RISK ASSESSMENT SUMMARY SHEET

Zander (*Sander lucioperca*)

- A freshwater fish, looks like a cross between pike and perch
- Prefers highly eutrophic, turbid waters
- Established in at least 18 river catchments
- A top predator which may have community-wide impacts as a result of predation and competition
- Considered a desirable sport fish by some anglers, but disliked by others because of a decline in other angling opportunities

History in GB

Native to central Europe. Introduced into still waters in GB in the 1800s, probably for food. Introduction to rivers did not occur until 1947 (River Ouzel), followed by a more successful introduction to the River Ouse Relief Channel (1959) from where the fish rapidly colonised connected water bodies. Further spread has likely been facilitated by illegal transfer.

Native Distribution

Native distribution shown in orange. Purple indicates non-native populations.

Source: Freyhof & Kottelat, 2008, 2018

GB Distribution

Source: NBN 2020

Impacts

Environmental

- A fish eating top predator that can impact fish populations and ecosystems via predation and competition
- Elsewhere in the world there is clear evidence of impact on native species, including European smelt (a UK BAP species)
- Evidence of impact in GB is limited and equivocal, it is unlikely to compete with pike but could impact on populations of other fish (e.g. roach)

Economic / social

- There are conflicting views among anglers. Some recreational anglers enjoy fishing this species and travel long distances to fish them, while other anglers attribute its presence to the decline of their sport

Introduction pathway

Already well established, previously introduced for culinary purposes.

Spread pathway

Natural – this is the primary method of spread through water catchments. Relatively slow but capable of migrating in excess of 30km.

Illegal movements – movements of fish to new, unpopulated areas is restricted; however, the distribution of this species indicates this has continued to occur in recent years. Individuals could also be moved with water transfer

Summary

	Response	Confidence
Entry	VERY LIKELY	VERY HIGH
Establishment	VERY LIKELY	VERY HIGH
Spread	INTERMEDIATE	HIGH
Impact	MODERATE	MEDIUM
Overall risk	MEDIUM	MEDIUM

GB Non-native Species Rapid Risk Assessment (NRRA)

Rapid Risk Assessment of: *Sander lucioperca* (L.) (Zander or Pikeperch)
Author: Gareth D Davies (Environment Agency)

Version: Draft 1 (*July 2018*), Peer Review (*Sept 2018)*, NNRAP 1st review (*Sept 2018*), Draft 2 (*Feb 2019*)
Signed off by NNRAP: September 2018
Approved by Programme Board: September 2020
Placed on NNSS website: November 2020, updated September 2021

Rapid Risk Assessment:

1 - What is the principal reason for performing the Risk Assessment? (Include any other reasons as comments)

Response:

Sander lucioperca (native to central and eastern parts of Europe) was not part of GB's post-glacial fish fauna. However, there has been a long history of their introduction to stillwaters, canal and river systems since the late 1800's. It is thought that their initial introductions were for culinary purposes (Maitland & Campbell, 1992). The first English record for their introduction was in January 1878, where 23 individuals were introduced to two lakes at Woburn Estate, by the Duke of Bedford (Sachs, 1878). It was not until 1947 that *S. lucioperca* were introduced to the lotic environment, when they were introduced to the River Ouzel, near Leighton Buzzard (Wheeler & Maitland, 1972). Their introduction to the Great Ouse Relief Channel was perhaps one of their most successful (Lever, 2009) with the rapidly increasing population swiftly colonising connected drains and rivers in East Anglia (Smith *et al*., 1998). Conflicting accounts of the actual date *S. lucioperca* were introduced into the Relief Channel exist. *Sander lucioperca* were removed from Woburn in the winter of 1959-1960 and held in a pond near Bury St. Edmunds, whereupon their progeny were subsequently released into the Relief Channel in 1963. Other sources report that *S. lucioperca* were introduced to the Relief Channel directly from Woburn in 1959-60 (Wheeler & Maitland, 1973, Lever, 1996, 2009).

Sander lucioperca is now regarded as a desirable sportfish by some anglers, which has contributed to its further introduction and establishment in at least 18 river catchments (Environment Agency, unpublished data). Natural migration certainly played a part in the range expansion of *S. lucioperca*, but illegal transfers facilitated their establishment into un-connected, isolated catchments (Lever, 2009). Current *S. lucioperca* populations are likely to continue their expansion through natural migration and subsequent colonisation.

Conflict over the introduction of *S. lucioperca* remains high, especially within the angling fraternity (Giles, 1993, Hickley, 1998, Hickley & Chare, 2004) and between anglers, fishery and environment managers. Additionally, the propensity for illegal introductions of fish has not waned.

Thus the purpose of this Risk Assessment is to help determine the risk posed by an invasive fish species, already present in GB, assess the potential for environmental harm and aid in informing regulatory positions and future management of *S. lucioperca*.

2 - What is the Risk Assessment Area?

Response: Great Britain (England, Wales, Scotland and their islands)

3 - What is the name of the organism? (Other names used for the organism can be entered in the comments box)

Response: *Sander lucioperca* (Linnaeus, 1758); Zander; Sandre; European pike-perch; Pike-perch; Pikeperch; Draenogyn cegfawr. Previous names include *Stizostedion lucioperca*.

4 - Is the organism in its present range known to be invasive?

Response: Yes.

The introduction of *S. lucioperca* can cause significant changes in fish fauna (Vehanen & Lahti, 2003), indeed, they have been used as a biomanipulation tool to reduce the number of 'unwanted' cyprinids (Lappalainen *et al.,* 2003). Subsequent to the introduction of *S. lucioperca* to Lake Egridir, SW Antolia, extinctions of endemic species (*Phoxinellus* spp.) were observed, with displacement of other species (such as *Alphanius chantrei*) documented (Crivelli, 1995). Predation on trout smolts (*Salmo trutta*) during their downstream migration from a reservoir in Denmark has also been reported by Jepsen *et al*., (2000). The introduction of *S. lucioperca* to a German lake induced habitat shifts in native perch (*Perca fluviatilis*) as a direct response to interspecific competition with *S. lucioperca*. Changes in habitat preference and in diel shifts of native roach were also observed from the same water, subsequent to the introduction of *S. lucioperca* (Schulze *et al*., 2006). Ilenkova (1977) noted an inverse correlation between *S. lucioperca* density and the density of smelt (*Osmerus eperlanus*). *S. lucioperca* may also show 'an outspoken preference' for *O. eperlanus* and where they (*O. eperlanus*) are abundant, they may constitute up to 100% of the diet of *S. lucioperca* (Welch, 1985). In GB, *O. eperlanus* are a commercially important species, but populations have seen significant decline in recent years, with *O. eperlanus* subsequently being designated a Priority BAP species.

Lammens *et al.,* (1992) demonstrated that *S. lucioperca* can directly affect fish community structure via predation pressure in Dutch lakes. Their findings showed that only roach *Rutilus rutilus* of fork length > 200 mm coexisted with *S. lucioperca* in open water, with the smaller *R. rutilus* (< 200 mm) confined to the littoral zones of lakes, where *S. lucioperca* numbers were low. Similar findings were presented by Brabrand & Faafeng (1993), who reported habitat shifts in *R. rutilus* and their avoidance of the littoral zones of Lake Gjersjøen, subsequent to the introduction of *S. lucioperca* and subsequent increased predation pressure. Given that young-of-year *S. lucioperca* are initially zooplanktivorous, switching to piscivorous at > 50 mm (Collette *et al.,* 1977), juvenile *S. lucioperca* can directly compete with juvenile cyprinids and other zooplanktivorous species during their early life stages. Kopp *et al.,* (2009) examined the diet of *S. lucioperca* in two French rivers and found *S. lucioperca* to occupy a higher trophic niche than both the native piscivore *E. lucius* and the introduced predator Wels catfish *Silurus glanis*: which is likely to induce consequences for the native predator guild.

For a non-native species to be classed as 'invasive', it not only has to negotiate each stage of the invasion pathway, but critically, threaten or harm native biota or the receiving environment (Convention on Biological Diversity, 2007). This is where a degree of ambiguity surrounding the 'invasive' status of *S. lucioperca* in GB becomes apparent. Smith *et al*. (1998) conclude that the evidence of *S. lucioperca* impact is equivocal at the moment. However, Linfield and Rickards (1979) found evidence of decline in numbers of the native pike *E. lucius* and perch *P. fluviatilis*, attributed to the presence of *S. lucioperca*. Lever (2009) reports that a very strong year-class (1975) for most cyprinids in East Anglia, particularly for roach *Rutilus rutilus* was 'noticeably subdued in waters holding zander'. Studies undertaken to investigate prey items consumed by *S. lucioperca* in East Anglian waters found native cyprinid species such as *R. rutilus* and common bream *Abramis brama* to form a significant component of prey items found in stomach contents analysis (Fickling, 1982). These findings are partly supported by a study on *S. lucioperca* diet by Nolan & Britton (1998), who list *R. rutilus* and *P. fluviatilis* as the principal food items found in *S. lucioperca* stomachs from a Northamptonshire (UK) canal.

From a UK perspective, limited work has been undertaken to identify any impact associated with the introduction of *S. lucioperca*. Additionally, the few studies that have been conducted have returned contradictory conclusions. Attempts to quantify any impacts exerted by *S. lucioperca* introductions have usually followed two themes: comparison between two adjacent waters, with and without *S. lucioperca*, or long-term monitoring of fish communities, subsequent to the introduction of *S. lucioperca*. However, both study themes make large assumptions that any changes in biodiversity are due to the introduction or presence of *S. lucioperca* and difficulties determining other potential reasons for the biomass of native species observed (Smith *et al.,* 1998). Copp *et al*., (2009) reported a mean Fish Invasiveness Screening Kit (FISK) score of 23 for *S. lucioperca*, categorizing them as 'high-risk'.

In freshwater environments in GB, the dominant native piscivore is the pike *Esox lucius*. This solitary species tends to inhabit the littoral zone (Grimm, 1981; Pierce *et al.,* 2005), requiring vegetation and good water clarity to predate (Grimm, 1981). *S. lucioperca*'s habitat requirements are different to those of *E. lucius*, preferring highly eutrophic, turbid waters (Welch 1985) and generally inhabiting the limetic zone (Lammens *et al.,* 1992). *S. lucioperca* generally predate upon smaller prey than *E. lucius* due to their limited gape size (Popova & Sytina 1977; Kell 1985), thus, with the differentiation in habitat and dietary requirements, it is the general conclusion that *S. lucioperca* is unlikely to directly compete with pike (Smith *et al.,* 1998). However, Schulze *et al*. (2012) did observe a moderate niche compression in both *E. lucius* and *P. fluviatilis* subsequent to the introduction of *S. lucioperca* into a temperate freshwater lake. Additionally, a study on the diet of *S. lucioperca* and the native *E. Lucius* within the River Severn (GB), revealed that whilst some niche partitioning did occur between the species, dietary overlap was evident and indicated that the invasion of *S. lucioperca* led to increased predation pressure on prey species Nolan (2020).

Thus, evidence of impact of *S. lucioperca* in UK waters remains limited and equivocal, with Hickley & Chare (2004) summing up the *S. lucioperca* situation in Britain with 'zander populations have settled into an uneasy balance with native stocks (in East

Anglia) whereas, in the canal systems of the Midlands, this species (*S. lucioperca*) remains a significant threat to roach populations'. Smith (1998) also highlighted the risks posed by *S. lucioperca* invasion of canal systems, noting that impacts on native fish species in heavily-trafficked canal sections was greater than in those where boat traffic was reduced. He attributed this to the advantage *S. lucioperca* have over native piscivorous fishes, gained by their hunting strategy and ability to detect prey at low light levels. It is of note that studies on the impacts of *S. lucioperca* populations introduced outside of their natural range have demonstrated their invasive potential and subsequent adverse consequences for native biota.

5 - What is the current distribution status of the organism with respect to the Risk Assessment Area?

Response:

Widespread in England, not detected in Wales or Scotland. By the late 1960's *S. lucioperca* were well established in the Great Ouse Relief Channel after their initial introduction in the winter of 1959-60/ 1963 (See response to Q1 for ambiguity surrounding date), with the Great Ouse River Authority reporting that *S. lucioperca* were prevalent and numerous in the Relief Channel (Lever, 2009). Natural dispersal from the Relief Channel, aided by the connectivity of the various waters and reaches, permitted *S. lucioperca* to inhabit large areas of East Anglia. Illegal fish movements then accounted for their further range expansion, with Rickards and Fickling (1979) listing 15 English counties with established *S. lucioperca* populations by 1979. *S. lucioperca* have then since formed established populations in SE England, in the River Thames, the Midlands canal and river systems, including the Severn, Trent, Avon, Teme, Soar and Stour (Smith *et al.,* 1998; Copp *et al.,* 2003). In 2016, *S. lucioperca* were captured and removed from the Sankey Canal, Merseyside (Environment Agency, unpublished data) in an attempt to halt their further invasion. Reports of juvenile *S. lucioperca* in the River Dee (Wales) have been reported, but remain unsubstantiated (Lever, 2009).

See NBN atlas for a distribution map:
https://species.nbnatlas.org/species/NHMSYS0000544754#overview

6 - Are there conditions present in the Risk Assessment Area that would enable the organism to survive and reproduce? Comment on any special conditions required by the species?

Response: Yes.

Long established, self-sustaining populations of *S. lucioperca* (See Answer 4 for further details) demonstrate that environmental and biological conditions within GB are more than adequate for the survival and reproduction of *S. lucioperca*. Tolerant of moderately acid conditions (Giles, 1993), *S. lucioperca* can inhabit a range of both lentic and lotic waterbodies. Described as a partially euryhaline species (Copp *et al*., 2003) adult *S. lucioperca* are able to tolerate mildly brackish waters and relatively high salinities (9-10‰) but are capable of surviving even higher salinities up to 30‰, subject to acclimatization (Brown *et al*., 2001).

Larval *S. lucioperca* have a much lower salinity tolerance, with Olifan (1945) reporting values of <4.75‰. Age at sexual maturity can vary, with faster growing populations maturing 1-2 years earlier than populations with slow growth (Lappalainen *et al*., 2003). Fickling (1985) estimated English *S. lucioperca* to be 2 (♂) and 3 (♀) years old when they reach sexual maturity, with length at sexual maturity being 277 mm (♂) and 340 mm (♀).

Generally, spawning takes place when water temperatures are approximately 12 °C (Welch, 1985), but Deedler & Willemsen (1964) reported spawning activity as low as 8 °C. *S. lucioperca* undertake just a single reproductive event a year, usually in late April – May in England. Male *S. lucioperca* create nests and guards the ova until hatching is complete, increasing the likelihood of survival of the resulting progeny.

7 - Does the known geographical distribution of the organism include ecoclimatic zones comparable with those of the Risk Assessment Area or sufficiently similar for the organism to survive and thrive?

Response: Yes (see Figures 1 & 2).

Many of the Western European countries in which *S. luciopera* has successfully established populations are climatically matched to that of the UK, including countries such as France, the Netherlands and Belgium (Gallardo & Aldridge, 2013).

Figure 1. Distribution map of *S. lucioperca* (Freyhof & Kottelat, 2008, 2018). Mustard denotes native populations, purple is introduced populations.

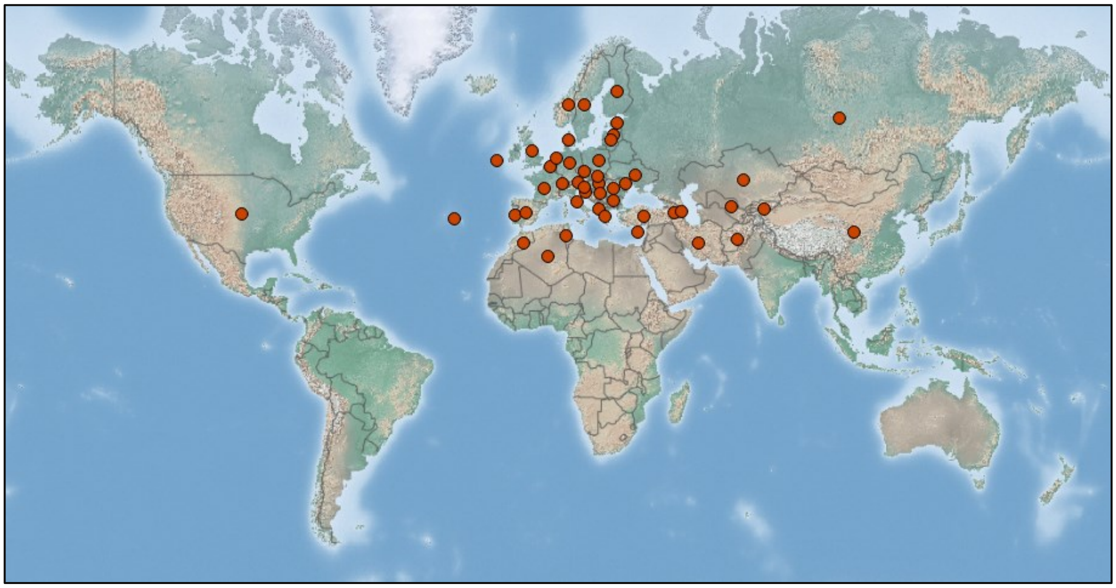

Figure 2. Map of global distribution of *S. lucioperca* (Godard & Copp, 2017).

8 - Has the organism established viable (reproducing) populations anywhere outside of its native range?

Response: Yes.

Out of the 26 countries where introductions of *S. lucioperca* have occurred, 22 have viable, naturally reproducing populations (Godard & Copp, 2017). *Sander lucioperca* has established populations in most European countries, in addition to those in Asia, Africa, Netherlands, France, Spain, Denmark and the UK (Froese & Pauly, 2011). Viable populations of *S. lucioperca* have been confirmed in both lentic and lotic waterbodies in England (Lever, 2009).

9 - Can the organism spread rapidly by natural means or by human assistance?

Response: Yes, both.

Sander lucioperca has the ability to spread via natural range expansion, in addition to anthropogenically mediated means. Arguably, one of the first lotic introductions to the Relief Channel was human-assisted and deliberate (Linfield & Rickards, 1979), with the spread of *S. lucioperca* thereafter occurring predominantly via natural mechanisms, through a highly interconnected drain system in East Anglia. Subsequent to this, humans have then assisted the further dispersal of *S. lucioperca* to new riverine catchments via illegal fish movements and introductions (e.g. Hickley, 1986, Copp *et al*., 2003).

Copp *et al*., (2003) suggest that locks may not be a hindrance to the upstream migration of *S. lucioperca*, with the discovery of a specimen upstream of Teddington Lock on the Lower Thames (presumed to have migrated from the River Lee). Additionally, mature *S. lucioperca* show a high level of hypo-osmoregulation, tolerating salinities up to 29-33 ppt. after gradual increases and up to 8-16 ppt. after sudden transfer (Brown *et al*., 2001), which suggests that *S. lucioperca* are capable of using brackish waters to reach un-invaded freshwater systems.

Sander. lucioperca are known to undertake spawning migrations, with Koed *et al*., (2002) reporting radio-tagged specimens travelling more than 30 km upstream. Fickling's (1982) findings support this behavior, with visual-tagged *S. lucioperca* traversing over 35 km in less than 60 days with one individual travelling 2.87 km in a single day.

Vehanen & Lahti (2003) traced radio-tagged *S. lucioperca* and found rates of movement up to 7.6 Km/day^{-1}, much greater than those reported by Fickling & Lee (1983) (Note: citation as published is Pickling & Lee, 1983) of 2.9 Km/day^{-1}. Thus, *S. lucioperca* are known to be a highly mobile species (e.g. Jepsen *et al*., 2000, Vehanen & Lahti, 2003) undertaking seasonal migrations with increased movement rates in summer to autumn and a more sedentary behavior during winter (Vehanen & Lahti, 2003). Such traits will facilitate their natural spread and further establishment in the UK, in addition to anthropogenic introductions. Indeed, it has been noted that canals invaded by *S. lucioperca* provide connections to novel drainages, further facilitating the dispersal and secondary invasion of *S. lucioperca* into new environments (Eschbach *et al*., 2014).

10 - Could the organism as such, or acting as a vector, cause economic, environmental or social harm in the Risk Assessment Area?

Response: Yes.

Sander lucioperca are an effective piscivore and often used in biomanipulation studies (Mehner *et al.,* 2004), suggesting *S. lucioperca* is a strong top-predator, which may have community-wide implications through intraguild competition and/ or direct predations (Kopp *et al.,* 2009). Not only is it an effective predator of small planktivorous cyprinids (Schulze *et al.,* 2011), young-of-year *S. lucioperca* directly compete with cyprinids for zooplankton (Collette *et al.,* 1977, Nolan & Britton, 2018) and lead to changes in community structure.

Sander lucioperca is also known to predate upon the already pressured, critically endangered European eel *Anguilla anguilla* (GBNNSS, 2016), BAP Priority Species *O. eperlanus* (Welch, 1985), bullhead *Cottus gobio* (Smith *et al*., 1996) and vendace *Coregonus albula* (Kangur & Kangur, 1988), the UK's rarest freshwater fish species. When Linfield (1984) examined the potential impact of *S. lucioperca* in East Anglian waters, he found that the traditionally high biomass of cyprinids in fisheries containing *S. lucioperca* had fallen to a level below those known not to contain *S. lucioperca*, with roach *Rutilus rutilus* populations suppressed where they existed in sympatry with *S. lucioperca*. Nolan & Britton (2018) also showed that the native *R. rutilus* and *P. fluviatilis* were the dominant prey items found in *S. lucioperca* stomachs, suggesting prey-selectivity. In France, Kopp *et al*. (2009) showed *S. lucioperca* to occupy a higher trophic position to the other piscivorous fish present (the native pike, *E. lucius* and the introduced Wels catfish, *S. glanis*), suggesting potential impacts on the predator guild.

The introduction of *S. lucioperca* into Lake Egridir, Anatolia in 1955 saw 'rapid and irreversible' consequences, with the extinction of endemic cyprinid species (*Phoxinellus* spp.), displacement of *Aphanius chantrei* and a significant reduction in number of other species, including *Cyprinus carpio* and *Vimba vimba* (Yerli *et al.,* 2013). Perhaps one of the most unexpected consequences of this introduction was the proliferation of the Turkish crayfish *Astacus leptodactylus* populations within Lake Egridir – an introduced species that was already present within the lake prior to the introduction of *S. lucioperca*, but populations were limited by depredation of their eggs by native cyprinids and cobitids (Crivelli, 1995). Suppression of the indigenous fish populations by *S. lucioperca* removed this predation pressure, facilitating the explosion of the *A. leptodactylus* population within the lake.

Sander lucioperca can hybridise with perch *P. fluviatilis* (Kahilainen *et al.,* 2011), the only species of the Genus *Perca* native to GB, but examples are scarce. A single specimen, genetically determined to be a hybrid of *S. lucioperca* x *S. volgensis* was found in Hungary (Müller *et al*., 2010) but instances of such hybridization are rare and no populations of the non-native *S. volgensis* are known to exist in GB. Lambert (1997) notes that *S. lucioperca* is a vector for the trematode *Bucephalus polymorphus*, a parasite attributed to the decline of cyprinid populations in France in the 1960's & 1970's. *S. lucioperca* are also a host for a variety of fish parasites common to UK freshwater fish, including the non-native copepod *Ergasilus sieboldi* (Moravec, 2001) which is currently subject to Environment Agency fish movement controls.

Debate still surrounds the desirability of *S. lucioperca* as a sport fish in UK waterbodies. Ecological risks aside, *S. lucioperca* have a strong following of recreational anglers who enjoy fishing for this species, travelling long distances to fish for them (e.g. Nolan *et al*., 2019). Conversely, other anglers attribute the presence of *S. lucioperca* for the decline of their sport and actively remove them upon capture. Indeed the Canal and Rivers Trust state that the result of *S. lucioperca* dominating fish stocks in their waters presents "a loss of (angling) amenity, income and participation opportunities" (Canal & Rivers Trust, 2013). Smith and Ellis (2018) estimated the loss of fishery income on some canals as a result of *S. lucioperca* invasion to be in excess of £96,000 per annum, with an additional cost of managing *S. lucioperca* populations through removals costing circa £40,000 per annum (Smith, *pers comm*.)

Entry Summary

Please estimate the overall likelihood of entry into the Risk Assessment Area for this organism (please comment on the key issues that lead to this conclusion).

Response: Very Likely

Confidence: Very High

Comments (include list of entry pathways in your comments):

Sander lucioperca has already entered GB and introduction pathways are still open, possibly permitting further introductions. That said, given the extent and number of established *S. lucioperca* populations in GB, it is likely that any subsequent introductions are to be from these populations, facilitating range expansion.

Establishment Summary

Please estimate the overall likelihood of establishment (mention any key issues in the comment box)

Response: Very Likely

Confidence: Very High

Comments (please state where in GB this species could establish in your comments):

Further to Q5, *S. lucioperca* has already established self-sustaining populations in several English catchments and stillwaters, with young-of-the-year individuals captured during the Environment Agencies Fisheries monitoring programme (Environment Agency, unpublished data) and Nunn *et al.* (2007) inferring the presence of 0+ *S. lucioperca* in the Rivers Trent and Avon as evidence of self-sustaining populations. Climatically, there appears to be no barrier to *S. lucioperca* colonization in Wales, Scotland or the north of England, as *S. lucioperca* have successfully established populations at greater latitudes in Europe (e.g. Gallardo & Aldridge, 2013)

Spread Summary

Please estimate overall potential for spread (using the comment box to indicate any key issues).

Response: Intermediate

Confidence: High

Comments (include list of entry spread in your comments):

Given *S. lucioperca* have established populations in numerous riverine catchments, their primary mechanism of spread will be natural colonisation of connected waterbodies, albeit at a relatively slow rate. Koed *et al.* (2002) and Fickling (1982) demonstrated that *S. lucioperca* are capable of undertaking migrations (upstream and downstream) in excess of 30 km. The ability of *S. lucioperca* to traverse in-river obstacles, such as locks and impoundments (Copp *et al.,* 2003) will further facilitate their range expansion.

Additionally, the propensity for humans to transfer *S. lucioperca* to previously uncolonised waterbodies, unconnected to established populations has not waned, despite such introductions being an offence under the Wildlife and Countryside Act and limited under the Keeping and Introduction of Fish Regulations 2015 (previously the Import of Live Fish Act, 1980).

Further dispersal may also be facilitated by water transfers between catchments containing *S. lucioperca* propagules and those which are currently free of this species, a pathway which has been attributed to the introduction of *S. lucioperca* into Anglian reservoirs. The invasion of canal systems by *S. lucioperca* also provides a mechanism for their further dispersal, with the canal network acting as conduits to currently un-invaded waters.

Impact Summary

Overall impact rating (please comment on the main reasons for this rating)

Response: Moderate
Confidence: Medium

Comments (include list of impacts in your comments):

Adult *S. lucioperca* are obligate piscivores and have been shown to predate upon native species subsequent to their introduction, exerting top-down depredation and inducing predatory-prey imbalance. Additionally, young-of-year *S. lucioperca* directly compete with young-of-year and juvenile cyprinid species due to niche sharing and dietary overlap. *Sander lucioperca* can also show a definite preference for certain prey choice and can almost exclusively predate upon a single species, including those already listed as Critically Endangered and Priority BAP species (see Q 4 for further details). Work undertaken by Smith (1998) suggests impacts attributed to *S. lucioperca* are greater in heavily-trafficked canals than in those where boat traffic is limited. *Sander lucioperca* have also shown to have a degree of dietary overlap of prey items with the native piscivore, *E. Lucius* and increase predation pressure across a wider range of prey items than would be exploited by native species alone. That said, evidence of impact directly attributed to *S. lucioperca* in GB waters is still limited, but this is likely due to the limited number of GB-specific studies and determination of the true ecological consequences of *S. lucioperca* throughout their invasive range would benefit from further work. Impacts on native biota subsequent to the introduction of *S. lucioperca* have been documented from countries outside of the risk-assessment area, supporting the response to this summary.

Economic implications have been noted as a result of *S. lucioperca* invasion. For example, Smith and Ellis (2018) estimated the loss of fishery income on some canals as a result of *S. lucioperca* invasion to be in excess of £96,000 per annum, with an additional cost of managing *S. lucioperca* populations through removals costing circa £40,000 per annum (Smith, *pers comm*.)

Climate change

What is the likelihood that the risk posed by this species will increase as a result of climate change?

Response: Medium
Confidence: Medium

Comments (include list of impacts in your comments):

Temperature has a strong effect on the growth of *S. lucioperca* with warm summers enhancing growth and reducing size-dependent mortality (Ruuhijärvi *et al.,* 1996). Hermelink *et* al. (2011) noted that temperature was also a key factor in the onset of maturity in *S. lucioperca*, with temperatures of 12-15 °C required for maturation. *Sander lucioperca* have also established populations throughout Europe, in countries climatically matched to GB and in those with greater mean annual temperatures. Additionally, Lappalainen *et al.,* (2003) notes that sexual maturity of *S. lucioperca* is attained at a smaller size and younger age in Southern (Baltic) populations, when compared to those in Northern populations. Further research is required to determine the mechanisms behind interannual variability of *S. lucioperca* reproduction and how this may be affected by climate change. However, Pekcan-Hekim *et al.*, (2011) found that warmer summers produce stronger *S. lucioperca* year-classes.

Copp *et al.,* (2003) suggests that spate events facilitated the downstream movement of *S. lucioperca* in the River Lee, which could be a viable transfer mechanism in other catchments, particularly if flooding magnitude, duration and frequency is increased as a result of climatic changes. Flooding events will also facilitate in the escapement of *S. lucioperca* out of stillwaters within floodplains, or those with direct hydrological connections to the fluvial environment.

Conclusion

Please estimate the overall risk (comment on the main reasons for this rating)

Response: Medium
Confidence: Medium

Comments:

Sander lucioperca are already present in a number of catchments within GB and have expanded their range through natural and anthropogenic means. At present, the vast majority of peer-reviewed literature on the biology and impact of introduced *S. lucioperca* populations is from countries outside of the risk assessment area (GB). However, GB specific examples have demonstrated that *S. lucioperca* can successfully establish viable populations within GB, with subsequent impacts on native fish species noted, in addition to depredation on critically endangered and threatened species. Economic losses have been attributed to the invasion of *S. lucioperca* in some canal systems, with additional on-going expenditure incurred as a result management activities. Further research is required to determine the long-term effects of *S. lucioperca* introductions and their impact on native biota, particularly with respect to climate change scenarios. Additionally, further work is required to investigate potential future management options.

References

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