Postbus 68 | 1970 AB Ijmuiden

Ministerie van Landbouw, Natuur en Voedselkwaliteit
Postbus 20401
2500 EK Den Haag

Evaluation of glass eel and ongrown eel restocking practices in The Netherlands

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OUR REFERENCE
1825402.TvdH-ih

POSTAL ADDRESS
Postbus 68
1970 AB Ijmuiden

VISITORS ADDRESS
Haringkade 1
1976 CP Ijmuiden

INTERNET
www.wur.nl/marine-research

CoC NUMBER
09098104

HANDLED BY
Dr. T. van der Hammen

TELEPHONE
+31 (0) 317 487180

E-MAIL
Tessa.vanderhammen@wur.nl

1. Introduction

The European eel (*Anguilla anguilla*) population is declining since the 1980's. To recover the stock, the EU adopted the Eel Regulation (Council Regulation No.1100/2007), requiring each Member State to set up an Eel Management Plan (EMP) describing measures to reduce eel mortality and contribute to the escapement of silver eel. The objective of the measures is to reach 40% of the pristine silver eel escapement. One of the suggested measures in the Eel Regulation is the restocking of glass eel. This resulted in that after implementation of the regulation, many countries started or increased their restocking practices. Also in the Dutch eel management plan, 'restocking of glass eel and pre-grown eel from aquaculture' is one of the measures to reach the objective of 40% of silver eel escapement.

A joint declaration by the European Commission and member states (5382/18, 2018) was adopted in January 2018 aiming to protect the stock of European eel. This 'Joint Declaration on strengthening the recovery for European eel' states that (point 3):

> *'Member States will review current restocking practices to ensure that publicly funded restocking contributes to increasing the escapement levels of silver eels in line with the objectives of the Eel regulation.'*

In this report we will give an overview of the publicly funded restocking practices in The Netherlands and discuss if this is in line with the objectives of the eel regulation

2. Current restocking practices in The Netherlands

Amount restocked and costs involved

In the Netherlands restocking of glass eel and ongrown eel (eels that are grown in culture facilities for some time before being restocked, also called "pre-grown", ICES 2016) exists for decades. After the decline of glass eel availability, this commercial restocking lessened, mostly because the glass eel prices increased. Since 2010, €375.000 of public money is spend on a yearly basis on the purchase and restocking of young eel to increase the number of escaping silver eel. The restocking is commissioned by the ministry of Agriculture, Nature and Food quality (LNV) and is executed by the DUPAN foundation (www.DUPAN.nl), a foundation representing Eel processers, fish farmers and eel fishermen. The purchase of glass eel and ongrown eel is done by putting out a request for tenders and selection of the best offer. The total number of eels purchased for restocking varies between years depending on the

offer (Table 1). Around 2/3 of the available amount is spent on glass eel and around 1/3 on ongrown eel. In recent years, the glass eel is almost always caught in France, but in earlier years, the origin was also the UK. Ongrown eel is usually bought from a aquaculture company in the Netherlands. The eel in the aquaculture usually originate from France as well (pers. comm. M. v.d. Meer). Glass eels are also restocked by fishermen for commercial purposes. The numbers of these commercially stocked eel are unknown and vary a lot between years, but are assumed to be much lower than the numbers restocked by publicly funded program (pers. comm. M. v.d. Meer).

Table 1 *Overview of publicly funded glass eel and ongrown eel restocked in the Netherlands between 2011 and 2017 (source DUPAN).*

	glass eel (kg)	*glass eel (#)*	*ongrown eel (kg)*	*ongrown eel (#)*
2011	164	529,230	1,395	408,376
2012	688	2,287,345	1,294	391,834
2013	652	1,894,857	1,543	506,073
2014	1,728	5,697,997	4,389	902,673
2015	278	863,226	3,374	742,375
2016	875	3,042,000	1,432	490,000
2017	915	3,044,060	1,447	574,000
2018	1,028	3,577,000	1,442	517,000

Restocking locations

The restocking locations are selected by DUPAN in consultation with the government. DUPAN made a list with suitable restocking locations (appendix A) based on three criteria:

1) Silver eel should be able to migrate to the sea;
2) the water quality is sufficient for young eel to grow and mature in healthy silver eel; and
3) the fish right holders (Dutch: visrechthebbenden) agree with the restocking under the condition that the fish right holder will not profit or have a disadvantage because of the restocking.

This resulted in that large rivers are excluded because of pollution and some areas are excluded because the fish right holders do not want to cooperate. In addition, relatively large water bodies were chosen, so large quantities could be restocked at one time (restocking density should not exceed 250 glass eel/ha or 150 ongrown eel/ha). This resulted in a list with suitable restocking locations (appendix A). From this list, in practice every other year the "Veerse meer" and the "Friese Boezem" were selected and the alternated year the "Veluwe Randmeren" and the "Zuidelijke Randmeren" were selected. Only, if sufficient glass eel/ongrown eel were restocked in these locations and budget was available, other locations were selected. The same locations were not chosen two years in a row to investigate if the restocked yearclasses could be detected. Another reason is that the spread of location will reduce the risk that the carrying capacity is reached, which might reduce eel growth.

Table 2 *Restocking locations, numbers and weights, from 2013 to 2018*

		location	*kg*	*number*
2013	glass eel	Zuidelijke en Veluwe	630	1,830,780
	ongrown eel	Veluwe Randmeren	1,170	397,959
		Overijsselse Vecht	350	100,575
2014	glass eel	Friese Boezem	805	2,682,204
		Grevelingen	737	2,406,410
		Veerse meer	187	609,484
	ongrown eel	Friese Boezem	1,442	480,785
		Markermeer	1,219	421,888
2015	glass eel	Veluwe Randmeren	278	863,226
	ongrown eel	Veluwe Randmeren	1,673	181,124
		Zuidelijke Randmeren	682	126,235
		Zuidelijke Randmeren	1,023	435,055
2016	glass eel	Friese Boezem	770	2,709,000
		Otheense Kreek en Braakman	26	81,000
		Veerse Meer	79	252,000
	ongrown eel	Grevelingen	1,432	490,000
2017	glass eel	Grevelingen	341	1,250,100
		Markermeer	150	469,350
		Veluwe Randmeren	253	792,680
		Zuidelijke Randmeren	170	531,930
	ongrown eel	Friese Boezem	1,447	574,436
2018	glass eel	Friese Boezem	480	1,517,000
		Veerse Meer	175	658,000
		Otheense Kreek en Braakman	344	1,293,000
		Zeeuws Vlaanderen	29	109,000
	ongrown eel	Friese Boezem	1,442	517,000

Figure 2 *Restocking locations since 2011. Veluwe randmeren (1); Zuidelijke randmeren (2); Overijsselse Vecht (3); Friese Boezem (4); Grevelingen (5); Veerse meer (6); Markermeer (7); Otheense Kreek (8); Braakman (9).*

Restocking protocol

DUPAN works with a restocking protocol, which is developed in collaboration with WMR (Kuijs and de Graaf, 2011; DUPAN, 2017, Appendix B). It describes the

preferred transport, getting used to the water, density of restocking (maximum 250 glass eel/ha or 150 ongrown eel/ha); water visibility (preferably turbid); water temperature (minimum 10 degrees before 2017, after 2017: 5 degrees), location (in inshore and shallow water); structure (rocks, plants) etc.
Before the restocking of ongrown eel, a sample of the eel is checked for diseases by an EU certified laboratory (CVI Lelystad). Glass eel is checked for diseases by the Company supplying the glass eel.

3. Benefit at recipient location

The objective of the eel Regulation is to enlarge the silver eel escapement in each Eel Management Unit (EMU). The Netherlands is a single EMU and hence this evaluation is narrowed to the consequences of restocking on silver eel escapement in The Netherlands, in contrast with silver eel escapement of the total population for which also the removal of the glass eel at the donor location should be taken into account (see chapter 4 for a discussion on this topic). As a consequence, even if a small proportion of the restocked eel escapes to the sea, there is already a net benefit for the silver eel escapement at the EMU level (the Netherlands).

In the Netherlands, the net benefit of restocking has never been investigated. The International Council for Exploration of the Sea (ICES, 2016) states that to evaluate the restocking practices the 'fate' of the restocked glass eel should be followed. However, restocked glass eel can only be discriminated from other eel if the eel is marked (ICES 2016), which was never done in The Netherlands. Therefore an accurate evaluation of the effects of restocking is not possible. However, restocking has been shown to increase the silver eel escapement in other countries and within ICES there is consensus that restocking increases the escapement of silver eel. Therefore restocking is expected to also contribute to the escapement of silver eel in the Netherlands.

Recommendations
Below are some recommendations to achieve 1) a more accurate evaluation of the restocking and 2) to further optimise glass eel restocking.

1. Marking of restocked glass eel
The fate of restocked eel after release is unknown, and therefore it is also unknown how much they contribute to the spawning stock. ICES has recommended the marking of restocked eel to quantify successful escapement of restocked eel in comparison to natural immigrants (ICES 2016). The fate of restocked eel can be followed by marking them before release. The marking will also allow to distinguish restocked eel from the natural population. Permanent chemical marking may be the best method to ensure conclusive traceability (Kullman et al., 2017, Appendix C), which is suitable for both glass eel and ongrown eel. Marked eel can be detected throughout its life (appendix C). In order to find out if marked eels are able to reach maturity, eels collected from market sampling or from the regular surveys should be analysed on the presence of marked otoliths. The proportions of restocked glass eel and natural immigrants could be analysed to study the relative contribution to eel escapement. In addition, growth and condition can be compared between restocked eel and naturally migrated eel. The question whether it is better to release glass eel or ongrown eel could also be researched if the eels are marked. Marking is already carried out in Sweden, where all eels are marked before release.

Another reason why marking is necessary especially for ongrown eel is that during the farming process, increased growth and stress-related annulus-like rings are formed in the otoliths (Kullmann et al 2018). These cannot be differentiated from

true annuli and cause an overestimation of the age of the eel at age readings. As a consequence these eels cause an underestimation in eel growth which affects the stock assessments (Kullmann et al 2018). Therefore the advice is to mark all eels before restocking. Especially it is advised to not restock unmarked eel that have been farmed in aquaculture. This advice does not relate to the contribution of ongrown restocked eel to the silver eel escapement, but to the quality of the eel data used in the assessments.

2. Restocking location

The choice of the restocking location (habitat) is crucial for obtaining potential spawners. Currently research is conducted to find out where eel grows fastest. This could be used to further select the optimal locations. Kullman et al (2017, and references therein) states that in brackish water bodies, eels display higher growth rates, better overall condition and are less loaded with parasites and PCB's compared to eels in fresh water. Thus, brackish waters with low natural recruitment might be more promising for restocking measures. Also carrying capacity and predation should be taken into account when selecting the best habitat. Current restocking practices take carrying capacity into account by setting a maximum density for restocking. However, this could be further optimised by estimating carrying capacity for each waterbody in each restocking location. It is unknown if carrying capacity is already limiting the growth and survival of restocked eel at some restocking locations.
Yellow eel and silver eel could be marked using tags or transmitters to follow site specific escapement, growth rate or general behaviour. In the Netherlands studies are currently carried out to quantify growth rate of different kinds of habitats (e.g. Hoogheemraadschap Delfland, DAK-project). This information can be used to validate different habitats to select the best possible restocking locations.
Possible good locations for restocking are not taken into consideration because fish right holders from these locations do not want to cooperate.

3. Commercial fisheries

Eel fisheries is allowed in most fresh water bodies in The Netherlands, but not in the main rivers, where eel fishing was closed due to high levels of pollutants in eel (closure from 2011 onwards). Governmental control of the fishery is restricted to on the one hand a set of general rules (gear restrictions, size restrictions, closed season), and on the other hand site-specific licensing. Since 1/1/2010 there is a general registration of landings. Commercial fishing also occurs in the areas where restocking takes place (Table 3). Restocked eel, as well as naturally migrated eel, will endure fishing pressure after being released. It is unknown what percentage of restocked eel are captured by fisheries.

***Table 3**. Eel landings in 2017 (source: visstat database).*

	landings (kg)	*ha*
Friese Boezem	34,910	14,000
Grevelingen	3,422	11,000
IJsselmeer en Markermeer	264,489	181,850
Veerse Meer	2,111	2,100
Veluwe Randmeren	8,594	6,100
Zuidelijke Randmeren	4,353	4,085

4. Migration

It is debated if restocked eel are able to find their way back to the spawning ground. A study by Westerberg et al (2014) showed that sequential imprinting of the route during immigration is not necessary for spawning migration (Westerberg et al., 2014). This conclusion is also seen in previous studies (Järvalt et al., 2010, Pedersen, 2009) and suggests that restocked eel would be able to find its way to the spawning ground. There are also studies that show that restocked eel have more difficulties to find outlets or meet migration speeds in comparison to eel of natural origin (Prigge et al., 2013, Sjöberg et al., 2017). However, there is still little knowledge on this potential effect of restocking and dedicated studies on this are needed.

4. Net benefit at population level

The underlying objective of the Eel Regulation is to increase the total eel population. Eel ranges from Norway to North Africa. A consequence of the adoption of individual management plans is that countries attempt to fulfil the local objectives. However, whereas at a local scale restocking could be contributing to the silver eel escapement, the total restock only profits if the chance of restocked eel to mature to silver eel, migrate to the sea and successfully reproduce is higher in the recipient locations compared to their donor location.

This was also mentioned by ICES. According to ICES the definition of net benefit of restocking is as follows (ICES, 2016):

> '...*where the stocking results in a higher silver eel escapement biomass than would have occurred if the glass eel seed had not been removed from its natural (donor) habitat in the first place.'*

To evaluate if there is a net benefit of restocking, ICES (2015, 2016) defined the following recommendations:

- ICES notes that restocking of eels is a management action in many eel management plans, and that this restocking is wholly reliant upon a glass eel fishery catch to provide "seed".
- There is evidence that translocated and restocked eel can contribute to yellow and silver eel production in recipient waters, but evidence of contribution to actual spawning is limited by the lack of knowledge of the spawning of any eel.
- Internationally coordinated research is required to determine the net benefit of restocking on the overall population, including carrying capacity estimates of glass eel donor estuaries as well as detailed mortality estimates at each step of the restocking process.
- When restocking to increase silver eel escapement and thus aid stock recovery, an estimation of the prospective net benefit should be made prior to any restocking activity.
- Where eel are translocated and restocked, batch marking to distinguish between groups recovered in later surveys should be undertaken to evaluate their fate and their contribution to silver eel escapement.

ICES (2016) concludes that while there may be a benefit at the restocking location, an assessment of net benefit to the wider eel stock is unquantifiable, because the fate of the glass eel at the donor habitat should be compared with the fate at the recipient habitat, which are both unknown. Whether restocking is successful thus depends on the difference between the conditions in the recipient area and in the donor area.

5. Conclusion

In the Netherlands, the net benefit of restocking has never been investigated. However, it has been shown to contribute to an increase in silver eel escapement in other countries and ICES (2016) states that "*there is ample evidence that the release of additional young eels in a water body contributes to the abundance of eel, (production and yield), creating an increased escapement of silver eels from the recipient waterbody"*. Therefore it is very likely that restocking also successfully contributes to the escapement of silver eel in the Netherlands. The objective of the eel regulation is that measures increase the escapement of silver eel. Therefore the conclusion is that the current restocking practices are in line with the objectives of the Eel regulation.

Recommendations

With the current information quantification of the contribution to silver eel escapement is not possible. To improve the evaluation of the restocking practices, all restocked eel should be marked, which is also advised by ICES (2016). Furthermore, the net benefit at the population level should be investigated to ensure that the chance of successful reproduction is higher at the recipient location than at the donor location.

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Justification

Projectnumber:

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research.

Approved:	Joep de Leeuw senior researcher
Signature:	
Date:	28 September 2018
Approved:	Jakob Asjes Manager integration
Signature:	
Date:	28 September 2018

Appendix A Stocking locations

Table 1 List with suitable stocking locations (source: DUPAN)

Location		*surface (ha)*
Zuidelijke Randmeren	Gooimeer	2,575
	Eemmeer	1,510
Veluwe Randmeren	Veluwemeer	3,070
	Wolderwijd	2,100
	Nuldernauw	420
	Drontermeer	510
Noordelijke Randmeren	Zwartemeer	1,800
	Zwartewater	340
	Overijsselse vecht	70
Zeeland	Veerse meer	2,100
	Grevelingen	11,000
Friesland	Friese Boezem	14,000
IJsselmeergebied	Markermeer	68,500
	IJsselmeer	113,350

Appendix B Stocking protocol (in Dutch)

Transport
Glasaal moet het liefst in het geheel niet aangeraakt worden met handen of netten. Indien dat toch nodig is dan moet er op gelet worden dat de netten of de andere materialen waarmee de vis in aanraking komt een regelmatig oppervlak heeft, geen scherpe kanten heeft en de mazen van het net zodanig klein zijn dat ook de staarten van de glasaal er niet doorheen kunnen.

Aflevering droog in boxen (vliegtuig)
Vervoer van glasaal tot aan de waterkant moet plaatsvinden in de boxen waarin de vis wordt afgeleverd. Bij het uitzetten glasaal geleidelijk laten wennen aan hetzelfde water waarin ze worden uitgezet. Het wennen aan het water heeft vooral betrekking op het aanpassen van de temperatuur. Wanneer de vissen overgaan van lucht naar water dan kunnen de veranderingen van temperatuur zeer abrupt zijn. Indien ijs aanwezig in de boxen, verwijder dat dan eerst en laat de dieren in de lucht eerst iets opwarmen. Daarna (liefst langzaam)overzetten naar het water.

Aflevering in water (over land)
Wordt de vis in water vervoerd dan is het cruciaal dat de glasaal van voldoende zuurstof wordt voorzien. Beluchting van het water is essentieel wanneer glasaal in relatief kleine volumes wordt vervoerd. (Bedenk dat transport glasaal van vangstgebied naar Nederland vervoerd wordt met de voorziening van zuiver zuurstof. Beluchting is veel minder efficiënt!) Vervoer glasaal bij voorkeur in hetzelfde water als waarin ze worden uitgezet. Vervoer op het water, met een boot dus, kan dat in een bak met water die belucht wordt of in een net in de bun. Het net moet gemaakt zijn van fijne stof (gordijnstof; maaswijdte maximaal 1 x 1 mm; bij zeer kleine glasaal zal dan nog steeds enkele glasaaltjes door de mazen kunnen gaan). Wanneer de vis uit een bak boven de waterlijn geheveld wordt zorg er dan voor dat het drukverschil beperkt is. Is er geen beluchting of een bun voorhanden, dan kan de aal vervoerd worden in een vochtige omgeving, maar wel zodanig dat de vis niet onder water zit.

Uitzet

Waar

Glasaal zal in een water uitgezet worden in een dichtheid van 250 stuks per ha. Dit betekend, uitgaande van een stuksgewicht van 3000 per kilo, dat één kilo glasaal verspreid moet worden over een wateroppervlak van 12 ha. Zet nooit een grote hoeveelheid glasaal of pootaal uit op een en dezelfde plek. Pootaal uit de kwekerij kan tijd nodig hebben om te wennen aan de nieuwe omgeving en kan de dagen direct na uitzetten een makkelijke prooi worden voor aalscholvers en andere predatoren. Glas- en pootaal wordt bij voorkeur uitgezet in troebel water. Doe het uitzetten zo verspreid mogelijk in ondiep water en bij voorkeur langs de oever. Planten langs de oever of in het water, of stenen langs oever of bodem zijn plaatsen waar aal bij voorkeur moet worden uitgezet. Uit veiligheidsoverwegingen kan er bij (harde) wind het best toe worden overgegaan om de aal uit te zetten langs de luwe oever met de minste golfslag. Voor het uitzetten dient er overleg te zijn met coördinator over de route die gevaren wordt bij het uitzetten van de glasaal.

Laat de vis even wennen

Bij voorkeur krijgen de glas- en pootalen voor het uitzetten de kans te wennen aan de temperatuur en de chemische samenstelling (opgeloste stoffen) van het water. Dit kan gebeuren door gedurende enige tijd steeds kleine hoeveelheden van het ontvangende water op de vis te scheppen. Bedenk echter wel dat aal in ademnood kan komen wanneer ze in weinig water zit. Er zal dus een evenwicht gezocht moeten worden tussen enerzijds de vis de tijd te gunnen om zich aan temperatuur en watersamenstelling aan te passen, terwijl anderzijds voorkomen moet worden dat de vis zich in te weinig water bevindt. Bovendien is het ook wenselijk dat de glasaal zo spoedig mogelijk na ontvangst wordt uitgezet.

Hoe

Bij het uitzetten van glasaal moeten onverhoedse bewegingen en drukverschillen zo veel mogelijk worden voorkomen. Laat de vis zo geleidelijk mogelijk het water in. Van een varende boot kan de aal goed uitgezet worden door ze op het dek te scheppen waar voorzichtig water op wordt gepompt zodat de vis soepel overboord worden gespoeld. Zorg er voor dat het dek schoon is, de vis niet langs scherpe hoeken komt en de vis ongehinderd in het water kan vallen (en verwijder dus boeien of autobanden die voor spuigaten hangen).

Wat te doen:

- Maak kaart van het water waarin de glasaal wordt uitgezet.
- Geef van te voren aan op welke plekken / op welke vaarroute de glasaal wordt uitgezet. Hou daarbij rekening met oeverzone, diepte van het water, beschutting (planten, stenen) en het verwachte weer.
- Bespreek uw plan met de coördinator van de CvB.
- Rapporteer na het uitzetten (1) of de uitzetting volgens plan is verlopen en, (2) indien relevant, geef aan op welke wijze van het plan is afgeweken en waarom en tenslotte (3) geef verbeterpunten aan voor het uitzetten.
- Indien mogelijk: maak foto(s) van de uitzet van de glasaal.

Wat dient er aan boord te zijn bij het uitzetten:

wanneer de vis aan boord wordt gehouden in bakken met water:

- netjes met een maaswijdte van 1 mm of kleiner
- schone emmers (voor het scheppen van glasaal)
- thermometer
- luchtpomp met de daarbij behorende bruisstenen en aansluiting op elektriciteit (aan boord)

wanneer de vis aan boord wordt gehouden in een net (maaswijdte max. 1 x 1 mm) in de bun:

- waterpomp voor verversen water in de bun
- schepnetten met maaswijdte max 1 x 1 mm.

Appendix C Marking of eel

The fate of stocked eel can be follow by marking them before release. The marking will also allow to distinguish stocked eel from natural immigrants. Multiple marking methods are available on the market and double marking is also possible (Kullman et al., 2017). Permanent chemical marking may be the best method to ensure conclusive traceability. Both glass eel and elver could be marked by Alazarin red S (ARS) and Strontium Chloride Hexahydrate (Sr). The use of Oxytetracyclin is not recommended given its antibiotic nature (ICES 2016) and Barium Chloride Dihydrate is not recommended, because it is more toxic compared to ARS or Sr (Kullman et al. 2017).

Single or double mass marking with ARS and or SR requires 3-24h hours in a specific concentration (ARS: 3h 0.15g/L 20°C, Simon and Dörner, 2005; Sr: 24h 1 g/L 19°C, Wickstrom and Sjoberg, 2014). Marked eel can be detected throughout is life by electron-microscopically via X-ray fluoresce or by laser ablation (Sr) or standard fluorescence microscopy (ARS, appendix, Fig. 1).

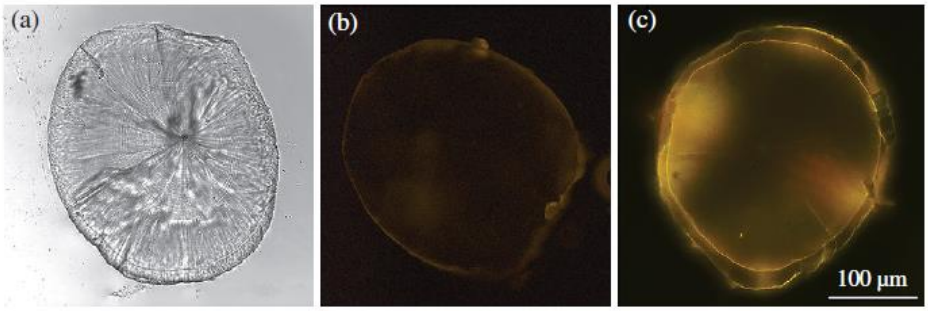

FIG. 1. Thin section preparations of glass eel otoliths that were removed 14 days after the marking process: (a) under bright-field conditions of a fluorescent microscope and under dark-field conditions with filtered light (530–580 nm) for (b) control-group *A. anguilla* without an alizarin red S (ARS) ring and (c) where the ARS ring appears as a yellow glowing band close to the edge where distinct refraction artefacts can be seen. The scale bar is for (a), (b) and (c).

* Figure 1 from: Kullmann, B., R. Neukamm and R. Thiel (2017).

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