Identifying Lamprey

A Field Key for Sea, River and Brook Lamprey

Petromyzon marinus, *Lampetra fluviatilis* and *L. planeri*

Conserving Natura 2000 Rivers
Conservation Techniques Series No. 4

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Conserving Natura 2000 Rivers

This field identification key for sea, river and brook lamprey has been produced as part of **Life in UK Rivers** – a project to develop methods for conserving the wildlife and habitats of rivers within the Natura 2000 network of protected European sites. The project's focus has been the conservation of rivers identified as Special Areas of Conservation (SACs) and of relevant habitats and species listed in annexes I and II of the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (the Habitats Directive).

One of the main products is a set of reports collating the best available information on the ecological requirements of each species and habitat, while a complementary series contains advice on monitoring and assessment techniques. Each report has been compiled by ecologists who are studying these species and habitats in the UK, and has been subject to peer review, including scrutiny by a Technical Advisory Group established by the project partners. In the case of the monitoring techniques, further refinement has been accomplished by field-testing and by workshops involving experts and conservation practitioners.

Life in UK Rivers is very much a demonstration project, and although the reports have no official status in the implementation of the directive, they are intended as a helpful source of information for organisations trying to set 'conservation objectives' and to monitor for 'favourable conservation status' for these habitats and species. They can also be used to help assess plans and projects affecting Natura 2000 sites, as required by Article 6.3 of the directive.

As part of the project, conservation strategies have been produced for seven different SAC rivers in the UK. In these, you can see how the statutory conservation and environment agencies have developed objectives for the conservation of the habitats and species, and drawn up action plans with their local partners for achieving favourable conservation status.

For each of the 13 riverine species and for the *Ranunculus* habitat, the project has also published tables setting out what can be considered as 'favourable condition' for attributes such as water quality and nutrient levels, flow conditions, river channel and riparian habitat, substrate, access for migratory fish, and level of disturbance. 'Favourable condition' is taken to be the status required of Annex I habitats and Annex II species on each Natura 2000 site to contribute adequately to 'favourable conservation status' across their natural range.

Titles in the Conserving Natura 2000 Rivers ecology, monitoring and techniques series are listed inside the back cover of this report, and copies of these, together with other project publications, are available on the project website: www.riverlife.org.uk.

Contents

Introduction

Three types of lamprey are found in the UK; the sea lamprey (*Petromyzon marinus*), the river lamprey (*Lampetra fluviatilis*) and the brook lamprey (*L. planeri*). Although the two *Lampetra* forms have traditionally been considered separate taxonomic species, there is some evidence (Schreiber & Engelhorn 1998) that raises questions about whether this view is the correct one, or whether the two types merely represent life history variants operating on the same gene pool.

Andy Strevens/Environment Agency

Louise Bond/SNH

Brian Morland

There are three lamprey species found in Britain, all of which spawn in fresh water. Clockwise from top left: sea lamprey, brook lamprey and river lamprey. The brook and river lamprey are termed 'paired' species.

All lamprey species spawn in fresh water in spring/early summer (depending on species). This is followed by a larval phase spent in suitable silt beds in streams and rivers. Full details of their requirements at that stage are included in Maitland (2003). The larvae are termed 'ammocoetes' or 'ammocoete larvae'. After several years in these silt beds, the ammocoetes cease feeding and start transforming (metamorphosing) in mid- to late summer into adult form with functional eyes and the mouth changed into a sucker (or oral disc) with teeth. The early stages of metamorphosis take place very rapidly, and by September or October, a stage referred to as the 'macrophthalmia' (literally, largeeyed) stage, with a well-developed disc and well-developed eyes, is reached. However, in this report, the term 'transformer' is generally used to cover all stages from the start of transition to adult form, to either migration to sea or to the clear development of secondary sexual characteristics. Schematic diagrams of an ammocoete and an adult/transformer are given in Key Figure 1 on page 22.

A few months or so after the onset of transformation, the river and sea lampreys migrate to the sea. Here they use their suckers, which, by then, have sharp teeth, to prey on other fish for one or more summers before returning to fresh water as full-grown adults to spawn. In contrast, brook lampreys do not feed as adults and remain in fresh water to mature and spawn in the spring. Hardisty (1986a, b, c, d) provides further information on the life histories, while Maitland (2003) provides life histories and ecological requirements for all three species.

The aim of the present study was to produce a key suitable for use in the field to identify ammocoetes and transformers as far as possible to the three species found in the UK.

Identification of ammocoetes

Ammocoetes of either river or brook lamprey are likely to dominate any samples taken in the UK. Those of sea lamprey, if present, are likely to be in much lower numbers (Hardisty 1986b).

Sea lamprey versus river or brook lamprey

In a careful and well-documented study, Potter & Osborne (1975) showed that ammocoetes of sea lamprey could be distinguished from those of river or brook lamprey by the different pigmentation patterns and morphology, and gave excellent diagrams and descriptions.

In sea lamprey, the entire oral hood was pigmented, although the intensity diminished towards the lower edge of the upper lip. In contrast, in river and brook lamprey, although the upper part of the oral hood was dark and well pigmented, this did not extend as far as the edge of the upper lip. In sea lamprey, the deeply pigmented area in the caudal regions was reported to reach almost to the base of the ventral surface of the body, in contrast to river and brook lamprey. In sea lamprey, pigment spread from the body into the caudal fin and second dorsal fin, in contrast to river and brook lamprey, where it was generally limited to a thin strand along the base of the fin, except in occasional large brook lampreys, when pigment cells could be found in the fin itself.

Differences in caudal fin shape were also reported between sea lamprey and river or brook lamprey, but Potter & Osborne (1975) considered these to be only apparent in larger individuals, and never an easy diagnostic character to apply. Trunk myomere counts were found to be able to provide an unambiguous corroboration of identification – the counts ranged from 69–75 in sea lamprey, but only 57–66 in river and brook lamprey.

Although Potter & Osborne's (1975) work was based on formalin-preserved specimens, Gardiner *et al.* (1995) found that all 3,723 live ammocoetes they examined from Scottish rivers could be identified to either sea lamprey, or to a river/brook lamprey category, on the basis of the criteria in Potter & Osborne's (1975) paper. In the Gardiner *et al.* (1995) study, trunk myomere counts were made on a number of *Lampetra* and sea lamprey ammocoetes to check identifications made on the basis of visual appearance. All were within Potter & Osborne's ranges (Gardiner unpublished).

River versus brook lamprey

In well-documented studies, Hardisty (1986c,d) and Potter & Osborne (1975) reported slight statistical differences at population level in pigmentation patterns and morphology between river lamprey and brook lamprey ammocoetes, but the differences were insufficient to classify individual *Lampetra* ammocoetes with certainty to river lamprey or brook lamprey. Although the possibility exists that better discrimination might be possible with other morphometric measurements not investigated by Hardisty (1986c,d) and Potter & Osborne (1975), this seems unlikely, and this report makes no attempt to develop a key to distinguish river lamprey and brook lamprey prior to transformation.

However, Hardisty & Huggins (1970) were able to distinguish many river lamprey and brook lamprey ammocoetes, (in the case of females but not males) for at least a year before transformation by internal examination of the gonad condition. Fewer eggs of a larger size were generally present in transverse sections of female brook lamprey than in river lamprey, although there was an overlap. It therefore seems likely that internal examination would allow many larger river or brook lamprey ammocoetes to be identified to species.

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Two age 0+ river or brook lamprey ammocoetes showing that the distinctive pigmentation patterns of the head and tail are already visible.

The accessibility of rivers to adult lampreys ascending from the sea may limit which species of lamprey can be present. In reaches of streams that are clearly inaccessible to ascending adult lamprey (because of high waterfalls, for example), all ammocoetes can normally be assumed to be brook lamprey. However, the occurrence of a freshwater-resident population of river lamprey, with adults of atypical morphology, in Loch Lomond (Morris 1989) makes it possible that other such populations occur in the UK, although none has been discovered to date.

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Two age 0+ sea lamprey ammocoetes showing that the distinctive pigmentation patterns of the head and tail are already visible.

Length frequency distribution of *Lampetra* ammocoetes should also provide some clues to their identity. In studies by Hardisty *et al.* (1970), river lamprey transformers had a narrow length range of 93 to 119 mm. Potter & Huggins (1973) reported that the river lamprey macrophthalmia in the main downstream migration into the Severn Estuary (March to early May) ranged from 83 to 133 mm in length, and Maitland *et al.* (1984) reported that most of the river lamprey macrophthalmia sampled in the inner Forth Estuary in April and May were 80 to 120 mm in length (apparently soon after they had entered the estuary). This contrasts with the size at which brook lampreys generally transform. In the studies of Hardisty *et al.* (1970), brook lamprey transformers were generally larger that those of river lamprey, and with a wider length range. Hardisty (1986d) gives the range in length of brook lamprey transformers of one southern UK population as 120 to 175 mm.

Gardiner & Stewart (1997) found mature adult brook lampreys from 111 to 187 mm in length in the River Endrick in Scotland, with the majority of length 120–170 mm. On a Loch Leven tributary inaccessible to adult lampreys from the sea, a sample of 10 brook lamprey transformers caught in 1994 ranged from 125 to 155 mm in length (Gardiner unpublished). Similar values have generally been reported elsewhere. On the basis of these observations, *Lampetra* ammocoetes of length greater than 120 mm will be more likely to be brook lamprey rather than river lamprey.

Identification of transformers

With the transformation of ammocoetes into adult form, some of the characteristics that can used to identify ammocoetes are lost, and new characteristics become available. Good descriptions of transformers of all three species are available from Hardisty *et al.* (1970) and Bird & Potter (1979a, b) (river lamprey and brook lamprey); Potter *et al.* (1978), Youson (1980) and Bird *et al.* (1994) (sea lamprey); Potter *et al.* (1982), and in Youson & Potter (1979) (all three species).

Sea lamprey versus river or brook lamprey

The descriptions referred to above confirm that sea lamprey transformers should be readily distinguishable from those of river or brook lamprey. The labial teeth of sea lampreys are numerous and arranged in slightly curved radiating rows with a steady gradation in size towards the central mouth opening, whereas those of river and brook lamprey are widely spaced, with a more complicated size pattern and not in radiating rows.

In the later stages of transformation, the disc length is notably greater in sea lamprey than in river or brook lamprey, reaching 8% or more of the total length (Potter *et al.* 1978), in contrast with river or brook lamprey, in which a disc length of only about 5% is attained (Bird & Potter 1979b; Hardisty *et al.* 1970). In these same later stages of transformation, sea lamprey transformers are reported to have changed from the dark brown dorsal/light brown ventral colour typical of ammocoetes to blue-black towards the dorsal surface, with a silver ventral surface (Youson & Potter 1979), and the eye length reaches about 2.7% of the total length (Potter *et al.* 1978).

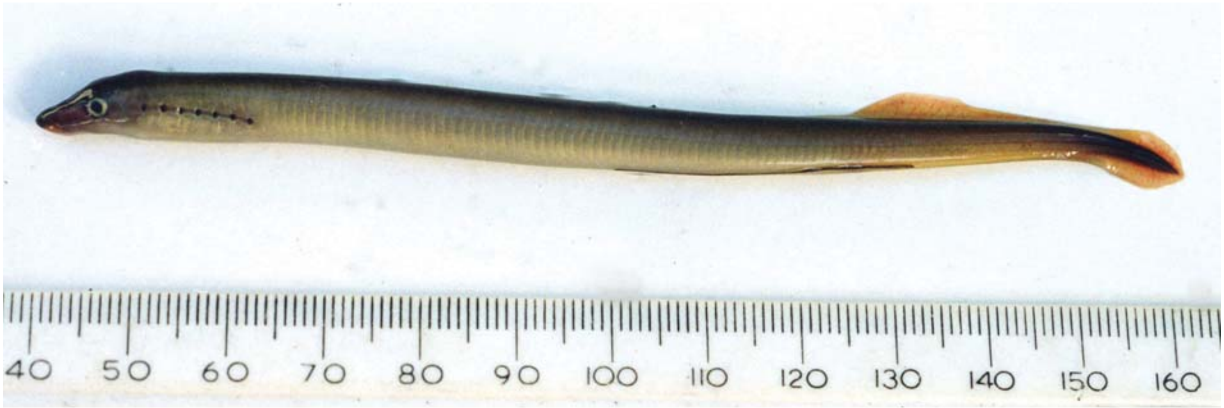
In the early stages of transformation, although the adult characters are not sufficiently developed to be of use, the characteristics of the ammocoetes can still be used to distinguish transformers of sea lamprey from those of river or brook lamprey.

Existing information on the timing of metamorphosis and downstream migration in sea lamprey, and the size of sea lamprey transformers, mainly comes from other countries, as sea lamprey transformers have rarely been reported in UK sampling. In North America, anadromous sea lampreys have been reported to transform at mean lengths between 119 and 130 mm (Potter *et al.* 1978). In the River Mondego in Portugal sea lampreys transform at approximately 140 mm to 200 mm in length and migrate to sea from September to January, with a peak between October and December (Pedro Raposo de Almeida, pers. comm.).

Only two sea lamprey transformers were observed in Potter & Osborne's (1975) samples from rivers in southern Britain (137 mm and 142 mm in length). However, their ammocoete samples only included one sea lamprey of length greater than 127 mm, which could suggest that metamorphosis may typically be at a shorter length. A sea lamprey ammocoete of 112 mm length, which was at an early stage of transformation, was caught in the River Spey (on 25 August, 1994) (Gardiner unpubl). Large numbers of feeding post-transformation sea lamprey were caught by an eel fisherman in the lower River Severn on the night of 30 November/1December (Bird *et al.* 1994). These had an average length of 182 mm, suggesting that they had emigrated some time previously and had grown considerably since metamorphosis.

River versus brook lamprey

In river and brook lamprey, as transformation proceeds, the different development trajectories of the two species become apparent, with brook lampreys progressively developing secondary sexual characteristics and ultimately spawning in the spring, while river lampreys prepare for emigration to estuaries or other coastal areas, mainly in early spring (Potter & Huggins 1973), where they will prey



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River or brook lamprey at an early stage of transformation, showing that the pigmentation pattern of ammocoetes is still apparent at this stage.

on other fish.

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Close up of the head of the transformer shown above.

Hardisty *et al.* (1970) described general differences in appearance between river lamprey and brook lamprey transformers for several rivers in the south of England and Wales. Over the winter, the two types became progressively more distinct in appearance, with the transforming river lamprey becoming more silvered, slender, and laterally flattened relative to brook lamprey as transformation progressed.

Although brook lamprey sometimes showed some silvering soon after transformation, this was transient, soon giving way to an often mottled, grey-brown colouration, especially towards the lateral and dorsal surfaces. In addition, brook lamprey typically showed a greater development of the lateral line organs on or around the head. Hardisty *et al.* (1970) considered that these differences in general appearance were sufficient to separate river lamprey and brook lamprey transformers from November onwards.

Although prior to this the transformers of the two species could not be always be distinguished from their external appearance, it would again seem likely that many would be able to be distinguished by an internal examination – of gonad condition in females, for example (see previous section).

Hardisty *et al.* (1970) included data on the relative body proportions of river lamprey and brook lamprey transformers on 1 December. The present author examined these to assess which would be most useful in separating river lamprey and brook lamprey, and provide a less subjective assessment. The most promising were the disc length, eye length and pre-orbital length relative to the total length, which were greater in the river lamprey transformers than in the brook lamprey transformers. Other parameters such as body depth looked less likely to be useful (Table 1).

The data indicated that, by 1 December, many river lamprey (but not brook lamprey) should be able to be identified from measurements of disc or eye length, and that preorbital-length measurements should provide an unambiguous identification of many river and brook lamprey. However, few, if any, transformers would be able to be identified as river lamprey or brook lamprey from depth measurements. If the measurements do vary independently, it is possible that a transformer not clearly identifiable on the basis of one parameter might be identifiable on the basis of another.

Table 1. Relative body proportions of river lamprey and brook lamprey transformers on 1 December according to Hardisty *et al*. (1970). The figures for standard deviation (SD) were estimated from the standard errors of the mean and approximate sample sizes given in the paper.

± SD		± SD		(%) ± SD		(%) ± SD	
Brook	River	Brook	River	Brook	River	Brook	River
2.0 ± 0.1	2.7 ± 0.8	4.3 ± 0.2	4.9 ± 0.7	6.1 ± 0.3	7.7 ± 0.8	6.3 ± 0.3	5.9 ± 0.4

Of course, if the wide range in parameter estimates for river lamprey merely reflects varying degrees of transformation among individuals on 1 December, it would seem unlikely that they will vary independently. In any case, better discrimination would be expected later in the winter. The capture of downstream river lamprey migrants by Bird & Potter (1979a) in the Severn Estuary between late October and February indicates that metamorphosis of river lampreys can sometimes be completed by early winter. Such transformers would be likely to be identifiable earlier than those where metamorphosis is not completed until the spring.

In Hardisty *et al.*'s (1970) study period, which lasted up to the end of February, too much overlap in the tooth sharpness of the two species was found for this to be a useful parameter for identification, in contrast to statements by some previous workers. However, the sharpest teeth were found in some of the river lamprey and the bluntest in some of the brook lamprey. It may be deduced from this that the very sharp teeth of ready-to-feed/feeding river lamprey macrophthalmia in the spring develop later. Hardisty *et al.* (1970) also reported a difference in the average number of teeth in the anterior field between the two species, with brook lamprey having a greater number than river lamprey on average. This character was not likely to be of use for identification because of considerable overlap.

Further useful quantitative data and illustrations on the changing morphology through all stages of the transformation of river and brook lampreys are provided in Bird & Potter (1979a, b), mainly for the same study rivers used by Hardisty *et al.* (1970). These confirmed the relatively greater eye, disk and preorbital lengths (in Bird & Potter [1979b] subsumed into a prebranchial length, which extends further to the anterior edge of the first gill opening) in river lamprey than in brook lamprey transformers. A summary of their observations on key measurements for their macrophthalmia stage (reached by September or October) and their immature adults stage (reached by January or February) is given in Table 2.

The absolute values of Bird & Potter (1979a, b) may not be directly transportable to the field situation, as the lampreys measured had been preserved in formalin, which may give uneven shrinkage. Similar considerations may also apply to Hardisty *et al.*'s (1970) work, as it is not made clear in the text whether their measurements were on anaesthetised or preserved specimens.

The earliest mature adult brook lampreys occurred in Bird and Potter's (1979a) samples in early March,

Table 2. Relative body proportions of river lamprey and brook lamprey transformers on 1 December according to Bird & Potter (1979b). The figures were read off their plots. It is not possible to give figures for standard deviation (SD) from the data presented.

	Brook		River	Brook		River	Brook		River
	Male	Female		Male	Female		Male	Female	
Macrophthalmia	2.35	2.20	2.75	4.13	3.95	4.02	10.6	10.0	11.5
Immature adults	2.47	2.13	2.88	4.70	4.38	5.24	11.1	10.2	12.6

and an excellent description is provided of the two sexes at this stage:

> The female is clearly distinguished by an upward curling of the tail, a distended trunk and a transparent ventral body wall through which can be seen the mature eggs. The latter have become released into the body cavity from the mesovarium and can be extruded through the cloaca by applying pressure on the ventral part of the trunk.
>
> By contrast, the males are slimmer, have a prominent urinogenital papilla projecting from the cloaca, and the fluid constituting the milt can occasionally be detected through the body wall. In both sexes, the gap between the two dorsal fins has disappeared and the second may even encroach on the region occupied by the first.
>
> The female also possesses a prominent heavily pigmented oedematous swelling at the base of the second dorsal fin and, just behind the cloaca, a fin-like fold which is separated from the most anterior part of the caudal fin. The teeth have degenerated and are much shorter and blunter than previously and in preserved specimens tend to be white rather than yellow. The nasopore is very conspicuous as a small elevated tube-like structure and the regions immediately surrounding the pits of the lateral line are raised. The oral fimbriae have increased in size and, in preserved specimens, the disc tends to remain open.
>
> Bird & Potter (1979a)

Such mature adult brook lampreys should be readily recognised, and morphometric measurements will not be needed to assist or confirm identification.

The lengths of river lamprey and brook lamprey transformers have already been discussed in the section on river versus brook lamprey ammocoetes.

Existing keys

There are three existing keys for the identification of lampreys found in the UK – in Maitland (1972), Maitland & Campbell (1992) and Wheeler (1998). These provide summary guides to the identification of full-grown adults, which can be identified to species with confidence. Maitland (1972) and Maitland & Campbell (1992) also include summary guidance on the identification of ammocoetes. However, there are inaccuracies in the descriptions, probably as a result of the incorporation of material from MacDonald (1959), which was shown by Potter & Osborne (1975) to be erroneous, and has not been used in the preparation of the present key.

Obtaining samples

Sampling was carried out by electrofishing from August 2001 to January 2002 to obtain samples of ammocoetes and transformers for photography, trials of best examination procedures and identification. No sea lamprey transformers were caught in the sampling visits. Most of the *Lampetra* transformers caught were successfully held in tanks over the winter.

23 August 2001. Water of Leith (National Grid Reference NT 179675)
This site was visited in connection with a survey of trout and grayling being carried out by the Fisheries Research Services (FRS) on the river. The site is inaccessible to any ascending river or sea lamprey as a result of an impassable weir of over 3 m in height downstream, and only brook lampreys can therefore be present. One transformer of length 140 mm was retained.

10 and 17 September 2001. River Tay on the Murthly Estate (NO 072404)
This site is within a reach that adult sea lampreys are known to access regularly, although there are breached weirs and rapids downstream, which could present problems for ascending lampreys. As a result, any or all of the three species could be present at the site. The sampling aimed to catch specimens of all types present. A total of 24 sea lamprey ammocoetes (length range 11–123 mm), 504 *Lampetra* ammocoetes (length range 18–123 mm), and 37 *Lampetra* transformers (length range 92–128 mm) were collected.

14 September 2001. River Teith between Steeds and Greenocks (NS 760969)
This site is within a reach readily accessible to adult lampreys ascending from the Forth Estuary, which is known to have a large population of adult river lampreys (Maitland *et al.* 1984). The sampling was to catch specimens of all types present, with an expectation that the *Lampetra* present would include river lamprey. Despite unexpectedly high water as a result of localised rain in the Teith headwaters, a total of two sea lamprey ammocoetes (lengths 17 and 42 mm), 22 *Lampetra* ammocoetes (length range 20–117 mm), and six *Lampetra* transformers (length range 95–116 mm) were collected.

7 December 2001 and 11 January 2002
Visits were made to sites on Loch Leven tributaries, which are inaccessible to any ascending river or sea lampreys as a result of impassable weirs downstream, but known from previous FRS survey work to support populations of brook lamprey. These visits were relatively unsuccessful, perhaps because of unfavourable sampling conditions and changes to stream habitat since the original survey work was carried out. Very few ammocoetes and no transformers were caught.

10 January 2002. River Tay on the Murthly Estate (NO 072404)
Eight *Lampetra* transformers (length range 98–112 mm) were collected.

17 January 2002. River Usk under and immediately downstream of the Chain Bridge (SO 346056)
This site was used to trial draft key material and field examination procedures with Tristan Hatton-Ellis of the Countryside Council for Wales (CCW) and Environment Agency (EA) staff. The EA staff collected a total of two sea lamprey ammocoetes (lengths 50 and 77 mm), 155 *Lampetra* ammocoetes (length range 26 to 132 mm), and two *Lampetra* (lengths 91 and 97 mm) transformers. All lampreys were returned live to the water after the identification trials.

Examining ammocoetes and transformers in the field

Anaesthetising

Whether or not to Anaesthetise
Although, if left undisturbed in water in a dish, ammocoetes will often rest on their sides, trials showed that anaesthetisation greatly aided examination, and was essential for measurements to be made. MS222 (Ross & Ross 1999) worked well, calming the lampreys in a few minutes to a level of consciousness allowing easy handling, but from which rapid recovery took place on transfer to clean water.

Examination of anaesthetised ammocoetes
A light background (such as a smooth, white formica board) worked well for looking at the pigment pattern in the caudal fin of ammocoetes. This was particularly true with small ammocoetes, as the spread of pigmentation into the caudal fin of sea lamprey ammocoetes is less intense in small ammocoetes. In contrast, medium to dark backgrounds, such as are often used in fish measuring boards, were unsatisfactory in that it was much more difficult to distinguish sea lamprey from river or

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Selection of equipment useful in the field examination of ammocoetes – soft fine-meshed net, bendy stainless steel tweezers, measuring board, smooth white formica board, headband magnifier, hand lenses, vernier calliper micrometer.

brook lamprey ammocoetes. For handling small ammocoetes, bendy stainless steel tweezers, such as some people use for sorting invertebrate samples, were found to be useful.

The trials showed the importance of having adequate magnification available, particularly with small ammocoetes. The testers preferred a x2 headband magnifier, but 3-dioptre reading glasses were also satisfactory. For examining 0+ ammocoetes and the dentition of transformers, greater magnification (such as provided by a x12 hand lens) was needed.

Ease of making measurements and counts
Because of the rigidity of the lamprey eye, it was relatively easy to obtain consistent measurements of the eye length of anaesthetised transformers using a calliper micrometer. This contrasted with disc size, preorbital length and depth, which it was more difficult to measure in a consistent fashion.

Trunk myomere counts were straightforward to do under field conditions with larger ammocoetes and transformers. A dissection needle was found to make a useful pointer for keeping count.

Other examination techniques

Examining anaesthetised ammocoetes in fresh water in a wide glass beaker during recovery was also found to be a useful technique. The beaker can be held above different backgrounds, which can aid examination of the oral hood and caudal fin pigmentation patterns. This was found to be a satisfactory alternative technique for screening ammocoetes for the presence of sea lampreys.

Although it was usually straightforward to examine the dentition of anaesthetised transformers, mouth closing can cause occasional problems. Once the disc of transformers is sufficiently well-developed, they will readily attach to suitable surfaces. Two-litre clear plastic drink bottles, after being washed out and delabelled, were found to make good containers for inspecting the dentition of transformers that had attached themselves to the inside. A plastic funnel was used for easy transfer of unanaesthetised transformers into the bottle.

Trials and validation of identifications

Identification of ammocoetes

Sea lamprey versus river or brook lamprey

It was found to be straightforward for people to identify sea lamprey and *Lampetra* ammocoetes in samples in the field on the basis of Potter & Osborne's (1975) descriptions, provided they had suitable equipment to allow careful inspection. Even with 0+ age group ammocoetes, the characteristic pigmentation patterns were present on the head and tail, although with less intensity than in larger ammocoetes.

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Examining sea lamprey (top two) and river or brook lamprey ammocoetes (bottom two) in fresh water in a wide beaker during their recovery from anaesthesia.

Identification of transformers

Sea lamprey versus river or brook lamprey

No trials of distinguishing sea lamprey transformers from *Lampetra* transformers were possible as no sea lamprey transformers were caught.

River versus brook lamprey

Most of the *Lampetra* transformers caught were successfully held in separate containers over the winter in small batches, so that length measurements would allow tracking of individual transformers. Samples were regularly examined, morphometric measurements made, and photographs taken for reference and possible use in the key. Tentative identifications into river lamprey and brook lamprey were made for checking against the outcome in the following spring as river lampreys that were ready-to-feed or close to this, or mature adult brook lamprey. Forty-one out of 52 transformers were held until they were either mature adult brook lampreys (33 transformers) or definite river lamprey transformers (i.e. ready-to-feed or close to this) (eight transformers). The details are given in Table 3.

Table 3. Samples used for verifications.

	verified as brook lamprey	verified as river lamprey
Water of Leith	1	0
River Tay	32	3
River Teith	0	5
Total	33	8

By and large, the limited observations made as part of this study closely fitted the descriptions of Hardisty *et al.* (1970) and Bird & Potter (1979a, b) and confirmed the value of the general appearance of transformers in identification. In October, the river lamprey transformers in the River Teith samples were already clearly distinct from the River Tay and Water of Leith brook lamprey transformers through their greater silveriness and less conspicuous development of the lateral line organs on and around the head. The River Tay river lamprey transformers were less well silvered, but could just be distinguished from the brook lamprey transformers. The silveriness of the River Tay and River Teith river lampreys intensified over the winter and into the spring, although that of the River Tay transformers continued to lag behind that of the River Teith transformers until early spring. In contrast, the brook lamprey transformers became browner in colour, and sometimes mottled, over the winter. By 21 February, eggs were visible in good light through the thin ventral body wall of seven (50%) of the female brook lamprey transformers.

It was relatively easy to obtain consistent measurements of the eye length of anaesthetised transformers. Those of the brook lamprey transformers did not change significantly over the winter (mean, as % total length, over the period 5/10/01 to 21/2/02 was 2.17, SD = 0.14, n = 47). Those of the river lamprey transformers showed little change over the period 5/10/01 to 27/12/01 and although generally larger (mean = 2.39, SD = 0.04, n = 7), there was some overlap with those of the brook lamprey transformers. From then on, the eye-length measurements of river lamprey diverged from those of brook lamprey transformers (mean over the period 24/1/02 to 21/2/02 was 2.53, SD = 0.09, n = 11; mean late April/early May 2.79, SD = 0.14, n = 5).

As has also already been noted, it was difficult to measure preorbital length in a consistent fashion on anaesthetised transformers. This might cause problems with its inclusion in a key. Nonetheless, those measurements made indicated a good separation with almost no overlap between brook lamprey transformers and river lamprey. Over the period 22/11/01 to 24/1/02, the mean measurement, as % total length, for brook lamprey transformers was 6.37 (SD = 0.16, n = 7), as compared with 6.86 (SD = 0.21, n = 8) for river lamprey transformers.

It was also difficult to measure disc length in a consistent fashion on anaesthetised transformers. The measurements, as % total length, made over the period 22/11/01 to 24/1/02 were similar in both the brook lamprey transformers and the river lamprey transformers, with a mean measurement for brook lamprey transformers of 4.43 (SD = 0.19, n = 10), as compared with 4.48 (SD = 0.14, n = 11) for river lamprey transformers. These limited observations suggested that this measurement would be of little value in a key for use in the winter.

Over the winter the tooth sharpness of both the river lamprey and brook lamprey was found to increase. By 21 February, there was still considerable overlap between the size and sharpness of the dentition of river lamprey and brook lamprey, although one of the Tay river lampreys had the sharpest teeth, which were also quite large. However, the large brook lamprey transformer from the Water of Leith also had quite sharp teeth at this stage, although they were small relative to the size of the lamprey. By April, the appearance of the teeth had changed markedly. Those of the river lampreys had grown considerably and were very sharp, while those of the brook lampreys had become more blunt.

One transformer in the River Tay sample caused problems in the validation process. Up to 21/2/02 its appearance indicated that it should be tentatively identified as a brook lamprey transformer. By 16/4/02, although still quite brown, it was silvering, and the teeth had become quite sharp. It was the only transformer, tentatively identified as brook lamprey, that had failed to develop any external sexual characteristics by April. In closely related species such as river and brook lamprey, there is, of course, the possibility that hybrids may occur, although these have not been documented in the wild. Data for this transformer were not included in the analysis.

Although not included in the analysis either, the two *Lampetra* transformers caught on the River Usk on 10 January were clearly river lamprey transformers. The characteristics indicative of river lamprey were more strongly developed than in those of River Tay or River Teith origin at the same time of year, with pronounced silvering, large eye (2.88 and 2.87 % of total length) and long preorbital length (8.52 and 7.98 % of total length). The discs were also relatively large (5.88 and 5.16 % of total length).

The validated river lamprey transformers were of length 97, 106 and 113 mm (Tay); and 105, 108, 109 and 111 mm (Teith). The Usk transformers were of length 91 and 97 mm. All were within the range that has generally been reported from elsewhere for river lampreys (see section on river versus brook lamprey ammocoetes).

The lengths of the validated Tay brook lampreys are of interest as they were markedly smaller than has generally been reported from elsewhere (see section on river versus brook lamprey ammocoetes). The 18 males ranged from 93 to 111 mm in length, and the 14 females from 93 to 115 mm.

Lessons learned from the trials and validations

- River lamprey transformers will be easily identified from their general appearance in October in some rivers. However, this will not always be the case.
- Morphometric measurements are useful in confirming the identity of river lamprey and brook lamprey transformers.
- Populations dominated by small *Lampetra* transformers should not be assumed to be of river lamprey.

Key development

A working key was drafted using the material reviewed, and the experience of the limited validation trials.

Best times to carry out survey work

Survey work to confirm the presence of sea lamprey can be carried out at any time of year, provided conditions are suitable.

Work to confirm the presence of river lamprey should be carried out when transformers are present and can be confidently identified. Too early, and confident identification may not be possible. Too late, and they may have emigrated. On the basis of the present information, October/November (depending on the situation) to February is suggested provisionally.

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A Field Key for Sea, River and Brook Lamprey

Slender, eel-shaped body; seven external gill openings; no paired fins; mouth lacks jaws.

LAMPREY 1

1a Teeth absent; eyes rudimentary and covered with skin; flexible, dome-like oral hood spreads over the subterminal mouth (Key Figure 1). Dark brown on dorsal surface, light grey brown on ventral surface.

LARVAL STAGE (ammocoete) prior to transformation into adult form 2

1b Clear eyes developed, or developing; mouth formed or forming into a sucker (disc), which is round when open, with teeth and a central tongue, also with teeth (Key Figure 1).

LARVA TRANSFORMING INTO ADULT FORM (transformer), or later stage 3

*NOTE: Any ammocoetes that show definite signs of transformation, such as enlargement and differentiation of the eye and changes to the head shape, should be classed as transformers, even if they still have normal ammocoete type colouration and the sucker not properly formed. However, in the early stages occurring in the summer, the adult characteristics are not sufficiently developed to allow their use in identification and the characteristics of ammocoetes (**2**) should be used, but with the lamprey being classed as a transformer, rather than as an ammocoete.*

2a Black pigment cells absent over the ventral part of the oral hood, typically leaving a half-moon-shaped clear area; black pigment cells typically do not extend far into the caudal fin or second dorsal fin (except in occasional large brook lampreys, when pigment cells can be found in the caudal fin). Number of trunk myomeres generally 57–66 (useful confirmation characteristic) (Key figures 2, 4, 5).

RIVER LAMPREY OR BROOK LAMPREY AMMOCOETE

NOTE: This is normally the dominant type of ammocoete in samples taken in the UK. The category is not identifiable further (to species) reliably from external appearance. River lamprey ammocoetes cannot be present in watercourses that are inaccessible to ascending adult lampreys. Ammocoetes of length greater than 120 mm are more likely to be brook lamprey than river lamprey.

2b Black pigment cells cover nearly all of the oral hood; black pigment cells extend out into the caudal fin, and can also be present out into the second dorsal fin, particularly in its posterior part. Number of trunk myomeres generally 69–75 (useful confirmation characteristic) (Key figures 3, 4 and 5).

SEA LAMPREY AMMOCOETE

NOTE: Where found, generally occurs with river lamprey or brook lamprey ammocoetes, but in much lower numbers. They are only present in rivers accessible to ascending adult sea lampreys. Most commonly found in larger rivers.

3a Over 500 mm in length (typically 600–900 mm).

RETURNING ADULT SEA LAMPREY

NOTE: These mainly occur in April to July at, and just before, spawning time, when they are yellowish or orange brown with black mottling. Creamy or yellowish white ventrally.

3b 180–500 mm in length (typically 250–400 mm).

RETURNING ADULT RIVER LAMPREY

NOTE: These mainly occur from October to May, and generally spawn in April or May. Often bluish or leaden grey, merging into whitish ventrally.

3c Under 180 mm in length **4**

4a Numerous labial teeth (i.e. the teeth on the main part of the disc, which surrounds the central tongue) arranged in slightly curved radiating rows with a steady gradation in size towards the central mouth opening (Key Figure 6). Number of trunk myomeres 69–75 (useful confirmation characteristic).

SEA LAMPREY TRANSFORMER

NOTE: These are uncommon in samples, but could occur from late summer to November or December. Towards the end of this period, blue-black towards the dorsal surface, with a silver ventral surface and with prominent disc (8% or more of the total length) and large eyes (about 2.7% of the total length) (Key Figure 7 and 8). Only present in rivers accessible to ascending adult sea lampreys. Most likely to be found in larger rivers.

4b Labial teeth widely spaced, with a more complicated size pattern and not in radiating rows.

RIVER LAMPREY OR BROOK LAMPREY TRANSFORMER 5

NOTE: One or other of these is normally the dominant type of transformer in samples taken in the UK. It may not be possible to distinguish the two species unambiguously in the field, particularly up to early winter (Key Figure 9).

5a Silvered, slender looking, and laterally flattened (Key figures 10 and 11). Prominent eye (eye length often 2.4 to 2.8% of total length). May have sharp teeth (Key Figure 12). Lateral line organs on and around the head generally not conspicuous. No signs of sexual maturation. Less than 120 mm, and typically 90–115 mm.

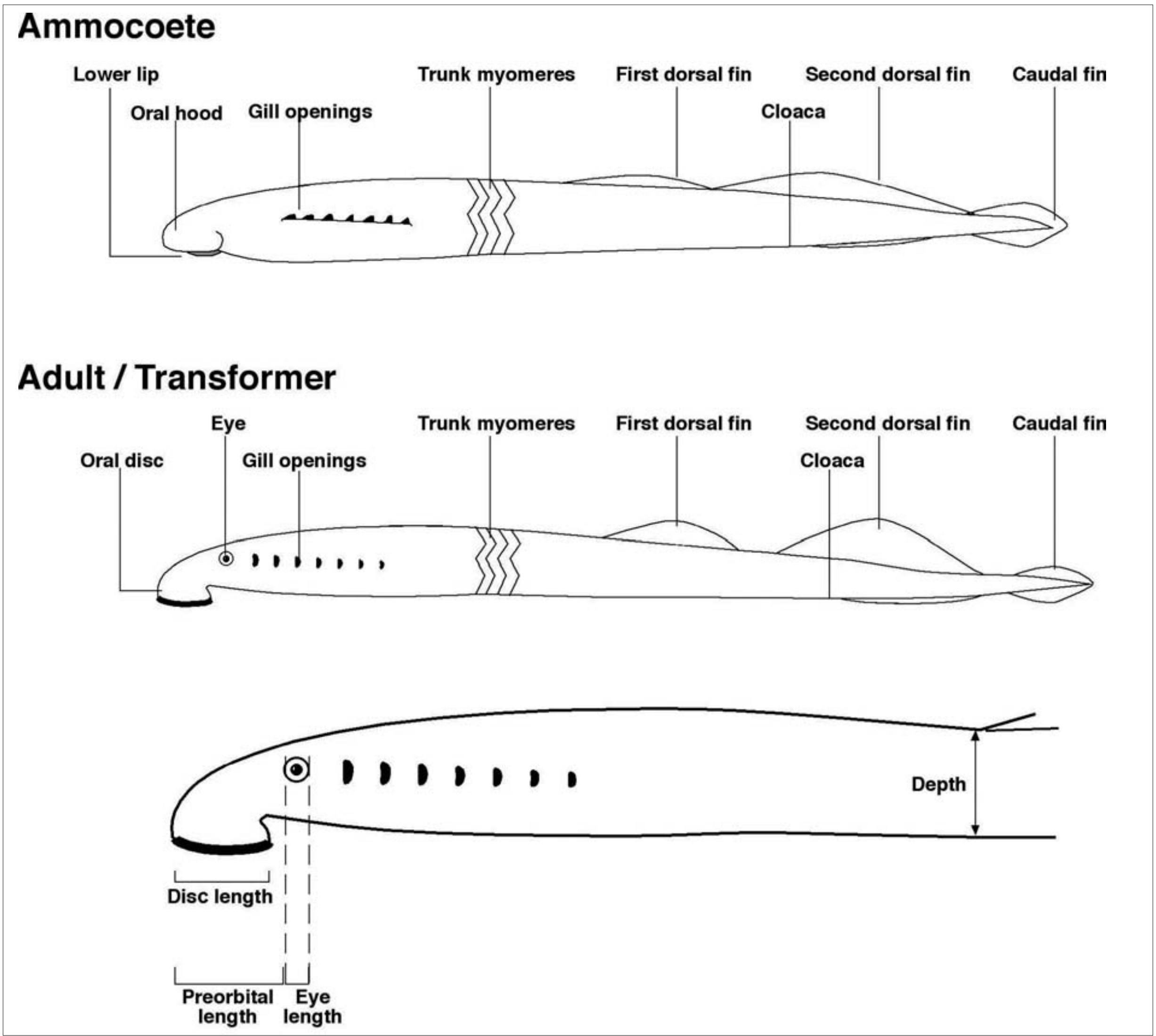
RIVER LAMPREY TRANSFORMER

NOTE: Late summer to April. Only present in rivers accessible to ascending adult river lampreys.

5b Not well silvered, and usually not well silvered on the lateral surfaces (Key figures 13 and 14). Grey-brown to brown in colour, sometimes with mottling. Eye less prominent, typically 2.0 to 2.4% of total length. Teeth never sharp (Key Figure 15). Generally, conspicuous development of the lateral line organs on and around the head. May show signs of sexual maturation (particularly from February on, when eggs, for example, may be seen within the body cavity in good light). Often exceeding 130 mm in length, but populations dominated by smaller individuals of length 90–120 mm also occur.

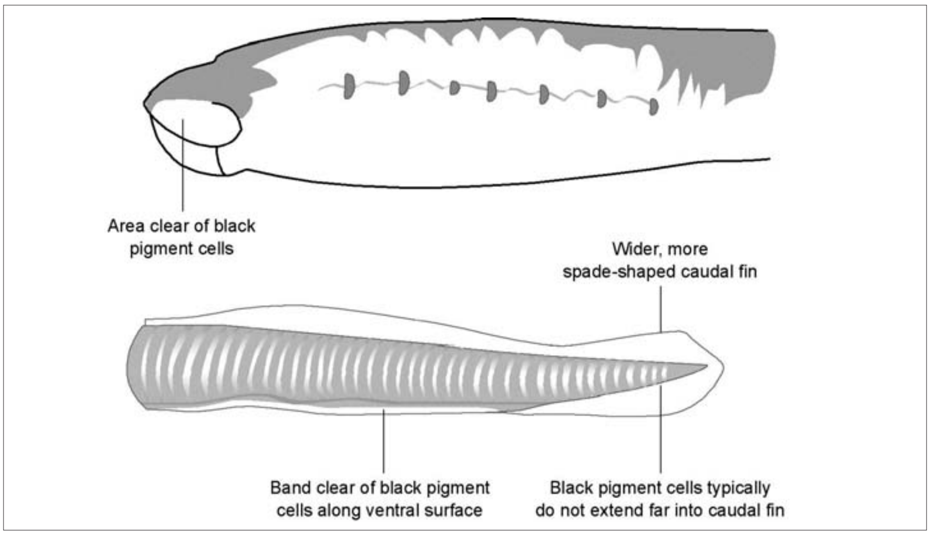
BROOK LAMPREY TRANSFORMER OR MATURE ADULT BROOK LAMPREY

NOTE: May be present in watercourses that are inaccessible to ascending adult lampreys.



Keith Mutch

Key Figure 1. Schematic diagrams of ammocoete and adult/transformer. *Note: The counts of trunk myomeres are made of each complete myomere between the last gill opening and the anterior tip of the cloaca.*



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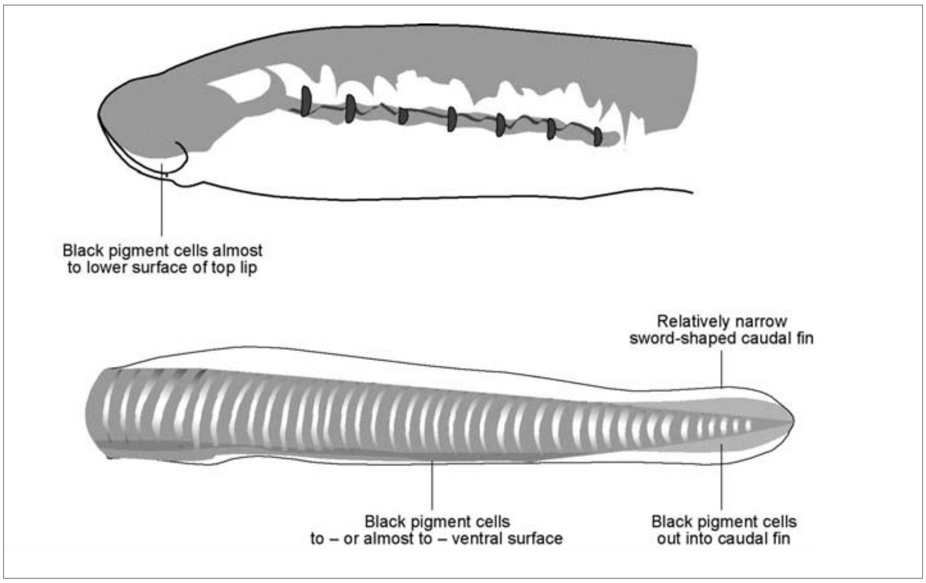
Key Figure 2. Diagrams of head and tail of river lamprey or brook lamprey ammocoete, illustrating important recognition features.



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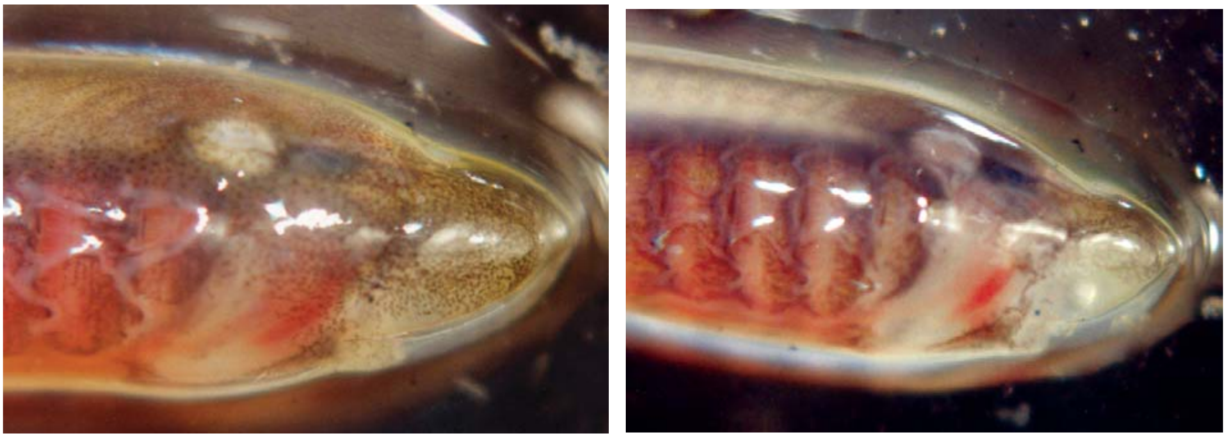
Key Figure 3. Diagrams of head and tail of sea lamprey ammocoete, showing important recognition features.

Both photos by Ross Gardiner

Key Figure 4. Heads and tails of sea lamprey ammocoete (upper ammocoete in each photograph) and river or brook lamprey ammocoete (lower ammocoete in each photograph).



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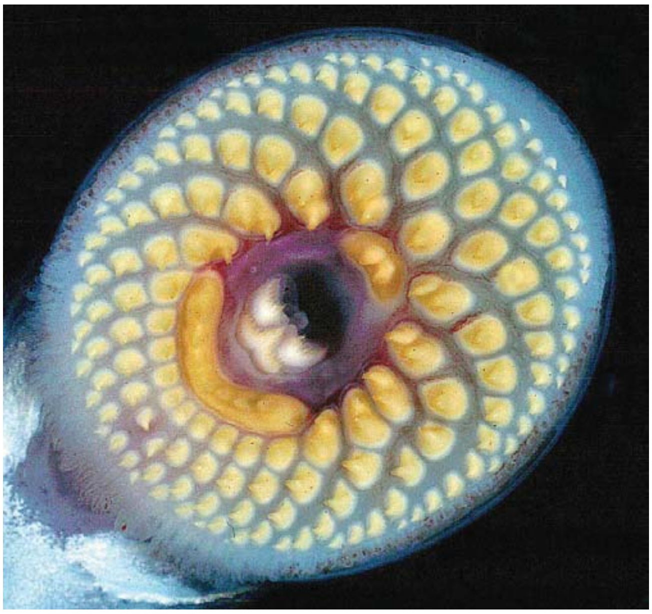
Key Figure 5. Head of small sea lamprey ammocoete (left) and head of small river or brook lamprey ammocoete (right).



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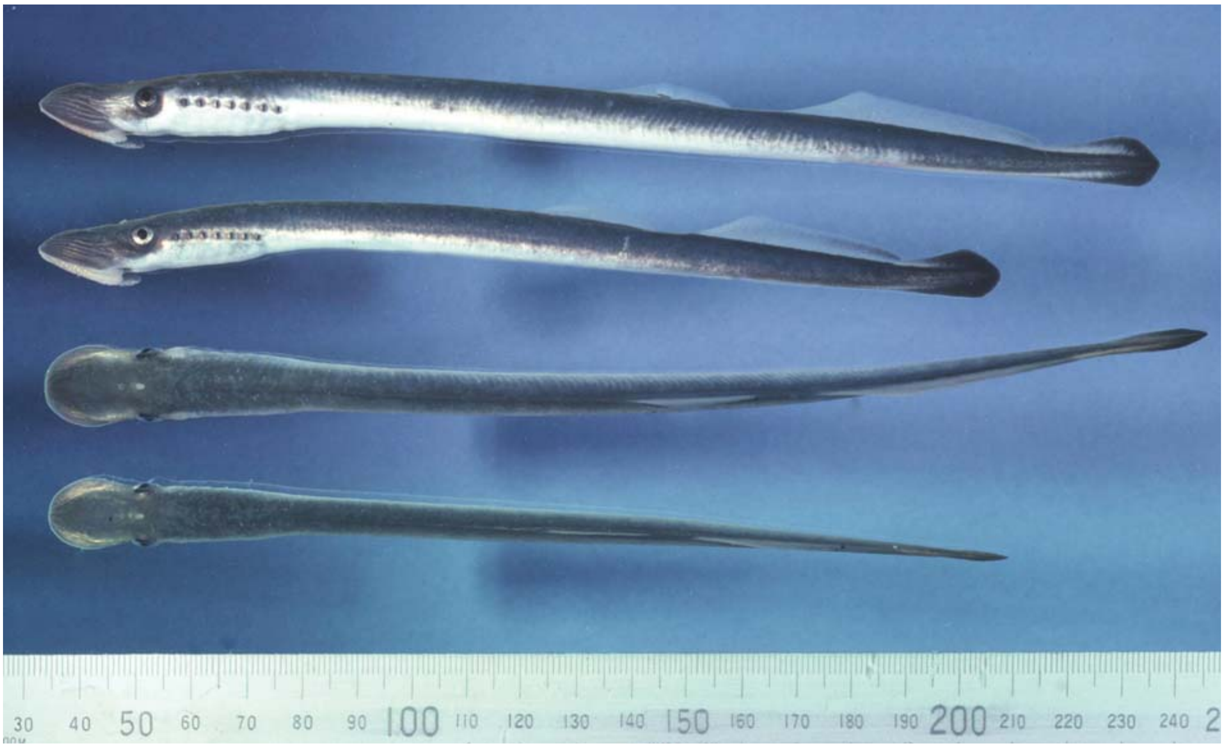
Key Figure 6. Sea lamprey disc after downstream migration. Those of sea lamprey transformers close to emigration will look similar to this.

Both photos by Mark Gartreau

Key Figure 7. Sea lamprey transformer from St John River, New Brunswick, Canada (top), and close-up of head (bottom).



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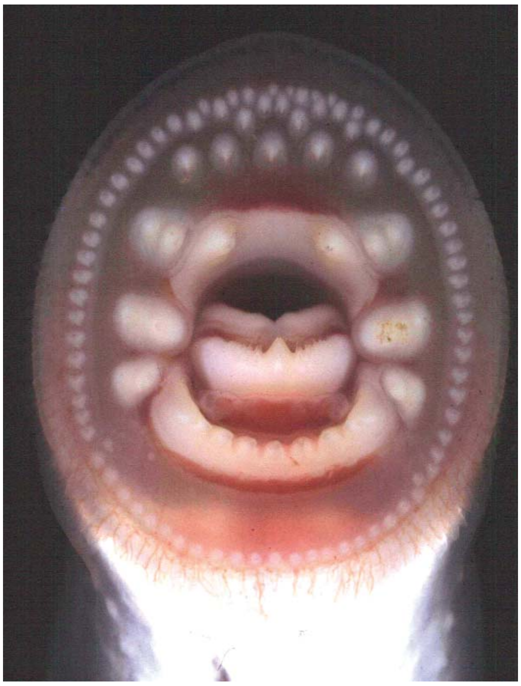
Key Figure 8. Sea lampreys in late November/early December after downstream migration. Sea lamprey transformers close to emigration will look similar to this.



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Key Figure 9. River lamprey transformer oral disc in winter, when discs of river lamprey and brook lamprey are similar.

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Key Figure 10. River lamprey transformer in January.

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Key Figure 11. River lamprey transformer in April.

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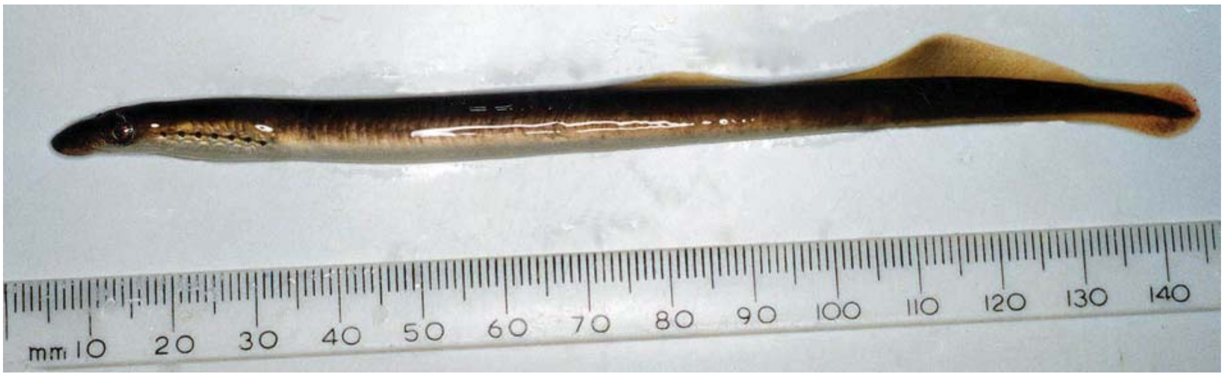
Key Figure 12. Oral disc of river lamprey transformer in April.



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Key Figure 13. Brook lamprey transformer in January.

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Key Figure 14. Mature adult brook lampreys in April. Female (top) and male (bottom).

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Key Figure 15. Mature adult brook lamprey disc in April.

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Set up by the UK statutory conservation bodies and the European Commission's LIFE Nature programme, the project has sought to identify the ecological requirements of key plants and animals supported by river Special Areas of Conservation.

In addition, monitoring techniques and conservation strategies have been developed as practical tools for assessing and maintaining these internationally important species and habitats.

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SNIFFER

The river, brook and sea lamprey are some of the most primitive of all living vertebrates, the jawless fish. They are unique in having a sucker filled with rows of teeth, with which they feed on other fish.

Lamprey undergo two distinct growth phases, with a dramatic transformation from larva to adult. Both phases need specific habitat for survival, so they are vulnerable to a wide range of impacts, including pollution, siltation of spawning gravels, and barriers to migration.

Although they can often be seen in relative abundance at spawning time, populations have been declining, and the sea, river and brook lamprey are now at the heart of a major European effort to conserve key freshwater animals and plants and the river habitats that sustain them.

This report provides an aid to identifying the different species of lamprey in a bid to assist the development of monitoring programmes and conservation strategies that are vital for their future.

Information on Conserving Natura 2000 Rivers and the Life in UK Rivers project can be found at
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