Risk assessment for rainbow trout *Oncorhynchus mykiss* in South Africa

Taxonomy
Oncorhynchus mykiss (Walbaum, 1792)
Class: Actinopterygii;
Order: Salmoniformes;
Family: Salmonidae;
Genus: *Oncorhynchus*;
Species: *Oncorhynchus mykiss;*
Morphs:

- *Oncorhynchus mykiss* morpha *irideus;*
- *Oncorhynchus mykiss* morpha *gairdneri;*
- *Oncorhynchus mykiss* morpha *aguabonita;*

Common name: Rainbow trout

Photo: AR McIntosh

Originating environment and climate constraints

Rainbow trout are native to the Pacific northwest of North America (Crawford & Muir 2008). Their range extends from the Beiring Sea and Bristol Bay, Aleutian Islands, Alaska, south throughout British Columbia, Washington, northern and southern California (Crawford & Muir 2008) (Figure 1). The species primarily inhabits freshwaters but may exhibit a facultative anadromous (moving from the ocean to spawn in rivers) life history under suitable conditions. They can inhabit both lentic and lotic environments, although specific spawning conditions (flowing water, gravel beds) are required to maintain a self sustaining populations. Due to their specific temperature requirements, they only occur in cooler environments with the optimal temperature being 14°C (Brungs & Jones 1977). At temperatures of around 20°C rainbow trout seek cooler thermal refugia (Ebersole et al. 2001) and the upper incipient lethal limit is 26.5 °C (Brungs & Jones 1977).

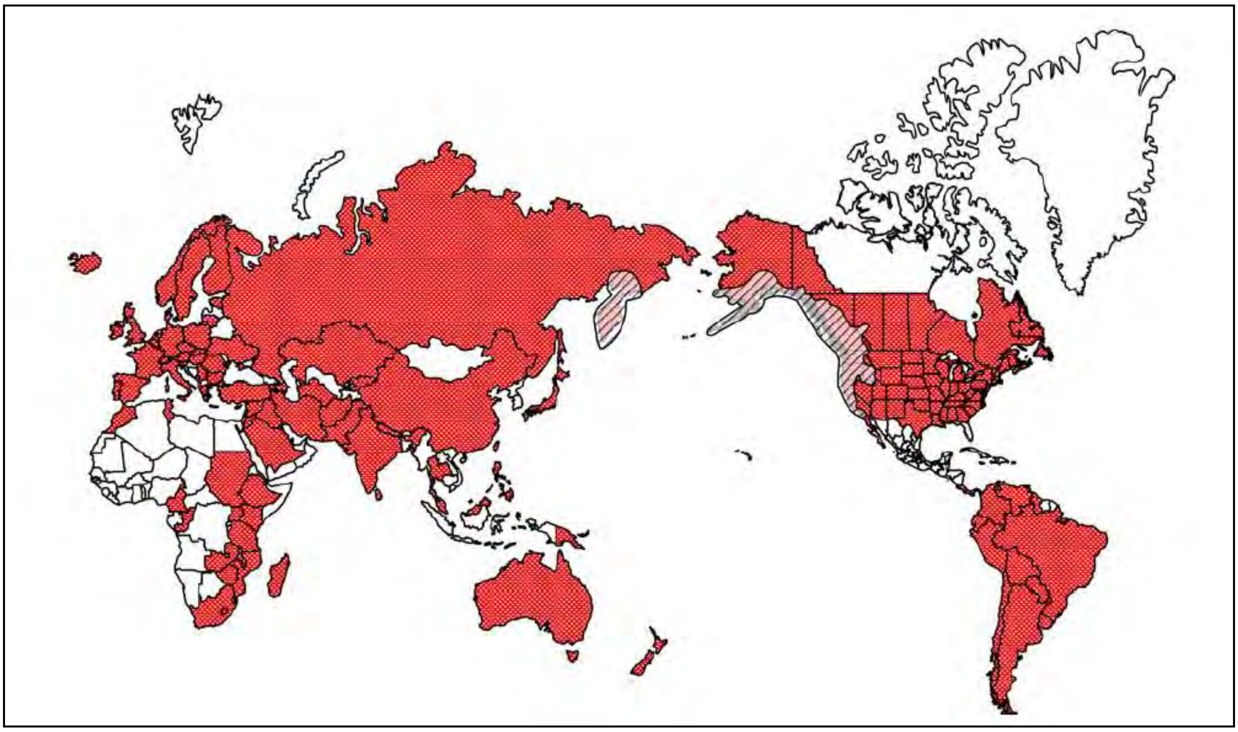

Figure 1: The global distribution of rainbow trout *Oncorhynchus mykiss* (by country; red = introduced range; shaded white = native range) (taken from Crawford & Muir 2008).

Reproductive strategy and potential, dispersal abilities
Rainbow trout is a short lived species (generally 5 yrs) that mature early (at 2-4 yrs of age) (Gall & Crandall 1992). Due to their plasticity in length at maturity, reproductive potential is highly variable and fecundity can range from 200 – 12749 eggs depending on the size of the individual (Gall & Crandall 1992). Rainbow trout movement is highly variable between individuals, with both highly migratory (>100km displacement from capture location during the spawning season) and non-migratory forms (Meka et al. 2003). Rainbow trout may undertake extensive migrations to reach favourable spawning grounds (Meka et al. 2003). In South Africa spawning takes place from June-September (Skelton 2001). Fish aggregate over suitable gravel beds and the female digs a redd (shallow depression in the gravel) where she lays eggs. Multiple redds may be used before the female is totally spent.

Invasive tendencies and taxonomic predisposition
Spread and established globally, rainbow trout are among the most widely introduced species and form part of the eight worst global invasive freshwater fishes (Lowe et al. 2000) (Figure 1). Other salmonids are also highly invasive (e.g. brown trout *Salmo trutta* also in top eight worst invasives) inferring taxonomic predisposition to become invasive in receiving ecosystems with favourable conditions (Garcia de Leaniz et al. 2010).

History of propagation, introductions and naturalization
Salmonids, including rainbow trout were some of the earliest fishes introduced and spread in temperate regions globally (Welcomme 1988; Crawford & Muir 2008). Initial motivations were to develop aquaculture, sport fisheries and food production and they have subsequently established populations in more than 80 countries (Welcomme 1988; Crawford & Muir 2008). In South Africa salmonids were introduced in the late 1800s and have subsequently been introduced into >75% of major river catchments (Limpopo, Incomati, Tugela, Umgeni, Umzimvubu, Kei, Great Fish, Gamtoos, Gouritz, Breede, Berg, Olifants, Orange, Vaal) (de Moor & Bruton 1988; Van Rensburg et al. 2011; SAIAB 2014). Where the conditions are suitable (high altitude catchments with suitable thermal regimes) they have established self sustaining populations which have persisted for >100 years. Range expansion from stocking localities into other suitable streams within these river systems has also been documented (Ellender 2013).

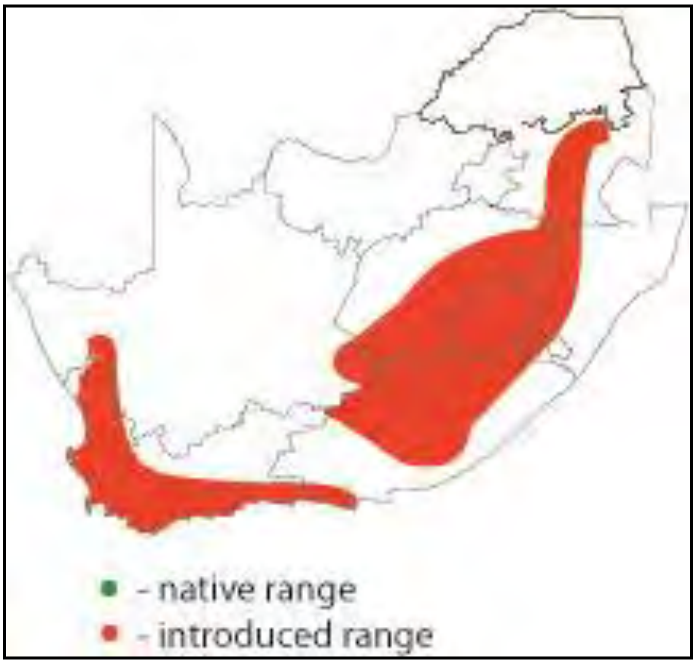

Figure 2: Map of current distribution of rainbow trout across South Africa (from Picker and Griffiths 2011).

Dietary requirements
Rainbow trout are generalists that prey opportunistically on aquatic and terrestrial invertebrates, amphibians (Gillespie 2001) and fish (Woodford & Impson 2004).

Ecosystem impacts
Where introduced, rainbow trout have had considerable impacts on fishes and recipient ecosystems (Fausch 2007). These impacts are particularly severe as they can span multiple biological domains (Dunham et al. 2004), ranging from hybridisation and competition with congenerics (Allendorf et al. 2001), alteration of population structure and recruitment,

habitat fragmentation of native fishes (Woodford & McIntosh 2010), extirpation through direct predation (Tilzey 1976) even extinction of the New Zealand Grayling *Prototroctes oxyrhynchus* (McDowall 1996). Rainbow trout have also been documented to cause cascading foodweb impacts at community and ecosystem level. For example, Baxter et al. (2004) showed that in streams invaded by rainbow trout, they out-competed native Dolly Varden charr *Salvelinus malma*, causing a shift in *S. malma* foraging from terrestrial invertebrates to invertebrate algal grazers. This foraging shift resulted in an increased algal biomass and decreased invertebrate biomass emerging from the stream to the adjacent forest, and consequently a 65% reduction in the density of riparian specialist spiders (Baxter et al. 2004).

In South Africa, although there is a paucity of available information on the impacts of salmonids on native fishes, a growing body of evidence suggests their impacts may be significant. Rainbow trout have been recorded preying on two native fish species. For example, in the Berg River system Western Cape, South Africa, native *Galaxias zebratus* have been found in the stomachs of rainbow trout and was the only native species not observed co-occurring with rainbow trout (Woodford & Impson, 2004). The Endangered Border barb *Barbus trevelyani* were also recorded from rainbow trout stomachs in the Buffalo River system (Jubb 1967). On analysing the distribution patterns of Border barbs in the Keiskamma River system, the only consistent predictor for their absence in headwater stream reaches was the presence of salmonids (Ellender 2013). The resultant loss of habitat for Border barbs was up to 24% of their global distribution (Ellender 2013). Similar patterns were evident in salmonid (brown and rainbow trout) invaded streams of the uKhahlamba Drakensberg Park World Heritage site, where differences in the abundance of tadpoles of the Natal cascade frog Hadromophryne natalensis Hewitt were detected above and below salmonid invasion barriers (Karssing et al. 2012). In a recent study in the Breede River system, Shelton (2014) demonstrated that the mean density and biomass of the native fish Breede River redfin *Pseudobarbus burchelli,* Cape kurper *Sandelia capensis* and Cape galaxias *Galaxias zebratus*, was 5-40 times higher in streams without rainbow trout than in streams with rainbow trout and that invertebrate species assemblage in streams with trout differed consistently from that in streams without trout. Based on comparisons of insect communities, Shelton (2014) also demonstrated that in the Breede River, trout do not functionally compensate for the native fish that they have replaced, being weaker regulators of herbivorous invertebrates than are native fish. As a result, there was also evidence of cascading effects with algal biomass being significantly higher at sites containing trout than at sites without.

Ability to hybridize with native species
Although in other parts of the world hybridisation with congenerics is a major issue (Allendorf et al. 2001), rainbow trout are not able to hybridise with any local species

Suitability of receiving environment in South Africa

i) Climate match
An analysis of the environmental suitability for salmonids in South Africa (using the following environmental factors: conductivity, altitude, mean annual rainfall, mean annual air temperature and the coldest months mean air temperature) indicated that the eastern escarpment (high altitude-dark green) stretching from the south-western Cape to Northern Kwa-Zulu Natal was the most suited habitat for salmonids (Weyl & Keevey 2012).

i) Habitat
Rainbow trout prefer cool (<20 °C), clear well aerated streams and impoundments. Such habitats are characteristic of headwater tributary streams in the Cape Folded Mountains and Eastern Escarpment, where the species is already extensively established (Figure 2).

ii) Presence of natural enemies, predators and competitors
Two native predatory eels occur in South African streams, longfin eel *Anguilla mossambica* and mottled eel *A. marmorata*, however, their predatory impact on rainbow trout is unknown. Observational reports of amphibians preying on rainbow trout fry exist but remain un-quantified.

iii) Presence of reproductively compatible species
No such species are native to South Africa.

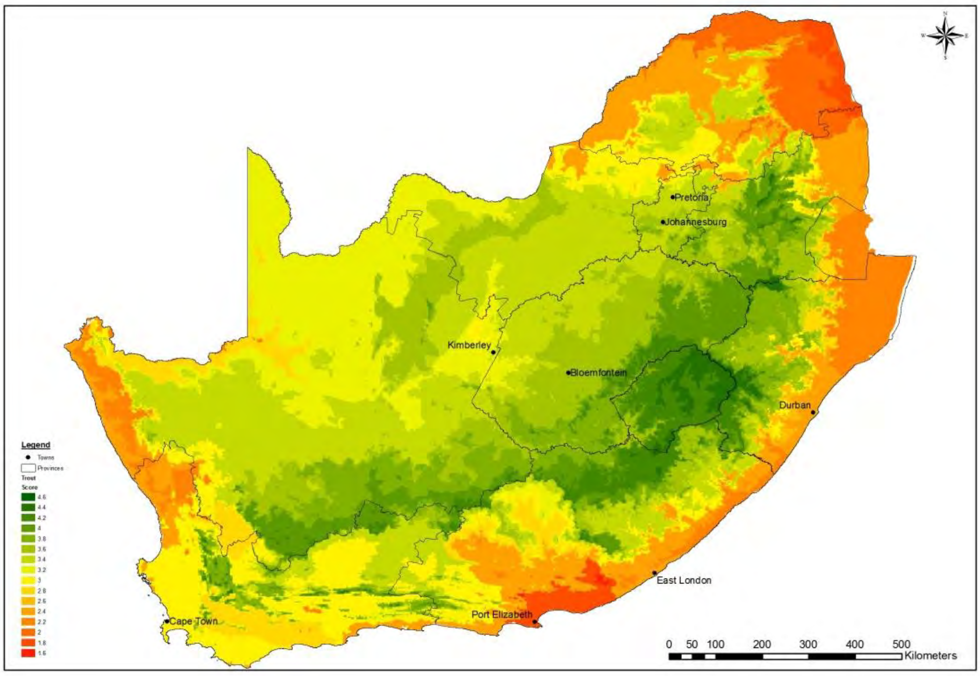

Figure 3: GIS map showing areas suitable for trout (in green), based on conductivity, altitude, mean annual rainfall, mean annual air temperature and mean winter air temperature (Weyl & Keevey 2012).

Potential as a vector for other introduced organisms

Rainbow trout have been the vector for whirling disease myxosporean parasite *Myxobolus cerebralis* throughout Europe in the late 1800s and early 1900s and then into North America (Bartholomew & Reno 2002). Whirling disease has impacted on native rainbow and cutthroat trout *Oncorhynchus clarki* populations in North America (Bartholomew et al. 2005). It is a salmonid-specific disease unlikely to have adverse effects on native fishes in South Africa.

South African case studies

Case study: Keiskamma River system, Eastern Cape Province.

Ellender (2013) conducted a study to determine the invasive potential and subsequent impacts of rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta* in the upper Keiskamma River system, Eastern Cape, South Africa. To do this, Ellender (2013) assessed fish distributions in at 75 riverine sites and in four impoundments on the upper Keiskamma River system and assessed these data in relation to habitat and temperature (recorded from multiple constant temperature loggers placed throughout the river system for one hydrological year July 2011- July 2012).

1. **Establishment and distribution of rainbow trout in the Keiskamma River system**

- Trout (both rainbow and brown trout) conformed to their documented thermal tolerances predominantly occupying cool-water sites (13.7 ± 3.5 °C)
- Rainbow trout exhibited natural range expansion from streams where they were stocked to streams where they were not (i.e. no evidence of stocking).
- Rainbow trout range expansion was impacted by physical (impoundments) and thermal barriers (downstream temperature increases) which limit dispersal ability.
- Rainbow trout did not occupy all sites which fell within their thermal preferendum, indicating invasion debt and further potential to spread despite being established in the Keiskamma River system for more than a century.

2. **Impacts on native fishes: the endangered Border barb *Barbus trevelyani*.**

- Border barbs were not recorded from any impoundments, and were limited to non-invaded streams, and non-invaded middle reaches of the headwater streams and mainstream Keiskamma River.

- Using replicate invaded and non-invaded streams, the best predictor of Border barb presence/absence was the presence or absence of trout.
- Trout (both rainbow and brown) invasion resulted in a loss of approximately 24% of the Border barbs global distribution.

Case Study: Rainbow trout impacts in the Breede River system, Western Cape Province

In a study conducted on 24 headwater streams of the upper Breede River, Sheldon (2014) assessed fish populations, benthic invertebrate assemblages, benthic algae and particulate organic matter in an attempt to determine the impact of rainbow trout on headwater ecosystems. After determining that the streams were comparable from an environmental perspective, comparisons between 12 streams that contained established rainbow trout populations with 12 that did not, provided quantitative evidence that trout have a strong impact on native fish communities and invertebrate assemblages in the upper Breede River catchment. Evidence is as follows:

1. **Evidence that trout impact on native fish populations**
    a. The mean density and biomass of the native fish Breede River redfin *Pseudobarbus burchelli,* Cape kurper *Sandelia capensis* and Cape galaxias *Galaxias zebratus*, was 5-40 times higher in streams without rainbow trout than in streams with rainbow trout
    b. Native fish were present at all 12 sites without trout, but native fish were only recorded at five of the 12 sites with trout present.
    c. Statistical analyses (distance-based linear models) identified trout density as the best predictor of Breede river redfin and Cape kurper density.
2. **Evidence that trout impact on invertebrate communities**
    a. The invertebrate species assemblage in streams with trout differed consistently from that in streams without trout.
    b. Overall herbivorous invertebrates were more abundant, in streams with trout than in streams without them.
    c. Statistical analyses (distance-based linear models) identified trout presence as the best predictor of these patterns.
    d. The results indicate that trout do not functionally compensate for the native fish that they have replaced, being weaker regulators of herbivorous invertebrates than are native fish.
3. **Evidence that trout impact on environmental processes**
    a. Algal biomass was significantly higher at sites containing trout than at sites without. This was most likely caused by differences in grazing pressure.
    b. Behavioural observations showed that while native redfin fed mostly from the stream bed, trout fed primarily from the drift. Gut contents and stable isotope analysis revealed that herbivorous aquatic invertebrates contributed more to the diet of redfin than to that of trout, and that trout augment their diet of aquatic invertebrate prey by consuming terrestrial prey more than do redfin. Collectively these results support the conclusion that trout and redfin occupy different trophic niches, and that trout may exert weaker top-down control over lower trophic levels than do Redfin.
    c. Data indicate that by reducing native fish abundance, trout indirectly reduce the predation pressure on herbivorous invertebrates, resulting in increased grazing pressure on benthic algae.

River specific case study: Historical retrospective assessment of the upper Berg River, Western Cape
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 rainbow 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 Woodford & Impson (2004).

Annexure A. Summary of data in as per Alien and Invasive Species Regulations Risk Assessment Framework – Rainbow Trout – *Oncorhynchus mykiss* – 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;	*Oncorhynchus mykiss* (Walbaum, 1792) Class: Actinopterygii Order: Salmoniformes Family: Salmonidae Genus: *Oncorhynchus* Species: *Oncorhynchus mykiss* Morphs *Oncorhynchus mykiss* morpha *irideus* *Oncorhynchus mykiss* morpha *gairdneri* *Oncorhynchus mykiss* morpha *aguabonita* Common Name Rainbow Trout	
(ii) the originating environment of the species, including climate, extent of geographic range and trends;	Native to the Pacific northwest of North America. Range extends from Beiring Sea and Bristol Bay, Aleutian Islands, Alaska, south throughout British Columbia, Washington, northern and southern California. Only occurs in cooler environments with optimal temperature being 14°C and the upper incipient lethal limit 26.5 °C Their habitat preferences and physiological tolerances are specific, limiting them to clear, cool perennial streams and lakes but they can also inhabit estuaries. *O. mykiss* are primarily freshwater species but may exhibit a facultative anadromous life history under suitable conditions.	Brungs and Jones (1977) Crawford & Muir (2008)
(iii) persistence attributes of the species, including reproductive potential, mode of reproduction, dispersal mechanisms and undesirable traits;	Early maturation (1-4 yrs). Undertake spawning migrations and may disperse via the ocean.	Gall & Crandall (1992)
(iv) invasive tendencies of the species elsewhere and taxonomic predisposition;	Among the most widely introduced species globally and form part of the eight worst global invasive freshwater fishes. Other salmonids also highly invasive (e.g. brown trout *Salmo trutta* also in top eight worst invasives).	Townsend (1996) Lowe et al. (2000) Fausch (2007)
(v) the history of domestic propagation or cultivation of the species, introductions and the extent of naturalization;	Introduced and spread globally, established in > 80 countries.	Welcomme (1988) Crawford & Muir (2008)
(vi) nutritional or dietary requirements of the species and, where applicable, whether it has a specialist or generalist diet;	Predatory by nature, feeding on a wide variety of aquatic and terrestrial invertebrates, fishes and amphibians. Generalist diet.	Gillespie (2001) Woodford & Impson (2004)
(vii) the ability of the species to create significant change in the ecosystem; and	Competition, alteration of population structure and recruitment, habitat fragmentation of native fishes, extirpation through direct predation even extinction of the New Zealand Grayling *Prototroctes oxyrhynchus.* Cascading foodweb impacts	McDowall (1996) Dunham et al. (2004) Woodford & McIntosh (2010) Woodford & Impson (2004) Ellender (2013)

	at community and ecosystem level.	Baxter et al. (2004)
(viii) the potential to hybridize with other species and to produce fertile hybrids; and	Not applicable in SA. No threat of hybridising with native fish.	
(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. Applies to all suitable rivers, lakes, wetlands 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;	The eastern escarpment (high altitude-dark green) stretching from the south-western Cape to Northern Kwa-Zulu Natal was the most suited habitat for salmonids.	Weyl & Keevey (2012)
(ii) habitat;	Rainbow trout prefer cool (<20 °C), clear well aerated streams and impoundments.	
(iii) the presence of natural enemies, predators and competitors; and	Two native predatory eels occur in South African streams, longfin eel *Anguilla mossambica* and mottled eel *A. marmorata*, however, their predatory impact on rainbow trout is unknown.	
(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 *O. mykiss* introduction to the Upper Berg River, WCP; Breede River WCP 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 populations in parts of most major river catchments. High risk of naturalization in areas introduced that meet physiological requirements of *O. mykiss.*	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 *O. mykiss* introduction to the upper berg River.	Woodford et al. (2004)
(i) the area in which the restricted activity is to be carried out; and	Confirmed impacts on distributions of *Galaxias zebratus.* Documented evidence of spatial exclusion of *G. zebratus* from *O. mykiss* invaded pools.	Woodford et al. (2004)
(ii) in any other area elsewhere in the Republic	Confirmed predation on native fishes. Direct predation by *O. mykiss* on native *Barbus trevelyani* was recorded from the Buffalo River system. Absence of the endangered Border barb in trout occupied reaches of the Keiskamma River system. Reduced densities of Natal cascade frog *Hadromophryne natalensis* tadpoles from the Mbovaneni and Sterkspruit Rivers. Documented evidence of changes in invertebrate species composition and native fish species abundance in the Breede River system,	Woodford et al. (2004) Jubb (1967) Karssing et al. (2012) Ellender (2013) Shelton (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. Potential for community and ecosystem level impacts.	
(d)	the risks of the specimen serving as a vector through which specimens of other alien species may be introduced;	No evidence for rainbow 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 *O. mykiss*.	
(f)	any measures proposed in order to manage the risks.	No mitigating measures addressing introductions of non-target species likely to be pursued.	

Annexure B: References

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Annexure C: Suggested Summary: Rainbow Trout

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. Salt-water aquaculture possible.

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, and for aquaculture (with apparent significant potential for growth). Opportunity for salt-water aquaculture, with little risk of invasion.
☐ 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 for 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 rainbow 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 (Bio-security Unit, Department of Environmental Affairs)

1. The rainbow trout should be listed as an invasive species.
2. It should be acknowledged that it will not be possible to eradicate rainbow trout in South Africa.
3. To extirpate rainbow 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. Rainbow trout has significant potential as an aquaculture species, both in salt-water systems and 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 aquaculture (and food security benefits), is very high.
5. 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. This will facilitate the optimising the industries in such invaded areas, and protect investments that have already been made. Need for
6. It is recommended that rainbow 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 rainbow 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 rainbow trout as an invasive species. It will also help to promote the optimising of rainbow trout in dams in systems in which trout have invaded.
7. There is no sense in restricting the catch-and-release of rainbow 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. Rainbow trout can be farmed in salt-water conditions. There is no invasive risk associated with this, and the recommendation is that this activity should not be listed. However, it may be that the sites for such salt-water aquaculture facilities may be in fresh-water systems in which trout do not occur. There must then be a prohibition on the translocation of rainbow trout from salt-water systems to fresh-water systems in which trout do not legally occur. Note that these facilities will require a Permit from DAFF, and so collaboration (see below) can resolve this.
9. The listing of rainbow 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 rainbow trout already exists. Investigate Permit for RAS systems.
10. The most important prohibition must be that rainbow 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.
11. 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 rainbow trout be exempted from the requirement for a Permit in terms of the NEM:BA Regulations on alien and invasive species.
12. Finally, it is recommended that those with Permits for rainbow 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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