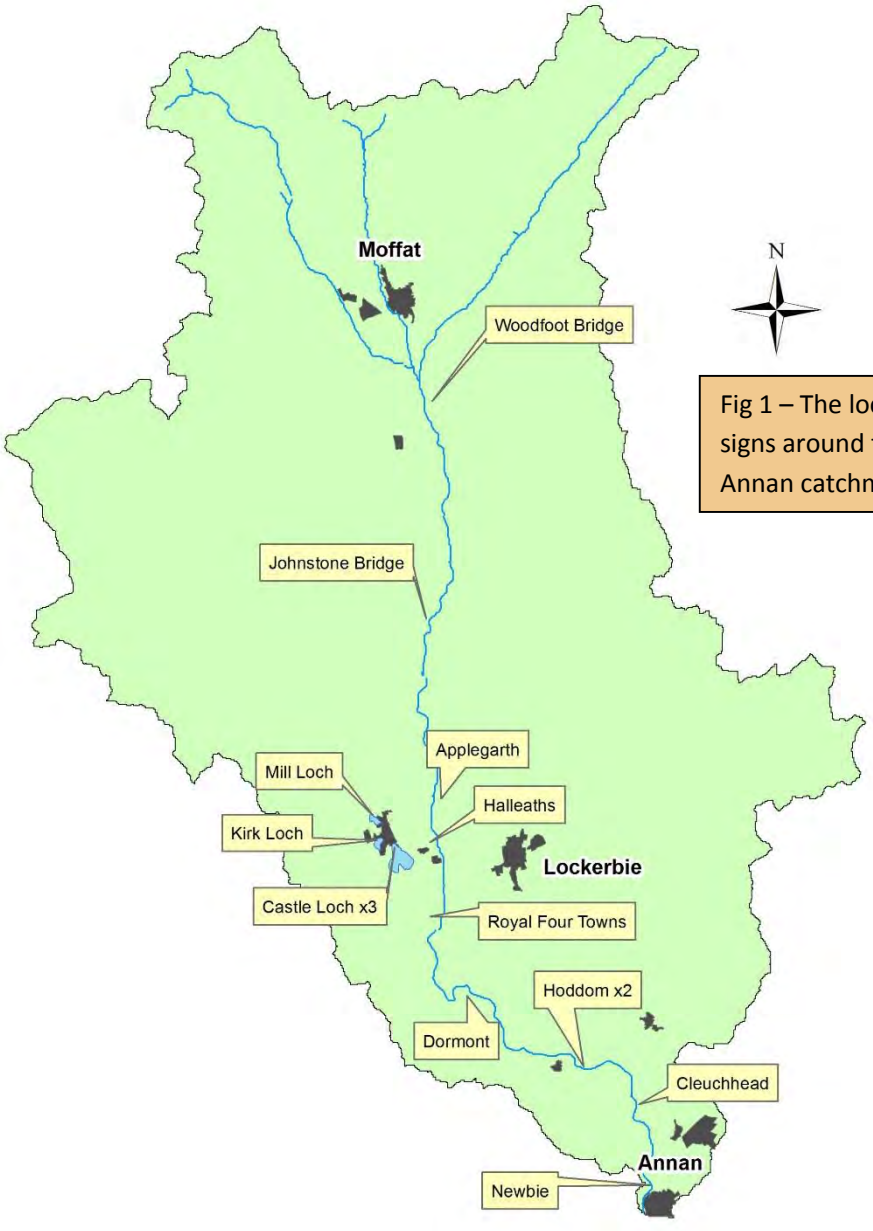

Fig 1 – The location of CCD signs around the River Annan catchment

Location	Grid Reference	Target Audience	Reason for Location
Kirk Loch	NY 08093 82385	Anglers	Car park and main access point for anglers
Mill Loch	NY 07792 83317	Anglers	Main access point for anglers
Castle Loch	NY 08445 82141	Anglers	Car park and main access point for anglers and boat users
Castle Loch	NY 08960 81909	Anglers	Main car park for accessing the loch
Castle Loch	NY 08639 82194	Boat Users	Annandale sailing club clubhouse.
Hoddom	NY 16371 72746	Anglers	Main access point to fishing beat
Hoddom	NY 16326 72704	Boat Users	Launch point for canoeists
Johnstone Bridge	NY 10047 91707	Anglers	Anglers car park and access to fishing
Applegarth	NY 10390 83992	Anglers	Anglers car park and access to fishing
Cleuchhead	NY 18759 71054	Anglers	Main access to fishing beat
Newbie	NY 19428 67632	Anglers	Main access point and footpath along fishing beat
Halleaths	NY 09927 82321	Anglers	Anglers car park and access to fishing
Dormont	NY 11680 76053	Boat Users	Access point for canoeists
Woodfoot Bridge	NT 10021 00722	Anglers	Anglers car park
Royal Four Towns	NY 09958 79302	Anglers	Main access to fishing beat

Table 1 – The location of CCD signs around the River Annan catchment, the main target audience and the reason for choosing the location

Check Clean Dry on the River Annan

The River Annan Trust fully supports the Check Clean Dry campaign as a way of promoting good biosecurity and advice to river users to prevent the spread of aquatic based Invasive Non-Native Species (INNS). INNS can directly impact on river users by spoiling fishing areas or clogging up waterways, limiting the recreational and amenity value of the water body. In addition, they can have devastating consequences for native flora and fauna. American signal crayfish have not been found in the River Annan catchment and the promotion of CCD is one of the tools we have been using to ensure that this remains the case.

The success of Check Clean Dry requires all the major relevant bodies and stakeholders to support the campaign helping to drive home the message. River users want to protect their waterways and CCD provides easy to follow guidance, taking very little time that allows them to do so.

In isolation erecting CCD signs isn't enough and the River Annan Trust attends a number of shows and events annually to promote the campaign (as well as the many other activities of the trust) and every fishing hut and shelter contains CCD and crayfish posters. Additionally CCD is promoted by our website and through our social media sites.

CCD Signs and Posters on the River Annan

Fig 2 – CCD sign at Johnstone Bridge providing advice for anglers

Fig 3 – CCD sign at Hoddom providing advice for boat users at a popular canoeing spot

Fig 4 – Fishing huts provide a good point to provide information for anglers.

ANNEX 5: Examples where biocides have been used

Box 1 Case studies: treatment with natural pyrethrum biocide

Treatments with natural pyrethrum (Pyblast)
North Esk sites, Aberdeenshire and Montrose (Peay 2006a)
Gravel Pit, Edzell, an enclosed site, approximately 0.9 ha, 6000m^3. It was treated in September 2004 with a deoxygenating pre-treatment of sodium sulphite, followed by Pyblast sprayed onto the surface for a target dosage of 0.1 mg l^{-1} natural pyrethrins. The deoxygenation treatment reduced the effectiveness of the treatment with Pyblast so the site was re-treated in October 2004 with a target dosage of 0.15 mg l^{-1}. This has been successful, with no crayfish being recorded in 5 years of post-treatment monitoring and eradication assumed to have been achieved (Peay unpublished).

Mains ponds, Drumtochty consists of a group of three dammed ponds with a through flow and a lot of vegetation. The largest pond, where crayfish were known to have been stocked, was 0.6 ha and the total volume of the three ponds combined was approximately 6500 m^3. This was treated immediately after the initial treatment at the gravel pit and also had a deoxygenation treatment. The inflow was stopped. Although a sump was installed downstream of the last pond (Lower pond) there was minimal seepage to return by pumping. In 2005 monitoring confirmed that there some survivors at very low abundance. The ponds were re-treated, without any deoxygenation, at a target dosage of 0.2 mg l^{-1} natural pyrethrins (Peay *et al*. 2006). Subsequent monitoring has shown crayfish increasing from the upstream end (Peay unpublished). The treatment did not achieve eradication. The most likely reasons for this are either that some crayfish were present in the small inlet ditch in rush pasture upstream of the ponds and missed being treated, or that the most upstream pond was not treated effectively because at the time of re-treatment it had only shallow water over a bed of ochreous silt and dense cover of grass (*Glyceria fluitans*). The fine spray of Pyblast used may not have penetrated the vegetation effectively and would have been decayed rapidly in the presence of so much vegetation and silt. Later improvements in treatment methods would give this a greater likelihood of success if treated with current knowledge.

Castle pond is a pond which was 5450 m^2 in area and approximately 6000 m^3 in volume at the time of treatment. It is fed from a river via a culvert, a ditch and small weir. The pond was constructed by enlarging an older pond. An earth dam was set up in a pasture, with an outfall pipe to another ditch. It was found to leak through the bed via old field drains and a few crayfish were found immediately downstream of the pond. It was treated in December 2004 by spraying on Pyblast from a boat at a target dosage of 0.15 mg l^{-1} and the treated leakage was re-circulated by pumping for 17 days. The outfall ditch was treated by spraying and recirculation. It is evident that eradication was not achieved because a crayfish was caught in the second year of monitoring and the population is now increasing. Efforts by the owner to maintain the water level by increasing throughflow have increased the rate of leakage. This treatment would have had greater likelihood of success with a higher target dosage to make up for the basal silt and the increased turbidity during re-circulation.

Barmbyfield Reservoir, Pocklington, East Yorkshire is an enclosed farm irrigation reservoir, dug into calcareous clay. It was 5640 m^2 in area at the time of treatment in September 2005, with approximately 19,000 m^3 water, 3.4 m deep. It had Pyblast applied to give a target dosage of 0.18 mg l^{-1}, by spray application then pumped to mix. This appears to have been successful, with no crayfish being recorded in 4 years of post-treatment monitoring (Peay 2009).

Ballintuim, Strathardle, Perthshire comprised a garden pond about 900 m^2 and 700 m^3, dammed on one side and partly lined with an artificial liner in 2000. It overflowed via a pipe to a small stream 300 m away. The stream flowed in a spring-fed ditch 0.5 m wide for approximately 670 m to another pond about 1800 m^2 and 1.4 m deep in a depression in a field. The garden pond was treated to achieve a target dosage of 1mg l^{-1}, left for 10 days then dewatered and re-filled. The stream and seepages were treated in five sections successively for 3 hours with a target dosage of 2 mg l^{-1} Pyblast before being dewatered and flushed until clean. The lower pond was treated last 1 mg l^{-1} and flushing started after 1 day. The whole treatment from arrival on site until all areas confirmed recovered took 26 days (Peay, 2006b). All crayfish in test cages and burrow cages were killed. A large crayfish was found in the second year of monitoring in the garden pond, probably having survived in a seepage among stone blocks in the banks. Banks there could not be treated as thoroughly as intended because of restrictions imposed by the owner.

Quarry pond, Ballachuilish, is an enclosed pond in a disused slate quarry, 2.0 ha, 46,000m^3, average depth 2.35m, with two deep holes of up to 12m. The pond was treated in June 2012 with 460 litres of Pyblast sprayed onto the surface for a target dosage of 0.3 mg l-1 natural pyrethrins. The next day, cages in deepest part of the pond were found to contain live crayfish, therefore a further 120 litres of Pyblast were applied to the two holes using 6m long pipes. A smaller pond some 50m away was left untreated. This appears to have been successful, with no crayfish being recorded in either pond in 2 years of post-treatment monitoring (Baum and Ballantyne, 2012).

Box 2. Case studies with synthetic pyrethroids and other biocides

Fish farms, Kansas, USA *Orconectes nais* was competing with fish in rearing ponds in Pratt, Kansas (Ray and Stevens, 1970). Treatment was carried out using an organophosphate insecticide fenthion formulated as Baytex. Seven individual ponds were treated, ranging in size from 0.25 ha, 1.1 m deep to 0.58 ha, 0.7 m deep. Baytex concentrations used were 22, 40, 50, 100 or 250 ppb (µg l^{-1}). The pond at 22 ppb had an estimated mortality of 75% and was re-treated. Ponds treated at 100 ppb and above had estimated 100% mortality at four days after treatment as did one of two at 50 ppb. None of the doses used killed the fish. Long term outcomes are not known.

Lorraine, France Three ponds with *Orconectes limosus* were treated with the organophosphate fenthion as Baytex (Laurent, 1995). One of the ponds was in a granite area and oligotrophic, 1,015 m^2 area and average 1.5 m deep. The other two were in chalk soils; 8000 m^2, 1.2 m deep and 6480 m^2, 0.85 m deep. Target dosages of fenthion in the pond differed, 130, 83 and 60 µg l^{-1}. All the treatments killed all the crayfish in cage tests, although only low numbers were used, maximum 96, with the highest concentration being effective in less than 60 hours. Recovery tests were carried out which showed at the lowest dosage the pond was no longer toxic to crayfish after two weeks. Long term outcomes are not known.

Two Rivers, Wisconsin, **USA** Invasive *Orconectes rusticus* had established in a pond 0.45 ha area and up to 4 m deep (Bills and Marking, 1988). It was treated with 25 µg l^{-1} Baythroid, containing cyfluthrin, a synthetic pyrethroid. Although laboratory tests indicated it was lethal to crayfish at only 0.05 µg l^{-1}, it required a higher dosage in field conditions, which was also toxic to fish (fathead minnows). Caged crayfish were killed within 24 h. None were caught in traps the following year, but the long term outcome is not known.

Dammane, Norway A population of signal crayfish was found in the largest two on-line ponds in a series of five in 2006 (Sandodden and Johnsen 2010). Sizes ranged from less than 0.04 ha to 0.3 ha and depth average 0.8 to 2.2 m. The biocide used as a synthetic pyrethroid cypermethrin formulated as Betamax Vet, a product used to treat salmon against sea lice. The ponds were all treated in one day in May 2008, from a boat and by knapsack sprayers, together with the margins. Several small inflows were dosed with drip feeds as were the connecting streams, with a flow of 2-10 l sec. A second treatment was carried out two weeks later and the ponds were drained a week afterwards to check for mortality. No surviving crayfish were found after the treatments, which also killed an unwanted population of rudd. Monitoring was carried out in 2008 with none found. Ponds were drained in winter and refilled in spring. No crayfish have been found in summer 2009.

Gotland, Sweden Gotland is a large off-shore island, with signal crayfish in only a few sites, hence a potential ark site for noble crayfish if the signal crayfish can be eradicated. Three sites were treated in 2008 with synthetic pyretroid deltamethrin formulated as Decis with a target dose of 0.6µgl^{-1} deltamethrin (Ljunggren 2009). One of these was a farm irrigation reservoir 2.3 ha in area, holding 100,000 m^3. The other two were interconnected limestone quarries, both about 1 ha in extent and with about 30,000 m^3. The application was carried out with sprayers and pumps, with particular attention to hosing the crevices in the limestone. The pond was stocked with noble crayfish some weeks after treatment. The long term outcome on these sites is not known.

Germantown, Wisconsin, USA Red swamp crayfish were established in two adjacent ponds. Trapping (2000+ crayfish removed) was not effective. The authorities want to use natural pyrethrum biocide but have not yet obtained a formulation that has been authorised for use in USA. A treatment was carried out using sodium hypochlorite at 50 ppm in November 2009 (Schumacher 2009). The treatment killed crayfish in test cages, but there are no results yet as to whether the chlorine has persisted long enough to kill crayfish in burrows.

The case studies above have been reproduced with the kind permission of Stephanie Peay, with the exception of Ballachuilish Quarry which was added subsequently.

References

Baum, D. and Ballantyne. L. (2012) Biocide Treatment of the Ballachulish Quarry Ponds to Eradicate American Signal Crayfish. Lochaber Fisheries Trust

Bills, T. D. and L. L. Marking. (1988). Control of nuisance populations of crayfish with traps and toxicants. Prog. Fish-Cult. 50(2), 103-106.

Hiley, P. D. and Peay, S. (2006). Signal crayfish eradication – preliminary biocides trial. Freshwater Crayfish 15, 261-270.

Laurent, P. J. (1995). Eradication of unwanted crayfish species of astacological management purposes. Freshwater Crayfish 8, 121-133.

Ljunggren, N.(2009). County Administrative Board of Halland County, Nature Conservation Division, Halmstad, Sweden. Personal communication.

Peay, S. (2006a). Biocide trial to eradicate signal crayfish in the North Esk catchment. Scottish Natural Heritage Commissioned Report No. 122

Peay, S.(2006b) Eradication of signal crayfish at Ballintuim. Report to Scottish Natural Heritage and the Tay District Salmon Fisheries Board.

Peay S. (2009). Eradication of signal crayfish: biocide treatment of Barmbyfield Reservoir and monitoring 2006-2008. Report to Environment Agency, Northumbria and Yorkshire Region.

Peay, S., Hiley, P. D., Collen, P. and Martin, I. (2006). Biocide treatment of ponds in Scotland to eradicate signal crayfish. Bulletin Français de la Pêche et de la Pisciculture, 380-381, 1363-1380.

Ray, J., and Stevens, V. (1970). Using Baytex to control crayfish in ponds. Progressive. Fish-Culturist. 32, 58–60.

Sandodden, R. and Johnsen S. I. (2010). Eradication of introduced signal crayfish Pacifastacus leniusculus using the pharmaceutical BETAMAX VET. Aquatic Invasions 5(1).

Schumacher, R (2009). Taking on the Red Invader http://dnr.wi.gov/invasives/