Risk assessment for brown trout *Salmo trutta* in South Africa

Taxonomy
Salmo trutta Linneaus, 1758
Class: Actinopterygii;
Order: Salmoniformes;
Family: Salmonidae;
Genus: *Salmo*;
Species: *Salmo trutta*;
Morphs: *Salmo trutta* morpha *trutta*;
Salmo trutta morpha *fario*;
Salmo trutta morpha *lacustris*
Common name: brown trout

Originating environment and climate constraints
Brown trout are native to Europe and western Asia (Figure 1), occurring naturally as far north as Scandanavia and as far south as the Mediterranean coast (Picker and Griffiths 2011; McIntosh et al. 2012). They are thus adapted to climates ranging from sub-arctic to warm-temperate. The species has a diadromous and potadromous form, thus can occur in mountain streams, large rivers, lakes, estuaries and in marine environments (McIntosh et al. 2012). In freshwater environments, its major physical constraint appears to be temperature. Brown trout have been recorded in the laboratory to have an optimal growth range of 13.1-13.9°C, and incipient lethal maximum temperature (not survivable for more than a week) of 24.7°C, and an ultimate lethal temperature (not survivable for more than 10 minutes) of 29.7°C (Elliot 2000). They are nonetheless able to occupy rivers that breach these biological constraints by seeking out thermal refugia such as deep pools within the river (Elliot 2000).

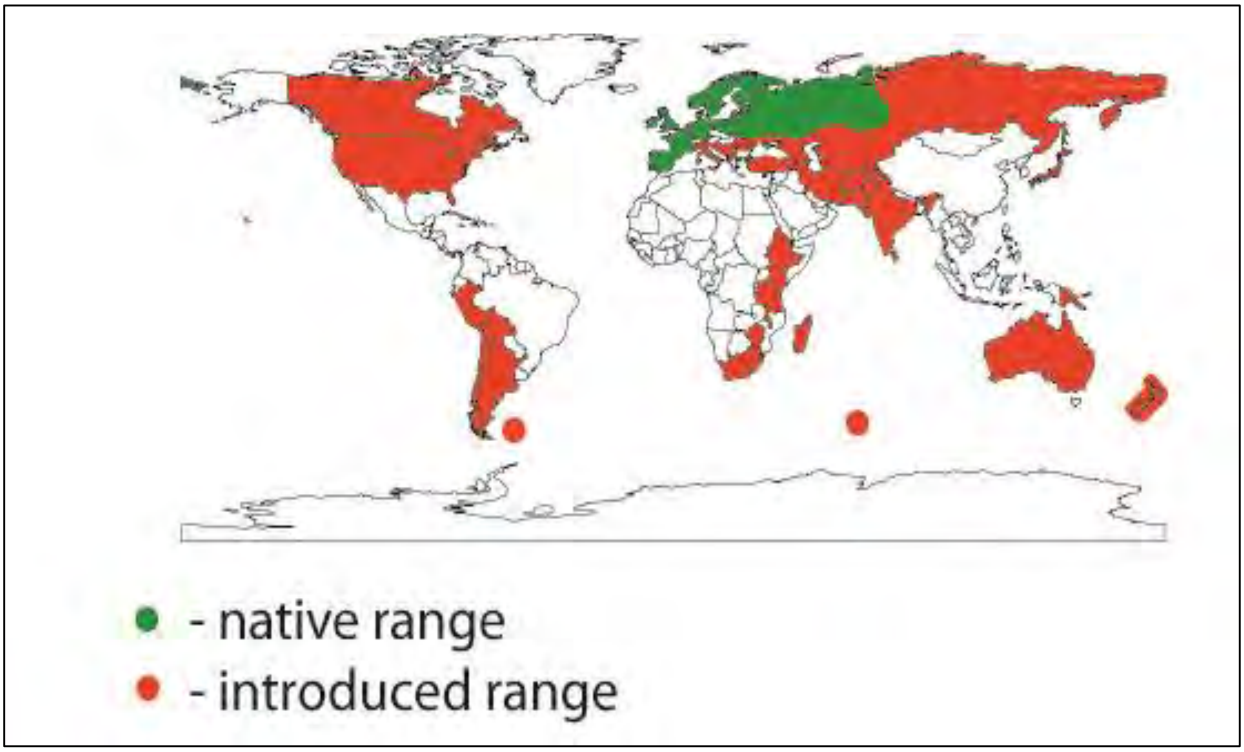

Figure 1: Global native and introduced range of brown trout (from Picker and Griffiths, 2011).

Reproductive strategy and potential, dispersal abilities
Brown trout spawn in autumn-winter, using gravel nests (redds) in fast flowing river reaches to lay their eggs (McIntosh et al 2012). Spawning occurs at temperatures of 4-6°C, with incubation restricted to temperatures below 16°C

(Ojanguren and Brana 2003). Fecundity is widely variable, ranging from 147 to 10000 eggs per female (Froese and Pauley 2014), with environmental variables such as local food availability potentially driving clutch size (Lobon-Cervia et al. 1997). They are known to migrate up to 23 km within a river network to access suitable spawning habitat (Ovidio et al. 1998).

Invasive tendencies and taxonomic predisposition
Brown trout are listed among the world's top 100 worst invaders (Lowe et al. 2000). The Salmonidae are one of the most widely introduced groups of fishes in the world, and have successfully established populations on most of the world's continents (Welcomme 1988). In the southern hemisphere, the brown trout and rainbow trout (*Oncorhynchus mykiss*) have both shown a propensity to rapidly establish successful populations, many of which have had a negative effect on the receiving environment (Garcia de Leaniz et al. 2010).

History of propagation, introductions and naturalization
Brown trout have been transported and propagated for fisheries in North America, South America, southern and eastern Africa, the Indian sub-continent, Oceania, and several other islands around the world (Welcomme 1988; Garcia de Leaniz et al. 2010; Figure 1). In many of these countries, government sponsored rearing and stocking programmes ensured the successful establishment of the species within the receiving river environments (Garcia de Leaniz et al. 2010). The result is that naturalization of brown trout has occurred in the majority of countries in which it was introduced, with the populations persisting after the stocking programmes were discontinued in Kenya, Lesotho, Madagascar, Malawi, South Africa, Swaziland, Zimbabwe, India, Japan, Pakistan, Cyprus, Canada, U.S.A., Australia, New Zealand, Papua New Guinea, Argentina, Bolivia, Chile, Falkland Islands, Panama and Peru (Welcomme 1988).

Dietary requirements
Brown trout are generalist predators, feeding primarily on aquatic invertebrates in their native range, but able to feed on fish as well as terrestrial invertebrates and vertebrates such as amphibians, reptiles and small mammals (Gillespie 2001; Gray and Zollhoefer 2006; Budy et al. 2013). Brown trout have been shown to switch to larger, more nutritious prey such as fish across their introduced range, in what appears to be a behavioural adaptation to maximize metabolic performance and thus enhance survival (Budy et al. 2013).

Ecosystem impacts
In the U.S.A, and in countries throughout the southern hemisphere, brown trout have been demonstrated to negatively impact the receiving ecosystem (Garcia de Leaniz 2010; Budy et al. 2013). The impacts of the species are evident at the individual, population, community and ecosystem level (Townsend 2003; Simon and Townsend 2003). At the individual level, native insects have been shown to alter their drift behaviour to avoid predation, while native fish species have been forced into marginal habitats through competition with and predation by brown trout (Townsend 2003).

At the population level, extirpations and catchment-wide extinctions, particularly among galaxioid fish species, have been recorded in New Zealand, Australia, Chile and Argentina following the establishment of brown trout (McDowall 2006). The complete extinction of the New Zealand grayling (*Prototroctes oxyrhynchus*) has been attributed to the introduction of brown trout and rainbow trout, together with habitat modification (McDowall 2006). Population-level impacts have also been recorded amongst amphibians. Population declines of spotted tree frog (*Litoria spenceri*) in Australia have been demonstrated to be the result of predation by brown trout and rainbow trout (Gillespie 2001). In South Africa, brown trout and rainbow trout together were implicated in the disappearance of Natal cascade frog (*Hadromophryne natalensis*) from streams in the uKhahlamba Drakensberg Park World Heritage Site (Karssing et al. 2012). In the Keiskamma River system, Eastern Cape, the presence of brown and rainbow trout was the only consistent predictor for the absence of native fishes in trout-occupied river reaches (Ellender 2013). This absence represented the loss of 30% of the native species historical global distribution (Ellender 2013).

At the community level, brown trout in New Zealand have been shown to alter algal biomass in streams by suppressing grazing by invertebrates, which the trout preyed upon more efficiently than native fish predators (Simon and Townsend 2003). This trophic cascade has ecosystem-level consequences, including altered nutrient cycling. Streams where native fish have been replaced by brown trout were found to have higher nitrogen retention than those streams where the native fish still occurred (Simon et al. 2004).

Ability to hybridize with native species

Brown trout hybridize with Atlantic salmon (*Salmo salar*) in Spain where both species are native (Garcia de Leaniz and Verspoor 1989), and in Newfoundland where brown trout are introduced (Verspoor 1988). There are however no species native to South Africa that would be vulnerable to hybridization with brown trout.

Suitability of receiving environment in South Africa

Brown trout have been successfully established in mountain streams within several river catchments in South Africa (Figure 2). These include the Umkomaas, Umgemi, Umvuti, Tugela, Bushmans, Buffalo, Phongolo, Breede, Olifants-Doring, Keiskamma, Orange, Blyde and Incomati catchments (de Moor and Bruton 1988). National Fish Collection locality records for the species also include the Mtshezana, Mooi, Diep, Keurbooms and Mgeni catchments, though the establishment state of these populations is unclear (SAIAB 2014).

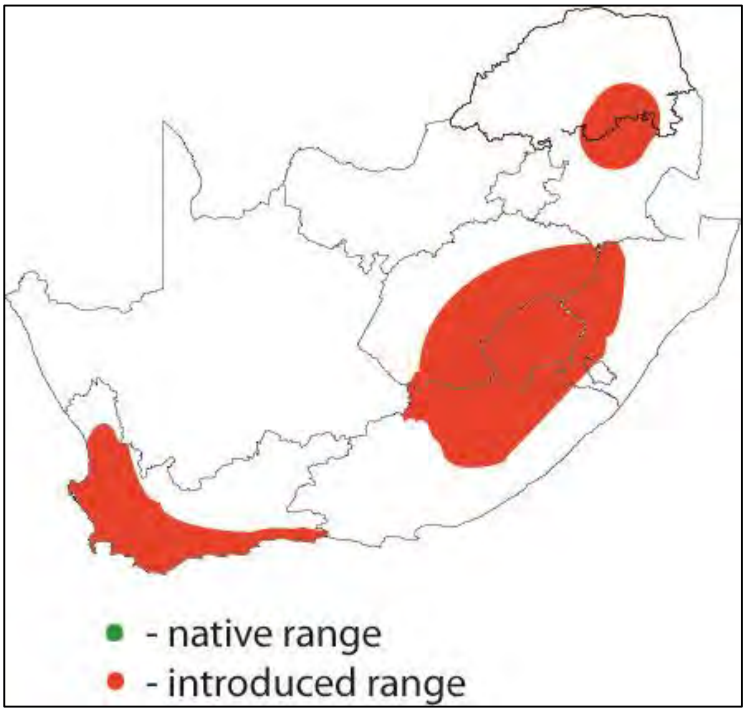

Figure 2: Map of current distribution of brown trout across South Africa (from Picker and Griffiths 2011)

i) Climate match

A country-wide analysis of environmental suitability for salmonids (using environmental associations between brown trout and rainbow trout and the habitats they currently persist in) was performed as part of a fisheries development scoping study for the Water Research Commission (Weyl and Keevey 2012). The analysis indicates that many mountainous areas, from the Cape Folded Mountains to the Eastern Escarpment, are suitable for the establishment of these species (Figure 3).

ii) Habitat

Brown trout require clear, well-oxygenated streams with rocky substrates that do not exceed water temperatures of 16°C in winter and 25°C in summer (Elliot 2000; Skelton 2001; Ojanguren and Brana 2003). Such habitats are characteristic of headwater tributary streams in the Cape Folded Mountains and Eastern Escarpment, where the species is already established in multiple localities (Figure 2).

iii) Presence of natural enemies, predators and competitors

In South Africa, the longfin eel (*Anguilla mossambica*) is the only fish species that has a congeneric analogue in Europe (the European eel, *Anguilla anguilla*) that could be considered a natural predator and/or competitor for brown trout, and interactions between these species has been shown to be minor (Mann and Blackburn 1991). No other native South African fish species pose a credible competitive or predatory threat to brown trout, though other introduced sport fishes such as rainbow trout and black basses (*Micropterus* spp.) could do so in streams where they occur. It is also likely that piscivorous birds like the malachite kingfisher (*Alcedo cristata*) would feed on juvenile brown trout if they occurred in the vicinity of a stream where the trout were introduced.

iv) Presence of reproductively compatible species

No such species are native to South Africa.

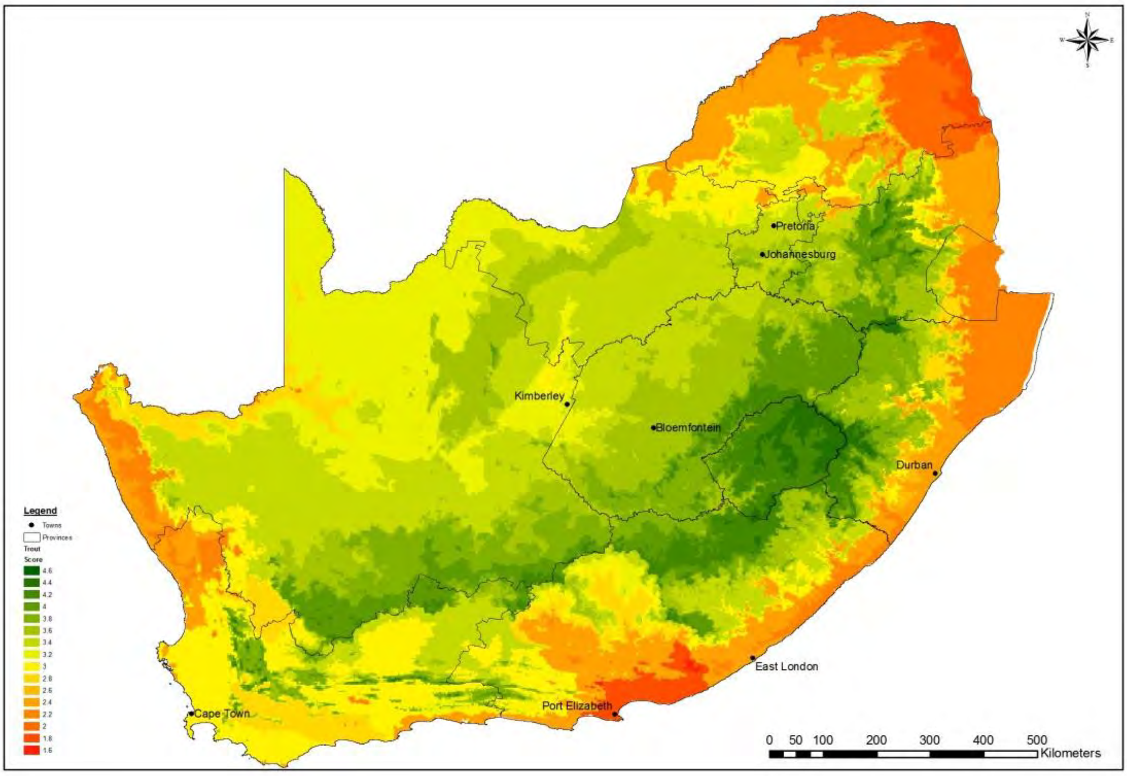

Figure 3: GIS map showing areas suitable for trout (in green), based on conductivity, altitude, mean annual rainfall, mean annual air temperature and mean winter air temperature (from Weyl and Keevey 2012).

Potential as a vector for other introduced organisms

Although brown trout introduced into New Zealand have been shown to host 17 parasites in that country (Townsend 2003), it is unclear as to whether any of these were introduced with the trout. The international transfer of brown trout primarily as ova has mitigated their ability to act as a vector of invasive pathogens (Townsend 2003).

River-specific case study: Historical retrospective assessment of the Sterkspruit River, KwaZulu-Natal

In the following risk assessment, we use data from the published literature to provide a hypothetical risk assessment for one "case study" river, in order to demonstrate how a full risk analysis for brown trout would be completed on a single stream. The main information source for completing this historical retrospective risk analysis (Section 2 in the table) is Karssing et al. (2012).

Annexure A. Risk Assessment Table – Brown Trout (*Salmo trutta L.*) – In South Africa

Risk Assessment Framework Considerations	Synopsis of information	Reference
(1) A risk assessment must consider-		
(a) information regarding the relevant species, including-		
(i) the taxonomy of the species, including its class, order, family, scientific name (if known), genus, scientific synonyms and common names of the species;	*Salmo trutta L* Linneaus, 1758 Class: Actinopterygii Order: Salmoniformes Family: Salmonidae Genus: Salmo Species: *Salmo trutta*	

	Morphs *Salmo trutta* morpha *trutta* *Salmo trutta* morpha *fario* *Salmo trutta* morpha *lacustris* Common Name Brown Trout	
(ii) the originating environment of the species, including climate, extent of geographic range and trends;	Native to Europe and western Asia, adapted to a range of climates from sub-arctic to Mediterranean. Primarily limited by water temperature. Metabolic growth ceases below 2.9°C and above 19.5°C. Incipient lethal temperature is 24.7°C; ultimate lethal temperature is 29.7°C.	McIntosh et al. (2012) Elliot (2000)
(iii) persistence attributes of the species, including reproductive potential, mode of reproduction, dispersal mechanisms and undesirable traits;	Brown trout require gravel nests in fast flowing river reaches to lay their eggs. Spawning occurs at 4-6°C, with incubation restricted to temperatures below 16°C. Fecundity ranges from 147 to 10000 eggs per female, can migrate 23 km to spawn.	Froese & Pauley (2014) McIntosh et al. (2012) Ojanguren & Brana (2003) Ovidio et al. (1998)
(iv) invasive tendencies of the species elsewhere and taxonomic predisposition;	The Salmonidae are successfully established on most continents. Many successful populations have had a negative effect on the receiving environment.	Welcomme (1988) Garcia de Leaniz et al. (2010)
(v) the history of domestic propagation or cultivation of the species, introductions and the extent of naturalization;	Brown trout have been transported to, and become naturalized within Kenya, Lesotho, Madagascar, Malawi, South Africa, Swaziland, Zimbabwe, India, Japan, Pakistan, Cyprus, U.S.A., Australia, New Zealand, Papua New Guinea, Argentina, Bolivia, Chile, Falkland Islands, Canada, Panama and Peru.	Welcomme (1988)
(vi) nutritional or dietary requirements of the species and, where applicable, whether it has a specialist or generalist diet;	Generalist predators on aquatic vertebrates and invertebrates. Tend to shift from eating insects to fish when introduced into new ecosystems.	Gillespie (2001) Budy et al. (2013)
(vii) the ability of the species to create significant change in the ecosystem; and	Behavioural changes in prey invertebrates and fish. Population-level declines and extirpations of fish and amphibian species. Shifts in community structure resulting in trophic cascades and changes in nutrient cycling.	Ellender (2013) Gillespie (2001) Karssing et al. (2012) Simon & Townsend (2003) Townsend (2003)
(viii) the potential to hybridize with other species and to produce fertile hybrids; and	No SA species vulnerable to this impact.	
(b) information regarding the restricted activity in respect of which the permit is sought, including-		
(i) the nature of the restricted activity;	Aquaculture, release and restocking of riverine systems	
(ii) the reason for the restricted activity;	Fish production and recreational fishing	
(iii) the location where the restricted activity is to be carried out;	Not specified in this assessment but suitable rivers and dams in South Africa	
(iv) the number and, where applicable, the gender of the specimens of the species involved; and	Not specified in this assessment	
(v) the intended destination of the specimens, if they are to be translocated; and	Not specified in this assessment	
(c) information regarding the receiving environment, including-		
(i) climate match;	Temperature mapping suggests much of South Africa's mountainous regions would support brown trout establishment.	Weyl & Keevey (2012)

(ii) habitat;	Headwater streams favoured by brown trout are available throughout South Africa's mountainous regions.	
(iii) the presence of natural enemies, predators and competitors; and	Only Longfin eel (*Anguilla mossambica*), but this species is likely not a significant natural enemy. Piscivorous birds may prey on juvenile trout.	Mann & Blackburn (1991)
(iv) the presence of potentially reproductive compatible species.	None present.	
(2) A risk assessment carried out in terms of subregulation (1) must identify-	Retrospective case studies of *S. trutta* introduction to Strerkspruit River, KZN, and Keiskamma River ECP	
(a) the probability that the species will naturalize in the area in which the restricted activity is to be carried out or in any other area elsewhere in the Republic;	Self-sustaining population in parts of most major river catchments. High risk of naturalisation in areas introduced that meet physiological requirements of *S. trutta*.	De Moor & Bruton (1988) SAIAB (2014)
(b) the possible impact of the species on the biodiversity and sustainable use of natural resources of-	Retrospective case study of *S. trutta* introduction to Strerkspruit River, KZN	
(i) the area in which the restricted activity is to be carried out; and	Confirmed impact on densities and distributions of native frog (*Hadromophryne natalensis*) in Sterkspruit River.	Karssing et al. (2012)
(ii) in any other area elsewhere in the Republic;	Confirmed impact on densities and distributions of native frog (*Hadromophryne natalensis*) in Mbovaneni River. Confirmed impact on native minnows in Keiskamma River system, Eastern Cape.	Karssing et al. (2012) Ellender et al. (2014)
(c) the risks and potential impacts on biodiversity by the species to which the application relates;	High risk of density reduction as well as decreased spatial distribution within the stream.	Karssing et al. (2012)
(d) the risks of the specimen serving as a vector through which specimens of other alien species may be introduced;	No evidence for brown trout acting as a vector for introduced pathogens.	
(e) the risks of the method by which a specimen is to be introduced or the restricted activity carried out serving as a pathway through which specimens of other alien species may be introduced; and	Low risk of introducing other species via directed stockings of *S. trutta*.	
(f) any measures proposed in order to manage the risks.	No mitigating measures addressing introduction of non-target species likely to be pursued.	

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Annexure C: Summary for Brown Trout in South Africa

Invasive status: ☒ Invasive ☐ Under surveillance ☐ Not invasive *[If invasive, fill in the rest of the section.]*

Range:
☐ Whole of South Africa
☐ Specific Provinces/Biomes:
☒ Specific habitats: Cool, clear waters throughout South Africa.

Ability to spread:
☒ High: In suitable environments (i.e. cool headwater streams).
☐ Moderate
☐ Mild

Ability to control:
☐ Eradication possible
☐ Effective control possible
☐ Very difficult to control in areas invaded
☒ Beyond control in areas invaded: Control not possible, except in discrete tributaries, and at a high cost.

Impacts:
☒ High Significant threat in suitable waters in which it has not yet invaded. Possible extirpation of indigenous fish species in some areas introduced. High risk of significant impacts on fish, amphibians, invertebrates, and functioning of systems.
☐ Moderate
☐ Low

Known utility:
☒ High Highly valued species for recreational fishing, with significant tourism benefits. Aquaculture potential.
☐ Moderate
☐ Low

Recommended Category:
☐ Category 1a ☐ Category 1b ☒ Category 2 ☐ Category 3 *[Tick as many as apply, where differentiation needed.]*
Prohibit in all systems in which it does not occur. In areas already invaded, Category 2 for Protected Areas, aquaculture facilities and stocking of rivers, but not listed in dams and rivers, and stocking of dams. Exempt catch-and-release. Fishing unrestricted.

Recommended Restricted Activities:
☒ a. Importing into the Republic, including introducing from the sea, any specimen of a listed invasive species.
☒ b. Having in possession or exercising physical control over any specimen of a listed invasive species. Not prohibited areas.
☒ c. Growing, breeding or in any other way propagating any specimen of a listed invasive species, or causing it to multiply. No Permit required for breeding in dams in catchments in which brown trout occurs. Permit required for aquaculture facility.
☒ d. Conveying, moving or otherwise translocating any specimen of a listed invasive species. Depends on circumstances.
☐ e. Selling or otherwise trading in, buying, receiving, giving, donating or accepting as a gift, or in any way acquiring or disposing of any specimen of a listed invasive species. Acceptable for live specimens – threat covered in (h) and (l) below.
☒ f. Spreading or allowing the spread of any specimen of a listed invasive species. Depends on circumstances.
☐ g. Releasing any specimen of a listed invasive species. Not necessary as key threat covered in (h) below.
☒ h. The transfer or release of a specimen of a listed invasive fresh-water species from one discrete catchment system in which it occurs, to another discrete catchment system in which it does not occur; or, from within a part of a discrete catchment system where it does occur to another part where it does not occur as a result of a natural or artificial barrier.
☒ i. Discharging of or disposing into any waterway or the ocean, water from an aquarium, tank or other receptacle that has been used to keep a specimen of an alien or a listed invasive species. Important for aquaculture, including RAS systems.
☐ j. Catch and release of a specimen of a listed invasive fresh-water fish or listed invasive fresh-water invertebrate species.
☒ k. The introduction of a specimen of an alien or a listed invasive species to off-shore islands.
☒ l. The release of a specimen of a listed invasive fresh-water fish species, or of a listed invasive fresh-water invertebrate species, into a discrete catchment system in which it already occurs. Requires Permit for aquaculture, in rivers and Protected Areas.

Annexure D: Recommendations for Brown Trout (Bio-security Unit, Department of Environmental Affairs)

1. The brown trout should be listed as an invasive species.

2. It should be acknowledged that it will not be possible to eradicate brown trout in South Africa.

3. To extirpate brown trout (remove completely in local areas) is only possible in a small number of cases, and should only be considered if this has significant benefits for critically endangered or endangered fish species, or critical ecosystems. As this is an option open to Government, there is no need to reflect this in the listing of trout.

4. Brown trout has potential as an aquaculture species (although rainbow trout preferred), in fresh-water systems, aside from its established and important status for fly-fishing, and the associated tourism and recreational benefits thereof. Although the exact current value of these industries is not quantified, it is said to be worth billions of Rands, and that the potential for growth, particularly for trout aquaculture (and associated food security benefits), is high.

5. Given the clearly important economic value of brown trout, and the fact that it will be virtually impossible to extirpate the trout from areas that they have already invaded, trout should not be listed in these areas, other than requiring a Permit for aquaculture facilities, in Protected Areas or for stocking in rivers. This will facilitate the optimising the industries in such invaded areas, and protect investments that have already been made.

6. It is recommended that brown trout should not be listed for being in dams in systems in which the species has already invaded. No Permit is regarded as necessary. It is further recommended that the stocking of brown trout in dams in these systems should not require a Permit. A consequence of this would further be that the transportation of live trout for this purpose would not require a Permit. The stocking and keeping of trout in these dams will have no impact on the damage caused by brown trout as an invasive species. It will also help to promote the optimising of brown trout in dams in systems in which trout have invaded.

7. There is no sense in restricting the catch-and-release of brown trout. It will not have a material impact on the invasion impact of trout in rivers, wetlands and lakes, and will be functionally impossible to regulate. It is recommended that this activity be exempted.

8. The listing of brown trout as Category 2 species is recommended to be for (a) aquaculture facilities; (b) key Protected Areas (National Parks, Provincial Reserves, Mountain Catchment Areas and Forestry Reserves), and (c) for introduction into rivers in systems in which the brown trout already exists. Investigate Permit for RAS systems.

9. The most important prohibition must be that brown trout should be prohibited from introduction into discrete catchment systems in which they do not occur. It is acknowledged that the Aquaculture Unit in the Department of Agriculture, Forestry and Fisheries is interested in promoting aquaculture in all areas, using Recirculating Aquaculture Systems (RAS) and/or triploid specimens and/or single-sex specimens. The recommendation is that this should be explored further, and that the Notice can later be changed to allow for this (with a joint Permit from DAFF and DEA), should the potential be seen to pose no threat for further invasions.

10. It is recommended that the above combination of measures will give the necessary legal protection for the potential further invasions by trout, whilst enabling the full economic and social benefits from trout in areas in which they already occur. Given the sensitivity of the issue, and because more work must be done to establish where trout legally occur, it is further recommended that all those with existing, legal Permits or permissions for brown trout be exempted from the requirement for a Permit in terms of the NEM:BA Regulations on alien and invasive species.

11. Finally, it is recommended that those with Permits for brown trout should not be at risk of losing their Permits as a result of a transfer of the property on which the trout are stocked. Permits should only be considered for refusal or retraction if there is a failure to adhere to Permit conditions, or if there is a general retraction of Permits in an area where all invasives are to be extirpated.

May 2014.

Comments on the Risk Assessments on rainbow trout and brown trout produced by the Environmental Programmes Directorate of the Department of Environmental Affairs, South Africa: May 2014

Professor Mike Bruton MSc, PhD, DSc, FLS, FRSSAfr

1. The Department of Environmental Affairs should be congratulated for the fair way in which it has handled this delicate and complex issue. I believe that the Department has achieved the right balance between protecting indigenous aquatic biodiversity and ecosystem processes and promoting commercial and recreational activities associated with trout.

2. The Department has also been realistic about what can practically be achieved and what cannot be achieved.

3. The Department has provided a very adequate and accurate overview of our knowledge of the biology and environmental impacts of rainbow and brown trout worldwide.

4. It is good to see, and be able to quote, studies done abroad on the complex impacts of trout, not only on direct prey species, but also on species further out in the food web and on broader ecosystem processes, even on land. This is the next phase of studies on the impacts of invasive animals as we have tended to oversimplify their impacts by only examining their impact on direct prey species.

5. The lack of studies in South Africa on the 'downstream' impacts and trophic cascades of trout on indigenous fishes, aquatic invertebrates and the whole aquatic and riparian biota has been exposed.

6. We also need to do more comprehensive quantitative studies on how the physical tolerances (e.g. of water temperature) of alien invasives such as trout may have changed in South African waters.

7. When considering our overall strategy for the conservation of freshwater ecosystems in South Africa, it is important that we retain (if practically possible) some complete systems that have not been invaded by invasive fishes (and other aquatic organisms) but which fall within the environmental tolerances of the major invasive fishes. If no such systems exist we need to identify those that are closest to this ideal and to manage them in such a way that they are restored as close as possible to their pristine state.

8. Furthermore, we should not 'abandon', from the conservation point of view, those systems that have been invaded by trout but which still harbour populations of endemic and indigenous species. We need to continue to manage them in such a way that the survival of the indigenous species is optimized notwithstanding the continued presence of trout (and other invasives) in them.

9. I fully endorse the two sets of recommendations made by the Department of Environmental Affairs on the rainbow and brown trout.

10. I have an uneasy feeling, though, that the brown trout has 'got off lightly' as my gut feeling, from my own field studies and also from the literature, is that it is a more harmful and aggressive invader than the rainbow trout.

Mike Bruton

1st June 2014

Comments on Risk Assessments for Rainbow Trout and Brown Trout

Professor Steven Chown, PhD

I am writing in response to your request that I review the risk assessments made for Rainbow Trout and Brown Trout and the associated regulatory framework proposed.

In advance, let me confirm that I have knowledge of the regulatory framework given my previous position at Stellenbosch University (concluded in June 2012), and of invasive species in general. Moreover, I am not currently a resident of South Africa, and neither stand to benefit from or to be disadvantaged by my remarks. The review is being provided *pro bono*.

In both cases I find the reviews thoroughly researched and in keeping with the state of the art for assessments of realized and potential impact of invasive species.

Both reviews highlight substantial impacts of the species elsewhere, across a range of global regions, and are comprehensive in this assessment. The only exception is for the omission of assessments of impacts in southern South America, which would further strengthen the case presented in favour of substantial impacts, though the Crawford & Muir (2008) work cited by the rainbow trout assessment does cover this region. Nonetheless, work by Soto et al. (2006) Rev. Chil. Hist. Nat. and by Pascual et al. (2009) Front. Ecol. Env. may be insightful. There's also some work on the impacts of salmonids on amphibians that further emphasizes the impacts of the fish (Piiliod et al. 2010 Div. Distrib.).

The assessments highlight the fact that while substantial impacts have already been documented in South Africa for both species, additional information would be helpful to manage South Africa's aquatic diversity. In this regard it is important to note that the catchments in which these species are already found typically are known for high endemism. Threats to endemic species may be higher than the current data suggest.

It is also clear from the literature and the reviews that changing climates are likely to be having and will have impacts on the species and the systems in which they are found, as well as on the industries associated with these species. These climate change-associated impacts should not be cause for stalling any immediate regulatory action. Rather they suggest that such action should be taken now, and further studies undertaken to examine the integrated consequences of changing climates for these species, the systems they inhabit in South Africa, and the long-term future of the associated industries.

I find the conclusions reached by the assessments to be accurate. Both species are having and will continue to have substantial impacts on the biodiversity and ecology of the catchments in which they are already found. In consequence, they should not be transferred to any new catchments or unoccupied parts of catchments as suggested.

There is little discussion of spatial separation of the areas where these species are and are not found. This may be worth considering into the future such that where occupied and unoccupied areas are in very close proximity regulation be adjusted further to minimize risk to unoccupied catchments or areas thereof.

In terms of the proposals made to accommodate existing industries for these species, I found them appropriate. Indeed, the regulations seem to be generous in this regard given the risks these species pose to indigenous systems and South Africa's endemic biodiversity.

It would be useful to consider ways in which catchments that are occupied by one or both of the trout species could be managed to ensure benefits both to those who gain from these trout species and to the biodiversity of those systems. Such management will require additional research if it is to be fully beneficial.

The statements about little risk from salt-water aquaculture require qualification. It is my opinion that some risks have not been considered adequately and particularly not from a parasite and disease perspective. Evidence does exist of parasite transfers between aquaculture and wild individuals (see Marty et al. 2010 PNAS), but how extensive such a risk might be to South African saltwater species is not clear. From a disease perspective feeding fish in aquaculture has risks that I do not think have fully been considered (see e.g. Diana 2009 BioScience). Such assessments should not prevent current regulation from being implemented, but warrant thorough assessment prior to aquaculture commencing.

In conclusion, the risk assessments are comprehensive and accurate in my view. Furthermore, my view is that given the evidence presented, the proposed regulatory measures are appropriate.

Steven L. Chown
Melbourne, Australia
2 June 2014

Comments on Risk Assessments for Rainbow Trout and Brown Trout in South Africa

Associate Professor Mark Lintermans

University of Canberra, ACT, Australia

I commend the Department of Environmental Affairs for the balanced review of brown and rainbow trout impacts and values. The management of trout is a difficult issue worldwide, where considerations for conservation of ecological integrity and biodiversity must be tempered by the social and economic benefits of these long-established salmonid species.

I find that the ecology and evidence of impacts for both species has been well reviewed, and acknowledge that there is a large literature on demonstrated and likely impacts of salmonids worldwide.

The impacts of salmonids can be difficult to determine, as these species have been established for more than a century in many locations, usually long before quantitative assessments of the composition or abundance of native species were documented. The predatory impacts of both rainbow and brown trout are well documented (e.g. on galaxiids see McDowall 2006) but more subtle interactions (competition, behavioural effects, food web interactions) are difficult to quantify. Further research on these impacts is necessary in South Africa and worldwide.

The potential impacts of disease and parasite transmission are also less well known, but worth further investigation. Although trout may not be responsible for introducing pathogens to a country, they can contribute to inter and intra catchment spread. Australian studies have demonstrated high loads of the parasitic copepod *Lerneae* sp on trout, which can then transfer to native fish, as well as Rainbow trout being a host and potential vector for the Epizootic Haematopoietic Necrosis Virus (see Langdon 1989;, J Fish Diseases; Whittington *et al*. 1994, J Fish Diseases) which can have substantial impacts on Australian native fish species.

While trout may be present in many catchments, they often do not occupy all waters within a catchment, and control or prevention of spread within catchments is an important management option that should not be forgotten. Such fine-scale management can provide important opportunities for biodiversity conservation, often in small streams where salmonids may have little social or economic value.

The risk of introducing or translocating other non-native species (fish, amphibians, invertebrates, pathogens) via contaminants of trout stocking should also not be discounted, as this has certainly occurred elsewhere in the world.

I fully endorse the conclusions and recommendations made by the Department of Environmental Affairs on the rainbow and brown trout. Both species have had substantial impacts worldwide, and their invasiveness is well borne out by their global distributions and persistence.

Mark Lintermans

Canberra, Australia

10 June 2014

Comments on Risk Assessments for brown trout *Salmo salar* and rainbow trout *Oncorhynchus mykiss* in South Africa

Daniel Kluza, PhD
Senior Adviser, Biosecurity Risk Analysis (Animals and Aquatic) Biosecurity Science, Food Science & Risk Assessment Directorate, Regulation and Assurance Branch Ministry for Primary Industries, New Zealand

1. These documents do a good job of summarising the general biology of Brown Trout (*Salmo salar*) and Rainbow Trout (*Oncorhynchus mykiss*) and presenting the key pieces of research that demonstrate the impacts that non-native salmonid fishes have had on receiving ecosystems.

2. *Potential as a vector for other introduced organisms* -- these sections fall well short of adequately addressing this issue. Both species are affected by a variety of disease agents:
   http://www.fao.org/fishery/culturedspecies/Oncorhynchus_mykiss/en#tcNA00D9
   http://www.fao.org/fishery/culturedspecies/Salmo_trutta/en#tcNA00D9

   In this particular context, many of these diseases aren't an issue because they either already occur in South Africa (e.g., potentially pathogenic organisms such as *Vibrio* spp. and *Ichthyophthirius multifiliis*) or are salmonid-specific (e.g., *Myxobolus cerebralis* and salmon pancreas disease virus).

   Of particular concern and relevance are infectious haematopoietic necrosis virus (IHNV), infectious pancreatic necrosis virus (IPNV) and viral haemorrhagic septicaemia virus (VHSV). The assessment should specifically address these viruses—they are important pathogens of trout, and can potentially affect non-salmonids (VHSV especially so).

3. The case studies are informative, highlighting the impacts of trout in South Africa. As risk assessments, however, the case studies are site-specific; there's no consideration of the potential impacts that further introductions/spread may have on trout-free systems. Given this limited scope, the assessments potentially understate the risks posed by trout in South Africa.

   The generality of the assessments can be improved by identifying the potential impacts on areas outside of trout current distribution. This information could be included in Sections (2)(b)(ii) and (2)(c) of the assessment, drawing upon the observed impacts in South Africa and elsewhere: general types of impact could be noted in Section (2)(b)(ii) [e.g., Predation on native fishes; displacement of native fishes;], and potential impacts on specific species could be noted in Section (2)(c).

   At the very least, the assessment should explicitly address whether any species with a legal status (e.g., threatened, endangered) could be affected by trout.

4. *Case Study: Rainbow trout impacts in the Breede River system, Western Cape Province* – items 3a and 3b appear to be contradictory, and would benefit from further clarification.

Daniel Kluza
3 July 2014

Comments on Risk Assessment for Rainbow Trout and Brown Trout

Professor Peter Britz,
Department of Ichthyology and Fisheries Science, Rhodes University, South Africa

Decaration of Interest

Although I serve on the Aquaculture Association of South Africa's executive holding the research portfolio, and have provided advice and opinion on trout aquaculture to the DAFF Aquaculture Chief Directorate and TroutSA, I write in my personal capacity as an academic.

The impact review component of the risk assessement provides a concise and well organised synthesis of the state of knowledge of the invasiveness of rainbow and brown trout which forms a useful baseline for application of the NEMBA legislation, specifically the development of species management and control measures. My comments relate mainly to linking the evidence provided in the review to the motivation of practical species control and management measures. They mainly address environmental good-governance, and the need to integrate the proposed biodiversity objectives for trout into a broader sectoral management and development approach.

The Review of Trout Invasions

In my opinion, the only significant omissions in the review of the impacts of trout, is a discussion of 1) the temporal aspects of the invasions and 2) the human agency and institutions responsible for them, as these factors are important in assessing the risk of the further spread of the species, and hence for devising species management and control measures. As is briefly mentioned, trout were introduced as part of a systematic state-hatchery stocking policy which was conducted from the 1890's to the mid-1980's. This resulted in the widespread establishment of trout in the river systems referred to in the review. The case study rivers have long-established trout populations, with the most recent stockings probably in the early 1980's (this can be verified through the very complete provincial hatchery stocking annual reports). My point is that the trout invasion (for both rainbow and brown trout) can be assumed to be a 'mature' one, and that most 'invadeable' habitat has already been colonised. The most important mitigation measure effectively terminating the spread of trout would have been the cessation of state-hatchery stockings in the mid-1980's (Britz, 2014). It should be mentioned that private trout stocking has continued under permit from provincial environmental authorities since the mid-1980s into water bodies where trout are already present. There does not appear to be evidence of sigificant illegal translocations of trout into uninvaded water bodies post the 1980's (as has been the widespread with other invasive species attractive to anglers such as tilapia and catfish). As the report implies, some range extension could still be possible through natural spread and illegal translocations, but the main geographical colonisation and ecological impact has probably occurred - with the effects as as documented in the risk assessment. (By contrast, invasion by tilapia and African catfish species is much more recent and these species are still spreading rapidly). The chronology of the invasion and available anecdotal evidence suggest that trout populations and the associated fishing and aquaculture sectors are in a relatively stable state and this point should be made in the report as it informs the proposed management measures. Having said this, there is a high demand for trout, with imports of trout and salmon of ca. 3000t, so there is market and policy imperative to expand production.

The 'risk assessment framework' indicates the likely impacts of trout introductions into South African upper catchment ecosystems based on the case studies evidence. A risk assessment is by definition an assessment of the future likelihood and severity of a proposed introduction in a specific locality. As trout invasion has already occurred in South Africa, the risk assessment should consider two scenarios to motivate the proposed species control measures 1) assessment of the risk to uninvaded habitats and 2) the risk posed by stocking trout into systems which already have established trout populations, which could occur due to aquaculture escapes or as part of a stock enhancement strategy. Implicit in the document, and the proposed control measures, is that the main extant threat is illegal introductions into un-invaded waters. A secondary, probably transient, impact that should be considered is the release (accidental or deliberate) of hatchery stock into systems with established breeding trout populations. These considerations should be explicitly used to motivate the recommended control measures.

Comments on Recommended restricted activities

The restricted activties should address the biodiversity management and conservation goals motivated in the review, as well be harmonised with other relevant policies and laws such as the Constitution, NEMA, and the National Aquaculture Strategic Framework. The main problem with the NEMBA is that the only instrument that is provided to manage the trout sector is a series of permits following risk assessment, and other more modern instruments such as 'best practise guides', industry 'norms and standards', and market driven self-regulation are not provided for. The DEA has made admirable progress to accommodate these approaches, but the permit-based restricted activity list remains an awkward management tool. In the short run, the gaps in the NEMBA and the proposed integrated management innovations could be accomodated by means of a gazetted trout management policy, however revision of the NEMBA should be considered to provide more wider options for the cooperative governance and management of invasive species with utility. Such revision would serve to align the NEMBA with the NEMA cooperative governance objectives.The NEMBA and/or trout management policy gazetted under NEMBA should thus recognise that other aquaculture management instruments such as the Western Cape Province Department of Environmental Affairs and Development Planning's "*Generic Environmental Best Practice Guideline for Aquaculture"* (Hinrichsen, 2007) and the DAFF's National Aquaculture Strategic Framework and stakeholder based system of managing the aquaculture sector. Sectoral environmental management is an on ongoing function, of which permits are just one component. Dedicated managers and industry liaison are required to respond to issues as they arise on an ongoing basis as embodied by the organisational capacity and stakeholder forums that the DAFF has developed to manage the sector.

As stated by Dr Preston in the DEA-DAFF workshop with aquaculture and biodiviersity stakeholders in October 2013, the DEA's primary goal is to prevent introduction of trout into un-invaded suitable habitats and that the department does not wish to issue unecessary permits. This was the rationale behind the shift to listing trout as a category 2 species to be controlled by area. Following this rationale, it appears anomalous that trout in permitted aquaculture operations situated on non-listed invaded catchments should be listed as a 'Category 2' invasive species due to the low risk they pose to species spread. However, it is in the interests of trout aquaculture to be certfiied as NEMBA-compliant to demonstate that trout aquaculture is environmentally sustainable. My comments on the restricted activities are guided by these considerations.

The main point is that aquaculture operations operating under the proposed DAFF 'norms and standards' do not pose a significant risk to biodiviersity and a single harmonised permit for trout farming should be issued to spare industry and the management authorities the regulatory burden and transaction costs of issuing multiple permits under different legislations. As DAFF do not have legislation governing inland aquaculture, Ministerial delegation of authority to DAFF to issue NEMBA permits would be required.

If revision of the NEMBA is required to achieve the required harmonisation this should be done. For example, NEMBA prescribes a maximum 5y permit tenure which is in conflict with the sectoral requirement for secure, long-term, transferable rights if investment is to be attracted. The NEMBA definition of species management is retricted to 'eradication and control', and does not provide for harmonisation with other policies based on the beneficial use of trout such as DAFF's economically driven species management requirements including veterinary requirements, aquaculture husbandry best practises and so on.

Specific comments on proposed permit requirements

a*) Importing into the Republic, including introducing from the sea, any specimen of a listed invasive species*. Trout ova are responsibly imported by the aquaculture sector into the republic under permit from the Department of Agriculture and inspected by DAFF's Plant and Seed Control at the point of entry. Samples are sent for viral disease testing under supervision of the Veterinary authorities. The question is thus are ova imports a threat in terms of controlling the spread of trout? Or are existing industry 'best practises' and regulations for stocking trout sufficient to ensure ova imported under permit are not irresponsibly introduced into aquatic ecosystems? I would argue that the existing ova import system is sufficient and that a NEMBA permit is either 1) not required or 2) that the existing DAFF import permit automatically include delegated NEMBA approval.

b) Having in possession or exercising physical control over any specimen of a listed invasive species. For the aquaculture industry which is subject to incentivised high level self-regulation and accountability through 'best practise' norms, compliance with market based sustainability instruments and the proposed DAFF "norms and standards' for trout, NEMBA the NEMBA permit should be part of single DAFF issued permit certifyfing the farm is compliant with the required norms and standards which would include NEMBA and other requirements such as veterinary, animal welfare, water quality and so on. A permit to possess trout for aquaculture should be a long term right, subject to compliance with operating standards. Interventions for breaches of operating conditions could include noticies to correct certain practises, fines, quarantine, suspension of movement of stock, and so on depending on the issue.

d. Conveying, moving or otherwise translocating any specimen of a listed invasive species. A distinction should be made between moving by 1) permitted aquaculture operations and other agents and 2) moving for the purpose of stocking and moving between farms. For aquaculture farms, permission to move should be part of the suggested DAFF general permit.

e. *Selling or otherwise trading in, buying, receiving, giving, donating or accepting as a gift, or in any way acquiring or disposing of any specimen of a listed invasive species*. For permitted aquaculture farms operating according to DAFF norms and standards, e) should be part of the general permit.

i. Discharging of or disposing into any waterway or the ocean, water from an aquarium, tank or other receptacle that has been used to keep a specimen of an alien or a listed invasive species. For aquaculture incude in the general permit with DAFF 'norms and standards' specifiying prevention of escapes from farms and other 'discharge or disposal' requirements.

Comments on Recommendations

The recommendations reflect an emerging pragmatic approach to harmonising the management of trout both in terms of biodiversity objectives and aquaculture and fishing sectoral interests. This is to be welcomed. My comments and suggestions are as follows:

- **Listing of Trout as invasive on Aquaculture Facilities.** In Recommendation 5 it is stated that: "*Given the clearly important economic value of rainbow trout, and the fact that it will be virtually impossible to extirpate the trout from areas that they have already invaded, trout should not be listed in these areas, other than requiring a Permit for aquaculture facilities, in Protected Areas or for stocking in rivers*". If the species is not listed as invasive for an invaded catchment, it seems anomalous to list the species as invasive for 'aquaculture facilities' which are legally permitted. An alternative regulatory approach to listing trout species as invasive on aquaculture facilities, would be to certify that trout from aquaculture farms are considered non-invasive and NEMBA compliant if they conform to DAFF 'norms and standards' for trout farming. The norms and standards would address both NEMBA concerns and other issues such as veterinary control. Irresponsible stocking or release of trout from fish farms would be managed via the norms and standards.
- **Exemption of Legal Aquaculture Operations from Permits.** As indicated in point 11 working out the details may take some time and the proposed exemption of legal operations is a sensible one.
- **Recommendation of a Trout Management Policy to Clarify NEMBA application.** I would suggest that the above recommendations, and including a brief rationale flowing from the risk assessment, be Gazetted as a "Trout Management Policy' to clear up any ambiguities and uncertainties regarding specifics management measures. For example, the interpretation of 'eradication and control' has been the subject of much discussion and is the prime source of concern in the trout farming and fishing sub-sectors. A policy could provide clarity, and give substance to DEA's 'harmonised' approach to 'control' and 'species management'. It could even state an intention to revise the NEMBA definitions and permit requirements, if required in legal opinion, to be aligned with NEMA requirements for harmonised policy and legislation regarding environmental management.

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