# A MARISCO Situation & Vulnerability Analysis for Eurasian Beavers on the River Otter, Devon, England


**By**

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**Abstract**

There is consensus across the scientific community that anthropogenic influences are resulting in widespread biodiversity losses and ecosystem degradation. The products and materials provided by these unique entities are vital for human prosperity. There has been emphasis surrounding the conservation and maintenance of ecosystem functioning. The services provided by ecosystems depend on the state of a given systems functionality. It is thought that the ecosystem approach, adaptive management and integrating focus on ecosystem functionality can provide ecosystems with flexibility to risk and threat and resilience to external negative factors. These concepts can be seen in the forefront of conservation management in times of unpredictability and accelerated environmental change. New initiatives branching from restoration ecology, rewilding and species reintroductions such as the use of ecosystem engineers for ecological restoration in degraded agricultural landscapes is being applied in Britain. The Eurasian beaver *Castor fiber* is a keystone species which relative to the species biomass and abundance can play a significant positive role on ecosystem functioning. In Britain, after being extirpated by man, Eurasian beaver has been reintroduced in a number of different projects. The River Otter Beaver Trial (ROBT) was the first to gain a license from governing bodies in England following positive outcomes from experience of beaver reintroduction to Scotland. The overall aim of this research was to carry out a situation & vulnerability analysis of the River Otter ecosystem and the Eurasian beavers on the River Otter, Devon, applying a methodology called MARISCO. A combination of an ecosystem diagnostics analysis, a comprehensive assessment of risk and threat and a rural participatory appraisal questionnaire was integrated for this research. It was determined that without the presence of humans and their interests, risk and threat to the beaver population was relatively low. However, it is the socio-cultural dynamic that will require the greatest deal of attention to enhance probabilities of success of the ROBT which can result in ecosystem restoration.

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# 1 Introduction

## 1.1 *Biodiversity and Ecosystems*

In times of accelerated environmental change, it is unequivocal amongst the global scientific community that a loss of biodiversity is dramatically altering the services provided by ecosystems for human prosperity (Diaz *et al*., 2006; Hooper *et al*., 2012; Reed, 2016). Biodiversity is widely recognised as a unique feature of our planet and a key measure of the earth's health, providing a wide range of direct benefits producing biological materials which have helped build at least 40% of the global economy (Diaz *et al*., 2006; Reed, 2016; UNEP, 2017). Compelling evidence displays intricate relationships between biodiversity, ecosystem function and services (Balvanera *et al*., 2006; Haines-Young & Potschin, 2010; CBD, 2014). Understanding these relationships has potential to inform management strategies and policies in the future for the provision of these complex entities (Harrison *et al*., 2014; Petrosillo & Zurlini, 2016). Research has stated that for all ecosystems, biodiversity has a significant number of key roles that influence functionality and services provided at many different scales (Mace *et al*., 2012; O'Connor *et al*., 2017). In any natural ecosystem, there are dynamic processes including interactions of organisms and intricate networks that are never static and continuously evolve temporally and spatially (JNCC, 2014; Ibisch & Hobson, 2014). These complex relationships can be described as ecological processes and when functioning correctly result in providing a wide range of beneficial resources, known as ecosystem services (Haines-Young & Potschin, 2010; JNCC, 2014; UKNEA, 2018).

The importance of biodiversity and its rapid decline was notably brought to the attention of world political leaders at the first earth summit in Rio, Brazil, 1992 (Cardinale *et al*., 2012). The Convention on Biological Diversity (CBD) set ambitious targets to reduce and if possible eradicate biodiversity loss by 2010, which ultimately failed despite agreements from a wide range of nations (CBD, 2010; Perrings *et al*., 2011). Overall, on a global scale, efforts to work towards sustainable growth and halting a loss of biodiversity have been slow in development (Mooney & Mace, 2009; CBD, 2010). During this time, between 2001-2005 the Millennium Ecosystem Assessment (MEA) was produced as requested from United Nations (UN) in order of analysing anthropogenic impacts on ecosystems and potential outcomes for humanity (MEA, 2005). The MEA integrated scientific data for actions required to conserve ecosystem services and functions (Mooney *et al*., 2004; Carpenter *et al*., 2009; Ibisch & Hobson, 2014). The assessment produced concerning evidence highlighting anthropogenic alterations resulting in significant, permanent loss of global biological diversity (MEA, 2005). It appears in recent human history, degradation of biodiversity and ecosystems may have come as a trade-off for gains in the wellbeing of humans and global development (MEA, 2005; Singh *et al*., 2016). However, the same services provided by ecosystems for this growth in human societies, if diminished will reduce benefits for further generations to prosper (*ibid*). The synthesis resulted in stating the challenges of reducing ecosystem degradation while meeting global demand for the vital services which will require changes in practices, societies and policies worldwide almost in a shift of socio-cultural paradigm (*ibid*).

After failing to reach previous targets globally, in Nagoya, Japan, 2010 the beginning of a new direction and vision was set out for biological diversity policy and strategy with the AICHI 2020 targets (CBD, 2014). There is growing evidence that with continued trends of ecosystem degradation and biodiversity loss, these targets will also be challenging to achieve (CBD, 2014). In a study by Shepherd *et al*., (2016), the six indicators for measuring progress towards the CBD's AICHI target 14 for the conservation of ecosystem services was assessed and found that little to no progress had been made in achieving this target for 2020.

1.2 *Drivers of Change.*

There are a significant number of direct and indirect drivers of ecosystem degradation and biodiversity loss (MEA, 2005). Evidence outlined at the convention on biological diversity CBD (1992) and in the millennium ecosystem assessment MEA (2005) declared results that anthropogenic influences were degrading and destroying the earth's ecosystems, extirpating species, genes and biological processes at rates faster than any other time in human history (CBD, undated; MEA, 2005b). It has become ever more apparent that these anthropogenic operations and actions are the leading driver of such rapid change (Diaz *et al*., 2006; Hooper *et al*., 2012; Johnson *et al*., 2017), with habitat destruction and land conversion causing widespread declines in biodiversity (Newbold *et al*., 2015). The widespread consumption and use of resources to produce fuel, freshwater, food and building materials such as timber, has come at negative costs to the natural environment through aspects such as habitat loss and the generation of pollutant sources (MEA, 2005; Diaz *et al*., 2006). A prime example is that of habitat fragmentation, which will alter the relationship between biodiversity and ecosystem function negatively, through changes in species community composition and shifting environmental conditions (Liu *et al*., 2018). Fragmentation due to habitat loss and land-use change resulted in the conversion of approximately 50%+ of terrestrial habitats by the year 2000 (Chapin *et al*., 2000). The significant growth of agriculture throughout human history, while successful for our growth, has come at large costs to the global environment (CBD, 2014; Ramankutty *et al*., 2018). The increased areas of urban and agricultural land have resulted in significant levels of nutrient run-off creating large scale ecological changes to freshwater habitats and river systems (Chapin *et al*., 2000). Other pressures from the facilitation of invasive species to human accelerated climate change can work synergistically, dramatically altering ecosystem properties and functions resulting in a lack of resilience to change (Dukes & Ziska, 2014). Many of the direct threats to species, if high in severity, can result in rapid population declines however, research by Brook *et al*., (2008) highlights intensifying feedbacks leading to synergies forcing final extinctions. As separate threats or processes work simultaneously, they can provide a greater output than the individual impacts from processes working alone, known as a synergy (*ibid*). It is concluded that synergies may not only be the final driver to extinction of species but place greater risk on estimated extinction rates than previously discovered (*ibid*).

### 1.3 *Ecosystem Function*

The current trends of biodiversity decline and ecosystem degradation, coupled with the ever-changing global environment, has produced focus on the conservation and maintenance of ecosystem functioning (Jax, 2010). It has been recognized as a key solution halting both biodiversity and ecosystem loss as well as protecting vital services provided for human well-being (*ibid*). There is a dynamic relationship between biodiversity, ecosystem services and ecosystem functioning which has been at the attention of scientists for many years (Jax, 2005, 2010; Reiss *et al*., 2009). It is recognised that ecosystem services are dependent in the state of ecosystem functionality and processes (Diaz *et al*., 2006; Truchy *et al*., 2015). Consensus is also that biodiversity, species and their traits are potentially the key regulator, determining the state of ecosystem functionality and dynamics (Vaughn, 2010; Tilman *et al*., 2014). Ecosystems functionality and efficiency also evidently benefit from aspects such as increased biomass, information and complexity of organization with significant levels of networking and interaction of ecosystem elements (Ibisch & Hobson, 2014). The term ‘function’ is expressed in differing forms across the ecological spectrum, of which all have significant importance such as that meaning processes, interactions, or referring to the workings of a whole ecosystem (Jax, 2005). Global biota can be the key regulator of numerous matter and energy fluctuations which include oxygen productivity, the cycling of nutrients and the uptake of carbon, referred to as ecosystem processes at the local scale (Reiss *et al*., 2009). When dynamics such as that of biological assemblage attributes are integrated, for example, type or number of organisms and interactions, they result in the determination of ecosystem processes and assets such as resilience to invasive alien species and sustainability of the processes and assets over space and time (*ibid*). Essentially the characteristics of ecosystem processes, assets, and their conservation represent ecosystem function (*ibid*). In healthy ecosystems, functionality will provide the natural system with flexibility to external negative factors such as climate change and develop resilience without alteration of ecosystem assets and geographic distribution of organisms (Ibisch & Hobson, 2014). Ecosystem functionality is also fundamental for ecosystem service provisioning, the dissipation of energy, resilience and adaptive capacity (Biber-Fraudenberger *et al*., 2012).

### 1.4 *Valuing Ecosystems*

There has been a great deal of emphasis in placing values to ecosystems and their services as they have been integrated into strategy and management in a range of different approaches (Daily *et al*., 2009; De Groot *et al*., 2010a; Chan *et al*., 2012). It was stated that the way in which biodiversity and ecosystem services are valued by societies needs essential reform (De Groot *et al*., 2010a). The services provided by ecosystems are, directly and indirectly, an integral part of life for human welfare resulting in being representative as part of the earth's economic value (Constanza *et al*., 1997; Defra, 2013; De Groot *et al*., 2017). Studies such as that by Costanza *et al*., (1997, 2014) have attempted to estimate the economic value of global ecosystem services and estimated values totaling $33 trillion per year which at the time (1997), was a significantly greater total than worldwide gross domestic product (GDP) (Costanza *et al*., 2014). Updated estimates followed in continued studies by Constanza *et al*., (2014) and in 2011 estimates for global ecosystem services reached a total of $145 trillion per annum. It was also found that ecosystem service loss because of land use change was estimated between US$4.3 and $20 trillion per annum placing large scale economic value to healthy ecosystems globally (*ibid*). Ecosystem services such as provisional, supporting and regulatory services are vital factors for human life that can be valued economically, socio-cultural factors such as spirituality, aesthetics, education and recreation also key to human health and prosperity are also being recognized for their value (JNCC, 2014; UKNEA, 2018).

Placing value on ecosystems, biodiversity and wildlife conservation from a social perspective appears to be mixed across Britain (Defra, 2011). Defra (2011), conducted a survey which provided insight into public knowledge and perspective on aspects such as ecosystem services and biodiversity. When referring to how much participants thought about biodiversity loss in Britain, in 2011 only 6% answered '*a great deal'*, 17% '*a fair amount*', 40% '*a little*', and 33% '*none at all*' (Defra, 2011).

1.5 *Ecosystem Approach & Adaptive Management*

The emergence of the ecosystem approach to conservation management has gathered momentum and is now in the forefront of strategy formulation at a range of spatial scales from global to regional (CBD, 2010; IUCN, 2017). Beginning to understand one of the most wide-ranging, significant threats of climate change has focused scientific attention towards the complexities of ecosystem dynamics in a future of uncertain outcomes and non-linear processes (CBD Secretariat, 2004; Ibisch & Hobson, 2014). Historically the natural environment was described applying concepts and principles built on deterministic, predictable beliefs in a steady-state with balance representing stability (Ibisch & Hobson, 2014). Strategy and management was often based on the probability that a balance may resume when the systems properties had been altered through restoration (*ibid*). The ecosystem approach outlines strategic management for integrating aquatic, terrestrial, living resources with the fundamental aim of the concept to conserve biological diversity, its sustainable usage and the equitable sharing of its services taking into consideration humans and our cultural diversity as part of the natural system (JNCC, 2014a; CBD, undated a.). It is co-immersed with adaptive management as the dynamic, complex nature of ecosystems, with fluctuations and non-linear processes result in many uncertainties which the approach is designed to combat (JNCC, 2014a). This approach is precautionary and sets out to ensure the best scientific evidence is available to formulate management decisions understanding the complexities of ecosystems without potential complete knowledge of its dynamic functioning (CBD Secretariat, 2004). Adaptive management is primarily focused on providing a new standardised agenda for conservation policy and practice for application across the broad range of socio-ecological systems (Ibisch & Hobson, 2014). The impacts of human accelerated climate change are evermore widespread and significant, it is thought that the integration of the ecosystem approach and adaptive management is a key factor in effective conservation and ecosystem restoration outcomes of the future (Ibisch & Hobson, 2014).

### 1.6 *Ecosystem Restoration*

Ecosystem restoration is the operation of assisting recovery of damaged, destroyed or degraded ecological systems to restore vital processes and functions that are fundamental for human prosperity and tackling human accelerated climate change (Harris *et al*., 2006; Palmer & Filoso, 2009; IUCN, 2017; SER, 2017). In recent times, the field of restoration ecology has developed considerably (Hobbs, 2007; Perring *et al*., 2015). Due to the growing number of recorded restoration outcomes, there are trends displaying some positive responses in ecosystem functionality and development (Hobbs, 2007; Benayas *et al*., 2009; Wortley *et al*., 2013). However, with continued global trends of ecosystem degradation and depletion of services provided, there are many challenges that require advances in research and inter-disciplinary approaches to fully restore and replenish ecosystems and their functionality (Hobbs & Norton, 1996; Hobbs, 2007; Perring *et al*., 2015). It is stated that ecological restoration requires the integration of a range of disciplines with the inclusion of conservation biology, science of soils and hydrology, organised with political and socioeconomical framework (Aradottir & Hagen, 2013). Although there is widespread, empirical evidence that restoration can assist in reversing biodiversity losses and conserving ecosystem services, other conflicts can arise such as outcomes resulting from efforts to restore isolated single services (Bullock *et al*., 2011). There have also been cases where restoration can facilitate alien invasive species (Ewal & Putz, 2004; Hobbs *et al*., 2009). One fundamental issue surrounding restoration is the use of historical states, baselines or restoration goals to re-establish (Hobbs & Norton, 1996; Balaguer *et al*., 2014). It is argued that with additional pressures from a rapidly changing climate, efforts to restore past ecological states can lead to failure which can lead to further conflicts economically and socially (Hobbs *et al*., 2009; Corlett, 2014; Higgs *et al*., 2014). This displays an importance to integrate adaptive management approaches (JNCC, 2014a). Essentially restoration of quality to soils, an improvement in pollination services, nutrient cycling and water retention with greater regulation of erosion can be beneficial to drivers of negative change such as agriculture by way of better crop production (Aradottir & Hagen, 2013). An improvement of these factors will further benefit a wide range of ecosystem services including carbon sequestration (*ibid*). Today, after large quantities of scientific research, guidelines and principles have been integrated into restoration ecology to assist in best restoration practices and mitigation of any conflict or negative outcomes in repairing damaged and degraded ecosystems (SER, 2017; IUCN, 2017). There are a wide range of different practices and approaches to ecosystem restoration operating at many different spatial scales, some applying non-intervention measures and others requiring intervention in order of speeding up restorative actions (Hobbs & Cramer, 2008).

1.7 *Rewilding*

Rewilding is increasingly gathering momentum amongst the scientific community as a new pathway in conservation management and strategy (Perriera & Navarro, 2015; Jepson, 2015). There has also been momentum behind suggestions of rewilding being the paradigm shift in management of landscapes and restoring wilderness areas (Soule & Noss, 1998). The term rewilding lies within the boundaries of restoration ecology and can be defined essentially as ecosystem restoration by way of reintroduction of species, however, there is controversy surrounding definitions (Nogues-Bravo *et al*., 2016; Corlett, 2014; Crowley *et al*., 2017). It has been documented that there is a significant lack of consensus in defining rewilding which is potentially resulting in conflicts of the concepts objectives, potential results, and benefits involved (Nogues-Bravo *et al*., 2016). It has been described as the reduction of anthropogenic control of landscapes with passive management of ecological succession with the aim of restoring functionality of ecosystems (Perriera & Navarro, 2015). It has also been described as a strategy for the protection of self-sustaining ecosystems (Brown *et al*., 2011), and a way in which will lead to greater engagement with biodiversity and the natural environment from the public (Nogues-Bravo *et al*., 2016).

Rewilding has been described as potential restoration of ecosystems by way of reintroduction of certain species (Nogues-Bravo *et al*., 2016), often referred to as ‘trophic rewilding’ (Jepson, 2015; Svenning *et al*., 2016). Historically, mankind has negatively impacted populations of species, which in many cases, numbers of apex consumers (predators) and large mammals are reduced or even extirpated from their distributional ranges (Estes *et al*., 2012; Smith *et al*., 2015). The degradation of these species populations took place on a global scale and was followed by a wide body of research and evidence that stated negative outcomes such as altering the dynamic processes of invasive/alien species, disease/pathogen cycles, fire regimes and carbon sequestration as well as changes to the atmosphere, water and soils (Estes, *et al*., 2012; Seddon *et al*., 2014). An example is the removal of large predators such as wolf, by humans from an ecosystem which can result in hyper-herbivory, a spike in herbivore populations resulting in vegetation shifts from over-grazing and eventually food chain and ecosystem collapse, this is known as trophic cascade (Terborgh & Estes, 2010; Ripple *et al*., 2016). There is now consensus amongst restoration scientists that there is significant potential for a keystone species to restore ecosystems and harbor resilience to mitigate against global threats such as that of invasive species and climate change (Ritchie *et al*., 2012). The apex predator or keystone species in an ecosystem, has major effects on prey and other biological properties, provides interactions and dynamics with competitors, and potentially influences organisms and food webs in a top-down regulatory fashion significantly influencing ecosystem function (Terborgh & Estes, 2010; Svenning *et al*., 2016). However, there can be potential problems to predict any outcomes of rewilding in an ever-changing environment due to rapid climate change (Corlett, 2014). It is also now considered how varied ecosystems are, making them context dependent as interactions between predators and prey and the impacts on plant communities by herbivores are not replicable between ecosystems (Shurin *et al*., 2002; Hillebrand *et al*., 2007).

Innovative ecosystem restoration projects such as the differing rewilding techniques, particularly trophic rewilding through species reintroductions, are becoming in the forefront of environmental planning and policy (Svenning *et al*., 2016; Nogues-Bravo *et al*., 2016).

1.8 *Species Reintroductions*

The focus of any species reintroduction is to reinstate either captured ‘wild’ or captive bred animals, to areas of the species historical distributional ranges where they have declined or been made extinct due to anthropogenic influences (Armstrong & Seddon, 2008; Jorgensen, 2013). Human beings have an ancient history of translocating plant and animal species for reasons from aesthetics to establishing constant food resources (Green, 1997; Armstrong & Seddon, 2008; IUCN/SSC, 2013). Species reintroductions are being applied across the globe for a range of conservation initiatives (Lipsey, 2007). The use of species reintroductions to mitigate against losses of biodiversity and enhancement of ecosystem restoration is a relatively new science (Seddon *et al*., 2007; Polak & Saltz, 2011; Jorgensen, 2013). During the 1970’s a range of large charismatic species such as the Arabian oryx were reintroduced which helped gather momentum for reintroductions among the public and scientific community as a feasible conservation tool (Seddon *et al*., 2007; Corlett, 2014). Publicity appeared to have found attraction in species reintroductions as aspects such as handling, transporting and releasing species, display actions made by authorities to report positive progress to members of the public (Seddon *et al*., 2007, 2014). However, it has tended to be short term interest as outcomes for reintroduced populations remained seldom seen and, in some cases, un-monitored to determine any success (*ibid*). In a study by Seddon *et al*., (2007) it was suggested as for the limited data for reintroductions of the 1970’s and 80’s, only a small minority of projects found success while many reintroduced species populations failed to establish. Similar factors appear with plant species reintroductions highlighting success rates declining over time due to aspects such as a fall in monitoring after initial phases and a lack of definition in criteria and indicators of success (Godefroid *et al*., 2011). There are reintroductions that have been successful however, it has been determined that these have been achieved due to the removal of the factors surrounding an initial population decline, releasing a large quantity of individuals and having had a healthy remaining wild source population (Fischer & Lindenmayer, 2000). In recent times, it has been attempted to combat the underlying issues surrounding species reintroductions with the formulation of IUCN reintroduction guidelines (IUCN/SSC, 2013). The underlying objective of producing these guidelines is for conservation benefit including for the ecosystem in which the species is present or for achieving a viable population status amongst the species (*ibid*). However, with the integration of these guidelines and advances in reintroduction biology there is still some degree of uncertainty surrounding what defines a successful outcome of a project (Robert *et al*., 2015). Any reintroduction project should integrate a study of feasibility that places emphasis on ecological, environmental and socio-economical probabilities of success (Goodman *et al*., 2012).

It is now considered the two fields of restoration ecology and reintroduction biology can combine to enhance probabilities of conservation success of a project (Lipsey *et al*., 2007). Early reintroductions focused usually on a single species often overlooking the role of the species in the ecosystem context and reintroductions were rarely applied specifically for restoration of ecosystem function purposes (*ibid*). Applying reintroductions focused on restoration of ecosystem functionality has gathered momentum (Polak & Saltz, 2011). An example of this is the reintroduction of the Eurasian beaver *Castor fiber* which is a unique species that plays a significant role on ecosystem function relative to its biomass and abundance (Janiszewski *et al*., 2014). Specifically, in degraded agricultural freshwater ecosystems *Castor spp.* can contribute significantly to restoration targets and objectives enhancing ecosystem function and resilience (Law *et al*., 2017).

# 2 *Literature Review*

## 2.1 *Aquatic/Freshwater Ecosystems*

One of human societies most valuable natural resources are aquatic ecosystems from coastal waters, freshwater lakes, ponds and river systems producing industry, fresh drinking water, areas of recreation, and a wide range of important habitats for a diverse range of species (JNCC, 2014b; Mainstone *et al*., 2018). MEA synthesis reports were produced for wetlands and freshwater ecosystems (2005a), which were stated to have suffered some of the most significant, degradation (MEA, 2005a; Horwitz & Finlayson, 2011). With changes in the climate and anthropogenic impacts working synergistically, in some cases, these ecosystems have been stated as the most rapidly degrading of all, which correlates with the loss of organisms and species, greater than any other ecosystem type (MEA, 2005a). Marine, aquatic & freshwater environments underpin global economies and societies, and can provide wide-ranging diversity of flora and fauna but has faced centuries of over-exploitation and degradation due to unsustainable anthropogenic activities (Aronsen & Alexander, 2013; SER, 2017; CBD, 2017). As a result of a wide range of factors biodiversity losses in freshwater systems have also been stated to be far greater than other terrestrial ecosystems (Dudgeon *et al*., 2006).

Natural processes strongly influence functioning of freshwater ecosystems with determining factors such as landscape and catchment characteristics and climate (Mainstone *et al*., 2018). Nutrient cycling and delivery, geomorphology with deposition and erosion and the hydrological regime can create a wide ranging diversity of mosaics and marginal, aquatic habitats (*ibid*). The MEA (2005a) have stated that a lack of understanding and recognition of the ecosystem services provided by freshwater systems is an integral driver behind management and decision making that continues to convert and further degrade the associated habitats and species within.

Freshwater river systems are integral to human wellbeing and development and have many direct and indirect drivers of negative change (MEA, 2005a). Aspects such as the alteration of flow regimes to river systems are set to intensify as a result of anthropogenic climate change (Hannaford, 2015). Coupled with aspects such as increased storm events the severity of flooding is set to increase (*ibid*). The impacts on river flow regimes from accelerated climate change are thought could lead to wide ranging negative impacts on human societies through results such as increased flooding, diminishing water availability, poor water quality, and ecosystem services degradation (*ibid*). Other habitats associated with river systems such as flood plains, in their natural state, have been recorded to be amongst the most diverse ecosystems and can be one of the most biologically productive (Tockner & Stanford, 2002). The rapid decline in aquatic diversity is closely linked to floodplain degradation through negative processes such as alteration of habitat, facilitation of invasive species, pollution and control of floods and flow regimes (*ibid*). As a result of such negative impacts it has been stated that in Europe up to 90% of flood plains have been converted and concluded ‘functionally extinct’ (*ibid*). despite the urgent requirements of conserving these habitats future degradation is said to increase and potentially widespread extinctions and elimination of ecosystem services will occur in the future (*ibid*). Anthropogenic influences and actions such as dredging, canalisation, drainage management and large scale removal and alteration of vegetation have been instrumental in such degradation of rivers (Mant & Janes, 2006).Other interventions such as reducing and negatively impacting connectivity with the construction of dams and weirs have been widespread particularly in Europe (*ibid*).

In Britain, despite actions by government bodies and new initiatives to combat environmental degradation of aquatic ecosystems, in 2017, it was assessed that 36% of surface water bodies in Britain achieved ‘good ecological status’ (JNCC, 2018b). It has also been stated that there are no freshwater ecosystems in Britain that are considered ‘pristine’ (UKNEA, 2011). Anthropogenic influences disturb many of the UK’s river catchments (Hannaford & Buys, 2012). Several of Britain’s rivers estuaries have increased concentrations of nitrogen and Phosphorus and many symptoms of negative eutrophication (Maier *et al*., 2008). There are several direct and indirect causes including agricultural run-off, diffuse pollution, and urban groundwater discharges as well as others (*ibid*).

From an EU perspective the conservation and protection of these ecosystems gathered momentum in December 2000 with the introduction of the legislation EU Water Framework Directive (WFD) (EC, 2016). The WFD is a novel approach produced by the EU integrating habitats, water resource and quality, flood management and promotes management of whole river catchments (Willby *et al*., 2006). However, There have been concerns raised from the WFD such as the true definition of ‘good ecological status’ (Neale & Heathwaite, 2005), required of aquatic systems in EU member states (EC, 2016). Other issues such as the threats to aquatic ecosystems from climate change and their impacts on the WFD objectives are not covered in depth (Willby *et al*., 2006).

The development and introduction of effective management strategies and practices for aquatic freshwater ecosystems is vital as for the greatest biological diversity, the largest proportion of threatened species, and the most unsustainable resource use by humans in comparison to other terrestrial ecosystems (Finlayson *et al*., 2017). It was predicted that the pressures and degradation of all aquatic ecosystems will reduce the capacity of wetlands to mitigate against losses of human well-being (*ibid*), seen by increased storm events and increased water born diseases since the

MEA (2005) was published (MEA, 2005a; Layke *et al*., 2012; Turak *et al*., 2016). Global demand for wetland ecosystem services and the products provided by them are set to ever increase (MEA, 2005a). However, there is considerable recognition that the implementation of management strategies for conservation of biodiversity and ecosystems, do not necessarily halt development and rather benefit growth with generation of economical, ecological and social benefit (De Groot *et al*., 2010).

In few ground-breaking projects, Eurasian beaver, a keystone species in these ecosystems, have been reintroduced for restoration purposes in the UK (Campbell-Palmer *et al*., 2016; Law *et al*., 2017).

## 2.2 *The Eurasian Beaver*

### 2.2.1 *Identification*

*Castor fiber* is a large herbivorous semi-aquatic rodent with some adults weighing in excess of 20kg (Campbell-Palmer *et al*., 2015). It can be difficult to identify the sex of individual beavers from sight alone, male or female, unless a female is lactating or pregnant despite females on average being slightly larger than male beaver's (Muller-Schwarze, 2011; Campbell-Palmer *et al*., 2015). They characteristically have large, orange incisor teeth to gnaw and cut through woody material (Wilsson, 1971; Campbell-Palmer *et al*., 2015). There is also a great deal of similarity with the Eurasian beaver's North American cousins *Castor Canadensis* (Rosell *et al*., 2005; Gaywood *et al*., 2015; Batbold *et al.*, 2016). *Castor spp.* have unique large, scaled, flat tail like a paddle, that has a wide range of uses (Campbell-Palmer *et al*., 2015). Senses such as hearing and particularly sense of smell are very good, however, fairly weak vision and small eyes is a feature of *Castor fiber* (Wilsson, 1971; Campbell-palmer *et al.,* 2015). The species has webbed feet to assist with swimming with a specially adapted grooming claw (Campbell-Palmer *et al*., 2015). Eurasian beavers have been found to have a lifespan of 7-8 years on average

(Gaywood *et al*., 2015). However, this has also been documented as 12-14 years in the wild (Campbell-Palmer *et al*., 2015). *Castor fiber* are social animals that live in family groups that usually consist of a pair of breeding, monogamous adults, sub-adults or yearlings, and kits (Rosell *et al*., 2006; Gaywood *et al*., 2015; Mayer *et al*., 2017). Both male and female individuals come to sexual maturity at approximately twenty months (Campbell-Palmer *et al*., 2015) which correlates with average juvenile dispersal age (Hartman, 1997; Mayer *et al*., 2017). The female will have one litter per year with an average of 1 to 4 kits (Campbell-Palmer *et al*., 2015). However, on the River Otter up to 6 kits have been recorded in one litter (DWT, 2017).

Plate 1. DWT (2018) *Castor fiber* release, River Otter (Upton, N., cited in: DWT, 2016a).

2.2.2 *History of the Eurasian Beaver (Castor fiber)*

The Eurasian beaver is a species with a dynamic, long term relationship with mankind. Historically, by the early 20$^{th}$ century, only eight populations remained throughout their natural range, which were isolated, it was believed that figures fell to approximately 1200 individuals (Dewas *et al*., 2011; Halley *et al*., 2012; Batbold *et al*., 2016). It is widely accepted this was a result of overexploitation and persecution from anthropogenic activities (Halley & Rosell, 2002; Halley *et al*., 2012; Batbold *et al*., 2016). Due to pressures from habitat loss and over-hunting the species for its meat, fur, and castoreum, dramatic population losses occurred over the Eurasian beaver's natural range (Kitchener & Conroy, 2008; Dewas *et al*., 2011; Campbell-Palmer & Jones, 2014; Batbold, *et al*., 2016). In more recent times, the species has seen a significant recovery in population figures and has occupied most of its former distributional range, (MacDonald *et al*., 1995; Halley & Rosell, 2002; Halley *et al*., 2012; Campbell-Palmer & Jones, 2014). It is found occurring in a variety of freshwater systems such as rivers, streams, canals, lochs, lakes, reservoirs and even man-made irrigation ditches inhabiting ideal habitat with surrounding woodland, to sub-optimal agricultural and urban landscapes (Halley & Rosell, 2002; Dewas *et al*., 2011; Swinnen, *et al*., 2017).

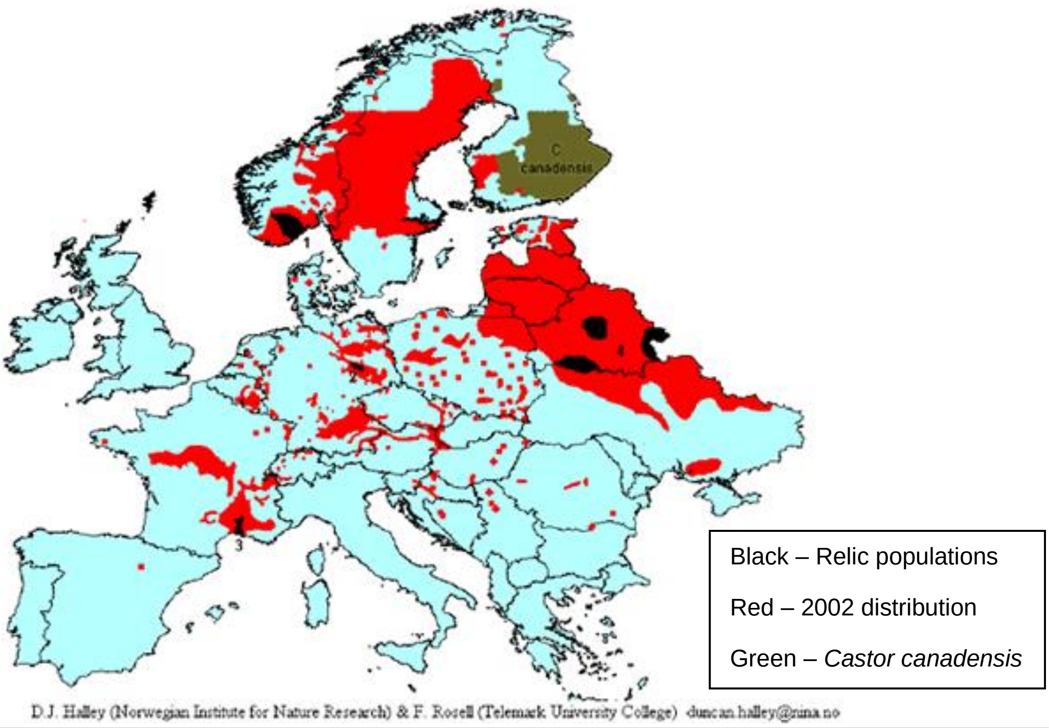


Figure 1. *Castor fiber* 2002 Distribution Map (Halley & Rosell, 2002). Natural recovery assisted by protection laws, reintroductions and successful translocations has seen populations colonising areas where they have been absent for centuries (Halley, 2010; Dewas *et al*., 2011; Batbold *et al*., 2016), with population estimates of above 1 million individuals by 2012 (Halley *et al*., 2012).

There are several reasons why such emphasis has been placed into the restoration of *Castor fiber*, such as, its decline resulting from human operations, which create a duty to conserve them socially and integrated into policy through the EU habitats directive (Campbell-Palmer & Jones, 2014). They are also often referred to as ecosystem engineers with their characteristics and behavior gaining significant interest from the scientific community and more specifically restoration ecologists (Rosell *et al*., 2005; Law *et al*., 2017). Current figures on *Castor fiber* population growth are set to continue to rise (Halley & Rosell, 2002; Halley, 2010; Halley *et al*., 2012) which may lead to human-beaver conflict as landscapes that are dominated by anthropogenic operations, are recolonised by the species (Swinnen *et al*., 2017). This has been recorded in a study by Dewas *et al*., (2011) assessing the species population recovery in France. Beaver's began to occupy sub-optimal habitat areas creating conflict with landowners through crop damage and flooding from damming which can however, be mitigated against effectively, in a range of ways (Dewas *et al*., 2011; Elliott *et al*., 2017). Scattered throughout the UK, there has been reported field signs and photographic evidence to suggest free living wild beaver populations in small numbers in the environment (Campbell-Palmer *et al*., 2016). Therefore the species is already present in the landscape highlighting the need to fully understand *Castor fiber* behaviors minimising probability of human-beaver conflict and allowing beavers to provide the benefits for ecosystem restoration (*ibid*).

In present times in Britain, beaver populations may not be impacted by persecution and overexploitation by humans due to protection laws and cultural changes. This can only benefit probabilities of success as the removal of the drivers that forced extinctions or declines is a key factor in IUCN guidelines on reintroduction (IUCN/SSC, 2013).

## 2.3 *Ecosystem Engineer*

### 2.3.1 *Eurasian beaver Modifications*

*Castor fiber* is seen as a keystone species in riparian ecosystems with the ability of modifying and manipulating the habitat due their behavioral characteristics creating multi-habitat structures and dynamic wetland environments giving the species a label of ecosystem engineer (Collen & Gibson, 2001; Rosell *et al*., 2005; Law *et al*., 2017; Elliott *et al*., 2017). The concept of ecosystem engineering from reintroduced Eurasian beavers to restore ecosystems and biodiversity in degraded agricultural systems that makes up much of the UK, has been rarely applied (Kemp *et al*., 2011; Law *et al*., 2017; Puttock *et al*., 2017). It has been stated that the species can have multiple benefits for riparian ecosystem restoration both ecologically and economically (Jones *et al*., 1997; Thompson *et al*., 2016a).

A behavioral characteristic of *Castor fiber* is dam construction (Rosell *et al*., 2005). A typical beaver dam is constructed with the use of materials such as mud, stones, branches, logs and twigs with the desire of creating a safe refuge, feeding areas, and to retain deep water, particularly around the natal lodge (Campbell-Palmer *et al*., 2015; Gaywood, 2017). It has been established that damming can create a range of hydrological, ecological and geomorphological feedbacks which result in increasing floodplain-channel connectivity and river/stream complexity which provides wide ranging benefits for terrestrial and aquatic communities (Macfarlane *et al*., 2017). Research by Hood & Larson (2014) found that beaver modified habitat with dams can promote connectivity by greater volume to surface area ratio of wetlands by up to 50% and having dramatic increases of riparian perimeters by 575%. There is widespread scientific evidence that the dams and associated canals constructed by beavers significantly increase habitat diversity, add habitat mosaic complexity and provide added resilience to the ecosystem against external negative factors (Gurnell *et al*., 2009). Beavers also can influence changes in valley and channel morphology through such damming activity (Giriat *et al*., 2016).

In England, on a tributary draining from intensively managed grasslands, two captive Eurasian beavers were introduced to an enclosure to investigate how the species impacted aspects such as water quality, flow regimes and storage of water (Puttock *et al*., 2017). These river and stream features can be altered by the installation of beaver dams (Collen & Gibson, 2001; Hartman & Tornlov, 2006; Gaywood *et al*., 2015; Puttock *et al*., 2017). Overtime, the beavers installed a total of thirteen dams on the site which resulted in significant positive changes in flow attenuation, increased storage of water, and a reduction of nitrates, phosphates and suspended sediments leaving the enclosure (Puttock *et al*., 2017). There can also be benefits to downstream communities following events such as heavy storms as there is a substantial fall in discharge peak levels in lower river reaches resulting from beaver dams (Nyssen *et al*., 2011; Puttock *et al*., 2017). The dams built by *Castor fiber* can be a natural measure for the control of flooding (Nyssen *et al*., 2011).

It has also been made evident that ponds and pools created by dam building, can act as nitrogen and carbon sinks attributing to a vital ecosystem service (Wohl, 2013; Lazar *et al*., 2015; Wegener *et al*., 2017). As a beaver dam ages, without maintenance from individuals it will rapidly overgrow and decline in height will occur (Campbell-palmer *et al.,* 2015; 2016). The area immediately behind the unmaintained dam will drain and pioneer riparian species will establish, and succession occurs creating a diverse beaver meadow (*ibid*). Once a beaver meadow has established, soils have been found to sequestrate greater levels of carbon density than forest habitat (Johnstone, 2014).

It appears that *Castor fiber* can have a widespread positive influence on a range of species present in aquatic riparian ecosystems. Over the period of 12 years, a *Castor fiber* population was monitored following being reintroduced for ecosystem restoration purposes in a degraded fen resulting from agriculture (Law *et al*., 2017). Results concluded that plant species richness rose by 46%, total of species recorded had risen 148% and a 71% increase in heterogeneity was recorded, highlighting that this species may assist in meeting restoration goals and objectives (*ibid*). A previous study by Law *et al*., (2014), also recorded selective grazing by beaver increases diversity and richness of macrophyte communities. Beaver damming and pond creation has also been found to have wide ranging benefits for amphibian and fish populations (Dalbek *et al*., 2007; Stevens *et al*., 2007; Kemp *et al*., 2011; DWT, 2016a) and increases in bird species diversity and abundance (Gurnell *et al*., 2009). Their modifications have also been found to benefit other mammals and reptile species resulting in overall positive effects on biodiversity (Gurnell *et al*., 2009; Stringer & Gaywood, 2016).

In the case of any new initiatives and practices relating to the ecological restoration of rivers and streams, it is increasingly accepted that habitat heterogeneity is a key factor in assisting and enhancing aspects such as the decomposition of organic matter, a vital property that underpins ecosystem function (Frainer *et al*., 2017). It has also been documented that river systems and other fresh water habitats can be improved by adding woody debris and re-meandering (Palmer *et al*., 2014). These operations carried out by human intervention can be potentially costly and time consuming whereas there is evidence to suggest *Castor fiber* can implement these features naturally through their behavioral traits and modifications (Rosell *et al*., 2005; Pollock *et al*., 2014; Campbell-Palmer *et al*., 2015).

### 2.3.2 *Feeding/Foraging Behavior*

The herbivorous Eurasian beaver displays selective feeding patterns and foraging behavior with their diet being made up of tree bark, new stems and leaves, aquatic/riparian plant spp., as well as other terrestrial plants such as herbs, and ferns (Haarberg & Rosell, 2006; Campbell-Palmer *et al*., 2015). However, the plant species selected for foraging vary upon season (Nolet *et al*., 1995). Before winter, foraging activity can be focused on producing a food cache close to the natal lodge or burrow, which can be vital over particularly cold, icy winters as food can be constantly accessed (Campbell-Palmer *et al*., 2015). Predominantly, *Castor fiber* display habitual tendencies when feeding, often returning to the same area, producing what is referred to as a feeding station made up of woody debris such as peeled sticks and wood chips (*ibid*). Foraging and feeding activity has been found to usually occur close to the water's edge, within 20-25m (Campbell *et al*., 2005; Campbell-Palmer *et al*., 2015). However, in flatter terrain, Eurasian beaver can actively create networks of canals which can open new feeding areas, provide essential escape routes when threatened, and to transport forage and building materials (Campbell-Palmer *et al*., 2015). They also will be dammed by beaver in periods of drought and can create wet woodland habitat (*ibid*). Wet woodland created by *Castor fiber* can hold significant amounts of diverse deadwood types which can be a key ecological attribute to an ecosystem (Thompson *et al*., 2016). Invasive, alien species such as Himalayan balsam *Impatiens glandulifera* and Japanese knotweed *Fallopia japonica* are also fed upon during summer months (Campbell-Palmer *et al*., 2015). The complex foraging activities by Eurasian beaver have been found to have significant positive effects on plant community structure, composition of species and ecological succession (Rosell *et al*., 2005; Campbell-Palmer *et al*., 2016).

## 2.4 *Risk/Threat to Eurasian beaver*

### 2.4.1 *Mortality*

Mortality in *Castor fiber* can occur from a range of sources including old age, disease, predation and climatic variations (Gaywood, 2017). In a study by Campbell *et al*., (2012a) it was found that in Norway, mortality annually is 28-36% for juveniles and adults without dominance, 13% for dominant adults and 8% kits. Kit survival is dependent on a range of factors that include habitat quality, population densities and age of parents (Campbell *et al*., 2012a; Campbell-Palmer *et al*., 2015). In the past there has been little published information describing beaver mortality post any reintroduction program (Goodman *et al*., 2012). Today there are health surveillance techniques to assist in monitoring post beaver reintroduction (*ibid*). Other mortality factors include predation, aggressive/traumatic interactions, disease and anthropogenic actions such as road incidents (Gurnell *et al*., 2009).

### 2.4.2 *Scent Marking & Dispersal*

A characteristic behavior of Eurasian beaver is scent marking with anal gland secretion (AGS) and castoreum (Campbell-Palmer & Rosell, 2010; Campbell-Palmer *et al*., 2015). This is a highly developed form of communication for *Castor fiber* that has been found to be important for territorial interactions (Rosell & Nollet, 1997; Campbell-Palmer & Rosell, 2010; Tinnesand *et al*., 2013). Olfactory signaling by beavers is well advanced and carries a wide range of information about the sender such as age, sex, relatedness and dominance (Rosell & Thomsen, 2006; Campbell-Palmer & Rosell, 2010; Campbell-Palmer *et al*., 2015). Scent mounds can be found throughout a beaver territory usually close to the edge of water, at resting and feeding areas, and mostly at the boundaries where neighboring family groups can respond aggressively to each other's scent marking (Tinnesand *et al*., 2013; Campbell-Palmer *et al*., 2015). Olfactory signaling can also play a key role when juvenile, sub-ordinate beavers disperse to find new territory (Tinnesand *et al*., 2013). Too many species, natal dispersal is a key factor determining the future success of an individual’s life and is often a very dangerous period (Tinnesand *et al*., 2013; Mayer *et al*., 2017). Beavers have been found to be aggressive at this stage and where population density is high, many young beavers will be injured or even killed during natal dispersal (Campbell-Palmer *et al*., 2015). Scent mounds can potentially minimize aggressive encounters with coding of age and dominance, potentially warning intruders (Tinnesand *et al*., 2013). Dispersal is likely to happen during the trial period of the River Otter Beaver Trial, which is a natural aspect of the species life-cycle (DWT, 2016a). Aggressive encounters can also be considered natural behavior and these interactions can be important for the species (Tinnesand *et al*., 2013). Due to low population densities of beaver on the River Otter and is unlikely to cause any vulnerability to the species (DWT, 2016a).

### 2.4.3 *Burrows & Lodges*

*Castor fiber* will usually have several burrows in a territory used for resting and a family group will have a natal burrow or lodge (Campbell-Palmer *et* al., 2015; DWT, 2016a). The kits are born in the protection of a lodge or burrow (Wilsson, 1971; Gaywood, 2015) and will remain there for the first two months (Campbell-Palmer *et al*., 2015). The focal point for a beaver family is a natal lodge or burrow of which, designs, sizes and shapes can largely vary (Campbell-Palmer *et al*., 2015). The entrances to beaver burrows require deep enough water to be under the surface, a minimum depth of 0.7-1m (Collen & Gibson, 2001; Campbell-Palmer *et al*., 2015). River and stream gradient plays a role in habitat selection of the Eurasian beaver due to this factor (Howard & Larson, 1985; Hartman, 1996; Campbell-Palmer *et al*., 2012; BACE, 2017a). In certain areas following years of many storm events, flooding of lodges and burrows can be a high mortality factor (Campbell-Palmer *et al*., 2015). If water levels fluctuate over a long period of time it can be devastating to a beaver family as *Castor fiber* have been found to rely on stable water levels, particularly during winter months around the lodge or burrow (Wilsson, 1971; Nilsson & Dynesius, 1994).

### 2.4.4 *Predation*

There are several species that will predate on *Castor fiber*, however, wolf *Canis lupis* is said to be the greatest threat, although populations of wolf are too small to have a regulatory effect on beaver in Europe (Tyurnin, 1984). *Castor fiber* populations in Britain will not encounter such species. In the UK, natural predators such as Eurasian lynx have long been extirpated, however beaver kits can face predation from dogs, foxes and badgers, raptor species and in few cases large pike (Campbell-Palmer *et al*., 2015). It has been documented how olfactory signaling by *Castor fiber* can act as an advertisement to predators giving away presence and location (Rosell & Sanda, 2006). Otter *Lutra lutra* have now also been recorded opportunistically predating on Eurasian beaver kits (Campbell-Palmer *et al*., 2015).

### 2.4.5 *Inbreeding Depression*

In many regions across *Castor fiber's* distributional range, the species were reduced to relic, fragmented, isolated populations (Gurnell *et al*., 2009; Campbell-Palmer *et al*., 2015; Batbold *et al*., 2016). Beavers have previously been found to be lacking in some aspects of genetic structure, potentially resulting from superimposition of bottlenecking pre-existing genetic structure (Babik *et al*., 2005; Gaywood, 2017). This may have led to phenotypic irregularities and a degree of inbreeding depression amongst Eurasian beaver (Halley, 2011). However, in further research it has been made unclear that historically *Castor fiber* has suffered from inbreeding depression (Rosell *et al*., 2011). This has placed emphasis and importance on the sourcing of *Castor fiber* for reintroduction as it is stated in IUCN guidelines that it is ideal if the source population is closely related genetically to the original native animals (Halley, 2011; IUCN/SSC, 2013). It has been argued that greater in-depth analysis of genetic data would be required before mixing source populations in a reintroduction program (Rosell *et al*., 2011). The greater the genetic data analysis will only benefit probabilities of reintroduction success and minimise any vulnerabilities from inbreeding depression (Rosell *et al*., 2011; Senn *et al*., 2014).

When *Castor fiber* is reintroduced to a catchment, there are trends that display a pattern of ranges rapidly extending before a period of large population growth and densities increasing (Halley & Rosell, 2002; Pinto *et al*., 2009). This can become a potential threat to beaver populations if permeability is constricted by barriers such as intensive agricultural land and human modifications or natural landscape features (*ibid*) which could result in increased pressures from inbreeding depression in Britain (Campbell-Palmer *et al*., 2015; Gaywood, 2017).

2.4.6 *Parasites & Diseases*

As with any wild species population, Eurasian beaver can carry some parasites and diseases (Gurnell *et al*., 2009). Resulting from genetic data analysis and rigorous health screening prior to any reintroduction, it can be determined if a source animal has any parasites or diseases that may cause health issues for the species itself or the general public (Rosell *et al*., 2001; Gurnell *et al*., 2009; Rosell *et al*., 2011). Although, it is believed that any risk from parasites, pathogens and diseases to human health will be very low (Gurnell *et al*., 2009; DWT, 2016a). Beavers have been found to contract diseases that can be of risk to their health such as Leptospirosis as well as others (Nolet *et al*., 1997; Rosell *et al*., 2001). It was found in 2015 during health checks of the River Otter beavers, that one individual was carrying the disease (DWT, 2016a). However, it was found to not be a risk to the individual or pose any threat to natural levels found across the environment (*ibid*). It has previously been a high factor of mortality post translocating beavers as it is believed that heightened stress to the animal and a weakened immune system can contribute to adverse effects (*ibid*). Furthermore translocation can contribute to the spread of parasites and pathogens to places where they are alien (Campbell-Palmer *et al*., 2015a). *Echinococcus multilocularis* can also become an issue as Eurasian beaver has been found to be a rare intermediate host to the pathogenic parasitic zoonoses which can pose significant health concerns (Gottstein *et al*., 2014; Campbell-Palmer *et al*., 2015c). In Europe the definitive hosts are canids including red fox and domestic dogs (*ibid*). Risk arises when potential translocation of infected beavers can introduce *E. multilocularis* to regions where it is absent (*ibid*). Cases have been recorded in individuals selected for reintroduction which has resulted in a level of risk placed on any translocation or reintroduction from both captive and wild Eurasian beavers (*ibid*). However, it is currently absent from the UK (Campbell-Palmer *et al*., 2015c).

Procedures of quarantine and health checks are an integral step in minimising any risk and threat prior to any beaver reintroduction (Gurnell *et al*., 2009; Rosell *et al*., 2011). The ROBT has outlined rigorous screening, health checks and quarantine measures in the management strategy to mitigate against risks of parasites and diseases (DWT, 2016a).

### 2.4.7 *Castor canadensis*

North American beaver, *Castor canadensis* have been recorded in several countries across Europe (Dewas *et al*., 2011; Campbell-Palmer *et al*., 2015). In many cases, captive bred *Castor canadensis* were used to supplement Eurasian beaver reintroductions as *Castor fiber* was facing extinction and many scientists and zoologists at the time, only recognised and categorised one beaver species (Parker *et al*., 2012). However future research on chromosomes revealed differences in the two species making *Castor canadensis* an invasive species in Europe (*ibid*). Furthermore, North American beaver have been found to out-compete its Eurasian cousin in areas where they interact and are considered a concern (Dewas *et al*., 2011; Parker *et al*., 2012). There has been no published or reported evidence of North American beaver being present in the wild at any time in Britain.

## 2.5 *Beavers and Humans*

### 2.5.1 *Human Conflicts*

The greatest threat to modern Eurasian beaver populations is said to be that their complex behavioral traits may conflict with anthropogenic operations and land management (Campbell-Palmer *et al*., 2015). In Europe it is illegal and prohibited to disturb, capture, or kill any beaver without authorisation through official procedure as *Castor fiber* is listed in the EU habitats directive (annex IV) and protected (Pillai and Heptinstall, 2013). It is also now illegal to prohibit the natural spread of *Castor fiber* in Scotland, placing high levels of protection on the species (Gaywood, 2017). Through natural spread and widespread reintroductions, the species is moving evermore into sub-optimal habitat and landscapes dominated by humans (Halley & Rossell, 2002; Swinnen *et al*., 2017). However, studies such as that by Swinnen *et al*., (2017), display that beaver populations can be supported in these areas, highlighting the importance of available wetland vegetation, and distance to water. It should be considered that it has been recommended that regulated hunting amongst healthy populations in highly-managed landscapes may be required (Nolet & Rosell, 1998; Halley & Rosell, 2002). The management of heathy beaver populations into the future may integrate both non-lethal and lethal control which is thought could assist with greater reception of the species being present in modern Britain (Campbell-Palmer *et al*., 2015).

### 2.5.2 *Infrastructure and Agriculture*

It has been documented that engineering activities and behavioral traits of *Castor fiber* can damage infrastructure and impact agricultural operations (Swinnen *et al*., 2017). Infrastructure can lead to increased risk to beaver from road fatality which has been recorded in Tayside, Scotland (Campbell-Palmer *et al*., 2015), Devon (DWT, 2018a), and has been a high mortality factor elsewhere in the Eurasian beavers distributional range (Batbold *et al*., 2016). It has been suggested that in most cases, beavers can inhabit areas very close to active road networks and no incidents have occurred (Cambell-Palmer *et al*., 2015b; 2016). The ROBT are fully aware of potential road incidents, however unlikely they may be, by securing liability insurance if any accident may occur (DWT, 2016a). Infrastructure can also be impacted from outcomes of beaver behavior such as burrowing activities (*ibid*) and blocking drainage culverts (Campbell-Palmer *et al*., 2016). However, there is tendency for this to only occur in populations with high density where sub-optimal habitat is occupied (Halley & Rosell, 2002; Swinnen *et al*., 2017). These factors are evidently integrated into the ROBT management strategy with a range of mitigation techniques signposted (DWT, 2016a). There is also ongoing research to monitor geomorphological changes and how beaver burrows may impact upon this (*ibid*).

*Castor spp.* can also feed on agricultural crops and in forestry plots (Batbold *et al*., 2016). However, any impact from beavers is likely to be far outweighed by impacts from other species such as deer (*ibid*). Areas where agriculture dominates land-use practices have been found to be where there are the most concerns surrounding beaver impacts (Perfect *et al*., 2015). Evidence from the Czech Republic by Krojerova-Prokesova *et al*., (2010), displayed that for a reintroduced population of beaver, foraging behavior showed seasonal variation between woody, and non-woody aquatic species and no damage to any agricultural crops or trees important to human communities economically, occurred. There are mitigation measures which can deter beavers from this activity if required such as many types of exclusion fencing (Campbell-Palmer *et al*., 2016).

### 2.5.3 *Beaver Modifications in Areas Valued for Alternate Objectives*

Potential conflict with land-owners and stakeholders can potentially arise from beaver activities and modifications in areas with other conservation interests (Jones, *et al*., 2008; Gaywood, 2017). It has also been stated that despite a positive impact on biodiversity, some habitats and species of importance for conservation can be negatively impacted without suitable management (Gaywood *et al*., 2017). A first beaver reintroduction license in Scotland was refused by government officials as the area that would be inhabited overlapped a designated Special Area of Conservation (SAC), where there was concerns regarding risk from beavers to ancient woodland (Jones *et al*., 2008). Following refusal, in research by Jones *et al*., (2008), regrowth of beaver felled trees was observed over a two-year period in two beaver enclosures. Willow *Salix spp.* and Aspen *Populus tremula* regrowth was measured and concluded that beaver felled trees can display annually up to 12x the rate of regrowth than growth observed in un-felled trees (Jones *et al*., 2008). It was also found that willow *Salix spp.* that were not completely felled by beaver, only amounted to 9% of felling activities on site resulting in a disproportionate contribution to the biomass of woodlands modified by beaver leading to complex structure of habitat (*ibid*).

In research by Rosell & Czech (2000), the hypothesis that felling of important trees and agricultural crop damage by *Castor fiber* can be controlled and managed by introducing predator scent odor was tested. Results were varied as the individual beavers displayed a range of different reactions with seasonal change which attaches many implications for this being applied as a viable management technique (Rosell & Czech, 2000). Many other mitigation measures are effective in reducing any damage by beaver to trees of importance such as appropriate beaver fencing (Campbell-Palmer *et al*., 2016; DWT, 2016a), and individual tree protection through a special anti-feed paint (DWT, 2016a).

### 2.5.4 *Damming Conflict*

Beaver dams have been recorded to significantly benefit downstream communities and minimize impacts from storm-events, sediment loads and pollutants (Puttock *et al*., 2017). However, if failure occurs in the structure of the dam, it could adversely contribute to peak flood levels (Butler, 1991; Butler & Malanson, 2005). Beaver dams can face breaching and potential collapse if unmaintained which will usually occur in either Autumn or Spring at peak water discharge times (Halley *et al*., 2009).This highlights the need for monitoring reintroduced beavers and potential mitigation may be required to minimise possibilities of dam failure in times of heavy, prolonged rainfall. However, the intricate design and installment of beaver dams makes them highly resilient in times of flooding (Campbell-Palmer *et al*., 2015).

The stereotypical behavior and conflict issue of *Castor fiber*, dam construction is not hereditary (Hartmann & Tornlov, 2006). The species will often occupy territories where they do not carry out this activity (*ibid*). In Scotland, in research by Stringer *et al*., (2016), estimations predicted that approximately 85-90% of the total length of Scotland's watercourses is unlikely to be dammed. Stream depth and width have been found to be a key factor influencing this behavior (Harmann & Tornolov, 2006; Campbell-Palmer *et al*., 2015). On the River Otter, Devon, individuals have begun damming in the upper reaches (Elliott *et al*., 2017).

Plate 2. Beaver Dam, River Otter Tributary (DWT, 2018a). Much of the occupied river body is reasonably wide and deep enough for damming not to occur (*ibid*). Despite this, damming activity is being recorded more frequently on the River Otter and its tributaries, recorded in early 2018 (DWT, 2018a).

In some cases, it has been concluded beaver dams can restrict fish species movement (Kemp *et al*., 2011). This has been documented in scientific articles, however, experts and published studies conclude an overall positive influence on fish populations resulting from improving channel habitat quality for overwintering and rearing areas, heterogeneity, invertebrate production and refuge of flow (Pollock *et al*., 2003; Gurnell *et al*., 2009; Kemp *et al*., 2011). There is also evidence to suggest this is the case for fish species considered important commercially (Gurnell *et al*., 2009).

2.5.5. *Flow Devices & Mitigation*

There is a reasonably long history and variety of mitigation measures to minimise conflicts that arise from dam creation by *Castor* spp., however the most effective and commonly applied solution is the installation of a flow device or 'beaver deceiver', of which many designs and models exist (DWT, 2016a; Vanderhoof, 2017). Essentially, flow devices can regulate the water levels created by beaver damming allowing the species to remain in areas where localised flooding could lead to conflict with human operations and infrastructure (Lisle, 2003; Boyles & Savitzky, 2009; Taylor & Singleton, 2013). It is excepted the species can hold a 'stimuli' to the sound and appearance of flowing water which can trigger dam building behavior, however, this is not universal for all individuals (Lisle, 2003; Taylor & Singleton, 2013; DWT, 2016a). Previous experience of mitigation such as the removal of beavers and dam destruction is only a brief solution and can be costly, as the species will likely return and continue this behavior (lisle, 2003; Boyles & Savitzky, 2009). This has been witnessed on the River Tay catchment, Scotland.

Plate 3. Flow Devices A, B, (Gow & Schwab cited in: Campbell-Palmer *et al*., 2016). Flow devices are designed to deceive the impoundment of water, allowing continued water flow through or around a dam applying deception to the species allowing water levels to be regulated (Lisle, 2003; Taylor & Singleton, 2013; DWT, 2016a; Campbell-Palmer *et al*., 2016). Various studies from North America have highlighted overall success of flow devices with Callahan (2005) concluding a 87% success rate and Boyles and Savitzky (2009) displaying 39 of 40 installed flow devices functioning properly and meeting management objectives.

There are also designs for mitigation measures against any blocking of culverts by beavers (Campbell-Palmer *et al*., 2016).

Plate 4. Drainage Culvert Beaver Mitigation (Schwab, G., cited in: Campbell-Palmer *et al*., 2016). Some culverts can act as damming points and removal of debris by humans can be effective but time consuming, as well as the knowledge that beavers having a persistence, will possibly return to continue dam construction. Therefore mitigation is focused on making the area surrounding a culvert appear unattractive to beavers. Plate 4 is a mitigation measure designed to hinder the transportation of woody material by *Castor fiber* to the culvert (Campbell-Palmer *et al*., 2016).

2.5.6 *Social Dynamics: Humans and Beavers*

Over time conservation management has integrated the advances made in the scientific community, however, human culture still plays a major role in the formulation of strategy and management of the environment (Vera, 2009; McLellan *et al*., 2014). It is the human socio-cultural dynamics of species reintroductions that usually require the greatest attention and detail to determine probabilities of success (Halley *et al*., 2009). There is widespread consensus that human values and ethics are integral drivers of conservation management (Ibisch & Hobson, 2014).

For a significant period of time, fresh water habitat and riparian landscapes have seen degradation, exploitation and widespread decline as a result of agricultural intensification and drainage management, for which, the value of reintroducing beaver will be significant for restoration (Campbell-Palmer *et al*., 2015; Law *et al*., 2016). However, if widespread reintroduction took place it may challenge socio-cultural views of clean, tidy, uniform canals and forests as the species will create a complex, diverse wetland environment (*ibid*). In a study by Kaphegyi *et al*., (2015), research assessed changes in the EU common agricultural policy and the re-intensification of farming practices and argued that an increase in beaver-human conflict portrayed in the media coincided with this. It was therefore found that alteration of land-use trends and policy could potentially result in further negative impacts on river systems in agricultural landscapes (Kaphegyi *et al*., 2017).

Good public perception and support are vital foundations to building a successful outcome of beaver reintroduction as the species behavior will not only be judged in scientific terms of ecological restoration but also by the local community who may interpret behavior differently (Gurnell *et al*., 2009). As such, transparency of projects, consultancy and education of beaver behavior can assist in gathering support of which, without can lead to possible sabotage and compromise of a reintroduction program (*ibid*). In research by Campbell *et al*., (2007), a range of studies from beaver experts throughout Europe were analysed on perception from people from different land-uses such as agriculture, fisheries, forestry and private or public gardens. Overall low-levels of any conflicts with land-use practices were recorded and there was mainly positive public attitudes towards beavers (*ibid*).

The collection of data regarding public attitudes and perceptions towards ecological issues are increasingly being carried out by questionnaires (White *et al*., 2005). An integral pillar of the IUCN guidelines on species reintroductions are social dynamics (IUCN/SSC, 2013). This is also the case for the MARISCO methodology (Ibisch & Hobson, 2014). There are a range of measures that can be applied to gather support networks for reintroductions from stakeholders and members of the public in and around the potentially affected areas (IUCN/SSC, 2013). Measures can have greater significance as there may be a disconnection between a reintroduced species and human communities if the species has been absent or extinct for a long time period (*ibid*), as may be the case for Eurasian beaver reintroduction to Britain.

## 3. *Scope: The beaver situation in Britain*

### 3.1 *Castor fiber in Scotland*

In 2009, Knapdale, Scotland, the first official Eurasian beaver reintroduction in Britain commenced under a five-year trial period managed by the Royal Zoological Society of Scotland and the Scottish Wildlife trusts, in partnership with the Forestry Commission, Scotland (Jones, 2009; Campbell-Palmer *et al*., 2015; Gaywood, 2017). There appears to have been varied levels of success with 10 individual beavers inhabiting the area at the end of the trial in 2014 from the 11 individuals released in 2009 (Jones, 2014). This includes an additional 5 released by 2011 (Gaywood, 2017), suggesting potential barriers in population growth. There have been issues which could have impacted the population growing such as a potential low success rate of breeding and kit survival (Gaywood, 2017). Further to this a second population have become established in Tayside, River Tay catchment, Scotland (Campbell *et al*., 2012; Gaywood, 2017). This population differs as it was unlicensed and it is believed that the beavers either escaped from captivity or were released intentionally, which was brought to the attention of the Scottish government back in 2006 (Campbell *et al*., 2012; Campbell-Palmer *et al*., 2015b; Gaywood, 2017). The government waited until 2012 to begin monitoring this population which continued through to 2015 (Gaywood, 2017), in which approximately 40 family groups were recorded (Campbell *et al*., 2012; Shirley *et al*., 2015). Scientific reports have been produced to attempt to predict population growth models of beavers in the Tay catchment (Shirley *et al*., 2015; Gaywood, 2017). At the licensed area in Knapdale, by 2039, 27 families of beaver were predicted providing a further 5 pairs are duly released (Shirley *et al*., 2015). In Tayside, by 2042 the same model predicted 160 family groups (Gaywood, 2017). Following these predictions, surveys from Tayside displayed findings of numbers far greater than earlier thought, with approximately 92 family groups recorded, almost double surveyed in 2012 (Gaywood, 2017; Campbell-Palmer *et al*., 2018). Natural expansion into nearby catchments, which was unpredicted, may be assisting rapid population growth at this early stage (Gaywood, 2017). In late 2016, a progressive move was applied by the Scottish government stating that both the Knapdale beavers and the Tayside beaver population will be legally protected, receive freedom for natural expansion and be allowed to remain in Scotland as a native species (Gaywood, 2017; ScottishWildlifeTrusts, 2017). These are not only the first beaver populations formally permitted, post-trial in Britain, but the first of any mammal species (Gaywood, 2017; ScottishWildlifeTrusts, 2017; RZSS, 2017).

3.2 *The River Otter Beaver Trial*

The Eurasian beaver has been reintroduced to Britain in a series of ‘ground breaking’ projects (Elliott *et al*., 2017). The Devon Wildlife Trusts (DWT) River Otter beaver trial (ROBT) in Devon, England, was granted a license to re-release captured beavers living on the river by Natural England (GOV.UK, 2015; DWT, 2016, 2017). In 2007, evidence emerged from sightings of a beaver inhabiting the river whose origin was unknown (DWT, 2016; Elliott *et al*., 2017). Further to this in 2012, a beaver was found deceased around the same location and it was believed the individual was of a single pair living on the river (DWT, 2016). In the following years it was confirmed in 2013 that a wild, breeding population of *Castor fiber* was present on the river and in early 2015, five individuals from two family groups were captured (DWT, 2016, Elliott *et al*., 2017). The individuals were given rigorous health checks which resulted in the beavers being confirmed as healthy (DWT, 2017). However, it was found through the DNA analysis of the individuals that inbreeding depression could become a significant factor in the future management of the River Otter population as they were found to be very closely related (DWT, 2016). Following the confirmation of good health, the beavers were released back on to the river under strict scientific research and monitoring guidelines in a five-year trial period (DWT, 2016, 2017). As part of the ROBT license from Natural

England, there is permission to release a further five individuals to assist in mitigating against inbreeding depression, in 2016 two individuals were released into the River Otter catchment (*ibid*). In 2017, the ROBT reached the half way point in the five-year trial with the population of beavers developing successfully (DWT, 2017). It was estimated at the beginning of 2017, there was 21 individual beavers living in 6 territories across the catchment with at least two-family groups giving birth to kits during 2017, further adding to population numbers (*ibid*). However in 2018, it has been reported that the population has approximately 8 pairs living in 8 family territories (DWT, 2018a). The project has been seen to gather much interest and excitement with beaver talks and walks getting high attendances from members of the public (DWT, 2016,2018a). The project receives no funding from the British government so relies on donations and causes such as beaver adoption packages (DWT, 2016, 2017) which appear to have gathered support. Professional support is a key asset of the ROBT, with partners including the University of Exeter, Clinton Devon Estates, Derek Gow Consultancy alongside the Devon Wildlife Trusts (Elliott *et al*., 2017). The ROBT has recently been awarded ‘Wildlife Success of the Year’ by readers of BBC’s Countryfile magazine (Clinton Devon Estates, 2017).

## 4 *Approaches to Assessment*

There have been many different approaches to management and planning for conservation of biodiversity and ecosystems (Ibisch & Hobson, 2014). With the gathering momentum behind species reintroduction projects, feasibility studies cover a wide range of dimensions and are advised to be carried out for each individual project before it commences (Goodman *et al*., 2012; IUCN/SSC, 2013). Post reintroduction, IUCN guidelines inform best practice to monitor outcomes of ecological, environmental and socio-economic importance (IUCN/SSC, 2013). However, underlying issues may still occur with non-linear processes and the unpredictability of climate change, the variability of interactions, impacts, and human culture in any given ecosystem being context dependent (Hillebrand *et al*., 2007; Ibisch & Hobson, 2014), and lack of definition surrounding successful outcomes (Robert *et al*., 2015). An assessment type that could be considered for reintroductions to measure impacts and changes both negative and positive and provide context to a projects implementation is a situation analysis. The IUCN have also produced a methodology for situation analysis (TNC, 2017). This method is focused on identification of the issues related to ecosystems and people that are impacted by a project, analysis of key stakeholders and communities as well as assessing the state and condition of the ecosystem and people with the inclusion of pressures and trends (*ibid*).

The Conservation Measures Partnerships (CMP) open standards for the practice of conservation is a wider framework for assessment which was created following results concluded from the Measuring Conservation Impact Initiative (MCI) in 2002 (cmp-openstandards, 2019a). The MCI integrated a wide range of fields including business, education, social services, development, public health and conservation in order of clarifying concepts of different approaches to sound project planning and design, management implementation and monitoring (*ibid*). Results compiled by the

MCI produced principles for management cycles and adaptive management measures and was further refined to focus on biodiversity conservation (*ibid*). In 2004 version 1 of CMP open standards was published and further updated in 2013 (*ibid*). This is now being applied to numerous projects globally and can be defined by 5 central pillars.


Figure 2. cmp-openstandards Project Cycle (2019). CMP open standards project cycle for planning, monitoring and management to be applied at all scales.

The key factors of CMP open standards include having a transparent, open, community-based procedure, widening the representation of stakeholders, applying a multi-disciplinary approach to strategic planning and situation analysis, and application that is not constrained by lacking evidence-based scientific knowledge (Ibisch & Hobson, 2014; cmp-openstandards, 2019).

MARISCO is a modified, daughter model of CMP open standards that has been adapted to greater emphasise socio-cultural dynamics, climate change, system dynamics and functionality as opposed to CMP's focus on viability (Ibisch & Hobson, 2014). It is suggested that an ecosystem approach coupled with adaptive management can widely benefit future strategy and management in times of change and unpredictability (JNCC, 2014a; Ibisch & Hobson, 2014). Due to the complexities of current ecosystems, networks and interconnections can become immeasurable (Ibisch & Hobson, 2012). MARISCO is a whole system analysis that embraces non-knowledge as complexity of systems may result in impossibility to record complete evidence, highlighting the need to integrate uncertainty and non-knowledge which can find blind-spots when carried out by different observers or groups (Ibisch & Hobson, 2012, 2014). Ecosystem based adaption principles however, are emphasized in the MARISCO process differing from the CMP approach (Ibisch & Hobson, 2014). The MARISCO methodology has been applied to larger landscapes and ecosystems placing emphasis on ecosystem dynamics and change, particularly focusing on the impacts and pressures from anthropogenic influences and climate change (*ibid*). The integration into the MARISCO methodology of ecosystem diagnostics analysis (EDA), spatial analysis and a more in-depth assessment of stresses adds additional skills to the process of ecosystem assessment (*ibid*). MARISCO has also introduced a vulnerability in adaptive management concept which can be completed in a situation analysis (*ibid*).

## 5 *Study Aims and Objectives*

The aim of this research is to carry out a MARISCO situation and vulnerability analysis for the River Otter ecosystem and reintroduced Eurasian beaver *Castor fiber* population, Devon, England. Key objectives include a.) providing context to the situation of the River Otter Beaver Trial, b.) to clarify the current state and character of the ecosystem, c.) determine any risk, threat and vulnerability to the River Otter ecosystem, d.) determine any risk, threat and vulnerability to the River Otter beaver population, and e.) gather an insight into the socio-cultural dynamics of the ROBT and public perception.

The current state of the ecosystem will be assessed with an Ecosystem Diagnostics Analysis (EDA), and assessment of ecological attributes. The EDA will also cover past and present trends in the River Otter ecosystem and risk, threat and vulnerability to the Ecosystem and Eurasian beaver population. A comprehensive assessment of stresses (pressures), risk and threat and contributing factors will complete the vulnerability dynamic and assist in the determination of potential outcomes and relationships between Eurasian beavers and the ecosystem. A Rural Participatory Appraisal questionnaire will review the socio-cultural dynamics surrounding the ROBT to complete the situation analysis.

# 6 *Materials and Methods*

## 6.1 *MARISCO*

The methodology used throughout this research is MARISCO and is an abbreviation of, ‘adaptive MAnagement of vulnerability and RISk at COnservation sites’ (Ibisch & Hobson, 2014). In the context of this study a MARISCO was applied not only to determine risk and vulnerability towards the ecosystem, but to analyse these factors with the management goal of the site (ROBT) and species of conservation interest, the Eurasian beaver in the form a situation analysis. The methodology is a risk-robust, rapid assessment technique that integrates adaptive management and the ecosystem approach as central pillars. It is believed to be a technique that can be replicated analysing risk and vulnerability towards any reintroduced or endangered species in any given landscape or system under anthropogenic pressures (Ibisch & Hobson, 2014). Throughout this research the MARISCO methodology was adapted to allow for an assessment of social dynamics and public perception of the ROBT. The social dynamic was recorded in the form of a Rural Participatory Appraisal RPA questionnaire. The MARISCO situation analysis was applied to determine risk and vulnerability to the ecosystem and Eurasian beaver population present, with the consideration of the issues surrounding beaver reintroduction and colonisation. To carry out this research, a certain degree of working knowledge of biodiversity conservation can be helpful to observe some risk and threat present which may add a degree of subjectivity to what is recorded, embraced by the process.

### 6.1.1 *Literature Review*

A review of current and historic published literature on Eurasian beaver *Castor fiber* was carried out and integrated to gain knowledge and understanding of the species and its behavioral characteristics. Due to the complexity of the behavioral traits of beavers this assisted in the ability to identify immediate risk and threat, direct or indirect. This also brought to the attention issues that may arise over time such as human-beaver conflict. The process helped identify areas to further investigate upon the EDA. The literature review was closely used to investigate impacts of beaver on the assessments of ecological attributes, stresses and risk and threat. .

### 6.1.2 *Ecosystem Diagnostics Analysis*

A key element and step of the MARISCO methodology is an ecosystem diagnostics analysis (EDA). This provided a scope of the study area integrating desktop study, spatial analysis and a ground-truthing exercise which was a fundamental step in gaining a knowledge base of the ecosystem, beaver population, and the risk and vulnerability impacts. The desktop study and spatial analysis applied the use of tools such as Google earth (2016-2018) and Environment Agency mapping (DATA.GOV.UK) including flood risk and LIDAR satellite imagery to understand aspects of landscape character and potential risk and threat to the system from external factors at a range of scales. The catchment and study area was divided into four areas (1-4) with the use of Google earth and OS mapping in order of creating manageable zones to survey during ground-truthing and desktop study. It was determined that each area would be able to be surveyed on foot over one day which would total a duration of 4 days for each site visit of the ground-truthing exercise. Areas 1-3 are similar in size whereas area 4 is larger but could be covered quicker due to restrictions in public access leaving some areas unable to be surveyed due to being located on inaccessible private land. Area 1 began at the River Otter estuary heading upstream ending with area 4 in the rivers headwaters.

Two people were sufficient for the exercise in this study, the researcher and an associate however, it can be beneficial to be carried out as a group made up of managers, stakeholders and members of the public (Ibisch & Hobson, 2014). The ground-truthing exercise investigated elements in-situ at ground level where all public access routes and footpaths of the main river body were surveyed through observations of risk and threat. MARISCO ecological attribute and stresses guidelines were used to categorise throughout the survey. Risk and threat were also recorded applying IUCN threat categories to be added to the risk/threat analysis (IUCN, 2018). The observations were noted by the surveyors and reviewed upon completion of the ground-truthing exercise. Impacts from beaver activity were observed indicating any risk, threat or conflict which may arise and where ecological processes, interactions, and outcomes from beaver colonisation are likely to occur. Ground-truthing also provided a more detailed scope of risk and threat to either the beavers or the ecosystem at ground-level where evidence could be recorded.

There are 3 essential details of EDA that were carried out for the analysis which are an interim evaluation of potential and existing risk and threat to the River Otter ecosystem and *Castor fiber* population, to characterise the study area, biodiversity objects and habitats within, and to identify potential boundaries and complexities that will require further in-depth investigation (Ibisch & Hobson, 2014). This MARISCO step integrates aspects of environmental impact assessment (EIA) with elements of landscape character assessment (LCA) (*ibid*).

The completed EDA will combat the aim of providing context to the ecosystem and assist in clarification of the current state of the ecosystem. It will also provide results of risk, threat and vulnerabilities to the system and beaver population. Knowledge obtained through the EDA is imperative for the following steps of the MARISCO analysis (Ibisch & Hobson, 2014). During the research exact location of beaver families present on the River Otter remain confidential in order of minimizing negative impacts on the population from conflicts and anthropogenic disturbances. This also respects the DWT ROBT management plan (DWT, 2016a).

#### 6.1.3 *Biodiversity Objects & Habitat Typologies*

The MARISCO situation analysis began formulation with an assessment of biodiversity objects and habitat typologies making up the River Otter ecosystem and study area. These factors were previously recorded as part of the EDA upon ground-truthing and desktop study. This provides justification to further isolate and investigate vulnerability to the ecosystem, habitat or species of conservation interest. Referring to the published literature on beaver ecology, it was determined which biodiversity objects and habitats may be modified or influenced by the species behavioral characteristics.

#### 6.1.4 *Ecological Attributes*

An assessment of ecological attributes was integrated to focus on the factors that underpin the healthy functionality of the ecosystem. This step identified aspects which play a role in the ecosystems function and can be placed under significant pressures from external negative factors (Ibisch & Hobson, 2014). With the direction of a whole system approach and adaptive conservation management it can be important to understand the essential elements for functionality of an ecosystem (Schlik *et al*., 2019).  key ecological attributes are elements of ecology or biology that if not present or altered, can result in ecosystem losses and degradation over time (*ibid*). The assessment will further explain and characterize the ecosystem state, begin complex understanding of risk, threat, and vulnerabilities, and can assist in management goal setting. The identification of ecological attributes is formulated applying guiding principles set out by the MARISCO methodology, Table 1. This process may require a degree of working knowledge of the biodiversity objects and habitat typologies recorded (Ibisch & Hobson, 2014).

Table 1. MARISCO Guidelines for Eco-Attributes (Ibisch & Hobson, 2014)

| |
|---|
| *Guiding questions for the identification of key ecological attributes are:* |
| *1. Which key characteristics are required for the functionality of the biodiversity object?* |
| *2. Which key characteristics would lead to the loss or total degradation of a biodiversity object when altered or missing?* |
| *3. Which key characteristics are required to ensure the resilience of a biodiversity object and for it to have a certain adaptive and buffering capacity against disturbance and environmental change?* |

The greater developed functionality of an ecosystem will indicate a wider capacity for self-ordering and self-regulation which can result in active contribution to self-maintenance (Ibisch & Hobson, 2014). The functionality of an ecosystem is dependent on the availability of *master factors* with the inclusion of *biomass*, *information* and a level of *networking* (*ibid*). Ecological Attributes were grouped into these categories.

### 6.1.5 *Current State of the Ecosystem*

A key factor was a brief assessment of the current ecosystem state. Measurable indicators formed by criteria set out by MARISCO were scored based on recordable elements in the field (*ibid*). Biodiversity objects and habitat typologies were grouped based on requirement of the same ecological attributes. For example, semi-natural broad-leaf woodland, plantation woodland and scrub having basic requirements such as species composition. The formulation of indicators to record the condition of eco-attributes is completed applying MARISCO S-U-M criteria (*ibid*).

Table 2. MARISCO S-U-M criteria for indicators (Ibisch & Hobson, 2014).

| **The S-U-M criteria for indicators** MARISCO |
|---|
| Sensitive: The change in indicator values must consistently correlate with changes in the condition to be managed, without showing any changes over time. |
| Unambiguous: It is clear from the evidence and understanding that the indicator relates directly to the condition to be managed. |
| Measurable: It must be possible to take reliable measurements with reasonably simple and cost efficient equipment or methods. |

If time and resource constraints are present, broader categorization of indicators can be carried out (Ibisch & Hobson, 2014). Large quantities of resources can be spent in the monitoring of habitat typologies and biodiversity objects which does not always ensure conservation action (*ibid*). Therefore there can be importance in finding significant indicators that are time and cost-effective to record (*ibid*). Indicators may be different between observers or participants of the MARISCO process depending on levels of knowledge and experience of the system (*ibid*). This is again embraced at later stages when knowledge gaps or blindspots may appear and add a more holistic, comprehensive assessment when carried out as a group or multiple times (*ibid*). Indicators selected were measurable factors recorded upon ground-truthing (EDA). An example is of the indicator of 'riparian plant species present'. This was determined briefly by applying a DAFOR scale to determine the abundance of riparian plant species against the invasive Himalayan balsam, recorded degrading the riparian habitat. Biodiversity objects and habitat typologies may be underpinned by ecological attributes, such as nutrient availability, functional diversity, and primary production which in some cases can also be very complex and difficult to measure. MARISCO identifies that habitat typologies and biodiversity objects that require many complex ecological attributes for a healthy state, are therefore more sensitive and less resilient to change (Ibisch & Hobson, 2014). The assessment of the conditioning of ecological attributes and their relationships provided a brief overview of ecosystem health. The scoring system for status of ecological attributes was applied using a MARISCO indicator scorecard.

Table 3. MARISCO Scorecard for Indicators

| 1 Very Good | 2 Reasonably Good | 3 Reasonably Poor | 4 Very Poor |
|---|---|---|---|
| *Indicator is in good condition/desirable state, Little or no intervention by management to continue functionality and condition* | *Indicator is reasonable in condition/level state, Intervention may be required* | *Indicator is in reasonably poor condition/undesired state, Attribute may face high risk without management intervention* | *Indicator is in very poor condition/undesired state, Intervention is required to attempt to restore functionality and condition* |

The situation analysis and conceptual model was then constructed to display key relationships between ecological attributes and biodiversity objects or habitat typologies in a cause-effect manner. The key relationships were identified during the EDA with the use and review of scientific literature to highlight relevance to this study focusing on the River Otter and Eurasian beaver population. This process further offers depth in the objectives of clarifying the state and character of the River Otter ecosystem and explaining risk/threat to the ecosystem.

#### 6.1.6 *Stresses Assessment*

An Integral part of the MARISCO methodology is the identification of stresses to the beavers and the ecosystem. The formulation and analysis of stresses is integral to the understanding of how threats impact biodiversity objects and habitat typologies (Ibisch & Hobson, 2014). This step is vital to begin obtaining knowledge of risk and threat generation to an ecosystem allowing the creation of hypothesis for cause-effect chains and the conceptual model (*ibid*). It is vital to understand how the ecosystem or habitat typologies are impacted by a threat (*ibid*). Stresses are symptoms for the improper functioning of an ecological attribute (Ibisch & Hobson, 2014; Schlik *et al*., 2019). A stress differs from a threat by way of threats being induced factors, direct or indirect that will result in a response or symptom (stress) in a conservation object or habitat typology (*ibid*). Stresses can also have significant relationships with each other (*ibid*), e.g. connectivity loss and isolation may influence inbreeding depression (Halley, 2011). In this study the criteria was also applied to stresses or pressures that could be placed on the beaver population. Stresses were recorded throughout the EDA process with the assistance of set criteria (Ibisch & Hobson, 2014). This added in-depth understanding of the risk, threat and vulnerability to the site and species. The formulation of stresses were identified applying criteria set out by MARISCO.

Table 4. MARISCO Criteria for Stress Identification

| MARISCO stresses |
|---|
| *1.* What negative changes can be recorded altering the biodiversity object/habitat typology? |
| *2.* What are the signs of alteration and illness? |
| *3.* Are there critical changes to environmental master factors such as water, soils or climate? |
| *4.* Are there losses of network, information or biomass within the ecosystem? |
| *5.* Are there losses of connectedness or network with other systems? |

Some stresses may have been observed upon ground truthing if the physical character or behavioral state of a biodiversity object or habitat typology appeared altered (Ibisch and Hobson, 2014). The same was applied when observations were made during the desktop study e.g. Environment Agency mapping (Nitrate Vulnerable Zones, NVZ's). MARISCO criteria for stresses may not apply when measuring factors that may impact the beaver population. Therefore the literature review on beaver ecology and habitat suitability could be used to determine if any stresses or pressures are present on the beaver population. Each identified stress is scored with the use of a MARISCO stress card to prioritise the most significant for potential future management.

Table 5. MARISCO Example of Score Card for Stresses

| Stress | 1. Criticality – Scope | 2. Criticality - Severity | 3. Criticality – Irreversibility | |
|---|---|---|---|---|
| | 4. Past Criticality (-20 yrs) | 5.Current Criticality (1+2+3) | 6. Trend of Change – of current criticality | 7. Future Criticality (+20 yrs) |
| | Chance of Conflict (Human-Beaver) | Management Intervention | | 11. Strategic relevance (5+6+7) |
| | 12. Manageability | | 13. Knowledge | |

The MARISCO scorecard scores different complexities such as (1.) *Scope* or scale, (2.) *severity* and (3.) *irreversibility* (Ibisch & Hobson, 2014). These factors result in a score for *current criticality* (5.). *'Past criticality'* was scored referring to literature on any obtainable knowledge of the stress historically. Following, the final score for each stress is known as '*Strategic relevance*' which adds *current criticality* with (6.) *trend of change* and (7.) *Future criticality* to provide an overall score for the stress. This final overall score will highlight the most significant stresses which can be integrated into management plans and actions to be addressed (Ibisch & Hobson, 2014). These can also be arranged into the MARISCO conceptual model as key relationships. The scorecard was adapted to allow for the impact to the Eurasian beavers with *'chance of conflict'* and *'management intervention'* if the species has a relationship with the stress and management may need to intervene. (12.) *Manageability* scores the stress for how easily and effectively managed it could be in the ecosystem context whilst (13.) *Knowledge* displays the level of knowledge of the stress identifying what may require further, in-depth investigation.

Scores are collated applying a 1-4 impact rating.

Table 6. MARISCO Scoring System (Impact rating)

| 1 – very low | 2- reasonably low | 3- reasonably high | 4- very high |
|---|---|---|---|

The score rating for each element of the stress was based on this 1-4 impact rating. Therefore, for (13.) *Knowledge* the score 4-very high is a positive factor. For all other elements of the scorecard 4- very high will represent a negative outcome e.g. (7.) *future criticality* = 4 very highly critical.

When complete, stresses were integrated into the MARISCO situation analysis and conceptual model which further highlights the key relationships stresses to the ecosystem and beaver have on ecological attributes. Stresses that scored highest '*strategic relevance*', supported by reviewing scientific literature assisted in determination of key relationships. This further adds to the objectives of determining risk, threat and vulnerability to the ecosystem and beaver population.

### 6.1.7 *Risk/Threat Assessment*

Risk and threat was mapped applying IUCN classification coding (IUCN, 2018) with the use of Google earth, (2015-2017). Approximate GPS locations of recorded risk or threat was taken upon ground-truthing (EDA) and assisted in positioning of where they may be generated and/or where impacts have occurred. Threats were grouped together in broader categories according to the IUCN classification. An example is the threats from Agriculture which include, annual & perennial non-timber crops, shifting agriculture, agro-industry farming and agro-industry grazing, ranching or farming. If any of these threats were recorded during the study they were grouped under the wider threat of agriculture. A full list of IUCN risk and threat categories are included within the appendix (appendix, 12.4). The ground-truthing exercise (EDA) assisted in determination of any immediate risk and threat to the ecosystem or beaver population recorded at ground level in-situ and through desktop study. Threats are negative factors that are induced usually by humans directly or indirectly that over varied time frames result in stresses on a habitat typology or biodiversity object (Ibisch & Hobson, 2014). In this research, threats have been selected that are present impacting the River Otter ecosystem and that may impact the Eurasian beaver population. When each threat was identified it was then scored with the use of a MARISCO scorecard which scores different complexities of risk such as *criticality*, *systemic activity* and *irreversibility* (Ibisch & Hobson, 2014).

Table 7. MARISCO Example of Score card for Risk/Threats

| Threat | 1. Criticality – Scope | 2. Criticality – Severity | 3.Criticality - Irreversibility | |
|---|---|---|---|---|
| | 4. Past Criticality (-20yrs) | 5. Current Criticality (1+2+3) | 6. Trend of Change (of current criticality) | 7. Future Criticality (+20yrs) |
| | 8. Systemic Activity (level of Activity) | 9. Systemic Activity (no. of influenced elements) | 10. Systemic Activity (8+9) | 11. Strategic Relevance (5+6+7+10) |
| | 12. Manageability | 13. Knowledge | 14. Chance of Conflict (Human Beaver) | 15. Management Intervention |

The MARISCO score card for threats slightly differs from the 'Stresses'. It has again been adapted to allow for relaying information on impacts to Eurasian beaver. With the addition of the *'Systemic activity'* dynamic, (11.) *Strategic relevance* (final scores) will be greater than those of stresses. *Systemic activity* records aspects such as the level of activity and number of influenced elements to greater understand the threat and their impact. *'Past criticality'* was again scored referring to literature on any obtainable knowledge of the threat historically. An example is that of the invasive riparian weed Himalayan balsam which has only got a foot hold in the catchment in recent times (OVA, 2018), resulting in a low past impact score. *'Future criticality'* is a projected future impact score referring to any literature on the threat e.g. Facilitation of invasive species is set to increase with climate change effects (Murray *et al*., 2011).

The criteria for scoring was based on the same 1-4 impact rating for stresses.

Table 8. MARISCO Scoring System (Impact Rating)

| | | | |
|---|---|---|---|
| 1 – very low | 2- reasonably low | 3- reasonably high | 4- very high |

The score rating for each threat was based on the 1-4 impact rating. Therefore, for (13.) *Knowledge* the score 4-very high is a positive factor. For the other elements 4- very high will represent a negative outcome e.g. (7.) *Systemic activity (level of activity)* = 4 very high level of activity.

Upon completion of the threat analysis, the MARISCO conceptual was model further completed in a cause-effect chain and situation analysis allowing the symptoms (stresses) of each threat to be determined. Key relationships were highlighted by observations made during the EDA and backed up with reviewing scientific literature. This provided greater depth to combatting the objectives of determining ecosystem and beaver risk, threat and vulnerability.

### 6.1.8 *Contributing Factors Analysis*

Formulation and identification of contributing factors completes the situation analysis and conceptual model and combats the key objectives of clarifying the ecosystem state, and determining vulnerability to the ecosystem and River Otter beavers. When this is carried out contributing factors linkage with threats highlight how the stresses, threats and vulnerability relate to root causes manifest in human actions (Ibisch & Hobson, 2014). Contributing factors are essentially the causes of threats giving an understanding of threat generation (*ibid*). For the majority of threats there will be more than one factor influencing negative outcomes that can be directly or indirectly responsible and contributing factors can work synergistically (*ibid*). Contributing factors were only determined for the ecosystem as Eurasian beaver can be considered as part of the River Otter system and not separate. MARISCO guidelines, coupled with observations made during the EDA also assisted in contributing factor formulation (Ibisch & Hobson, 2014).

Table 9. MARISCO guidelines for contributing factors

| Guidelines for identification of contributing factors MARISCO |
|---|
| *What are the reasons for the appearance of a threat or factor?* |
| *Which actors are involved in causing the threat? Are there reasons for doing so?* |
| *Are there any factors that have a positive relationship on a contributing factor or threat?* |

Following the formulation of contributing factors they were again scored on with the use of a MARISCO contributing factor scorecard, identical to that of threats.

Table 10. MARISCO Example of Scorecard for Contributing Factors

| Contributing Factor | 1. Criticality – Scope | 2. Criticality – Severity | 3.Criticality - Irreversibility | |
|---|---|---|---|---|
| | 4. Past Criticality (-20yrs) | 5. Current Criticality (1+2+3) | 6. Trend of Change (of current criticality) | 7. Future Criticality (+20yrs) |
| | 8. Systemic Activity (level of Activity) | 9. Systemic Activity (no. of influenced elements) | 10. Systemic Activity (8+9) | 11. Strategic Relevance (5+6+7+10) |
| | 12. Manageability | 13. Knowledge | Chance of Conflict (Human Beaver) | Management Intervention |

The MARISCO scorecard for contributing factors is identical to the scorecard for threats. As a result when completed the most significant factors can be determined which may potentially provide direction for future management. This also assisted in the formulation of relationships with threats in the ecosystem for the MARISCO conceptual model.

Contributing factors were scored applying a MARISCO impact rating for their influence on the ecosystem.

Table 11. Scoring System (Impact Rating)

| 1 – very low | 2- reasonably low | 3- reasonably high | 4- very high |
|---|---|---|---|

The score rating for each contributing factor was based on the 1-4 impact, or in this case influence rating. Therefore, for (13.) *Knowledge* the score 4-very high is a positive factor. For the other elements 4- very high will represent a negative outcome e.g. (7.) *Systemic activity (level of activity)* = 4 very high level of activity of the contributing factor.

Upon completion of integrating contributing factors to the situation analysis and conceptual model, conclusions can be drawn to assist in direction of recommendations for management strategies as root-causes of threats are determined (Ibisch & Hobson, 2014). Key contributing factors which scored the greatest *strategic relevance*, backed up by reviewing scientific literature was used to forge important relationships between factors and threats. This completed the objectives of clarifying the state and character of the ecosystem and the determination of risk, threat and vulnerability to the River Otter ecosystem and beaver population.

### 6.2 *Rural Participatory Appraisal: Questionnaire*

A Rural Participatory Appraisal (RPA) questionnaire was formulated and carried out to combat the objective of gathering a scope of social perspective of the ROBT. A key IUCN reintroduction guideline is to gather a scope into public attitudes (IUCN/SSC, 2013; Gaywood *et al*., 2015). With species reintroduction programs such as that with Eurasian beaver, it has been documented that gathering support from the local community that may be affected is a vital step determining probabilities of a successful outcome (Gurnell *et al*., 2009; Halley *et al*., 2009; IUCN/SSC, 2013).

#### 6.2.1 *Questionnaire Formulation*

Referring to literature on Eurasian beaver and their relationship with humans it was determined that questions would be formulated to gather scope on general public knowledge and perspective of the Eurasian beaver and ROBT. Integrating information on reintroduction feasibility studies such as that of Eurasian beaver (Gurnell *et al*., 2009), and rewilding in British lowland agricultural landscapes (Loth & Newton, 2018), with a review of other questionnaires relating to similar scenarios such as Eurasian lynx reintroduction (Smith *et al*., 2016), a total of 12 questions were formulated, including 2 open questions, closed questions were used to identify the demographic of the participants and a total of 6 scaling questions were also used for voluntary participants in and around the River Otter catchment. A full version of the questionnaire is attached in appendix 12.3.

#### 6.2.2 *Questionnaire Process and Demographic*

Members of the public were randomly selected and approached in and around the study area and voluntarily accepted invitation to participate in the questionnaire. A total of 26 participant’s aged 18+, 14 males and 12 females, volunteered to partake in the questionnaire on public perception of Eurasian beaver reintroduction to the

River Otter. All of the participants were recruited close to the River Otter area and were both locals and tourists.

#### 6.2.3 *Questionnaire Results*

The results from the RPA questionnaire were analysed with the use of brief thematic analysis. The data collected within the questions of the RPA were analysed by finding common themes throughout the participant's answers by grouping together answers that were similar and creating categories of answers. In the final open questions this was completed by finding regular and similar words used and collating them into negative and positive groups. Following data analysis any added vulnerability and risk was accounted for providing a scope into knowledge on socio-cultural factors which may affect future success of the project. This integral step will combat the key objective of providing a scope of public attitudes to the River Otter beavers.

### 6.3 *Considerations*

Throughout the ground-truthing exercise, careful consideration was taken to not disturb or interact with the beavers present on the river. This included any signs of presence such as feeding stations or food caches and feeding areas. The exact locations of any beavers inhabiting the river, unless published by DWT, will remain confidential. A risk assessment carried out for the ground-truthing exercise to ensure safety of the researcher and assistant, appendix 1. Ethical issues were also considered for the RPA questionnaire. An ethical approval form was completed and approval was received, appendix 12.2.

## 7 *Results: Ecosystem Diagnostics Analysis*

### 7.1 *Scope of the Study Area*

The River Otter catchment is located in the county of Devon in South-West England.


Figure 3. River Otter, East Devon, England (Google earth, 2018). The yellow circles represent the approximate geographic location of the river catchment in England.

The source of the River Otter rises in the Blackdown Hills, flowing South through the East Devon region towards its estuary on the Jurassic coast (EnvironmentAgency, 2016). The area has been designated an area of outstanding natural beauty (AONB) (*ibid*). Situated in a highly productive, modified, agricultural landscape the river passes urban areas such as the town of Honiton, flowing South-west through Ottery St. Mary, towards its estuary at Budleigh Salterton.

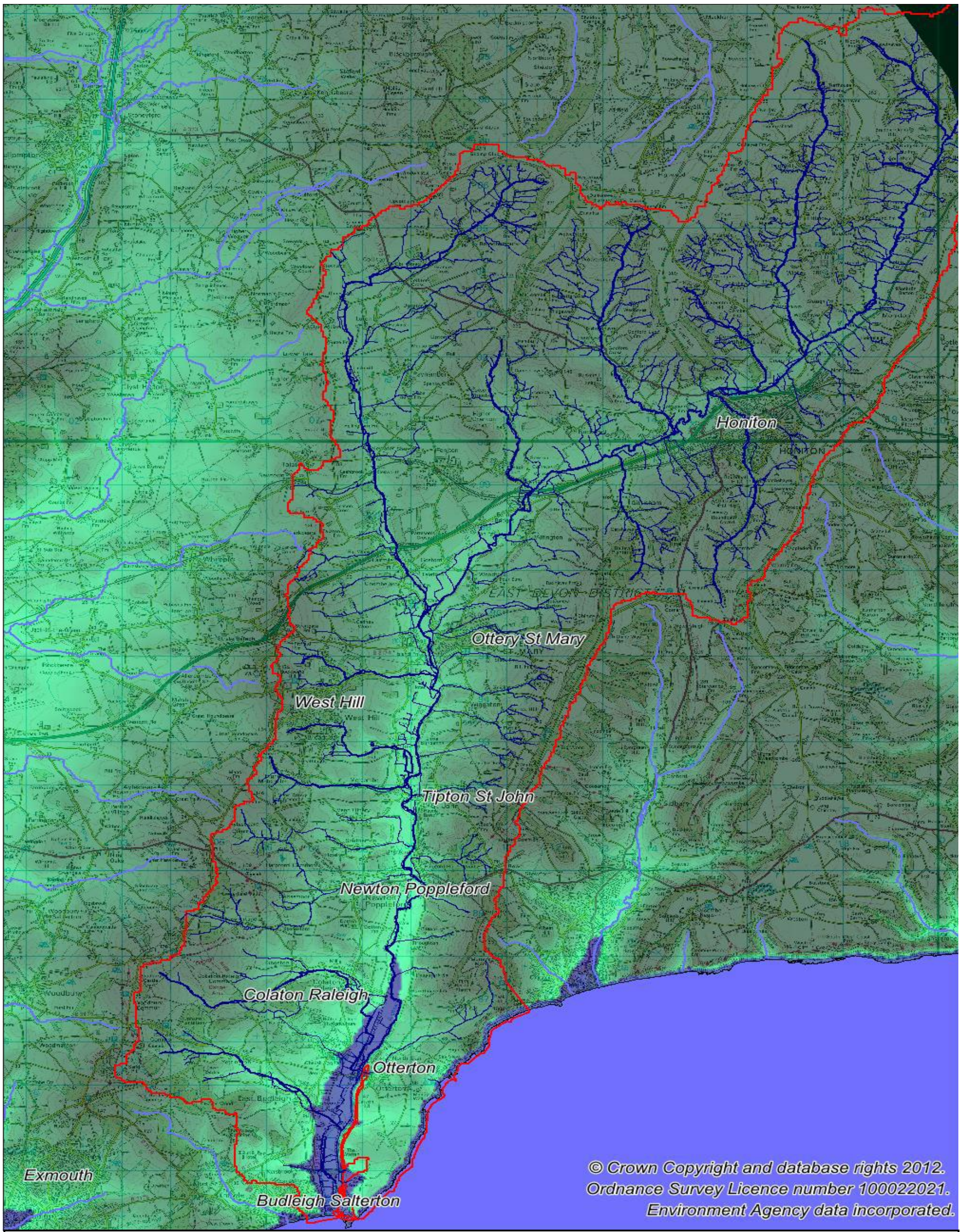


Figure 4. EA/DWT River Otter Catchment Map (DWT, 2016a). The Environment Agency (DWT, 2016a) produced a River Otter catchment map. The map assisted the Devon Wildlife Trusts management and monitoring plans for the ROBT. Results from monitoring have produced evidence of Eurasian beaver activity throughout the river (*ibid*). The catchment map assisted in planning for ground-truthing and represents the study area.

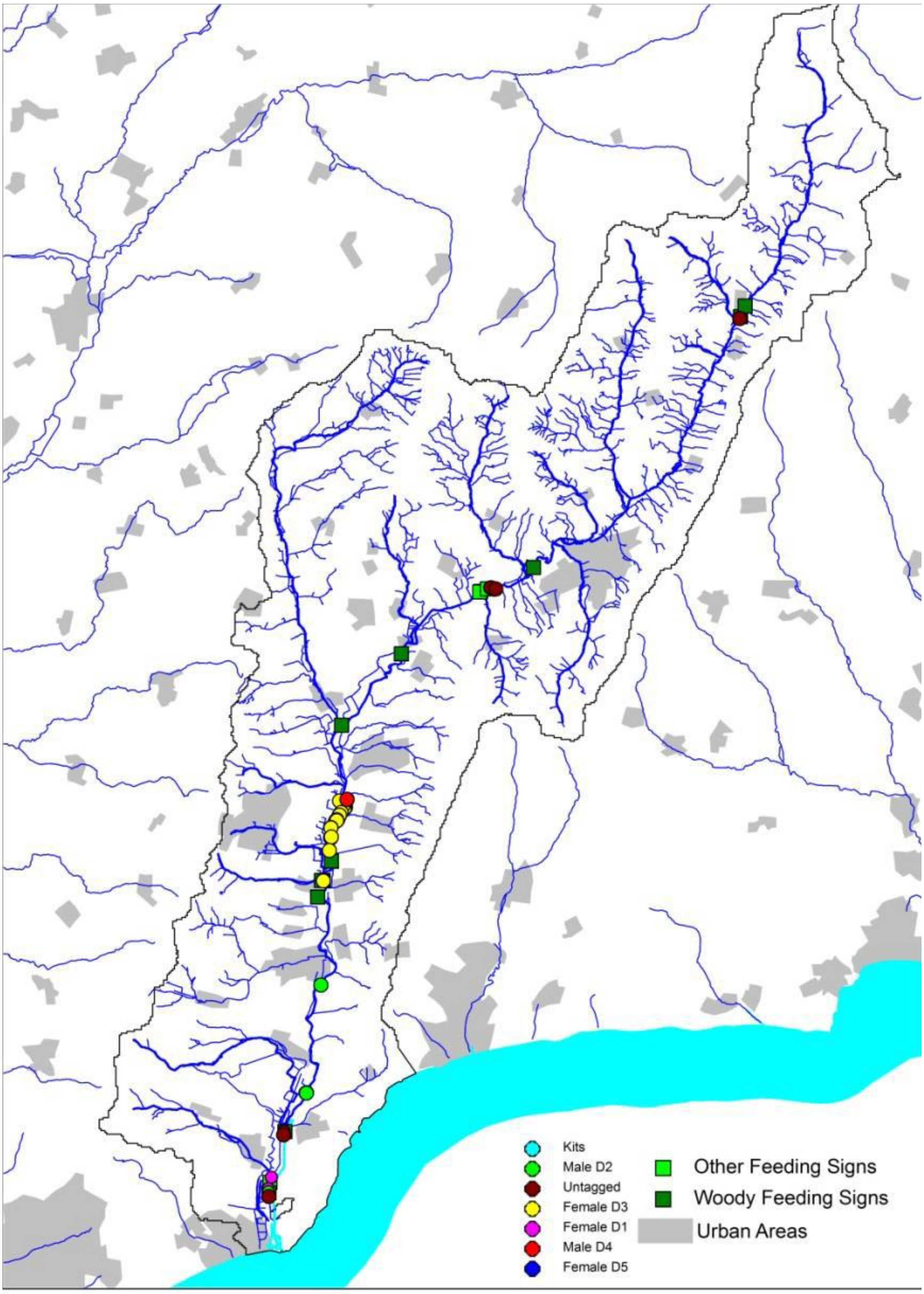




Figure 5. DWT Beaver Activity Map 2016 (DWT,2016a).The Devon Wildlife Trusts published a map of recorded beaver activity across the River Otter catchment in 2016 following data collected during monitoring. This map provided approximate locations to investigate further during ground-truthing.

Habitat typologies and biodiversity objects have been recorded in order of being integrated into the MARISCO situation analysis. Recording this can also help determine risk and threat, and suitability for beaver colonization identifying areas where there is increased risk of human-beaver conflict. These were added to at a later date following further investigation in-situ.

Table 12. Biodiversity Objects/Habitat Typologies of the River Otter.

| **Biodiversity Objects/Habitats** |
|---|
| Urban |
| Industrial |
| Infrastructure |
| Arable |
| Pasture |
| Improved Grassland |
| Rough Grassland |
| Semi-Natural Broad-Leaf Woodland |
| Plantation Woodland |
| Deadwood |
| Scrub |
| Hedgerows |
| Ditch Lines |
| Riparian Habitat |
| Tributaries |
| River Body |
| Woody Debris |
| Designated Nature Zones |
| Beaver *Castor fiber* activity |
| River Features (riffles, pools, vegetated/un-vegetated bars) |

The Environment agency produced a flood risk map of the River Otter and East Devon coast displays high level risk from flooding across the region, figure 2.3. With *Castor fiber* being present on the River Otter, the Devon Wildlife Trust (2016a) have projected flood risk to potentially be minimised in the future due to ecological traits of the species such as dam construction. If the beavers are able to colonise other rivers and water courses in the region, high risks of flooding could potentially be reduced saving large quantities of money for the local economy and potentially significantly enhancing regional biodiversity (Nyssen *et al*., 2011).

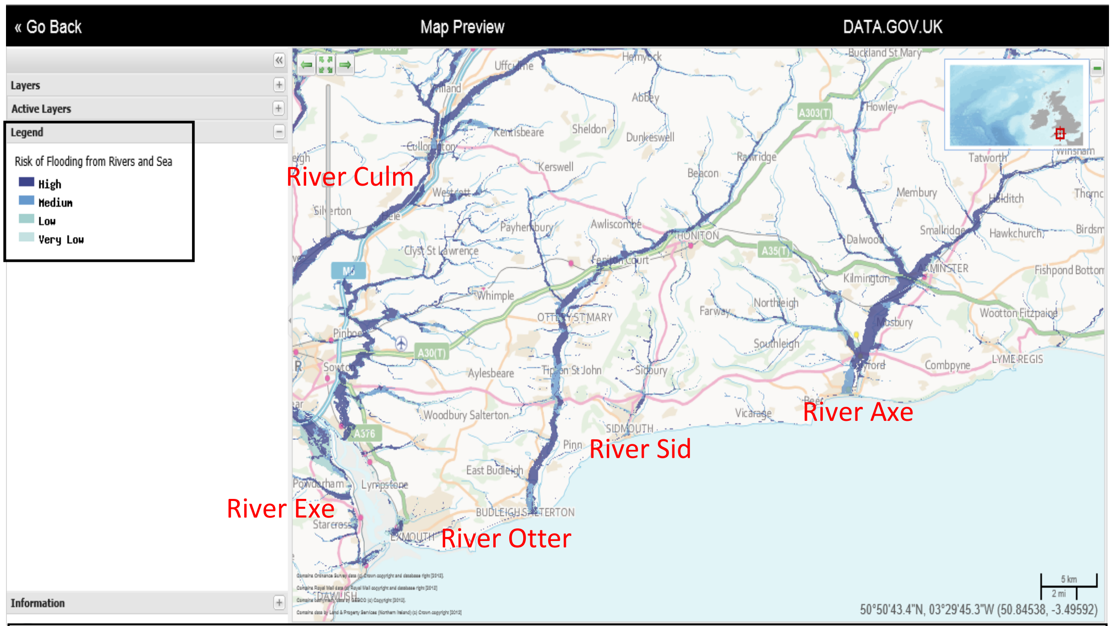


Figure 6. Environment Agency Flood Risk Map of the River Otter and East Devon Coast (DATA.GOV.UK, 2017). The names of the rivers have been added in red text next to the locations. High levels of flood risk are in place across the region which can have negative consequences both ecologically and economically. Areas of high risk are shaded in darker blue.

Elevation profile and gradient of a river can be an important factor in determining suitability of a site for a long-term beaver population (Gurnell *et al*., 2009; Muller-Schwarze, 2011; Campbell-Palmer, *et al*., 2015). Topography can play a key role in foraging with flood events and wetter years resulting in poorer growth of forage trees (Campbell *et al*., 2013). Low gradients are also considered important for food caches, dam building, and dens and lodges as low energy produced by the river system minimizes risks from damage to these vital habitat requirements (Gurnell *et al*., 2009). A study by Gurnell *et al*., (2009) expressed down river gradient as one of the greatest determining physical factor for beaver colonisation as it will control whether there is need for dam building, habitat creation, and controls velocity and river energy which can influence flood plain creation and bankside materials.


Figure 7. Elevation Profile/Gradient Ottery St. Mary to Estuary (Google earth, 2017). For this stretch of the river, gradient averages at 2.3% which is very suitable for beavers and could result in the species not creating dams which may minimise human-beaver conflict.

As the River Otter beaver population expands and territories become established, it may be important for the future of the population to disperse into adjacent catchments and watercourses, so they do not become isolated and face inbreeding depression. During the ROBT (2015-2020), as part of the Natural England licensing agreement, beavers are not permitted to disperse to these catchments and will be retrieved if this takes place (DWT, 2016a). However, the DWT have produced a map highlighting where this may occur in the future, figure 2.5 (DWT, 2016a). There is also a significant number of unoccupied stretches of the River Otter with good riparian habitat which are still to become established beaver territories suggesting that dispersal may not occur for some time (*ibid*).

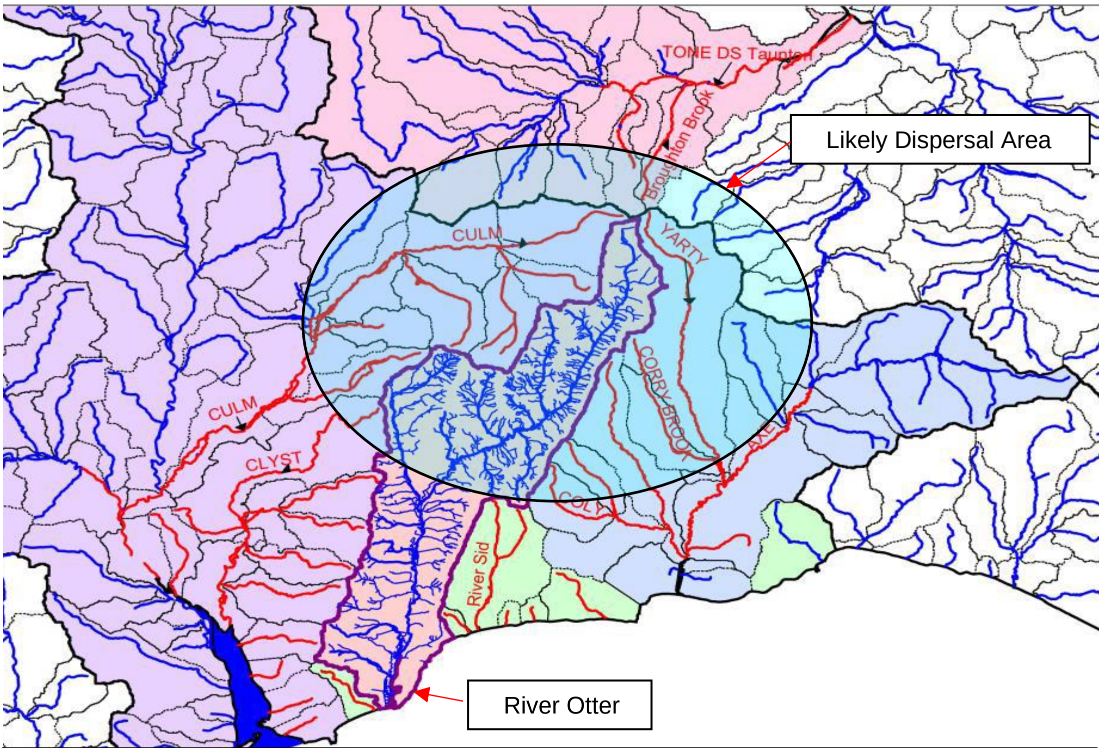


Figure 8. Potential *Castor fiber* Dispersal to Other River Catchments (DWT, 2016a). This map of the River Otter and adjacent catchments displays were dispersal may occur (*ibid*). Due to *Castor fiber* ecology there is a higher probability the species will disperse through the headwaters of the river where there is known opportunity for the population to develop further, highlighted by the blue circle (DWT, 2016a).

7.2 *Area 1*

The River Otter's estuary is located at Budleigh Salterton on the South-East Devon Jurassic coast, figure 3. The area is popular amongst tourists and has many attractions such as coastal paths and the estuary itself, which is a renowned bird watching area and site of special scientific interest (SSSI) (HeartofDevon, 2016). Beaver activity upstream is highly unlikely to impact the SSSI.


Figure 9. Budleigh Salterton and River Otter Estuary (Google earth 2017). The red polygon represents Area 1, the yellow polygon represents the catchment and study area.

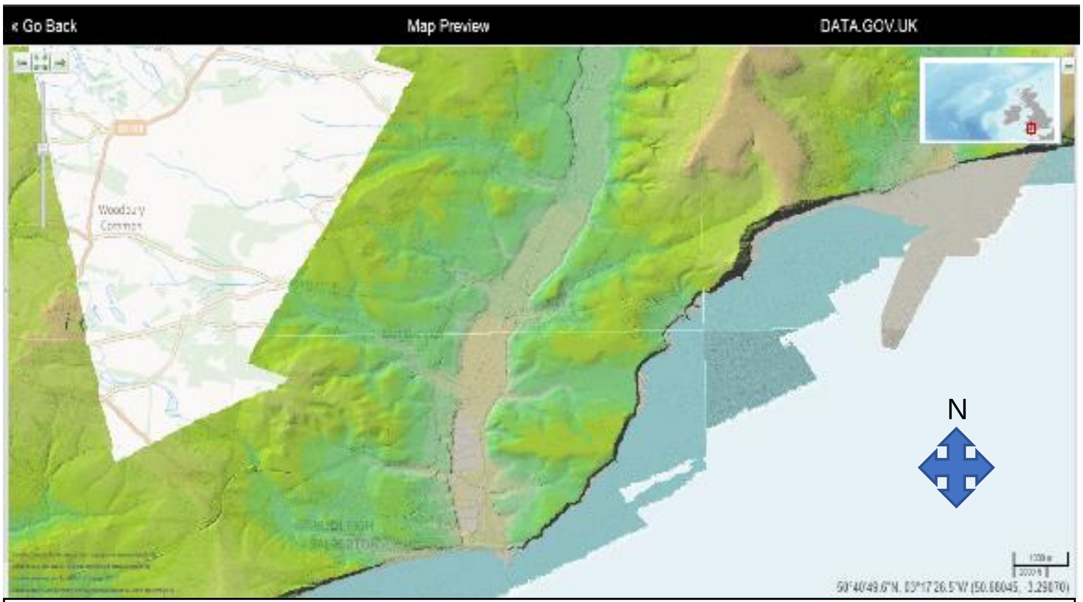


Figure 10. LIDAR Satellite Otter Valley Estuary (DATA.GOV.UK, 2017). The Otter Valley can clearly be observed along with the river basin and tributaries, LIDAR satellite image of area 1 (DATA.GOV.UK, 2017). The main river body runs along the eastern edge of the basin with flood plains in the West. This mapping assisted in determining areas that may susceptible to flooding.

### 7.2.1 *Ground-Truthing: Area 1*

There is an area within close-proximity to the river that is managed for forestry.

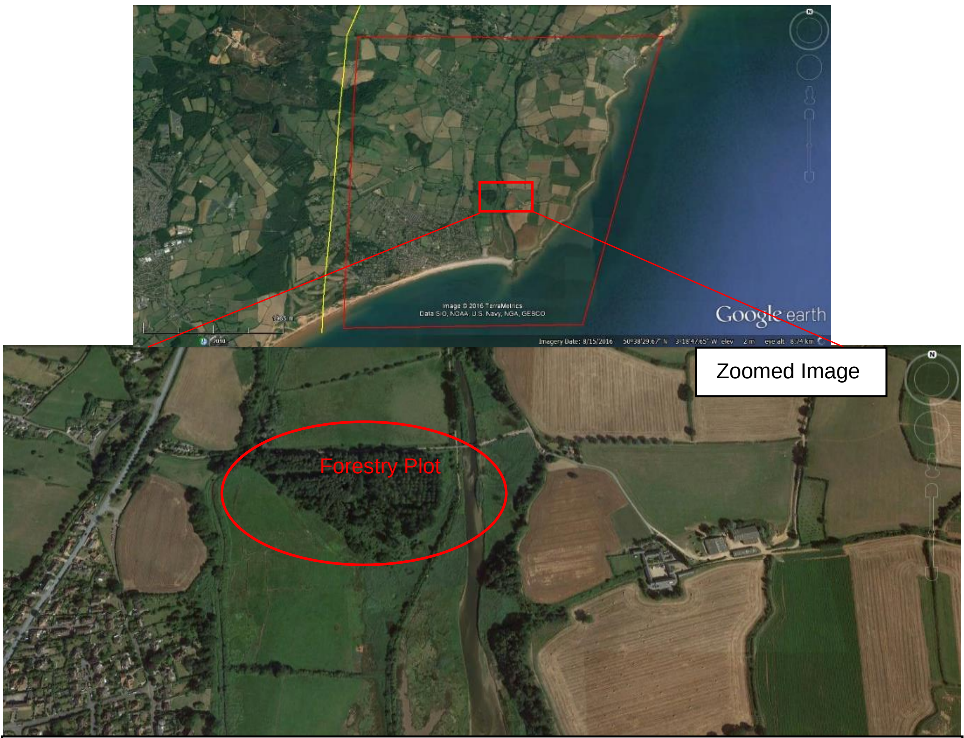


Figure 11. Forestry operations (Google earth, 2017). There are beavers active upstream, however, any conflict will be highly unlikely. Coniferous trees are rarely foraged and fed upon by beaver, with the species preference being broad-leaved species (Nolet *et al*., 1995; Haarberg & Rosell, 2006; Campbell-Palmer *et al*., 2015).


Plate 5. Forestry Plot (Frampton, 2017). Much of the area has been clear-felled at time of ground-truthing.

Reasonably large areas of riparian habitat run up the eastern bankside of the main river body, which holds many characteristics of favorable beaver habitat. Main tree species present are Willow *Salix spp.* and Alder *Alnus glutinosa*, favored food sources of *Castor fiber* (Jones *et al*., 2009; Elliott *et al*., 2017). The river here also has other features present such as mid-channel bars, vegetated side bars and point bars along with many other aspects which appear to alter flow rates and provide habitat for a diverse range of species.

Plate 6. Riparian Habitat Facing North, Upstream (Frampton, 2017). The river begins to feel more enclosed as the Otter Valley becomes more prominent in the landscape.

Plate 7. Poaching Lines (Frampton, 2017). The western bank of the river has less riparian habitat and a busy footpath running along its edge which has resulted in poaching lines.

The flood plain to the west of the river appears very wet in winter months.


Plate 8. Flood Plain (Frampton, 2017). These areas to the west of the river are under high flood risk. Reed beds, sedge and rush spp. are scattered throughout these fields as they appear very wet through the winter months.

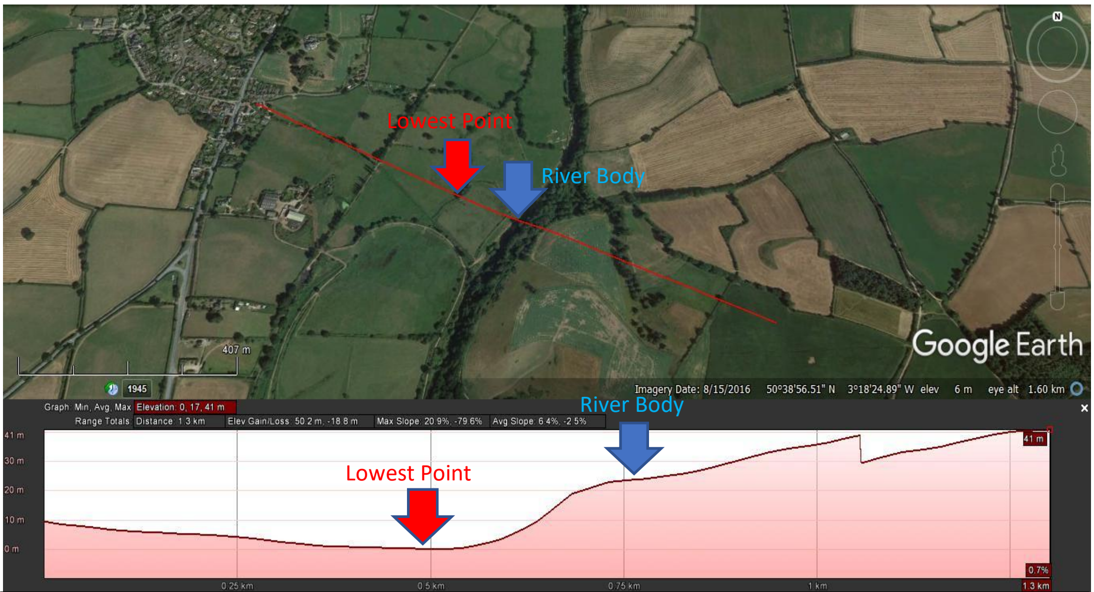


Figure 12. Flood Plain Elevation Profile (Google earth, 2017). The area immediately west of the main river is a degree lower than ground level at the river body, observed in the elevation profile. The topography may be a driver of flood risk attached to the area.

Flood risk has been prevalent for long period with evidence of floods seen in 1945. Forwarded to 2014, there is widespread evidence of floods to the West of the River Otter.

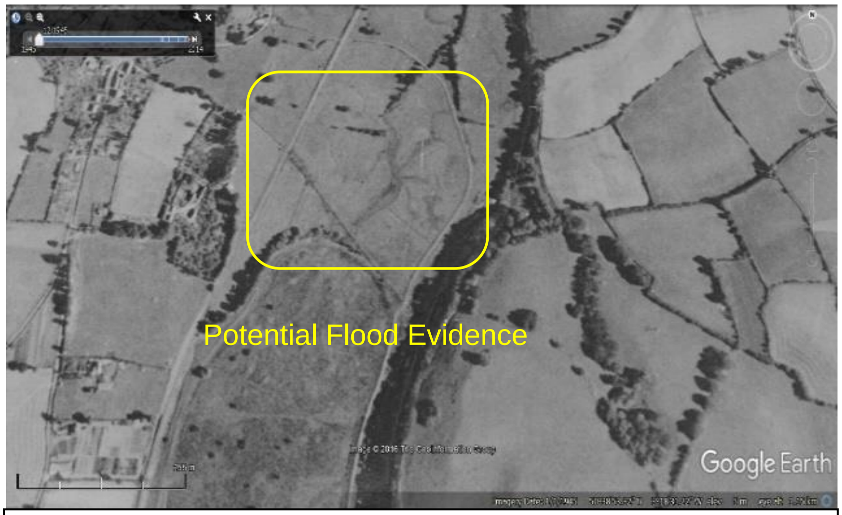


Figure 13. 1945 Floods (Google earth, 2017). The darker veins in the fields can be observed and are potential areas of flood damage as for the darker vegetation.

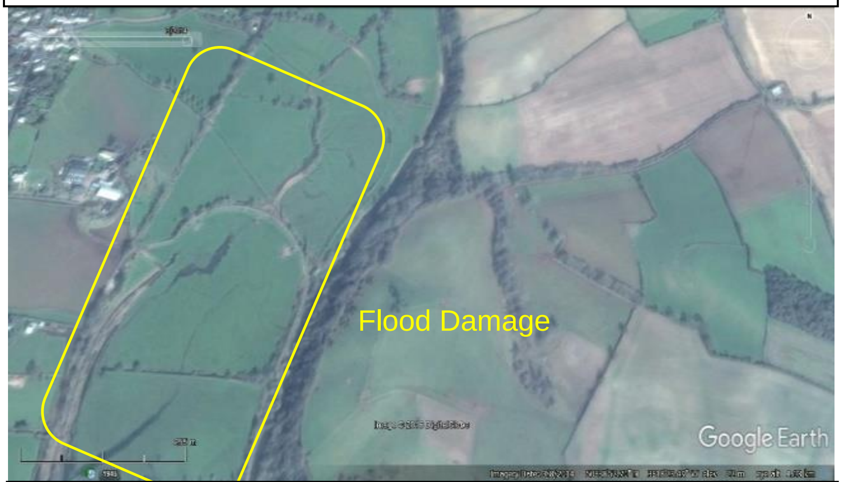


Figure 14. 2014 Floods (Google earth, 2017). Wet areas flooded in 2014 can be observed.

Floods can adversely affect local infrastructure as well as impacting agricultural practices and local economy. With presence of *Castor fiber* in the River Otter catchment, damming activity upstream has the potential to reduce effects from flooding downstream, attenuating flow in wetter months (Rosell *et al*., 2005; Elliott *et al*., 2017; Puttock *et al*., 2017).


Figure 15. Flooding Impacts (Google earth, 2017). Further flooding has appeared to damage agricultural crops potentially impact the region economically.

A line of relatively young willow *Salix* spp. makes up the western bank of the river and appears to be playing a key role in reducing erosion. Upon ground-truthing it was identified that beavers are foraging on the willow despite little riparian habitat and a footpath within close proximity.

Plate 9. *Castor fiber* Feeding Activity a (Frampton, 2017). This coppicing by beaver can enhance bankside stability and play a positive role in minimising erosion (DWT, 2016a).


Figure 16. River Otter Village (Google earth, 2017). The River Otter runs southwards through historic villages which are popular amongst tourists. *Castor fiber* are closely monitored on this river stretch.

Potential barriers to beaver such as an Environment Agency fish pass and the village itself do not restrict foraging activities and movement patterns.

Plate 10. EA Fish Pass (Frampton, 2017).

During ground-truthing in Winter 2016-2017, interpretation signage providing information on beaver monitoring by DWT was evident.


Plate 11. DWT Interpretation Signage (Frampton, 2017).

There was also traps for ROBT monitoring.

Plate 12. Monitoring Traps (Frampton,

On a return visit to the area in Summer 2017, widespread Himalayan balsam *Impatiens glandulifera* was recorded.

Plate 13. Himalayan balsam (Frampton, 2017).

A patch of Japanese knotweed *Fallopia japonica* Was also recorded.


Plate 14. Japanese knotweed (Frampton, 2017).

During ground-truthing in February 2017, riparian habitat appeared to be degraded and patchy in areas.


Plate 15. Facing North, Upriver, Broad River Body (Frampton, 2017).

On a return visit in July 2017, it appears this may be as a result of swards of Himalayan balsam.


Plate 16. H.balsam (Frampton, 2017).

The swards of Himalayan balsam may also be affecting erosion and bank stability.

Plate 17. Erosion, Poor Bankside Stability (Frampton, 2017).

This area of river is very popular amongst tourists and locals and is clearly valued recreationally. The Eastern bankside of the river is inaccessible to the public and features a high cliff face which falls into a significant area of riparian habitat which provides opportunity for a range of species both for nest/den sites and foraging with minimal disturbance. The western bank features a public footpath throughout which there are many evident poaching lines. Connectivity appears limited with tributaries in area 1 appearing reasonably unsuitable for species permeability. Throughout the lower reaches of the River Otter and area 1, the main body is broad and deep enough for *Castor fiber* to be unlikely to carry out dam construction. The EDA of area 1 has assisted in the key objective of determining the current state and character of the ecosystem and risk, threat and vulnerability to the ecosystem recording where potential stresses or threats are present.

7.3 *Area 2*

Throughout area 2 land-use continues to be dominated by agricultural land practices.

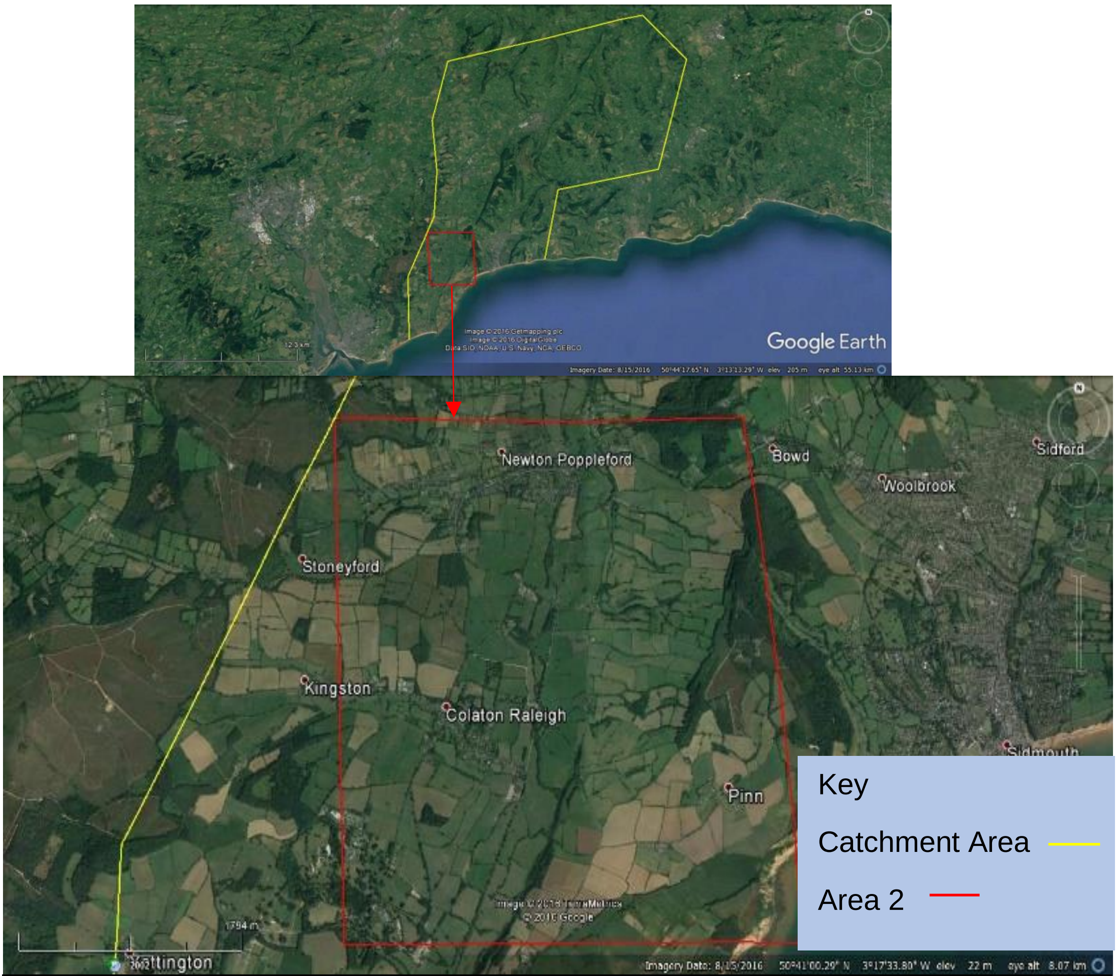


Figure 17. Area 2 River Otter (Google earth, 2017). The river continues to have a diverse range of features such as point bars, side bars and mid-channel bars as well as flow rates, riffles and pools/ponds. Area 2 has two reasonably large stretches of river which are inaccessible to members of the public because they lie on private land. Tributaries appear degraded and may not provide access to other river catchments,  potentially negatively impacting species permeability and connectivity.


Figure 18. LIDAR Satellite Area 2 (DATA.GOV.UK, 2017). Area 2 has an increasing enclosed feel within the Otter Valley. The western flood plain appears to reduce in size heading up river.

There are continued high levels of flood risk throughout area 2 (DATA.GOV.UK, 2017).


Figure 19. EA Flood Risk Area 2 (DATA.GOV.UK, 2017). Local industry can potentially face adverse effects of flood events in a variety of ways. This stretch of the river is under High to medium levels of risk.

7.3.1 *Ground-Truthing: Area 2*

During ground-truthing, *Castor fiber* activity was recorded. There are many river features such as side bars, point bars and mid-channel bars which can provide an element of seclusion to foraging areas for the species. During Winter 2017, feeding signs were evident.

Plate 18. Beaver Felled *Salix spp.* (Frampton, 2017).

Plate 19. Felled Willow (Frampton, 2017).

On a return site visit in Summer 2017, evidence of greater habitat complexity was recorded with excessive new growth on previously part-felled forage trees.

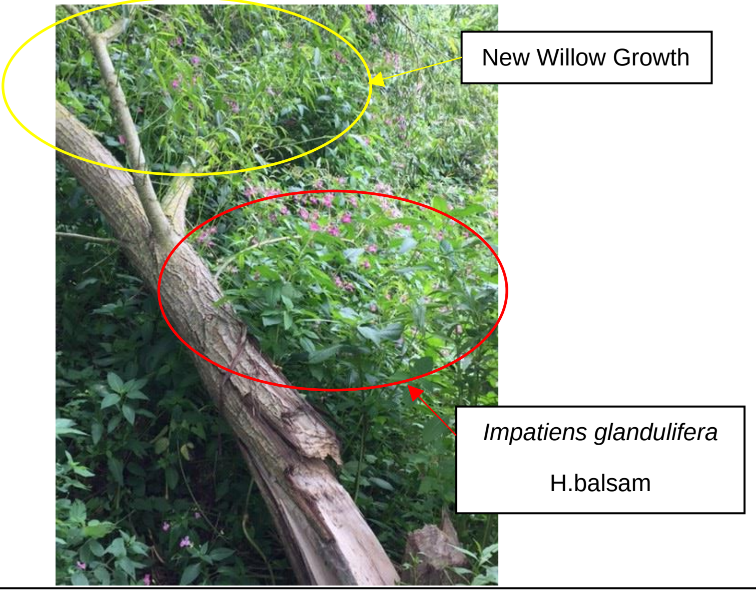


Plate 20. Willow Regrowth (Frampton, 2017). Himalayan balsam was widespread in some areas, potentially negatively impacting increased heterogeneity.

New, more permanent interpretation signage had been installed along this stretch of river to provide greater understanding of developments of the ROBT to the public.


Plate 21. Permanent Interpretation Boards (Frampton, 2017). These signs installed by Devon Wildlife Trusts offer information of best practice by the public around beaver territories.

There is a stretch of river in this location that is inaccessible to members of the public as it lies on private agricultural land where there are far less anthropogenic disturbances such as that from dogs. A potential barrier in the form of an Environment Agency monitoring station and weir were located.

Plate 22. EA Monitoring Station & Weir (Frampton, 2017). This obstacle should not restrict beaver movement patterns.

In this area there are high levels of erosion. Drainage outlets were also recorded.


Plate 23. Drainage Outlet Through Eroding Bankside (Frampton, 2017). This stretch of river appears to be important for agricultural land drainage, with high valley sides. However, this may be contributing to erosion of banksides due to excessive water levels and flow rates in wetter months.

Area 2 holds many landscape characteristics similar to area 1. Any immediate risk and threat continues to stem from similar sources such as increased erosion. The analysis of area 2 further contributes to combatting the objectives of clarifying risk and threat to the ecosystem and Eurasian beaver population and determining the character and state of the River Otter system.

7.4 *Area 3*

Area 3 continues to hold characteristics similar to areas 1 and 2.

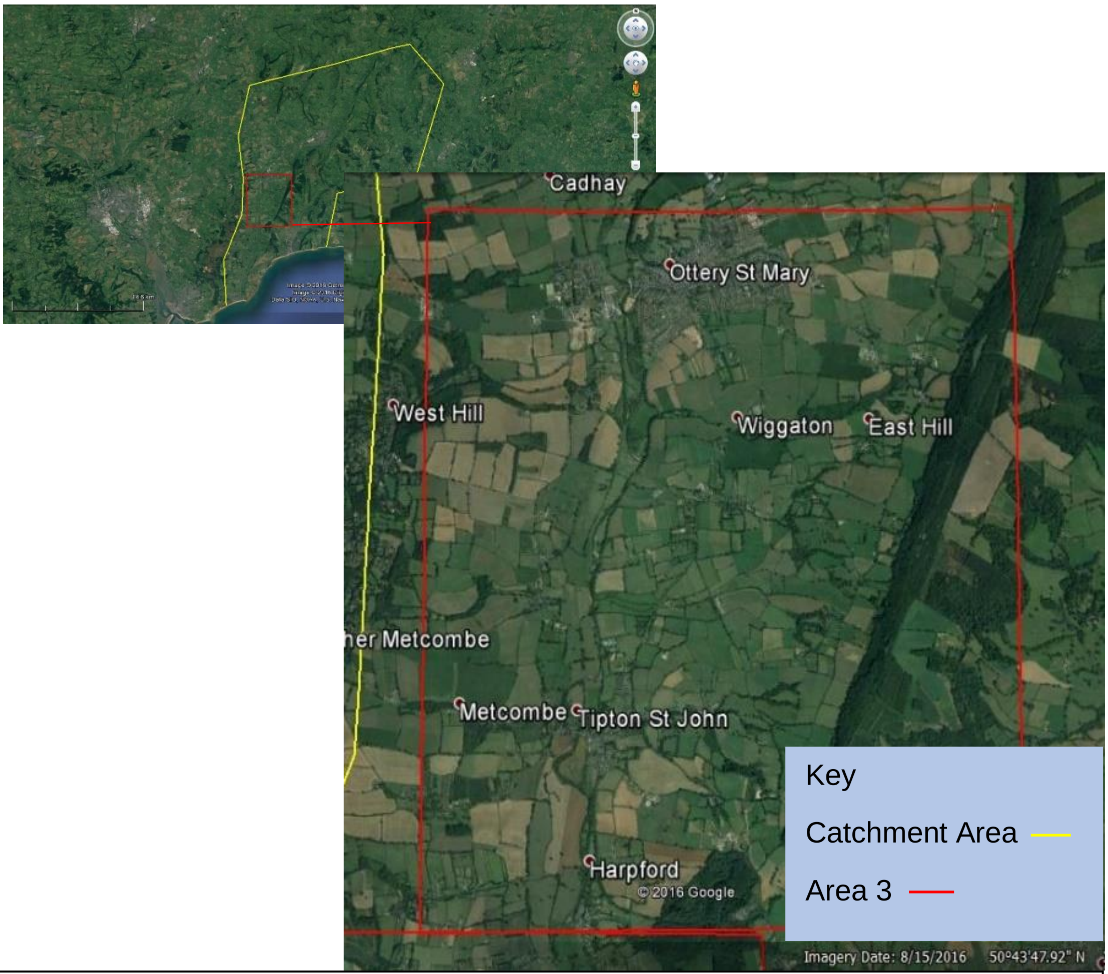


Figure 20. Area 3 (Google earth, 2017). The landscape is a mosaic of agricultural land-usage. There is a reasonably high level of fragmented riparian habitat, which may come as a result of erosion, incision and land-use change, recorded in many places upon ground-truthing. A number of potential issues may arise for beaver territory and dispersal and individuals may be forced into sub-optimal habitat increasing the risk of conflict with land-use practices (Swinnen *et al*., 2017).

There is continuing High risks of flooding in area 3, where *Castor fiber* activity has been recorded.

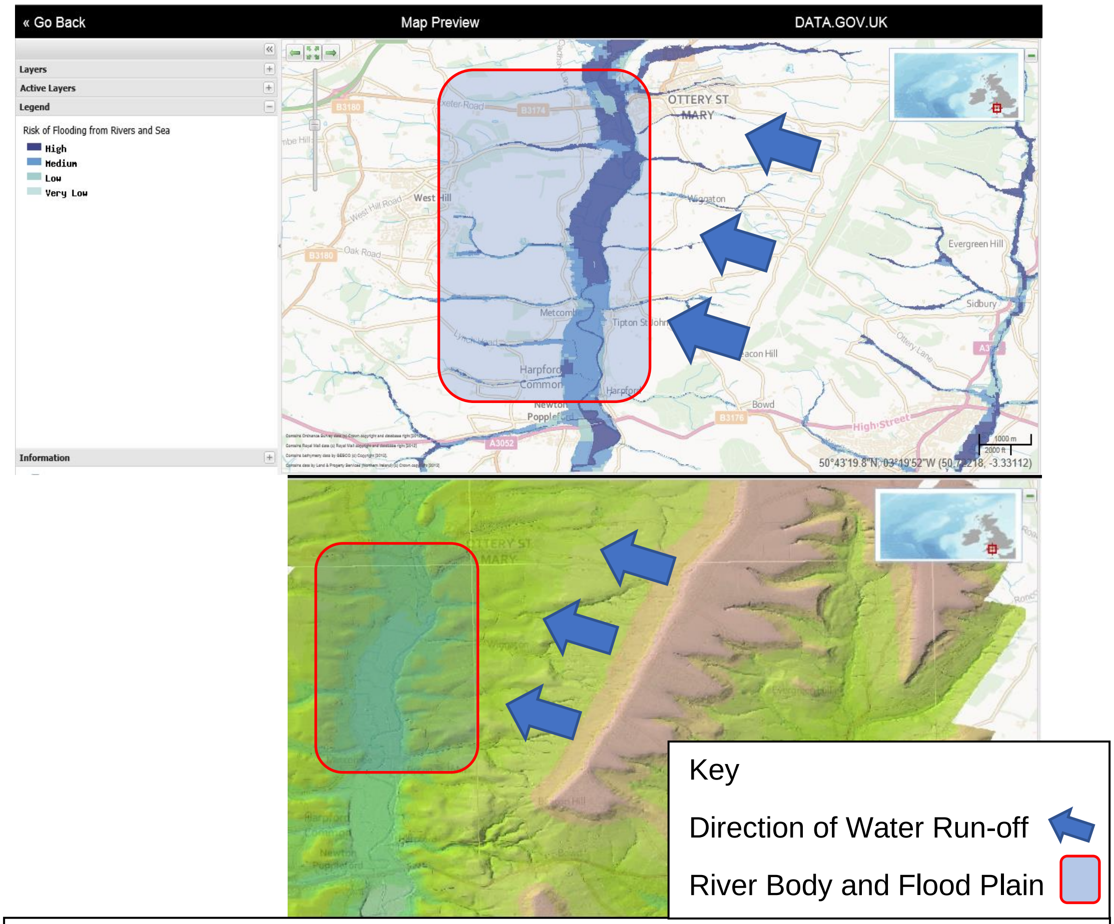


Figure 21. EA Flood Risk Area 3 (DATA.GOV.UK, 2017). The Otter Valley is evident and topography also appears to play a role and influence water levels in the River Otter.

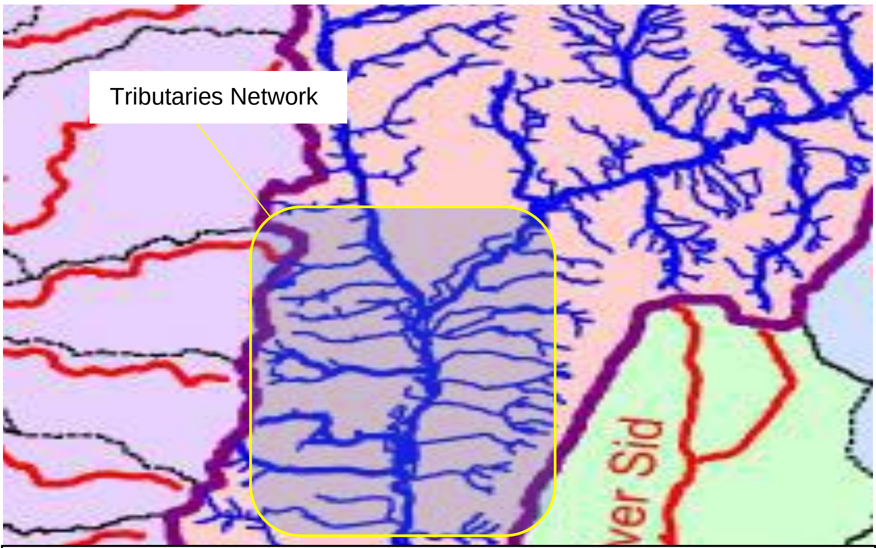


Figure 22. Tributary Networks (DWT, 2016a). There appears to be a greater area of riparian habitat with a greater network of tributaries, streams and drainage ditches in this area of the river. This may provide opportunities for the establishment of beaver territories reducing probabilities of leaving the catchment.

7.4.1 *Ground-Truthing: Area 3*

*Castor fiber* feeding activity was identified in what appeared to be a private garden.


Plate 24. *Castor fiber* Feeding Signs, Private Garden (Frampton, 2017). Many of the trees have been planted using basic tree protectors so may be of importance to the land owner which could cause conflict. There are various other types of tree protection measures, specifically designed to deter beavers which can be installed by DWT ROBT management if any such conflict occurs (DWT, 2016a).

In this area there is also potential for conflict with agricultural practices. A large arable field lies immediately adjacent to the river where issues could arise from crop damage from feeding by beavers, recorded elsewhere in the species distributional range (Batbold *et al*., 2016).


Plate 25. Arable Crop, Area 3 (Frampton, 2017). There are also various mitigation measures highlighted in the ROBT management strategy, such as deterrent, and permanent exclusion fencing (DWT, 2016a).


Plate 26. Erosion 3 (Frampton, 2017). This eroded bankside of the river has no riparian habitat reducing stability.

Also located in this area is a weir managed by the Environment Agency.


Plate 27. EA Weir, Area 3 (Frampton, 2017). Weirs located on the river appear to be no barrier for Eurasian beaver permeability.

An ox-bow lake has formed either created by human operation or natural geomorphology.


Figure 23. Morphological Change (Frampton, 2017).

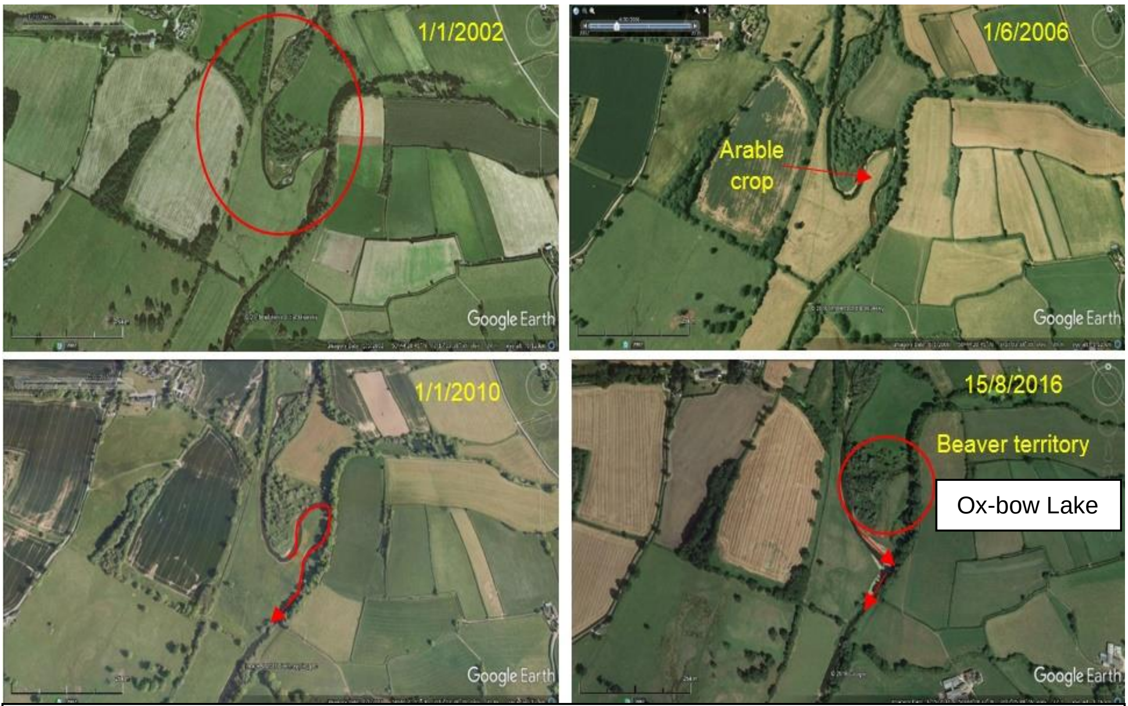


Figure 24. Geomorphological Change (Google earth, 2017). Within this stretch of the River Otter morphological change has occurred with the formulation of an ox-bow lake. From 2002-2010, the area cut off by the river body in 2016, had been intensively managed with rotational arable crops.

Due to the networks of watercourses, tributaries and drainage ditches in this area, this may have play a positive role in habitat selection for beaver.

Plate 28. Riparian Woodland (Frampton, 2017). There are reasonably large areas of riparian habitat and woodland with potential for *Castor fiber* to engineer with minimal human conflict.

Towards urban zones, the River Otter becomes increasingly used by members of the public for recreational purposes.

Plate 29. Garbage & Solid Waste (Frampton, 2017). There appears to be an increased level of pollutants and litter in areas close to urban settlements.

During ground-truthing, it was also observed that a new area broad-leaf woodland has been planted close to a second order tributary.


Plate 30. Plantation Woodland (Frampton, 2017).

This area is a busy stretch of the river that does not appear to have impacted species permeability.

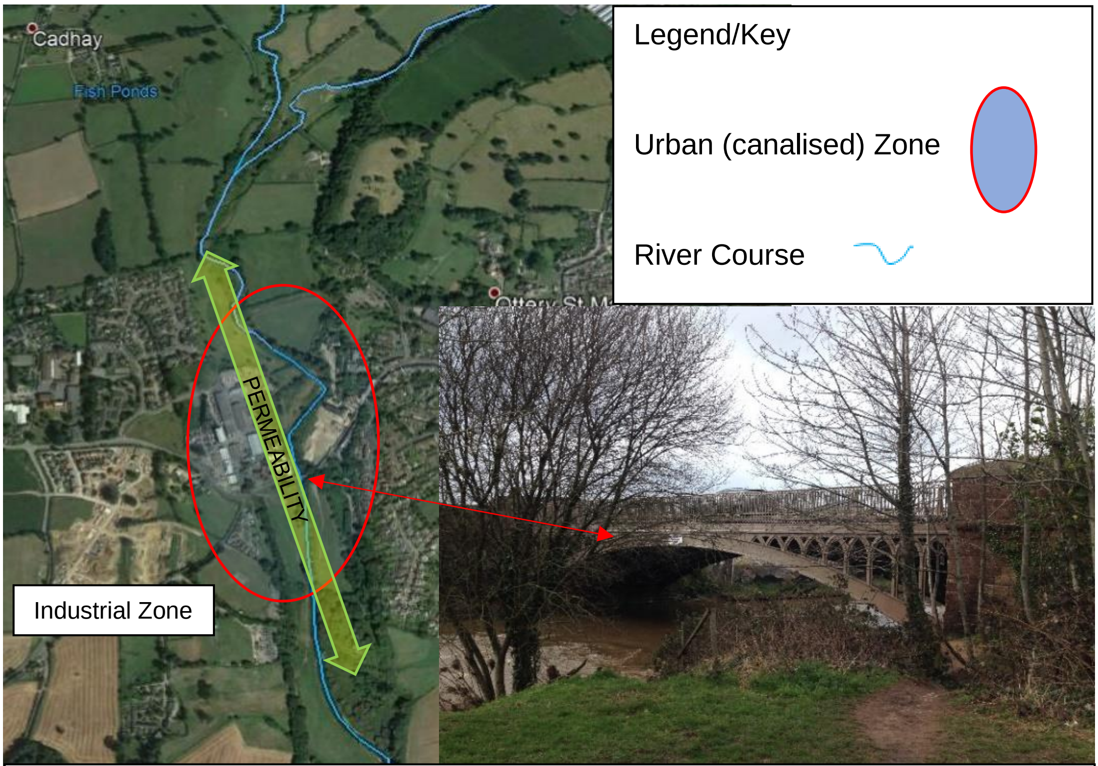


Figure 25. Species Permeability Area 3 (Google earth, 2018), (Frampton, 2017). Urban zones have not restricted movement of the beavers suggesting that risk and threat derived from these urban areas are not significant.

*Castor fiber* have been found to move past barriers such as culverts, human infrastructure and areas with little to no riparian habitat with ease, which has been recorded in Scotland (Campbell *et al*., 2012; Gaywood *et al*., 2015), Devon (DWT, 2016a), and elsewhere in Europe (Swinnen *et al*., 2017). In Urban areas this will increase the possibility of human-beaver conflict as the species have been found to damage infrastructure and manmade flood defense through burrowing activities (*ibid*). However, if there are sufficient riparian zones and habitat close to these areas, they will be favored for habitat selection, highlighting the requirements of food sources and their distance from the water (Campbell-Palmer *et al*., 2015).

## 7.5 *Area 4*

The assessment of area 4 will complete the River Otter ecosystem diagnostics analysis. The process begun a comprehensive understanding of risk and threat present in the system and contributed to the key objectives of providing context to the situation of the ROBT, clarification of the ecosystems state and character, and the determination of risk, threat and vulnerability to the river system and beaver population. The River Otter Headwaters hold very similar elements of homogenous landscape character with agriculture dominating the land-use practices through the Blackdown hills AONB.

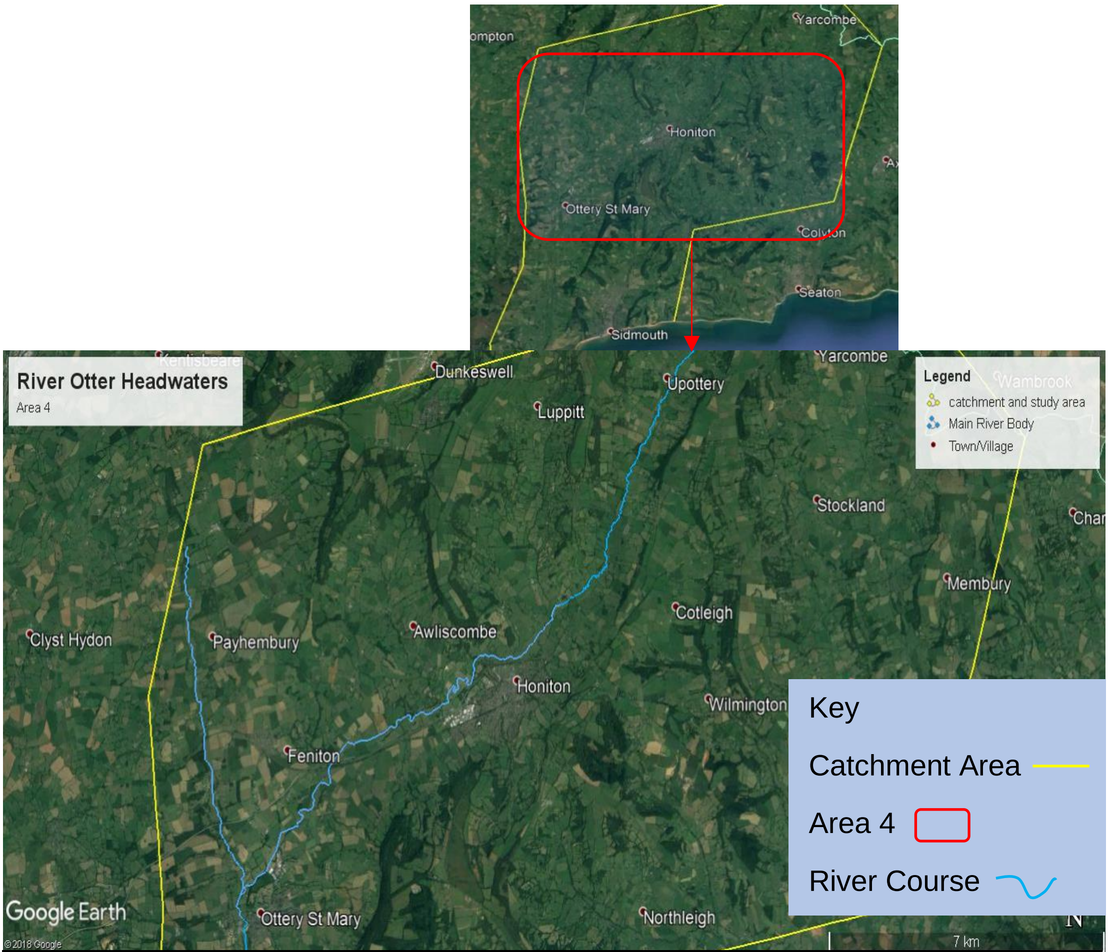


Figure 26. River Otter Headwaters Area 4 (Google earth, 2017). The majority of the headwaters are inaccessible to members of the public as they flow through privately owned land. This could be beneficial for *Castor fiber*, recorded in these areas as there is reduced risk of human or dog disturbance.

The main body of the River Otter flows south-west through the urban town of Honiton.

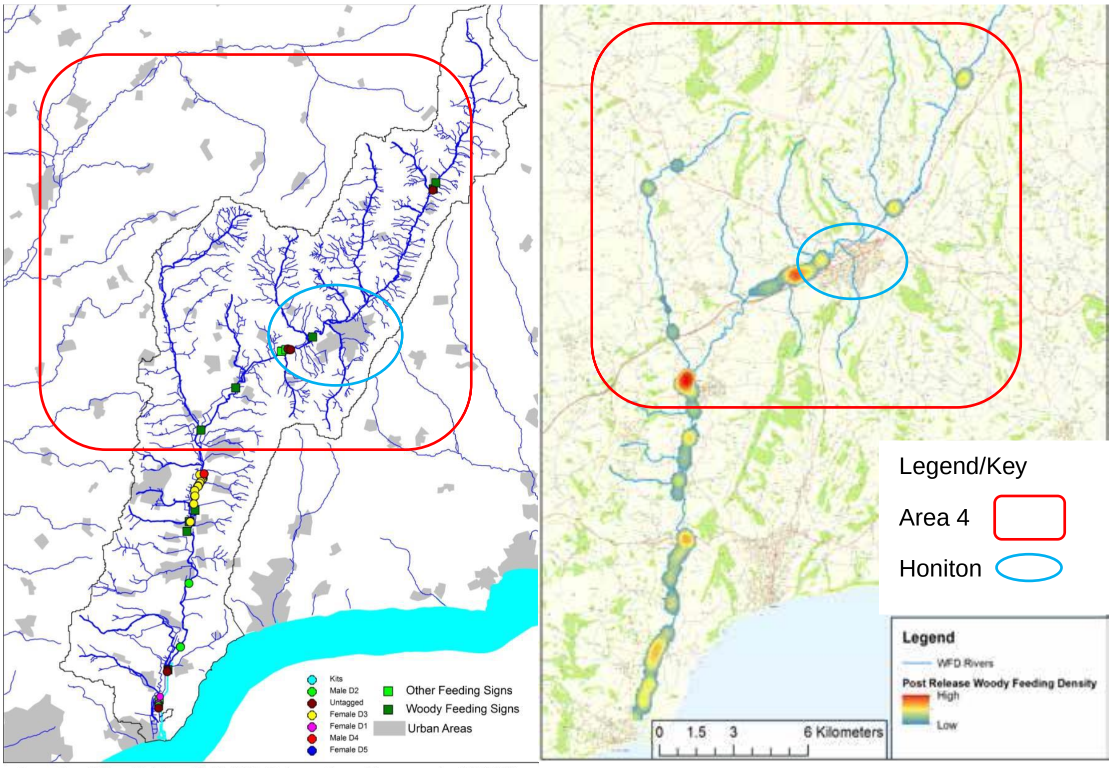




Figure 27. *Castor fiber* Activity Headwaters (DWT, 2016a). The town of Honiton does not appear to have had any influence on *Castor fiber* permeability and movement patterns with activity recorded either side of the town.

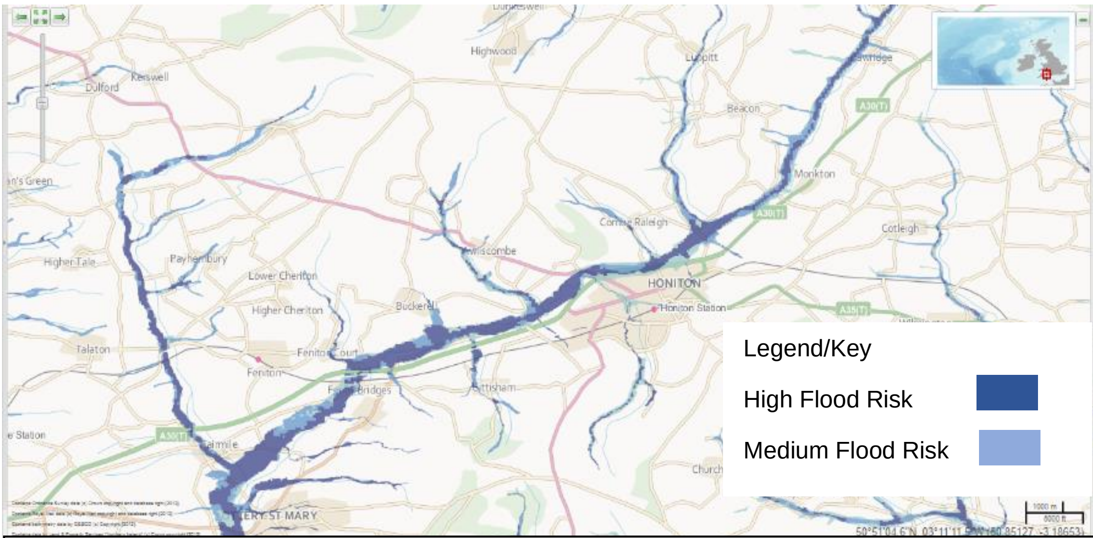


Figure 28. EA Flood Risk Headwaters (DATA.GOV.UK, 2018). There is continued high to medium flood risk throughout the headwaters and tributaries of the River Otter.

### 7.5.1 *Additional Risk & Threat: Area 4*

There are some major transport corridors such as the busy A30/A303 and the south-western trainline which run adjacent and cross the river in area 4.

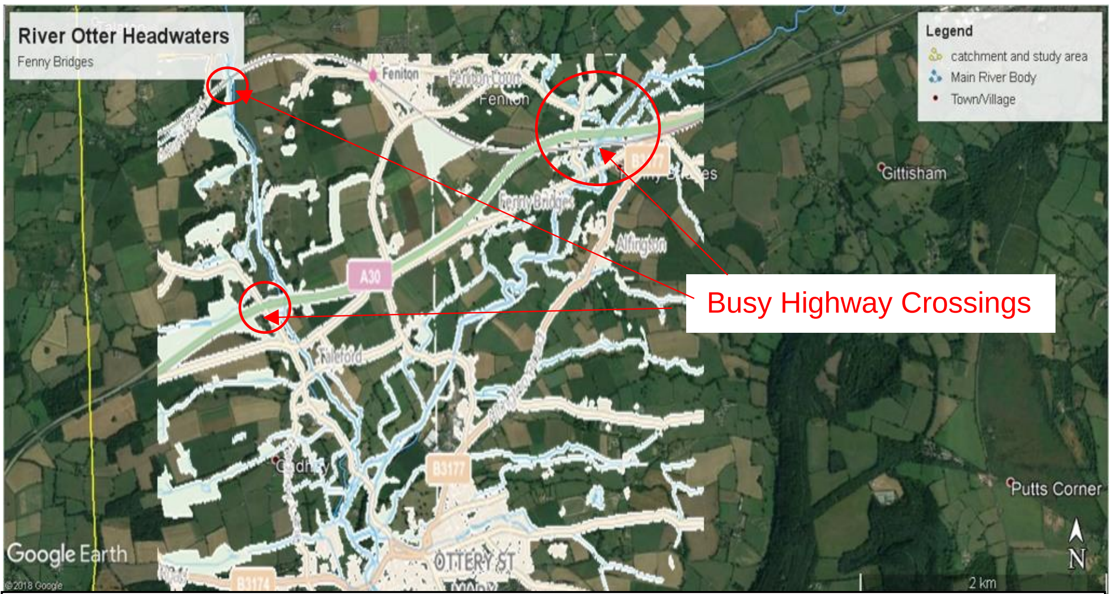


Figure 29. Transport Routes (Google earth, 2018), (DATA.GOV.UK, 2018). In this area, there is increased risk of road/traffic collisions if *Castor fiber* uses this infrastructure to move through or cross, as recorded with a dead male found on a road close-by in 2007 (DWT, 2016). Further to this, in 2018, another tagged adult was found close to a busy highway with sustained injuries resembling a road incident (DWT, 2018a).

A large proportion of the River Otter catchment lies within a designated Nitrate Vulnerable Zone (NVZ), figure 6.5 (EnivironmentAgency, 2018).

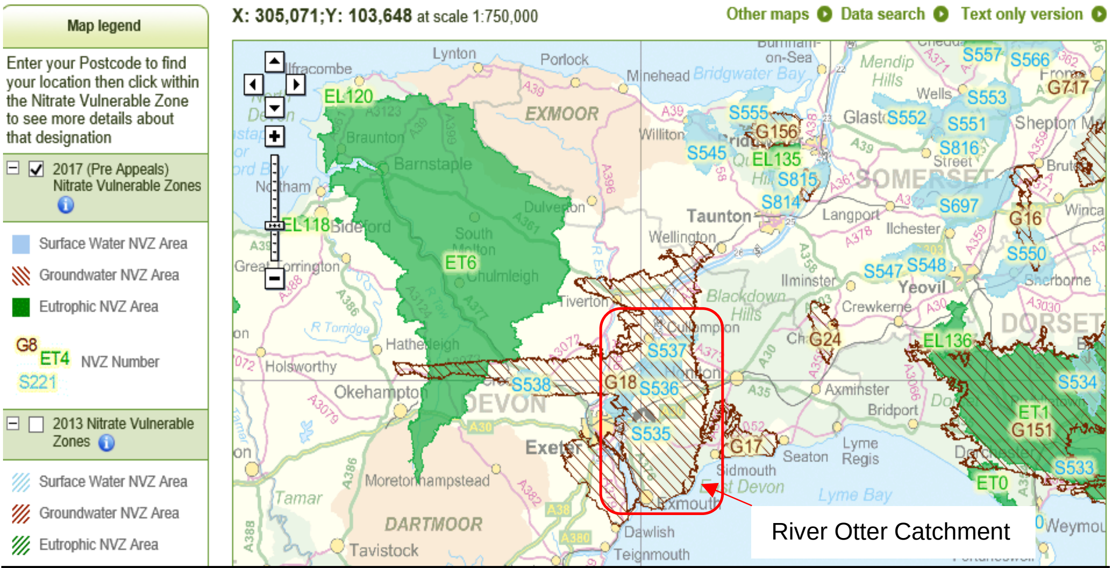


Figure 30. Nitrate Vulnerable Zones (Environment Agency, 2018). The increased levels of nitrates can have devastating effects on water quality, particularly where little riparian habitat is found (Hill, 1995). This may have been designated in this area due to the intensive agriculture across the region to mitigate against diffuse pollution (Macgregor & Warren, 2015). As *Castor fiber* is inhabiting the catchment there is potential for significant reductions in nitrates in the River Otter through damming activity (Puttock *et al.*, 2017).

7.5.2 *Ground-Truthing: Area 4*

The River Otter at Fenny Bridges was where the first *Castor fiber* sightings were recorded on the river, back in 2007 (Elliott *et al*., 2017).


Figure 31. River Otter at Fenny Bridges (Google earth, 2018).

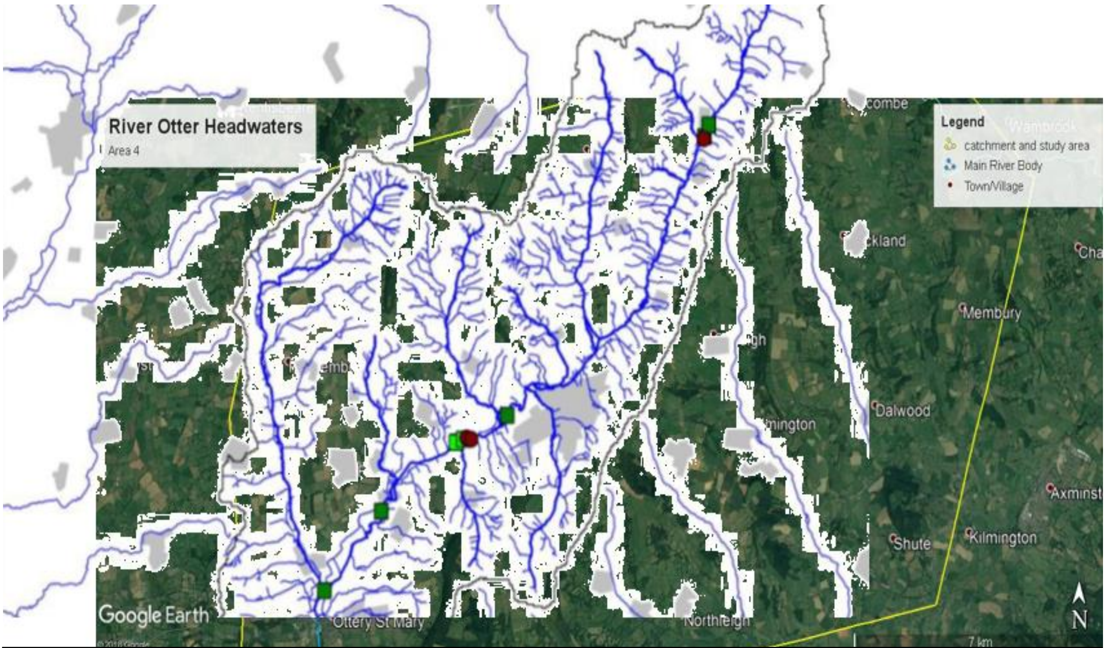


Figure 32. Beaver Activity Headwaters (DWT 2016a; Google earth, 2018). This map located at Fenny Bridges has been overlapped with the DWT (2016a) beaver activity map to highlight areas where the species have been recorded.


Figure 33. Ground-Truthing Area 4 (Frampton, T., 2017; Google earth, 2018). Where the River Tale meets The River Otter there is a significant network of tributaries, streams and drainage ditches. Some areas are incised and lack any significant riparian habitat. Other areas hold significant areas of riparian habitat with many foraging opportunities for *Castor fiber*. Patches of the invasive Himalayan balsam can be located sporadically occurring throughout. A number of the watercourse networks begin to lack depth and may increase the probability of damming activity, raising potential conflict with land owners.


Figure 34. Ground-Truthing Headwaters (Frampton, 2017; Google earth, 2018). The invasive Himalayan balsam becomes less frequent further upriver allowing native plant species to establish. Close to the town of Honiton there are increased pressures on the river from pollution sources. In the headwaters of the river, where it lacks sufficient depths and habitat is sub-optimal, *Castor fiber* damming behavior has been reported (DWT, 2017, 2018a). This has potential for wide-ranging benefits for the river downstream (Puttock *et al*., 2017).

7.6 *Case Study: River Tay Catchment, Scotland*

During this research an investigative visit to the River Tay catchment, Scotland, assisted in determining potential outcomes of beaver colonization over an extended time period. An area has seen the establishment of a beaver territory which has had implications for the landowners.

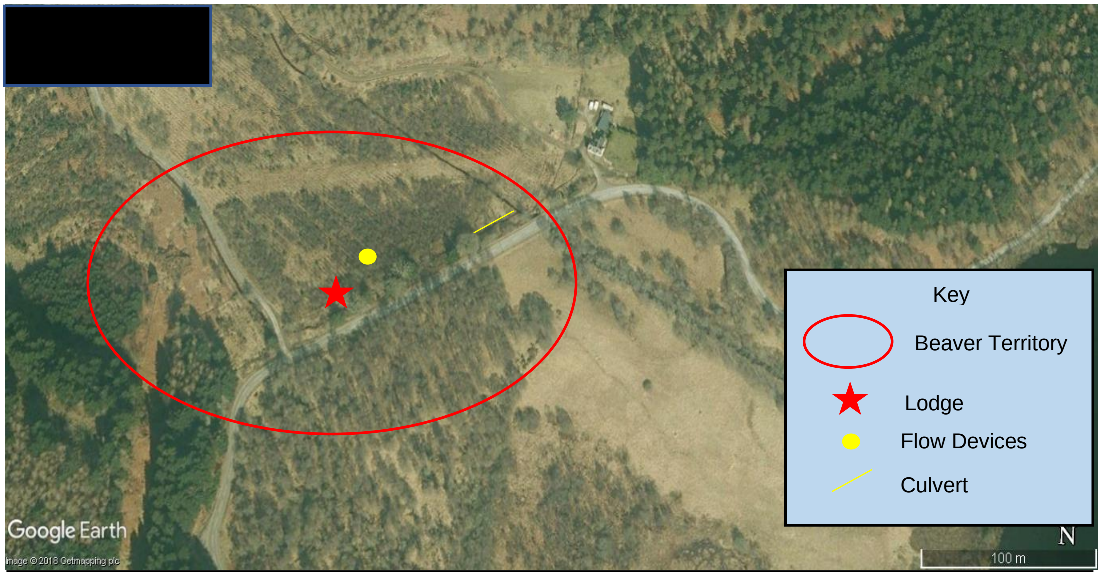


Figure 35. Beaver Territory (Google earth, 2018). A network of dams was created which led to flooding of a driveway, used for human access.

With consultation and communication between landowner and Scottish Natural Heritage (SNH) and the Royal Zoological Society of Scotland (RZSS), mitigation measures in the form of flow devices were installed.

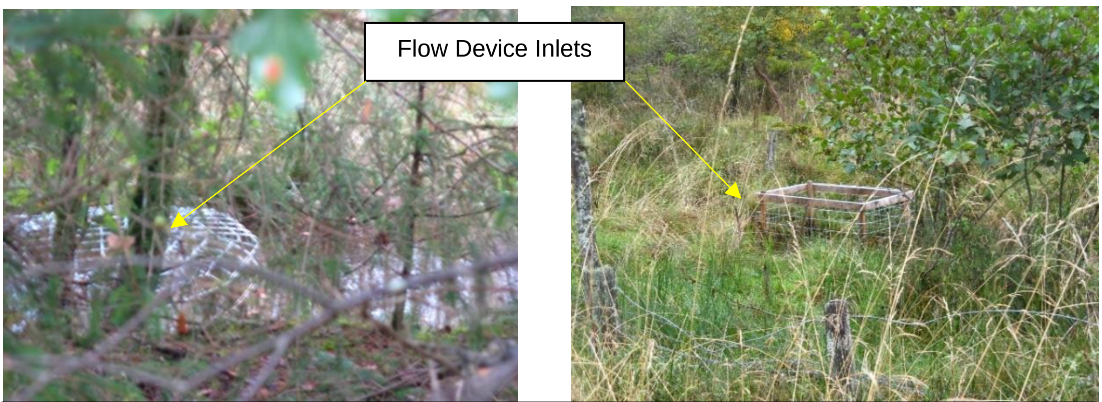


Plate 31., 32. Flow Device Inlet Gabions A, B (Frampton, 2017).

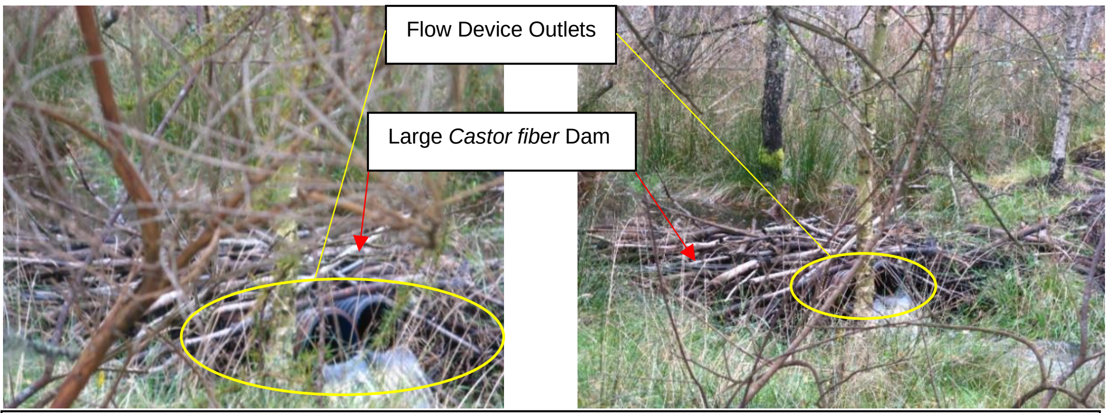


Plate 33., 34. Flow Device Outlet Pipes A, B (Frampton, 2017).

The main lodge used by the species also lies within close proximity to the roadside , and will need monitoring to determine any adverse impacts to both to the beaver family and human infrastructure.


Plate 35. *Castor fiber* Lodge (Frampton, 2017).


Plate 36. Beaver Meadow (Frampton, 2017).

It appears over time a diverse wetland has been created with the early stages of a beaver meadow forming. There was also good levels of heterogeneity.

Plate 37. Heterogeneity (Frampton, 2017).

Located in an urban, built up area of the region, another beaver family has established a territory in a small brook running through a residential estate.


Plate 38. Destroyed Beaver Dam (Frampton, 2017). It can be seen that some residents have attempted to destroy dams built by beaver. Ongoing consultation with the local community and mitigation measures can minimise any negative impacts to or from the species.

# 8 *MARISCO Situation & Vulnerability analysis: Results*

## 8.1 *Biodiversity Objects & Habitat Typologies*

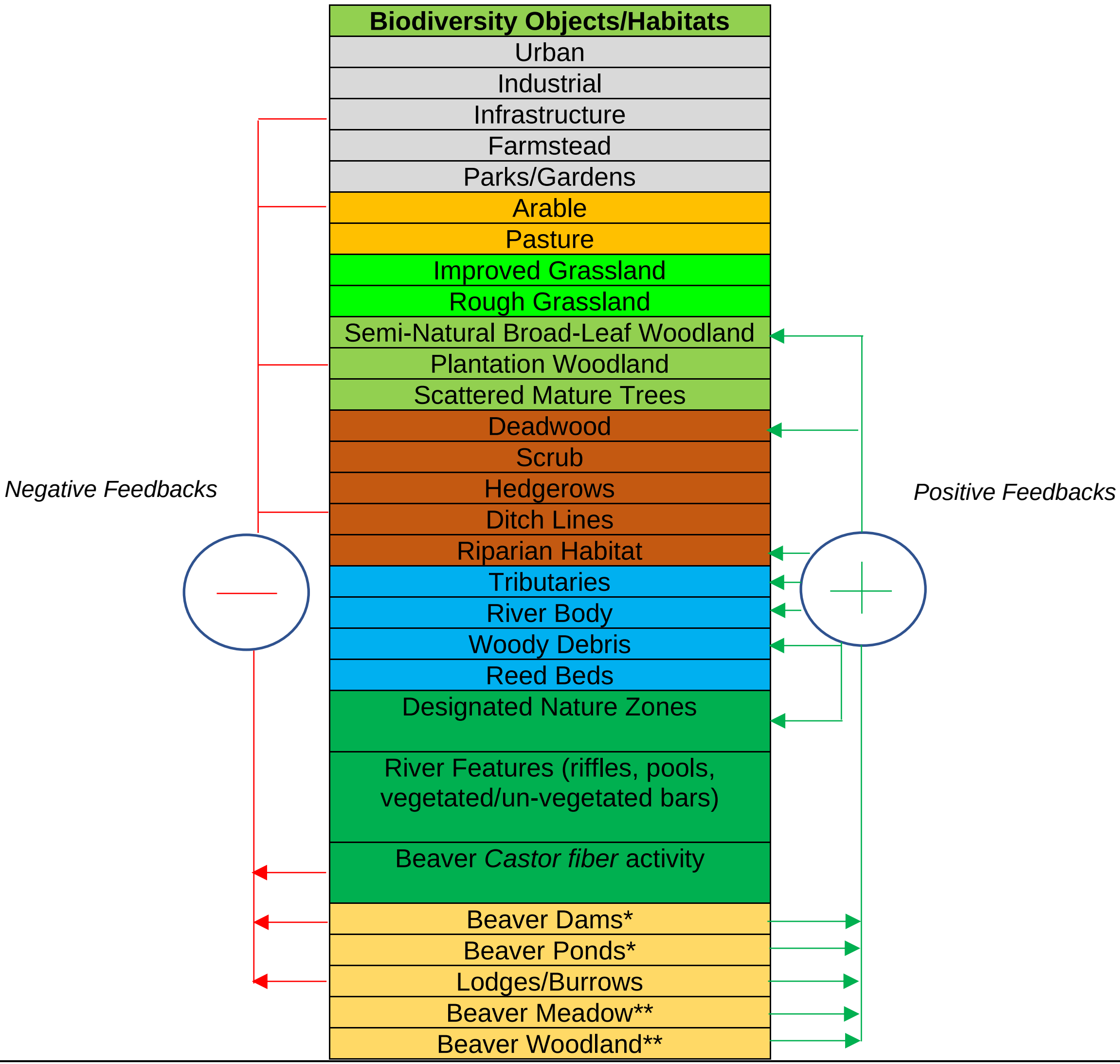


Figure 36. MARISCO Biodiversity Objects and Habitat Typologies. With the introduction of *Castor fiber* into the River Otter ecosystem, there can be both positive and negative feedbacks and outcomes from behavioral traits of the species to habitat typologies and biodiversity objects according to scientific published literature. Beaver dams and burrows can provide negative impacts to human infrastructure and seasonal foraging behavior can see them feed on arable crops (Gurnell, 2009). Damming can potentially impact drainage by flooding ditch lines (*ibid*). Although negative impacts can arise from these behaviors it appears a wide range of positive effects can also occur to outweigh negative feedbacks. Greater habitat complexity, increased heterogeneity, increased carbon sequestration and increased quality of floodplain connectivity are just some outcomes of potential *Castor fiber* modification that can assist in ecosystem restoration (Rosell *et al*., 2005; Gurnell, 2009; Hood & Larson, 2014; Gaywood, 2017). All associated beaver habitat and modification was grouped together for construction of the conceptual model. The different color sections of the table represent groups which require similar factors for functioning and output similar ecosystem services.

## 8.2 *Assessment of Ecological Attributes*

Ecological attributes are pillars that underpin the healthy functionality and processes of an ecosystem providing adaptive measures and resilience to changes in environmental conditions (Ibisch & Hobson, 2014). Due to these factors habitats and biodiversity objects identified within the River Otter ecosystem that require many ecological attributes in healthy condition, will display greater sensitivity to change and capacity to adapt (*ibid*).

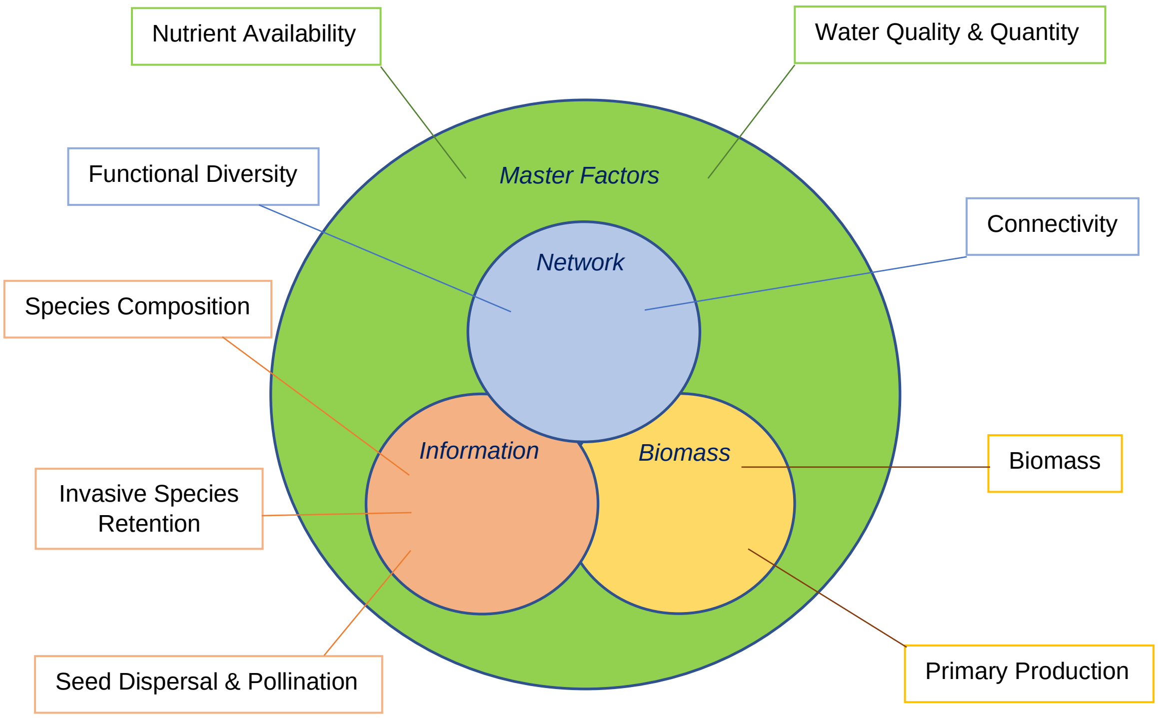


Figure 37. Key Ecological Attributes in Relation to Master Factors That Underpin Healthy Functioning of the River Otter Ecosystem. Following the selected criteria, identified ecological attributes have been grouped in to master factors including networking, information and biomass as ecosystem functionality is dependent on their availability (Ibisch & Hobson, 2014). Master factors in the River Otter ecosystem require a level of network, biomass and information for functionality (*ibid*), such as that of nutrient availability and water quality and quantity. Attributes such as connectivity, invasive species retention and species composition could be recorded as significant attributes to the ecosystem during the EDA which in a number of places were observed as altered. As a result, seed dispersal and pollination, biomass, primary production and functional diversity may also be altered.

Table 13. River Otter Ecological Attributes

| **Ecological Attributes** |
|---|
| ***Master Factors*** |
| Nutrient Availability |
| Water Quality/Quantity |
| ***Network*** |
| Functional Diversity |
| Connectivity |
| ***Information*** |
| Species Composition |
| Invasive Species Retention |
| Seed Dispersal & Pollination |
| ***Biomass*** |
| Primary Production |
| Biomass |

Table 13. Following MARISCO criteria ecological attributes can be determined and grouped in relation to master factors that underpin biodiversity objects and habitat typologies recorded making up the River Otter ecosystem.

8.2.1. *Current State of the Ecosystem*

Resulting from an assessment of ecological attributes, the state of the ecosystem was determined by measuring indicators that underpin healthy functionality of biodiversity objects and habitat typologies. Riparian habitat and ditch lines were found to be functioning incorrectly scoring ¾ by measuring ecological indicators such as visual pollutant signs, erosion levels and invasive species.

Table 14. MARISCO Scoring Criteria for Indicators

| | | | |
|---|---|---|---|
| 1. Very Good<br>*Indicator is in good condition/desirable state,*<br>*Little or no intervention by management to continue functionality and condition* | 2. Reasonably Good<br>*Indicator is reasonable in condition/level state,*<br>*Intervention may be required* | 3. Reasonably Poor<br>*Indicator is in reasonably poor condition/undesired state,*<br>*Attribute may face high risk without management intervention* | 4. Very Poor<br>*Indicator is in very poor condition/undesired state,*<br>*Intervention is required to attempt to restore functionality and condition* |

Table 15. MARISCO Assessment of Ecological Attributes

| **Biodiversity Object/Habitat Typology** | **Key Attribute** | **Indicator** | **Very Good** | **Reasonably Good** | **Reasonably Poor** | **Very Poor** | **Current Rating** | **Desired Rating** |
|---|---|---|---|---|---|---|---|---|
| Rough Grassland, Semi-improved, Improved Grassland | Seed Dispersal/ Pollination | Presence of associated pollination species, Plant species richness. | Good diversity of pollinating and plant species | Small numbers of pollinators, Little plant species diversity | Few pollinator species, Few (two or three) separate plant species | No pollinator species recorded, Monocultures/single plant species | 2 | 1<br>Castor fiber *can increase species richness and add complexity to vegetation* (Law et al., 2014, 2017). |
| Semi-Natural Broad-Leaf Woodland, Plantation Woodland, Scrub | Functional Diversity, Primary Production, Biomass, Species Composition, Connectivity | Heterogeneity, New tree growth, Standing and lying deadwood, Natural plant species communities (canopy-understory), Connectivity | Good levels of heterogeneity, New younger tree growth, Good levels of standing and fallen deadwood, Natural plant communities, Good connectivity | Reasonable heterogeneity, Some new tree growth, Reasonable levels of deadwood habitat, Some natural plant communities, Reasonable connectivity | Little heterogeneity, Minimal new tree growth, Little deadwood habitat, Few natural plant species communities, Little connectivity (patchy) | Homogenic in character, No new tree growth, No deadwood recorded, No natural plant communities (invasive/monoculture), Isolated/No connectivity | 2 | 1<br>Castor fiber *will increase heterogeneity significantly by creating complex habitat structures resulting from feeding behaviour, selective feeding will also assist in allowing new tree growth* (Campbell-Palmer *et al*., 2015). *The species behaviours will also create good levels of deadwood in a system* (Thompson *et al*., 2016). *Beaver will also increase connectivity* (Hood & Larson, 2014; Macfarlane *et al*., 2017). |
| Ditch Lines | Water quality/ quantity | Visual pollutant signs, | No signs of any pollutants, Clean/ clear water appearance, | Little pollutant signs e.g litter, Reasonably clean/clear water | Signs of pollutants, Evidence of run-off etc. in water, | High pollutant levels, Widespread evidence of run off and contaminated water, | 3 | 1<br>Castor fiber *have been found to use ditch lines both for permeability and inhabiting* (Campbell-Palmer *et al*., 2015). *Conflict can arise with land managers due to the species modifications* (ibid). *Run off was recorded throughout the River Otter building up in areas of woody debris. Beavers will increase woody debris and if dam building takes place these pollutants can be halted from causing further issues downstream* (Campbell-Palmer *et al*., 2015; Puttock *et al*., 2017). |
| Riparian Habitat | Soil structure, Species composition, Invasive species retention, Connectivity | Erosion levels, Riparian plant species present, Presence of invasive species, Continuous habitat without patchiness or incision, Good connectivity | Natural erosion levels present, Diversity/richness of riparian plant species, No visible invasive species present, Continuous riparian | Little erosion present, Reasonably good communities of riparian plant species, Little/no invasive species present, Reasonably good | Some accelerated erosion present, Few riparian plant species, Invasive species present, Patchy/incised riparian habitat little/some connectivity | Eroded banksides throughout, Monoculture/Single species dominant in riparian zone, Invasive species throughout, No connectivity | 3 | 1<br>Castor fiber *can significantly influence the riparian zone. Soil structure can be impacted positively by greater development and complexity of riparian trees and plant communities* (Rosell *et al*., 2005) . *This can offer stability* |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | habitat & floodplain connectivity | riparian and floodplain connectivity | | | | *to mitigate against erosion whilst creating richness and diversity to riparian plant species* (ibid). *The invasive* H. balsam *is present along large river stretches which may contribute to erosion and will need intervention to control.* Castor fiber *will increase riparian and floodplain connectivity* (Hood & Larson, 2014). |
| River Body/ Tributaries (+features) | Water quality/quantity, Biomass, Connectivity | Visual pollutant signs/ cleanliness (water), Riparian zones present, Woody debris, Watercourse connectivity | No pollutant signs, Clean/clear water, Good quality riparian habitat, Woody debris present, No barriers/good watercourse connectivity | Small pollutant signs e.g. litter, Riparian habitat present, Some woody debris, Reasonably good watercourse connectivity | Some pollutants present e.g. litter, Run-off, Small patchy riparian habitat, Little woody debris, Barriers present e.g. weirs, Minimal natural connectivity | High pollutant levels, No riparian habitat present, No woody debris, Poor watercourse connectivity, Significant barriers present | 2 | 1<br>*The presence of* Castor fiber *can have a range of impacts on the watercourse. Increased woody debris will add biomass and energy to the system* (Campbell-Palmer *et al*., 2015,2016). *however this can catch pollutants such as litter and run off, beneficial to downstream communities and overall water quality. Barriers such as weirs and urban zones have been found to not deter permeability of the species* (Swinnen *et al*., 2017) . |
| Eurasian Beaver Population | Genetic diversity, Connectedness, Species composition, Primary production | Good riparian and watercourse connectivity for dispersal (no isolation of family groups) – increased genetic diversity, Favourable riparian species e.g. *Salix spp.*, | No isolation of beaver population, Good connectivity, Good genetic diversity (ROBT info), Good diversity of favourable plant species | Some restrictions for dispersal, Reasonably good connectivity, Reasonably good genetic diversity (through re-intro etc.), Some favourable plant species | Restrictions for dispersal, Reasonably poor connectivity, Raised chance of inbreeding depression, Fairly isolated, One or two favourable plant species | Isolated population, No dispersal opportunities, High chance of inbreeding depression, No favourable plant species present | 2 | 1<br>*There is reasonably good connectivity for* Castor fiber *throughout the River Otter. However, NE licensing restrictions result in the species not being permitted to disperse to other adjacent catchments which could lead to further implications. After it was concluded the population was closely genetically related, other individuals were introduced to widen the gene pool. There are a significant number of favoured tree and plant species for the beaver.* |

Table 15. Indicators were formed to measure in the field during the EDA. Overall, for the surveyed stretches of the River Otter, surrounding ditches and riparian habitat were recorded to not be functioning to capacity. Ditches were measured by visual pollutant signs, evidence of run-off and vegetation. Very little vegetation was recorded in places and visual pollutants such as litter, garbage and solid waste were present. In some areas evidence of run-off was recorded resulting in ditches being scored 3 *'Reasonably poor'* status. Riparian habitat also achieved 3 *'reasonably poor'* status as for indicators such as accelerated erosion (resulting in habitat loss), the invasive Himalayan balsam being present and reasonably widespread and for minimal riparian plant species present in some areas. Patchiness and fragmentation of habitat also contributed to the final score. Accelerated erosion could be observed if for example, no riparian habitat was present or extra land drainage systems were recorded, or livestock entering the watercourse had collapsed banksides. This has combatted the key objective of determining the current state of the River Otter ecosystem. Referring to literature on beaver modifications there is potential for the species to have a complex relationship with the ecological attributes and indicators present and form a 'desired rating'.

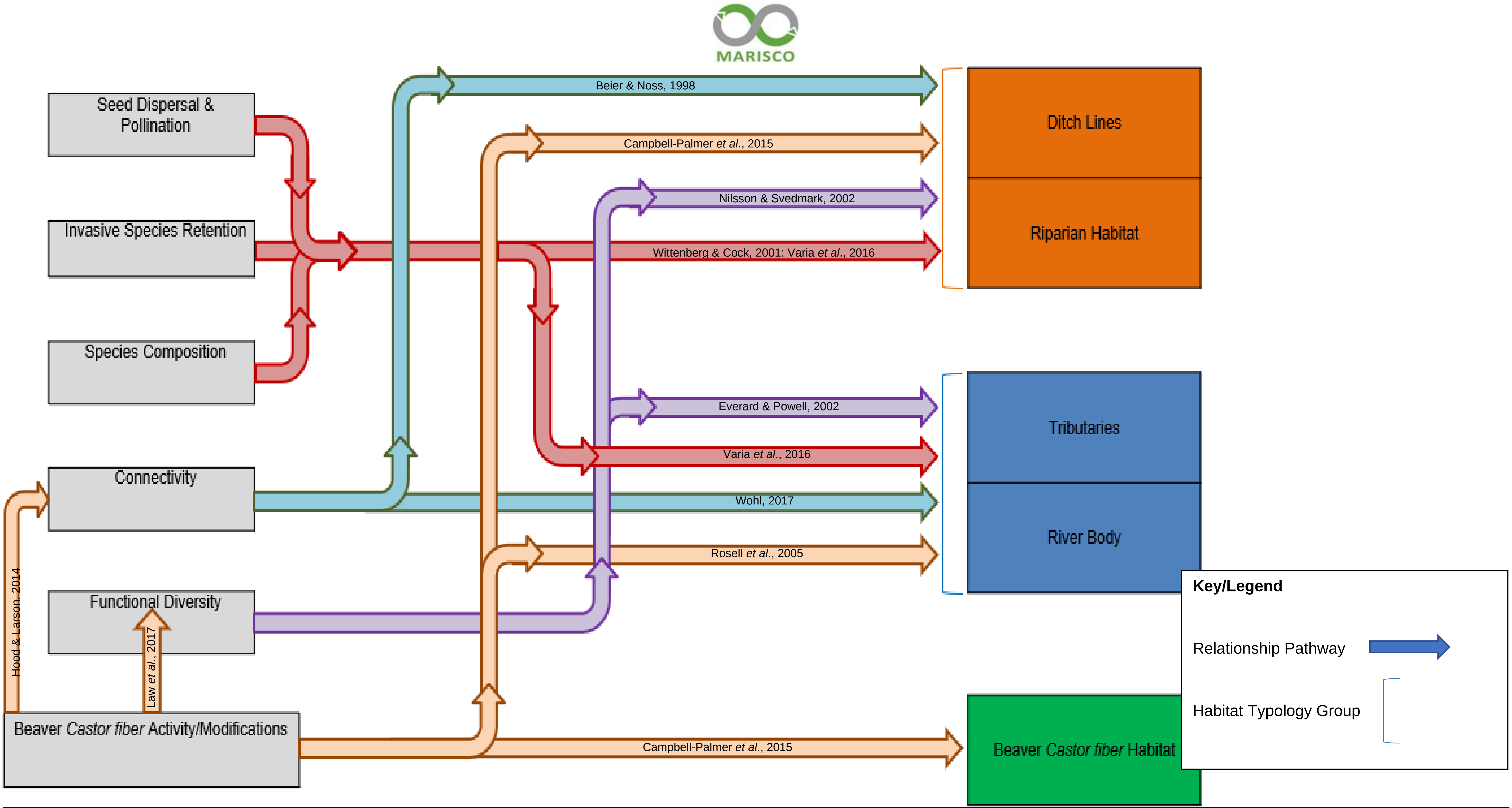


Figure 38. MARISCO Conceptual Model for Ecological Attributes. Key relationships between biodiversity objects/habitat typologies and their associated ecological attributes were constructed referring to results from the assessment of ecological attributes and state of the ecosystem assessment, published scientific literature, and the EDA. A primary example is the relationship between the ecological attribute of connectivity which can underpin the healthy functionality of riparian habitat (Beier & Noss, 1996), and the river body and tributaries (Scheimer, 1999; Wohl, 2017). However there are potential relationship feedbacks such as Eurasian beaver habitat promoting the ecological attribute of connectivity (Hood & Larson, 2014). Other significant relationships for this study is that of the attributes invasive species retention, species composition and seed dispersal and pollination (Wittenberg & Cock, 2001, Varia *et al.*, 2016), as for their measured impact of Himalayan balsam on the River Otter riparian zones and associated ditch lines in the current state of the ecosystem assessment. River catchments (river body, tributaries) and their relationship with ecosystem functionality (functional diversity) are of significant importance to human societies (Everard & Powell, 2002). The importance of the relationship between riparian habitat and ecosystem functionality has been emphasised by the importance of the habitats linkage between terrestrial and aquatic systems, and its importance to human society (Nilsson & Svedmark, 2002). It has been further highlighted by the potential influence the Eurasian beaver can have on this attribute (Law *et al.*, 2017), following widespread degradation (MEA, 2005a). The species activity and modifications can potentially influence a number of factors in riparian ecosystems (Rosell *et al.*, 2005; Campbell-Palmer *et al.*, 2015).

## 8.3 *Stress Identification and Assessment Results*

Table 16. MARISCO Scoring System (Impact rating)

| 1 – very low | 2- reasonably low | 3- reasonably high | 4- very high |
| --- | --- | --- | --- |

*Vegetation Structure & Composition Change*

Table 17. *VS Ecosystem Impact*

| Vegetation Structure & Composition Change | 1. Criticality – Scope<br>2 | 2. Criticality - Severity<br>2 | 3. Criticality – Irreversibility<br>2 | MARISCO |
| --- | --- | --- | --- | --- |
| | 4. Past Criticality (-20 yrs)<br>3 | 5.Current Criticality (1+2+3)<br>6 | 6. Trend of Change – of current criticality<br>2 | 7. Future Criticality (+20 yrs)<br>3 |
| | | | | 11. Strategic relevance (5+6+7)<br>11 |
| | 12. Manageability<br>3 | | 13. Knowledge<br>3 | |

A range of negative impacts to the river ecosystem can occur through changes to vegetation structure and composition as these elements play a key role in quality of the freshwater environment (SEPA, 2009). In some areas of the River Otter riparian zones, structure and composition of vegetation could be seen to be good with mosaics of different habitat structures and a good mix of riparian and marginal plant species. In other areas these elements have been considerably altered by anthropogenic actions and invasive species. *Strategic relevance (SR) – 11*

Table 18. *VS Eurasian Beaver Impact*

| Vegetation Structure & Composition Change | 1. Criticality – Scope<br>1 | 2. Criticality - Severity<br>2 | 3. Criticality – Irreversibility<br>2 | MARISCO |
| --- | --- | --- | --- | --- |
| | 4. Past Criticality (-20 yrs)<br>- | 5.Current Criticality (1+2+3)<br>5 | 6. Trend of Change – of current criticality<br>2 | 7. Future Criticality (+20 yrs)<br>2 |
| | Management Intervention<br>2 | | | 11. Strategic relevance (5+6+7)<br>9 |
| | 12. Manageability<br>2 | | 13. Knowledge<br>3 | |

*Castor fiber* can have a positive impact on vegetation structure and composition change through increased heterogeneity and complexity of riparian habitat resulting from feeding behaviors (Rosell *et al*., 2005; Jones *et al*., 2008; Elliott *et al*., 2017). Selective feeding patterns by beavers will increase riparian plant species adding complexity and greater resilience in the ecosystem (Gurnell *et al*., 2009; Jones *et al*., 2008; Law *et al*., 2014, 2017). However, if such negative changes have already occurred, and riparian species are not present the area may be unsuitable for habitat selection (Fustec *et al*.,2001; Campbell-Palmer *et al*., 2015). Any threat to the River Otter beavers from this factor have been seen to be reasonably low. *Strategic relevance (SR) – 9.*

*Monocultures* Himalayan balsam

Table 19. *M Ecosystem Impact*

| *Monocultures* Himalayan balsam | 1. Criticality – Scope 2 | 2. Criticality - Severity 3 | 3. Criticality – Irreversibility 2 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20 yrs) 1 | 5.Current Criticality (1+2+3) 7 | 6. Trend of Change – of current criticality 3 | 7. Future Criticality (+20 yrs) 4 |
| | Management Intervention 3 | | | 11. Strategic relevance (5+6+7) 14 |
| | 12. Manageability 3 | | 13. Knowledge 4 | |

If Invasive alien species are facilitated and enter a system, they can become dominant and out-compete other natural plant spp. (RHS, 2018). Himalayan balsam *Impatiens glandulifera* was found occurring in sporadic patches throughout the River Otter riparian zones. In some areas it has become dominant and created monocultures, degrading the riparian habitat. It appears that this may have also contributed to erosion from bare banksides left in winter months. Beavers were observed feeding on *H.balsam* in summer months. However, the species will have a minimal impact on this stress. It is apparent that a degree of management intervention is being carried out to mitigate further spread of the invasive plant species (OVA, 2018). However, it has been stated that it is a long-term project that has already been in place for a number of years (NaturalDevon, undated; OVA, 2018). *SR Ecosystem – 14,* (*Eurasian beaver – little/no impact*)

*Riparian Habitat Loss*

Table 20. *RHL Ecosystem Impact*

| Riparian Habitat Loss | 1. Criticality – Scope 2 | 2. Criticality - Severity 3 | 3. Criticality – Irreversibility 2 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20 yrs) 3 | 5.Current Criticality (1+2+3) 7 | 6. Trend of Change – of current criticality 3 | 7. Future Criticality (+20 yrs) 3 |
| | Management Intervention 2 | | | 11. Strategic relevance (5+6+7) 13 |
| | 12. Manageability 3 | | 13. Knowledge 4 | |

Riparian habitat made up of native species is a key factor in the correct functioning of any river ecosystem (Frainer *et al*., 2017; FCS, 2018). It can buffer against pollutants as well as invasive/alien species and pathogens (Harrison *et al*., 1999; MEA, 2005a; SEPA, 2009). It can also assist in minimizing anthropogenic disturbance and provides habitat for a range of plant and animal species (*ibid*). Historically, a vast amount of riparian habitat was removed for a number of reasons such as agricultural practices and public access (*ibid*). Long stretches of the River Otter's riparian habitat was removed and later replaced (Google earth, 2017), however areas remain without riparian habitat due to aspects such as accelerated erosion. *SR – 13.*

Table 21. *RHL Eurasian beaver Impact*

| | | | | |
|---|---|---|---|---|
| Riparian Habitat Loss | 1. Criticality – Scope<br>2 | 2. Criticality - Severity<br>2 | 3. Criticality – Irreversibility<br>2 | |
| | 4. Past Criticality (-20 yrs)<br>- | 5.Current Criticality (1+2+3)<br>6 | 6. Trend of Change – of current criticality<br>2 | 7. Future Criticality (+20 yrs)<br>2 |
| | Chance of Conflict (Human-Beaver)<br>2 | Management Intervention<br>2 | | 11. Strategic relevance (5+6+7)<br>10 |
| | 12. Manageability<br>2 | | 13. Knowledge<br>3 | |

Riparian habitat is also a key requirement in habitat selection for beaver colonisation (Fustec *et al*., 2001). If areas are without riparian plant species and habitat they will not be favoured by the species. The Eurasian beaver is a keystone species in riparian habitat and their modifications can have a wide range of positive impacts on functionality which can lead to wider benefits from ecosystem services (Collen & Gibson, 2001; Janiszewski *et al*., 2014; Campbell-Palmer *et al*., 2015; Puttock *et al*., 2017). A reasonably low impact score was recorded for stresses from riparian habitat loss on the River Otter beavers. *SR – 10.*

*Erosion*

Table 22. *E Ecosystem Impact*

| | | | | |
|---|---|---|---|---|
| Erosion | 1. Criticality – Scope<br>2 | 2. Criticality - Severity<br>2 | 3. Criticality – Irreversibility<br>3 | |
| | 4. Past Criticality (-20 yrs)<br>2 | 5.Current Criticality (1+2+3)<br>7 | 6. Trend of Change – of current criticality<br>3 | 7. Future Criticality (+20 yrs)<br>3 |
| | Management Intervention<br>3 | | | 11. Strategic relevance (5+6+7)<br>13 |
| | 12. Manageability<br>2 | | 13. Knowledge<br>3 | |

Although erosion is a natural process, it can be rapidly accelerated by human operations (Inman, 2006). It can lead to increased sedimentation and riparian habitat loss impacting aspects such as channel morphology and flood water capacity (Downs & Simon, 2001). The pressures from erosion can be increased by human activity such as dredging or canalising and also by increased storm events and flooding from climate change (Asselman *et al*., 2003). It was recorded upon ground-truthing areas where livestock had been entering the river leading to accelerated erosion. In an area close to Ottery St. Mary, an ox-bow lake has been formed over time from erosion. This can have a positive outcome as this can be habitat for a range of species under threat from riparian habitat loss (Koc *et al*., 2009). Erosion impacts were also recorded where land drainage systems entered the watercourse. The stress of erosion will have little to no impact on the River Otter beavers. However, erosion effects can potentially be influenced in a positive way by beavers through increased complexity of riparian habitat adding greater stability to banksides (Gurnell *et al*., 2009; Law *et al*., 2017). However, natural levels of erosion are an important process in ecosystem functioning (Florsheim *et al*., 2008). *SR – Ecosystem – 11,* (*Eurasian beaver – little/no impact*).

*Loss of Biomass*

Table 23. *LB Ecosystem Impact*

| Loss of Biomass | 1. Criticality – Scope 2 | 2. Criticality - Severity 2 | 3. Criticality – Irreversibility 2 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20 yrs) 3 | 5.Current Criticality (1+2+3) 6 | 6. Trend of Change – of current criticality 1 | 7. Future Criticality (+20 yrs) 3 |
| | Management Intervention 2 | | | 11. Strategic relevance (5+6+7) 10 |
| | 12. Manageability 1 | | 13. Knowledge 3 | |

Biomass is integral to healthy ecosystems and plays a major role in functionality (Barnes *et al*., 2016). A loss of biomass can occur from a range of factors such as anthropogenic land and water management practices, invasive spp., deadwood removal and overexploitation or loss of species or organisms in an ecosystem (Vaughn, 2010). Beavers can potentially benefit biomass in the River Otter system by creating deadwood (Thompson *et al*., 2016), and greater habitat structures which benefit a wide range of other species increasing biodiversity and biomass (Rosell *et al.,* 2005; Gurnell *et al*., 2009). They will also benefit levels of biomass through carbon sequestration (Gatti *et al*., 2018). Many *Castor fiber* traits will increase biomass in the ecosystem through significant levels of deadwood being created or potential dam building and beaver pond and meadow creation (Campbell-Palmer *et al*., 2015; 2016). Pressures from a loss of biomass to the Eurasian beaver will have little to no impact only potentially playing a minor role in habitat selection and territory establishment. *SR – Ecosystem – 10,* (*Eurasian beaver – little/no impact*).

*Loss of Connectivity*

Table 24. *LC Ecosystem Impact*

| Loss of Connectivity | 1. Criticality – Scope 3 | 2. Criticality - Severity 3 | 3. Criticality – Irreversibility 2 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20 yrs) 3 | 5.Current Criticality (1+2+3) 8 | 6. Trend of Change – of current criticality 3 | 7. Future Criticality (+20 yrs) 3 |
| | Management Intervention 2 | | | 11. Strategic relevance (5+6+7) 14 |
| | 12. Manageability 2 | | 13. Knowledge 4 | |

Connectivity loss can adversely impact a wide range of habitats and biodiversity objects as well as the species and communities occurring within having negative impacts on ecosystem functioning (Thompson *et al*., 2016). Riparian habitat was recorded as patchy in places along the main river body. Reasonably large zones without riparian habitat were also recorded. Aquatic connectivity of tributaries and the main river body were intact with some modifications recorded such as weirs, artificial banksides and transportation bridges. *SR – 14*.

Table 25. *LC Eurasian beaver Impact*

| | | | | |
|---|---|---|---|---|
| Loss of Connectivity | 1. Criticality – Scope<br>2 | 2. Criticality - Severity<br>1 | 3. Criticality – Irreversibility<br>2 | MARISCO |
| | 4. Past Criticality (-20 yrs)<br>- | 5.Current Criticality (1+2+3)<br>5 | 6. Trend of Change – of current criticality<br>3 | 7. Future Criticality (+20 yrs)<br>3 |
| | Chance of Conflict (Human-Beaver)<br>2 | Management Intervention<br>2 | | 11. Strategic relevance (5+6+7)<br>11 |
| | 12. Manageability<br>2 | | 13. Knowledge<br>3 | |

Connectivity is also very important for *Castor fiber* present on the River Otter as isolation of family groups can lead to inbreeding depression (Gaywood, 2017). However, there are many ways beavers will enhance and increase connectivity in river systems and floodplains (Hood & Larson, 2014). Connectivity on the River Otter is reasonably good for Eurasian beaver as they will not be restricted by the few man-made potential barriers such as weirs and urban areas. However, if losses of connectivity occur the species may be negatively impacted. *SR – 11.*

*Water Reduction/Increase, Flow Rates and Channel Depths*

Table 26. *WR/I Ecosystem Impact*

| | | | | |
|---|---|---|---|---|
| Water Reduction/ Increase, Flow Rates and Channel Depths | 1. Criticality – Scope<br>2 | 2. Criticality - Severity<br>2 | 3. Criticality – Irreversibility<br>3 | MARISCO |
| | 4. Past Criticality (-20 yrs)<br>2 | 5.Current Criticality (1+2+3)<br>7 | 6. Trend of Change – of current criticality<br>2 | 7. Future Criticality (+20 yrs)<br>3 |
| | Management Intervention<br>2 | | | 11. Strategic relevance (5+6+7)<br>12 |
| | 12. Manageability<br>3 | | 13. Knowledge<br>3 | |

Due to factors such as increased storm events and times of drought, flow rates can fluctuate and at times contribute negatively to aspects such as erosion (Asselman *et al*., 2003). These factors also will lead to water increases or reductions (*ibid*). The River Otter has been described as 'spatey' with fluctuating water levels (DWT, 2016a). This may potentially result in the river facing a higher level of pressure from this factor. *SR – 12.*

Table 27. *WR/I Eurasian beaver Impact*

| | | | | |
|---|---|---|---|---|
| Water Reduction/ Increase, Flow Rates and Channel Depths | 1. Criticality – Scope 2 | 2. Criticality - Severity 2 | 3. Criticality – Irreversibility 3 | MARISCO |
| | 4. Past Criticality (-20 yrs) - | 5.Current Criticality (1+2+3) 7 | 6. Trend of Change – of current criticality 2 | 7. Future Criticality (+20 yrs) 2 |
| | Chance of Conflict (Human-Beaver) 3 | Management Intervention 3 | | 11. Strategic relevance (5+6+7) 11 |
| | 12. Manageability 3 | | 13. Knowledge 3 | |

Dam building by *Castor fiber* will maintain water levels in a system by maintaining base flows in times of drought and holding back significant water levels in times of flooding (Gaywood, 2017; Puttock et al., 2017). This also may assist mitigation against stresses arising from fluctuating flow rates. Although there are many benefits to dam building by beaver there is increased chance of human-beaver conflict if this takes place on or by land where the owner does not permit it (DWT, 2016a). Beavers can be impacted by fluctuating flow rates around the burrow or lodge (Campbell-Palmer *et al*., 2015, 2016). However, *Castor fiber* modifications can help buffer against these stresses in a range of ways (Puttock *et al*., 2017). *SR - 11*.

*Anthropogenic Disturbances*

Table 28. *AD Ecosystem Impacts*

| | | | | |
|---|---|---|---|---|
| Anthropogenic Disturbances | 1. Criticality – Scope 3 | 2. Criticality - Severity 3 | 3. Criticality – Irreversibility 3 | MARISCO |
| | 4. Past Criticality (-20 yrs) 3 | 5.Current Criticality (1+2+3) 9 | 6. Trend of Change – of current criticality 3 | 7. Future Criticality (+20 yrs) 3 |
| | Management Intervention 3 | | | 11. Strategic relevance (5+6+7) 15 |
| | 12. Manageability 2 | | 13. Knowledge 3 | |

The River Otter and Otter Valley are popular amongst tourists with many visitors to the area. This appears to be important economically with many guesthouses and holiday accommodation in the area. The River has a busy footpath for recreational purposes. It was recorded that increased litter and pollution could be as a result of this as well as many poaching lines recorded resulting from human and dog intrusion. In some cases this appears to have degraded riparian habitat, recorded during ground-truthing and the EDA. The river also runs through urban and industrial areas where there are reasonably high levels of disturbance. *SR – 15.*

Table 29. *AD Eurasian beaver Impacts*

| | | | | |
|---|---|---|---|---|
| Anthropogenic Disturbances | 1. Criticality – Scope<br>4 | 2. Criticality - Severity<br>3 | 3. Criticality – Irreversibility<br>3 | MARISCO |
| | 4. Past Criticality (-20 yrs)<br>- | 5.Current Criticality (1+2+3)<br>10 | 6. Trend of Change – of current criticality<br>3 | 7. Future Criticality (+20 yrs)<br>3 |
| | Chance of Conflict (Human-Beaver)<br>3 | Management Intervention<br>3 | | 11. Strategic relevance (5+6+7)<br>16 |
| | 12. Manageability<br>3 | | 13. Knowledge<br>3 | |

Disturbances from humans may increase further because of popularity with tourists and visitors hoping to see the River Otter beavers (DWT, 2016a). However, this can have many positive outcomes such as raised public awareness and increased local economy which can lead to further support of the beaver project (Gurnell *et al*., 2009, DWT, 2016a). As for all species reintroductions, gaining support from the public and stakeholders can be a key factor in determining overall success (*ibid*). *SR – 16.*

*Inbreeding Depression*

Table 30. *ID Eurasian beaver Impact*

| | | | | |
|---|---|---|---|---|
| Inbreeding Depression | 1. Criticality – Scope<br>3 | 2. Criticality - Severity<br>3 | 3. Criticality – Irreversibility<br>3 | MARISCO |
| | 4. Past Criticality (-20 yrs)<br>4 | 5.Current Criticality (1+2+3)<br>9 | 6. Trend of Change – of current criticality<br>3 | 7. Future Criticality (+20 yrs)<br>3 |
| | Management Intervention<br>3 | | | 11. Strategic relevance (5+6+7)<br>15 |
| | 12. Manageability<br>2 | | 13. Knowledge<br>4 | |

Inbreeding depression can have negative effects on *Castor fiber* and a range of other species if populations become isolated in habitat patches or face significant barriers in dispersal and permeability (Gaywood, 2017). Devon Wildlife Trust has already taken steps to mitigate against this with the River Otter beavers introducing other well-sourced individuals to widen the gene pool (DWT, 2016, 2018a). Risk of inbreeding depression may require further management intervention if the population is restricted from leaving the catchment *SR  - 15*

.

Table 31. MARISCO River Otter/Eurasian Beaver Stresses

| ***Stresses*** MARISCO | *Strategic Relevance Ecosystem* | *Strategic Relevance Eurasian beaver* |
|---|---|---|
| Monocultures *H.balsam* | 14 | n/a |
| Erosion | 13 | n/a |
| Loss of Biomass | 10 | n/a |
| Vegetation Structure & Composition Change | 11 | 9 |
| Riparian Habitat Loss | 13 | 10 |
| Loss of Connectivity | 14 | 11 |
| Water Reduction/Increase, Flow Rates & Channel Depths | 12 | 11 |
| Anthropogenic Disturbances | 15 | 16 |
| Inbreeding Depression | n/a | 15 |

Table 9.15, The assessment of stresses has highlighted pressures or symptoms of the ecological attributes. The key stresses impacting the ecosystem are anthropogenic disturbances, loss of connectivity, riparian habitat loss and *H.balsam* monocultures as for scoring the greatest strategic relevance. Key stresses to potentially impact the beaver population are also include anthropogenic disturbances and connectivity loss with the addition of inbreeding depression.

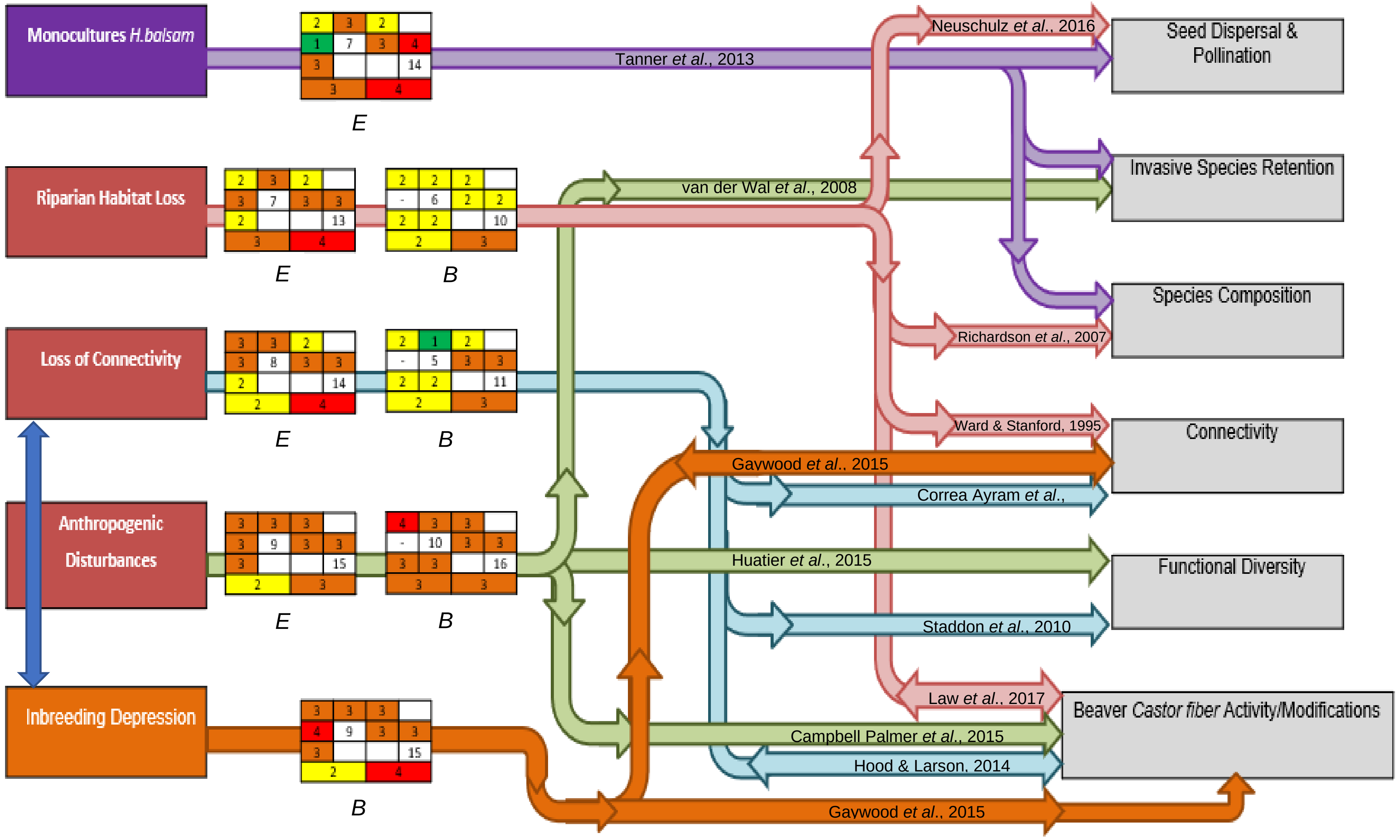


Table 32. MARISCO Stresses Scorecard Example

| Stress | 1. Criticality – Scope | 2. Criticality - Severity | 3. Criticality – Irreversibility | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20 yrs) | 5.Current Criticality (1+2+3) | 6. Trend of Change – of current criticality | 7. Future Criticality (+20 yrs) |
| | Chance of Conflict (Human-Beaver) | Management Intervention | | 11. Strategic relevance (5+6+7) |
| | 12. Manageability | | 13. Knowledge | |

Table 33. Impact Rating

| | | | |
|---|---|---|---|
| 1 – very low | 2- reasonably low | 3- reasonably high | 4- very high |

**Legend**

Relationship (any colour)

Relationship Feedback (any colour)

Ecosystem Impacts Scorecard - *E*

Beaver Impacts Scorecard - *B*

Figure 39. MARISCO Conceptual Model Stresses Relationships. As a result of the stresses assessment key stresses were recorded as for their '*strategic relevance*' and relationships with ecological attributes. Relationships were observed and recorded during the EDA with the integration of a review of scientific literature for confirmation of relationships. Monocultures of the invasive non-native Himalayan balsam was recorded sporadically occurring in the River Otters riparian zones. The species will outcompete native riparian plant species with a widespread seed dispersal facilitating further spread and altering species composition of vegetation and invertebrates (Tanner *et al*., 2013; Varia *et al*., 2016). Monocultures of Himalayan balsam can be less biologically diverse than areas with native species in a habitat which could lead to adverse impacts to trophic levels and the functionality of a system (Tanner *et al*., 2013). The loss of riparian habitat can cause widespread implications for river ecosystems such as impacts on connectivity (Ward & Stanford, 1995) and species composition (Richardson *et al*., 2007). Through behavioural traits and modifications Eurasian beaver may add complexity to riparian habitat in a range of ways (Law *et al*., 2017) adding a feedback to the relationship. Connectivity loss from riparian habitat removal or dams and weirs in the watercourse can have profound effects on ecosystem functionality and biodiversity (Staddon *et al*., 2010). The Eurasian beaver population present on the River Otter may have a complex relationship with connectivity. If territories or family groups become isolated, it may result in negative impacts however, the species modifications have been found to promote river and floodplain connectivity significantly (Hood & Larson, 2014). Anthropogenic disturbances are a key driver and have relationships with many negative factors induced on the ecosystem. Facilitating invasive species (van der Wal *et al*., 2008), and impacting ecosystem function (Hautier *et al*., 2015) appear to have had significant impacts on the river system highlighting the key relationships between humans and these factors. With Eurasian beaver reintroduction, risks of inbreeding depression are considered in management plans and genetics are closely monitored (Gaywood *et al*., 2015). This also includes the relationship with connectivity allowing for gene flow in reintroduced populations (*ibid*). Table 32. is an example of the MARISCO scorecard for stresses and table 33. is the scoring system and impact rating.

8.4 *Threat Analysis & Assessment: Mapping*

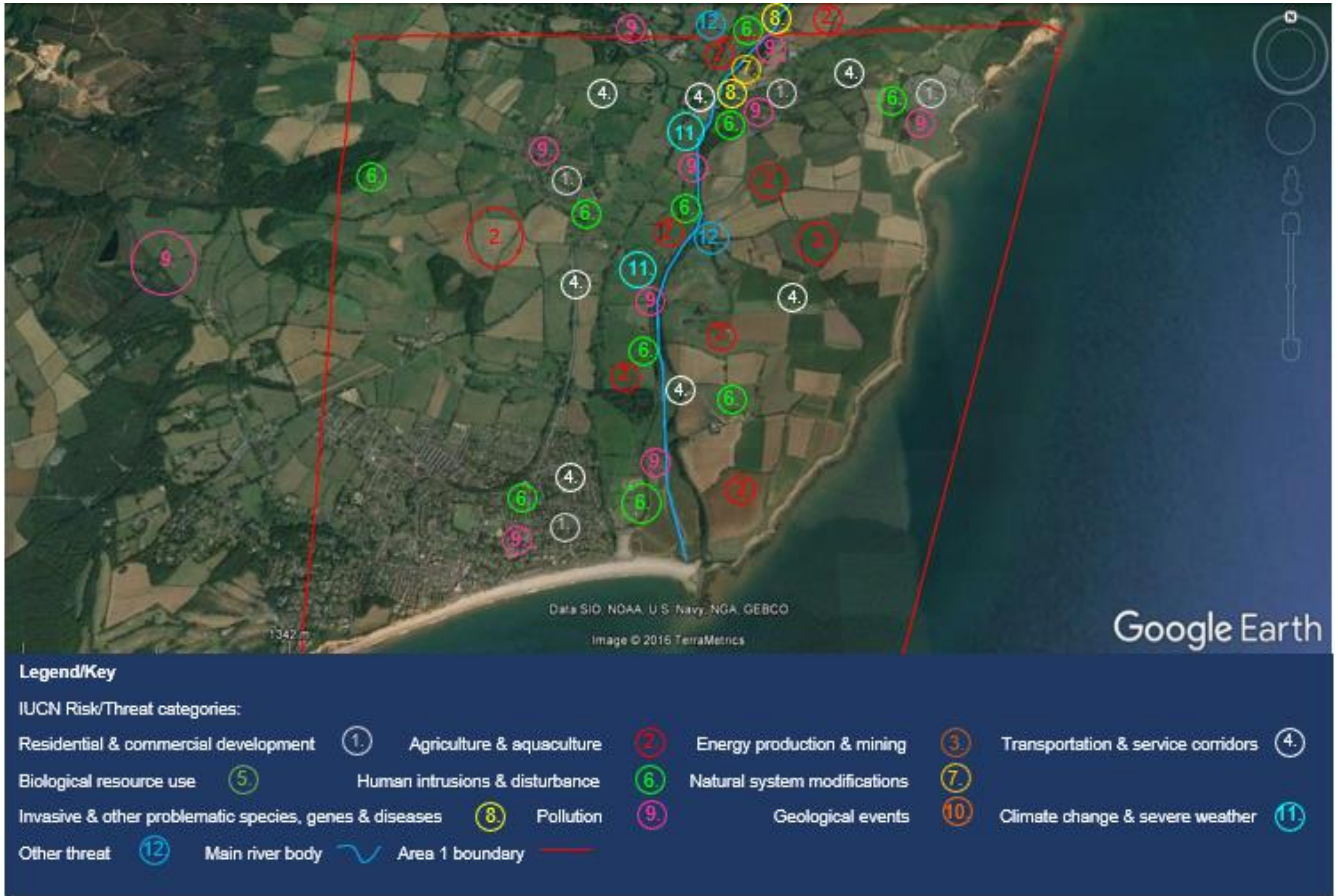


Figure 40. Threat Mapping Area 1 (Google Earth, 2018). The River Otter is situated in a highly productive agricultural landscape which could increase the probability of future human-beaver conflict. This area also appears important economically with strong tourist and agricultural industries. The threat of pollution appears to mainly stem from agricultural practices with reasonably high amounts of diffuse pollution observed upon ground-truthing. There is a high level of flood risk attached to area 1 which may cause negative impacts to beaver natal dens and burrows if river banks are not high enough (Campbell-Palmer *et al.*, 2015). flooding may also impact the local community, businesses and the agricultural industry negatively effecting the region economically. Upon ground-truthing, poaching by dogs was evidently frequent throughout this stretch of river. With an incident having been recorded of an aggressive interaction between a dog and a River Otter beaver (BACE, 2018a; DWT, 2018a), risks of disturbance by dogs to beaver may require management intervention.

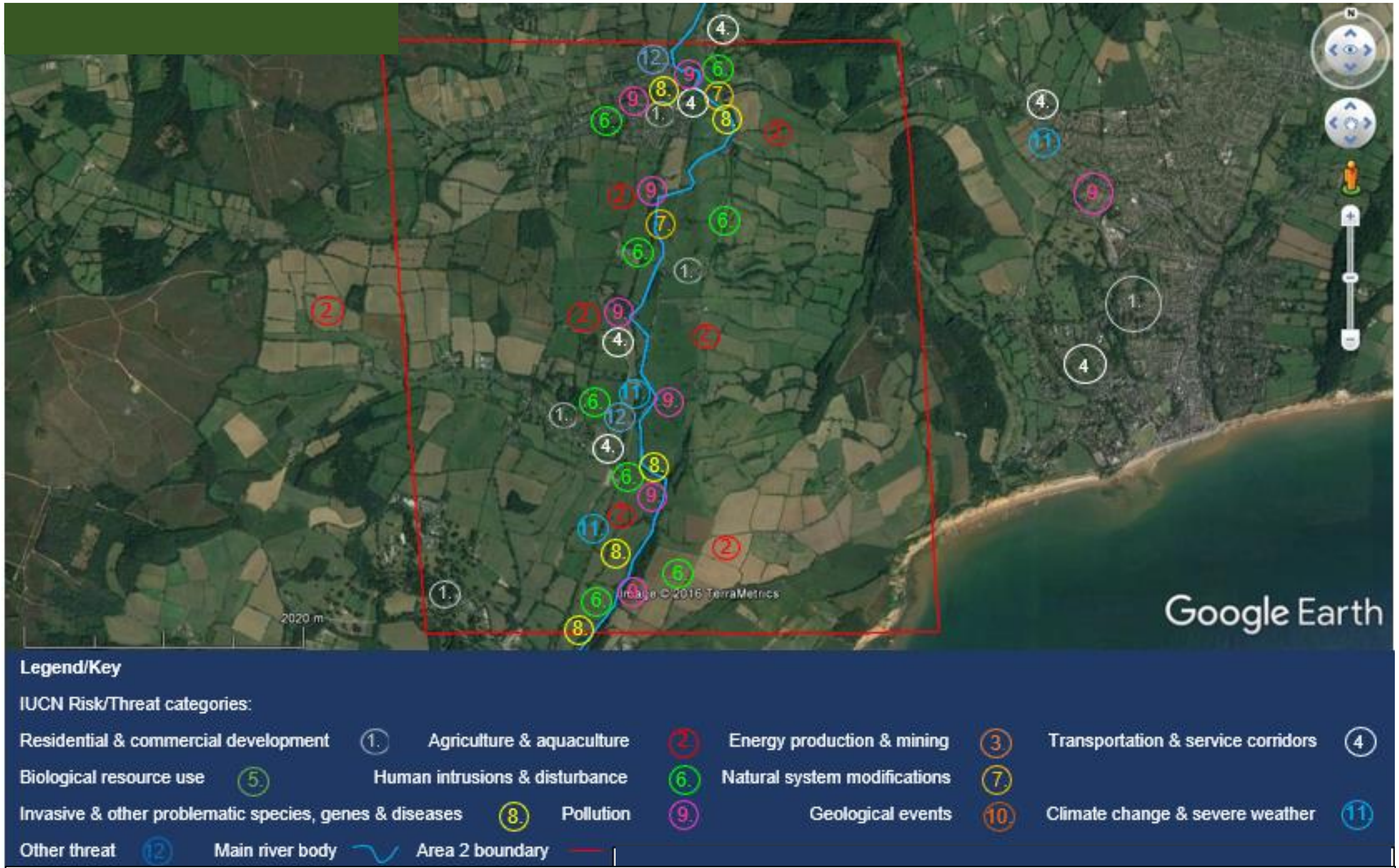


Figure 41. Threat Mapping Area 2 (Google Earth, 2018). In area 2, there are continued pressures from the risks posed by agricultural operations and various sources of pollution. A mix of arable crops and livestock pasture lie immediately adjacent to the river. Agricultural run-off and diffuse pollution were recorded in a number of areas throughout the river body whilst bankside erosion as a result of livestock entering the watercourse was also recorded degrading riparian habitat. Significant levels of floating woody debris recorded in the river can benefit the ecosystem adding to biodiversity and biomass (Palmer *et al*., 2014). However, in a number of areas it catches, builds up and creates a sink for garbage, solid waste, and diffuse pollution. Although this creates problems locally it may benefit by reducing further pollution downstream. There is continued high flood risk attached to area 2 potentially as a result of the wide river basin and flood plain as well as topography of the Otter Valley. Himalayan balsam was recorded in swards outcompeting riparian plant species in some areas resulting in bare banksides in winter which can lead to erosion. Beaver activity appears to have attracted wildlife tourists who try to see the species making this a busy stretch of river. There are also reasonably high numbers of locals who use the area for recreation such as exercise and dog walking which could pose a greater threat to beavers through human-dog-beaver interactions. There are continued widespread poaching lines. Risk and threat has been mapped in area 2 with approximate locations of where they may be generated applying IUCN threat categories.

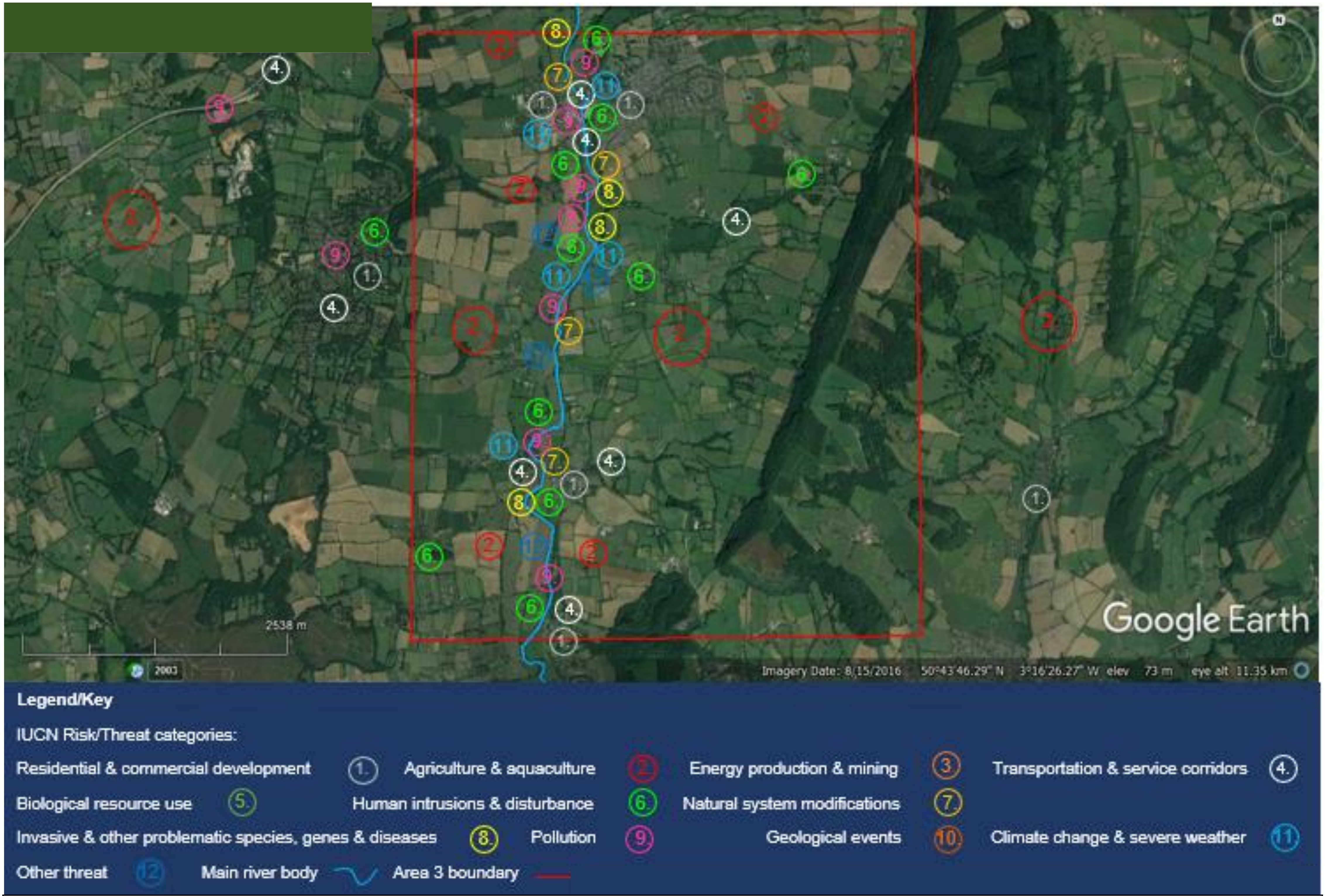


Figure 42. Threat Mapping Area 3 (Google Earth, 2018). Throughout area 3 risk and threat from agriculture and pollution continue to formulate stresses on the ecosystem. Area 3 also continues to have high flood risk. Due to the proximity of a busy town, the footpaths are significantly busier and much higher levels of garbage and solid waste were recorded. A high number of dog walkers use the footpaths. Significant levels of erosion were identified where in many places livestock have entered the water course collapsing banksides. Some large forestry plots line the top of the Otter Valley to the East however, land-use is predominantly arable and livestock pasture. Risk and threat was mapped using Google earth (2017) with approximate locations of where threats may be generated.

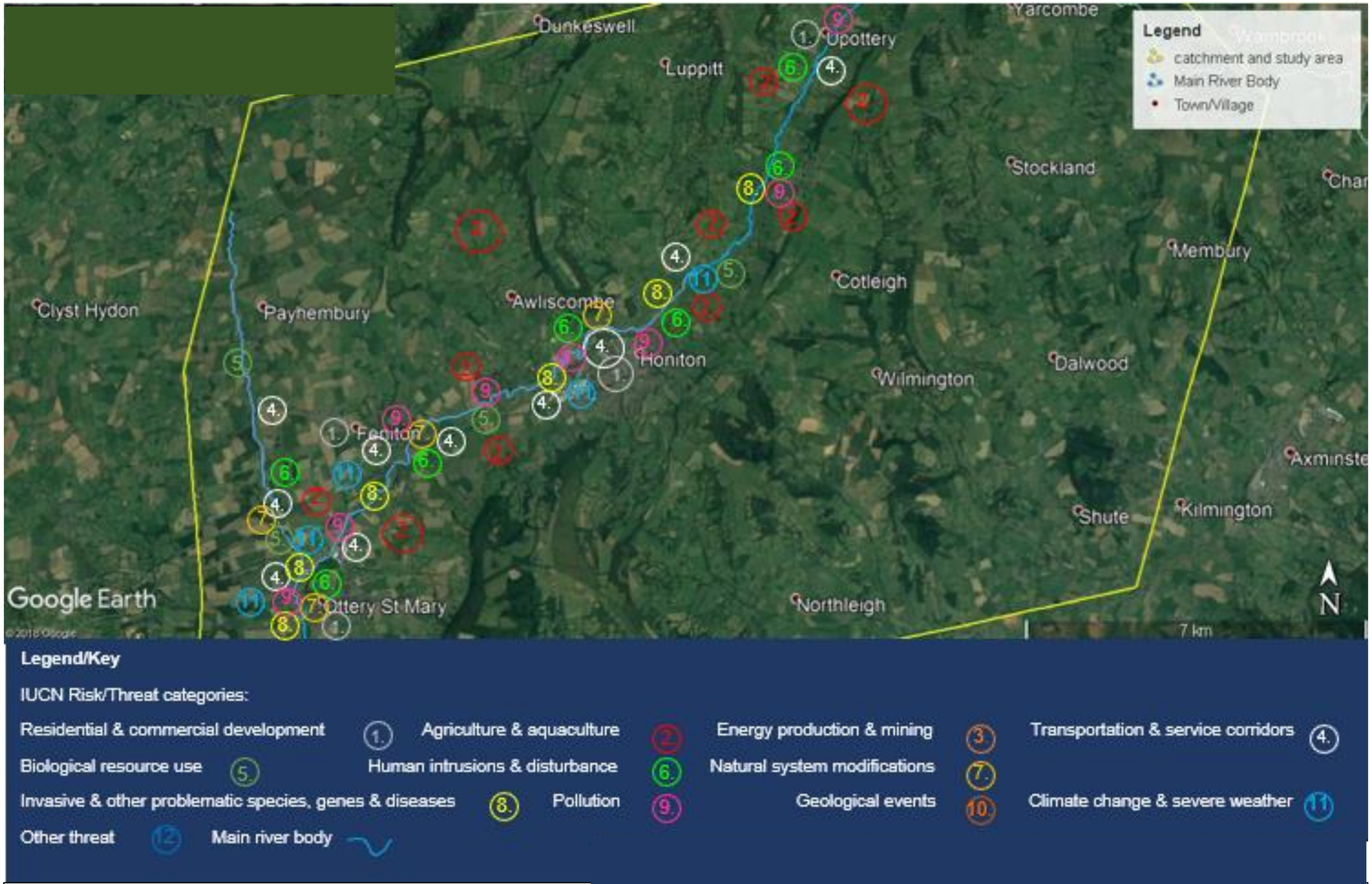


Figure 43. Threat Mapping Area 4 (Google Earth, 2018). Due to the homogenous landscape characteristics, risk and threat in area 4 continues to derive mainly from agricultural operations and pollution. On a broader scale the risk and threats and the approximate area where they are generated were mapped. In this area there are busy transportation and service corridors such as the A30 and South Western trainline that run over or adjacent to the river in places. This creates a greater level of pollution such as noise pollution. However, beaver activity has been recorded close to these areas suggesting minimal impact on the species.

## 8.5 *MARISCO Risk & Threat Analysis Results*

Risk and threat categories derived from IUCN risk and threat classification (IUCN, 2018), appendix 4.

1. Residential & Commercial Development. a.) *Housing & Urban, commercial & industrial.* b.) *Tourism & recreation.*

Table 34. *R & CD Ecosystem Impacts*

| | | | | |
|---|---|---|---|---|
| Residential & Commercial Development | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>2 | 3.Criticality - Irreversibility<br>3 | MARISCO |
| | 4. Past Criticality (-20yrs)<br>2 | 5. Current Criticality (1+2+3)<br>7 | 6. Trend of Change (of current criticality)<br>3 | 7. Future Criticality (+20yrs)<br>3 |
| | 8. Systemic Activity (level of Activity)<br>2 | 9. Systemic Activity (no. of influenced elements)<br>2 | 10. Systemic Activity (8+9)<br>4 | 11. Strategic Relevance (5+6+7+10)<br>17 |
| | 12. Manageability<br>2 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>- | Management Intervention<br>- |

The East Devon region and River Otter valley may face future urban development however, the region is designated an AONB and is characterized by large areas of countryside mainly for agricultural purposes. Due to the regions rural character current criticality was deemed to be reasonably low (2/4). However, with the towns of Ottery St. Mary and Honiton there is possibility for further urban sprawl, raising future criticality (3/4). The region is popular amongst tourists which appears important economically, however, this can result in further indirect threats such as that of increased pollution levels and anthropogenic disturbances (Hautier *et al*., 2015). *Strategic Relevance 17*

Table 35. *R & CD Eurasian beaver Impacts*

| | | | | |
|---|---|---|---|---|
| Residential & Commercial Development | 1. Criticality – Scope<br>1 | 2. Criticality – Severity<br>2 | 3.Criticality - Irreversibility<br>3 | MARISCO |
| | 4. Past Criticality (-20yrs)<br>- | 5. Current Criticality (1+2+3)<br>6 | 6. Trend of Change (of current criticality)<br>2 | 7. Future Criticality (+20yrs)<br>2 |
| | 8. Systemic Activity (level of Activity)<br>2 | 9. Systemic Activity (no. of influenced elements)<br>1 | 10. Systemic Activity (8+9)<br>3 | 11. Strategic Relevance (5+6+7+10)<br>13 |
| | 12. Manageability<br>2 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>2 | Management Intervention<br>2 |

Chances of human-beaver conflict can be increased in urban areas (Gurnell *et al*., 2009; Campbell-Palmer *et al*., 2016). Conflict can potentially arise if beaver modifications impact urban infrastructure as the species can be supported in these areas if suitable vegetation is accessible (Swinnen *et al*., 2017). However there are large stretches of the river that will be favoured for beaver territory that are unoccupied resulting in reasonably low criticality (6/12). Tourism and recreation is set to increase with the presence of beaver as wildlife tourist's visit to see the species (Gurnell, 2009; DWT, 2016a). With the increased human presence threats derived from tourism will also increase (DWT, 2016a). Management intervention is required to inform visitor's best practice to minimize any potential negative impacts or potential conflict (*ibid*). However, many positive outcomes such as an increase to the local economy through visitor spending can benefit both local businesses and the beavers through potentially increased funding from the public (*ibid*). *Strategic Relevance 13*

2. Agriculture. a.) *Annual & perennial non-timber crops & shifting agriculture.* b.) *Agro-industry farming.* c.) *Agro-industry grazing, ranching or farming.*

Table 36. *A Ecosystem Impacts*

| Agriculture | 1. Criticality – Scope<br>3 | 2. Criticality – Severity<br>3 | 3.Criticality - Irreversibility<br>2 | |
|---|---|---|---|---|
| | 4. Past Criticality (-20yrs)<br>4 | 5. Current Criticality (1+2+3)<br>8 | 6. Trend of Change (of current criticality)<br>3 | 7. Future Criticality (+20yrs)<br>3 |
| | 8. Systemic Activity (level of Activity)<br>3 | 9. Systemic Activity (no. of influenced elements)<br>3 | 10. Systemic Activity (8+9)<br>6 | 11. Strategic Relevance (5+6+7+10)<br>20 |
| | 12. Manageability<br>2 | 13. Knowledge<br>2 | Chance of Conflict (Human Beaver)<br>- | Management Intervention<br>- |

There are many areas with arable land-use practices being carried out adjacent to the River Otter placing a reasonably high criticality on this Threat (8/12). There are a range of threats to the river both direct and indirect derived from this. The Farming of livestock is widespread throughout the region appearing to hold economic and cultural importance. For large stretches of the River Otter adjacent land-use is livestock pasture. In some areas this threat is minimized by large buffer zones and riparian habitat. In other areas there is no riparian habitat or buffer zones present which has led to bankside erosion from livestock entering the watercourse, permitted by the land owner. In some areas there is evidence of these agricultural practices taking place on an industrial scale. Threats from agro-industry farming correlate with threats produced from other agricultural practices on a broader scale. Stresses and symptoms resulting from this can be widespread. *Strategic Relevance 20.*

Table 37. *A Eurasian beaver Impacts*

| | | | | |
|---|---|---|---|---|
| Agriculture | 1. Criticality – Scope 2 | 2. Criticality – Severity 2 | 3.Criticality - Irreversibility 1 | MARISCO |
| | 4. Past Criticality (-20yrs) - | 5. Current Criticality (1+2+3) 5 | 6. Trend of Change (of current criticality) 3 | 7. Future Criticality (+20yrs) 3 |
| | 8. Systemic Activity (level of Activity) 3 | 9. Systemic Activity (no. of influenced elements) 1 | 10. Systemic Activity (8+9) 4 | 11. Strategic Relevance (5+6+7+10) 15 |
| | 12. Manageability 3 | 13. Knowledge 4 | Chance of Conflict (Human Beaver) 3 | Management Intervention 3 |

There is potential for human-beaver conflict with farm owners and land managers as it has been recorded that beavers can feed on arable crops and induce flooding (Kaphegyi *et al*., 2015; Batbold *et al*., 2016). However, this is unlikely to occur as there is sufficient habitat with more favoured food sources such as riparian trees and vegetation (Krojerova-Prokesova *et al*., 2010; DWT, 2016a). Management requires communication and alliance with stakeholders and land owners in order of minimizing any potential conflicts from land management operations such as growing and harvesting non-timber crops (DWT, 2016a). As the River Otter beaver population expands, threats from conflicts with land owners may increase resulting in reasonably high future criticality (3/4). However, there is a wide knowledge base (4/4) and there are many mitigation measures that can minimise probabilities of this resulting in good prospects of irreversibility (1/4). *Strategic Relevance 15.*

3. Mining & Quarrying – not present

4. Transportation & Service Corridors. a.) *Roads & railroads*

Table 38. *T & SC Ecosystem Impacts*

| | | | | |
|---|---|---|---|---|
| Transportation & Service Corridors | 1. Criticality – Scope 2 | 2. Criticality – Severity 2 | 3.Criticality - Irreversibility 3 | MARISCO |
| | 4. Past Criticality (-20yrs) 2 | 5. Current Criticality (1+2+3) 7 | 6. Trend of Change (of current criticality) 2 | 7. Future Criticality (+20yrs) 2 |
| | 8. Systemic Activity (level of Activity) 2 | 9. Systemic Activity (no. of influenced elements) 1 | 10. Systemic Activity (8+9) 3 | 11. Strategic Relevance (5+6+7+10) 14 |
| | 12. Manageability 2 | 13. Knowledge 3 | Chance of Conflict (Human Beaver) - | Management Intervention - |

There are some roads ranging from small country lanes to busier highways that pass the River Otter (Google earth, 2017). This can add stresses on the ecosystem such as connectivity loss. However, due to the rural character of the region roads crossing the river can be seldom used resulting in reasonably low criticality (7/12). *Strategic Relevance 14*

Table 39. *T & SC Eurasian beaver Impacts*

| Transportation & Service Corridors | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>1 | 3.Criticality - Irreversibility<br>3 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20yrs)<br>- | 5. Current Criticality (1+2+3)<br>6 | 6. Trend of Change (of current criticality)<br>2 | 7. Future Criticality (+20yrs)<br>2 |
| | 8. Systemic Activity (level of Activity)<br>2 | 9. Systemic Activity (no. of influenced elements)<br>1 | 10. Systemic Activity (8+9)<br>3 | 11. Strategic Relevance (5+6+7+10)<br>13 |
| | 12. Manageability<br>2 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>2 | Management Intervention<br>2 |

Beavers will cross roads in order of moving through the riparian landscape (DWT, 2016a). A deceased beaver was found on a road close to the river in the early stages which confirmed the species presence in the area (DWT, 2016). Management may require intervention to minimize any threat to the beavers. There can be potential for beavers to damage infrastructure through burrowing activities and other aspects of their behaviour which can lead to further conflict (DWT, 2016a; Swinnen *et al*., 2017). However, there are many areas of suitable habitat that will be favoured by the species making the probability of damage and conflict reasonably low. *Strategic Relevance 13.*

5. Biological Resource Use. a.) *Hunting & collecting terrestrial animals, fishing & harvesting aquatic resources*

Table 40. *BRU Ecosystem Impacts*

| Biological Resource Use | 1. Criticality – Scope<br>1 | 2. Criticality – Severity<br>1 | 3.Criticality - Irreversibility<br>2 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20yrs)<br>2 | 5. Current Criticality (1+2+3)<br>4 | 6. Trend of Change (of current criticality)<br>1 | 7. Future Criticality (+20yrs)<br>2 |
| | 8. Systemic Activity (level of Activity)<br>1 | 9. Systemic Activity (no. of influenced elements)<br>1 | 10. Systemic Activity (8+9)<br>2 | 11. Strategic Relevance (5+6+7+10)<br>9 |
| | 12. Manageability<br>2 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>- | Management Intervention<br>- |

Hunting can be culturally important to communities despite having negative impacts on aspects such as biodiversity (Alves *et al*., 2018). Fishing is permitted in many places along the main river body of the River Otter. However, upon ground-truthing no anglers were recorded actively fishing. Due to this factor criticality for this threat was deemed very low (4/12).

Table 41. *BRU Eurasian beaver Impacts*

| Biological Resource Use | 1. Criticality – Scope<br>1 | 2. Criticality – Severity<br>1 | 3.Criticality - Irreversibility<br>2 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20yrs)<br>- | 5. Current Criticality (1+2+3)<br>4 | 6. Trend of Change (of current criticality)<br>2 | 7. Future Criticality (+20yrs)<br>2 |
| | 8. Systemic Activity (level of Activity)<br>1 | 9. Systemic Activity (no. of influenced elements)<br>1 | 10. Systemic Activity (8+9)<br>2 | 11. Strategic Relevance (5+6+7+10)<br>10 |
| | 12. Manageability<br>2 | 13. Knowledge<br>2 | Chance of Conflict (Human Beaver)<br>1 | Management Intervention<br>1 |

Threats from hunting are highly unlikely to impact beavers present in the UK (Campbell-Palmer *et al*., 2016). However, it has been suggested that in some areas of Scotland, beavers have been potentially shot by a disgruntled landowners (bbc.co.uk, 2016; DailyRecord, 2015). There are many areas on the River Otter where it is permitted to fish. This will have no impact on beavers inhabiting the river. It has been brought to attention concerns from anglers and the public about beavers preying or disturbing fish stocks (DWT, 2018a). *Castor fiber* is strictly herbivorous and can benefit fish stocks creating good habitat for spawning and nursery areas (Gurnell *et al*., 2009; Kemp *et al*., 2011). Due to the very low probability of beavers being hunted in Britain, criticality was scored very low (4/12). *SR 10.*

6. Human Intrusions & Disturbance a.) *Recreational Activities, Work & other activities.* b.) *Dams & water management/use, Other ecosystem modifications*

Table 42. *HI & D Ecosystem Impacts*

| Human Intrusions & Operations | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>3 | 3.Criticality - Irreversibility<br>2 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20yrs)<br>3 | 5. Current Criticality (1+2+3)<br>7 | 6. Trend of Change (of current criticality)<br>3 | 7. Future Criticality (+20yrs)<br>3 |
| | 8. Systemic Activity (level of Activity)<br>3 | 9. Systemic Activity (no. of influenced elements)<br>3 | 10. Systemic Activity (8+9)<br>6 | 11. Strategic Relevance (5+6+7+10)<br>19 |
| | 12. Manageability<br>2 | 13. Knowledge<br>2 | Chance of Conflict (Human Beaver)<br>- | Management Intervention<br>- |

The River Otter appears important for human recreational activities attracting many visitors to the region. There are a number of issues that can place stress on the ecosystem as a result of this such as increased pollution sources. Close to the Town of Ottery St. Mary a reasonably large construction site is situated very close to the river. Several utility service lines run through or close by the river which also may require maintenance or other work-related activities. Other potential barriers observed on the river include a small number of weirs and a environment agency monitoring station. However, these have had passes for wildlife installed. Wide ranging human disturbances can simultaneously impact resilience and productivity of the ecosystem (Hautier *et al*., 2015).

Table 43. *HI & D Eurasian beaver Impacts*

| | | | | |
|---|---|---|---|---|
| Human Intrusions & Operations | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>3 | 3.Criticality - Irreversibility<br>2 | MARISCO |
| | 4. Past Criticality (-20yrs)<br>- | 5. Current Criticality (1+2+3)<br>7 | 6. Trend of Change (of current criticality)<br>3 | 7. Future Criticality (+20yrs)<br>2 |
| | 8. Systemic Activity (level of Activity)<br>3 | 9. Systemic Activity (no. of influenced elements)<br>1 | 10. Systemic Activity (8+9)<br>4 | 11. Strategic Relevance (5+6+7+10)<br>16 |
| | 12. Manageability<br>2 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>2 | Management Intervention<br>2 |

Recreational activities may increase further due to the presence of *Castor fiber* (DWT, 2016a). Stresses on the beavers can derive from these activities and conflict issues with landowners can arise from increasing tourist numbers (*ibid*). Positively, this can place value on the ecosystem by the public gathering interest in the environment and ROBT (Gurnell *et al*., 2009; DWT, 2016a). During ground-truthing the River Otter a range of weirs and Environment Agency monitoring stations were located. Many have passes for wildlife and are not barriers for beavers as activity such as foraging was recorded closely either side of any potential barrier. Close monitoring is carried out by DWT for mitigation against any beaver modifications that may impact weirs or Environment Agency river monitoring stations to minimise probability of future conflict (DWT, 2016a). *Strategic Relevance 16*

7. Invasive & Other Problematic Species. a.) *Invasive Non-Native/Alien Species/Diseases*

Table 44. *IS & D Ecosystem Impact*

| | | | | |
|---|---|---|---|---|
| Invasive Non-Native/Alien Species/ Diseases | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>3 | 3.Criticality - Irreversibility<br>2 | MARISCO |
| | 4. Past Criticality (-20yrs)<br>1 | 5. Current Criticality (1+2+3)<br>7 | 6. Trend of Change (of current criticality)<br>3 | 7. Future Criticality (+20yrs)<br>3 |
| | 8. Systemic Activity (level of Activity)<br>2 | 9. Systemic Activity (no. of influenced elements)<br>3 | 10. Systemic Activity (8+9)<br>5 | 11. Strategic Relevance (5+6+7+10)<br>18 |
| | 12. Manageability<br>3 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>- | Management Intervention<br>- |

Both Himalayan balsam and Japanese knotweed have been recorded on the banksides of the River Otter. Impacts from these invasive species can be widespread altering many ecosystem properties and functions (RHS, 2018). Continued work is being carried out to eradicate the invasive plant species (OVA, 2018). The invasive plant species present will have minimal impact on the Eurasian beaver population. *Ecchinoccus multicularis* is a parasitic zoonoses currently not present in the UK but has been found in individual beavers during quarantine for translocation in Europe (Gottstein *et al*., 2014; Campbell-Palmer *et al*., 2015c). This highlights the importance of health screening and quarantine measures when sourcing beavers for reintroduction (*ibid*). *Strategic Relevance 18*

8. Pollution. a.) *Domestic & Urban Waste Water.* b.) *Nutrient Loads, Soil Erosion & Sedimentation.* c.) *Run-off, Herbicides & Pesticides, Garbage & Solid Waste*

Table 45. *P Ecosystem Impacts*

| Pollution | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>3 | 3.Criticality - Irreversibility<br>3 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20yrs)<br>3 | 5. Current Criticality (1+2+3)<br>8 | 6. Trend of Change (of current criticality)<br>2 | 7. Future Criticality (+20yrs)<br>2 |
| | 8. Systemic Activity (level of Activity)<br>2 | 9. Systemic Activity (no. of influenced elements)<br>3 | 10. Systemic Activity (8+9)<br>5 | 11. Strategic Relevance (5+6+7+10)<br>19 |
| | 12. Manageability<br>2 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>- | Management Intervention<br>- |

The threats from pollutants can have significant negative impacts on a river system. With the main river body passing through the towns of Ottery St. Mary and Honiton there is potential for domestic and urban waste waters entering the river system. However, no point sources of this pollution was recorded during ground-truthing suggesting minimal impacts. Nutrient loads and increased sedimentation are reasonably widespread throughout the main river body of the Otter. Increased nutrient loads were observed entering the river from livestock feedlots and manure. Increased soil erosion and sedimentation was recorded from a number of sources including livestock entering the watercourse. Run-off and pollutants such as herbicides and pesticides can cause stresses throughout the river system and riparian habitat (Hill, 1995; EnvironmentAgency, 2018). Evidence of run-off in the river was recorded during ground-truthing potentially herbicide from arable fields adjacent. Garbage and solid waste was recorded in the river and riparian zones of the River Otter. This appears to get trapped in woody debris which stops it traveling further downstream allowing it to be cleared. As part of the ROBT management strategy any problematic woody debris may be removed in these areas allowing for litter and waste to be cleared (DWT, 2016a). General municipal waste and litter from cars were recorded becoming more frequent towards the urban zones. Due to these factors criticality is recorded being reasonably high (8/12). *Strategic Relevance 19.*

Table 46. *P Eurasian beaver Impacts*

| | | | | |
|---|---|---|---|---|
| Pollution | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>2 | 3.Criticality - Irreversibility<br>2 | MARISCO |
| | 4. Past Criticality (-20yrs)<br>- | 5. Current Criticality (1+2+3)<br>6 | 6. Trend of Change (of current criticality)<br>2 | 7. Future Criticality (+20yrs)<br>2 |
| | 8. Systemic Activity (level of Activity)<br>2 | 9. Systemic Activity (no. of influenced elements)<br>1 | 10. Systemic Activity (8+9)<br>3 | 11. Strategic Relevance (5+6+7+10)<br>13 |
| | 12. Manageability<br>2 | 13. Knowledge<br>2 | Chance of Conflict (Human Beaver)<br>1 | Management Intervention<br>2 |

With the presence of beavers there is potential for negative pollution impacts to be reduced by beaver dams which can halt further pollution downstream (Puttock *et al*., 2017). Beaver modifications can also assist in mitigation by halting sediments and nutrient loads from further distribution downstream (Puttock *et al*., 2018). Greater complexity of riparian habitat by beaver can enhance bankside stability (Gurnell *et al*., 2009), and beaver ponds will reduce accelerated erosion (Puttock *et al*., 2018). The River Otter beavers have begun damming tributaries, however, the main river body is free from beaver modifications having minimal effect on mitigation. If pollutants are halted by damming, long-term exposure to beavers may require further investigation. Currently, threats from pollutants are minimal to the species. *Strategic Relevance 13*

9. Climate Change & Severe Weather. a.) *Habitat Shifting & Alteration*. b.) *Storms & Flooding*

Table 47. *CC & SW Ecosystem Impacts*

| | | | | |
|---|---|---|---|---|
| Climate Change & Severe Weather | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>2 | 3.Criticality - Irreversibility<br>3 | MARISCO |
| | 4. Past Criticality (-20yrs)<br>2 | 5. Current Criticality (1+2+3)<br>7 | 6. Trend of Change (of current criticality)<br>3 | 7. Future Criticality (+20yrs)<br>3 |
| | 8. Systemic Activity (level of Activity)<br>2 | 9. Systemic Activity (no. of influenced elements)<br>3 | 10. Systemic Activity (8+9)<br>5 | 11. Strategic Relevance (5+6+7+10)<br>18 |
| | 12. Manageability<br>3 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>- | Management Intervention<br>- |

Habitat Shifts and alteration can have significant adverse impacts and trigger a wide range of stresses on an ecosystem (MEA, 2005b). This could be observed with the facilitation of invasive species creating monocultures in patches of the River Otter riparian habitat. Through other negative factors such as that of climate change, droughts are increasing globally as well as in Britain (MEA, 2005b; EUCommission, 2016). Another negative factor of accelerated climate change is increased storm and flooding events also recorded globally (IPCC, 2001; MEA, 2005b). During the EDA desktop study it was notified that the River Otter Valley is under high risk of flooding. *Strategic Relevance 18*

Table 48. *CC & SW Eurasian beaver Impacts*

| | | | | |
|---|---|---|---|---|
| Climate Change & Severe Weather | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>2 | 3.Criticality - Irreversibility<br>3 | MARISCO |
| | 4. Past Criticality (-20yrs)<br>- | 5. Current Criticality (1+2+3)<br>7 | 6. Trend of Change (of current criticality)<br>2 | 7. Future Criticality (+20yrs)<br>3 |
| | 8. Systemic Activity (level of Activity)<br>2 | 9. Systemic Activity (no. of influenced elements)<br>2 | 10. Systemic Activity (8+9)<br>4 | 11. Strategic Relevance (5+6+7+10)<br>16 |
| | 12. Manageability<br>3 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>1 | Management Intervention<br>2 |

*Castor fiber* can have a major influence on mitigation against drought by dams maintaining base flows (Nyssen *et al*., 2011; Puttock *et al*., 2017). *Castor fiber* can have a similar positive impact with increased flood events by dams holding back vast quantities of water reducing impacts downstream(Campbell-Palmer, 2015; Puttock *et al*., 2017). However, Habitat shifts and alteration may result in habitat becoming unfavourable for beaver. Eurasian beaver burrows can be at risk from flooding during storm events and in some cases dams can be breached (Campbell-Palmer *et al*., 2015). *Strategic Relevance 16*

Table 49. MARISCO Risk & Threat Final Scores

| **Risk/Threat** | *Strategic Relevance Ecosystem* | *Strategic Relevance Eurasian beaver* |
|---|---|---|
| Residential & Commercial Development | 17 | 13 |
| Agriculture | 20 | 15 |
| Transportation & Service Corridors | 14 | 13 |
| Biological Resource Use | 9 | 10 |
| Human Intrusions & Operations | 19 | 16 |
| Invasive & Other Problematic Species | 18 | n/a |
| Pollution | 19 | 13 |
| Climate Change & Severe Weather | 18 | 16 |

Results from the assessment of risk and threat indicate agriculture, human intrusions and operations, pollution, climate change and severe weather, and invasive species as key threats to the ecosystem. For Eurasian beaver, human intrusions and operations, climate change and severe weather events, and agriculture are key potential threats.

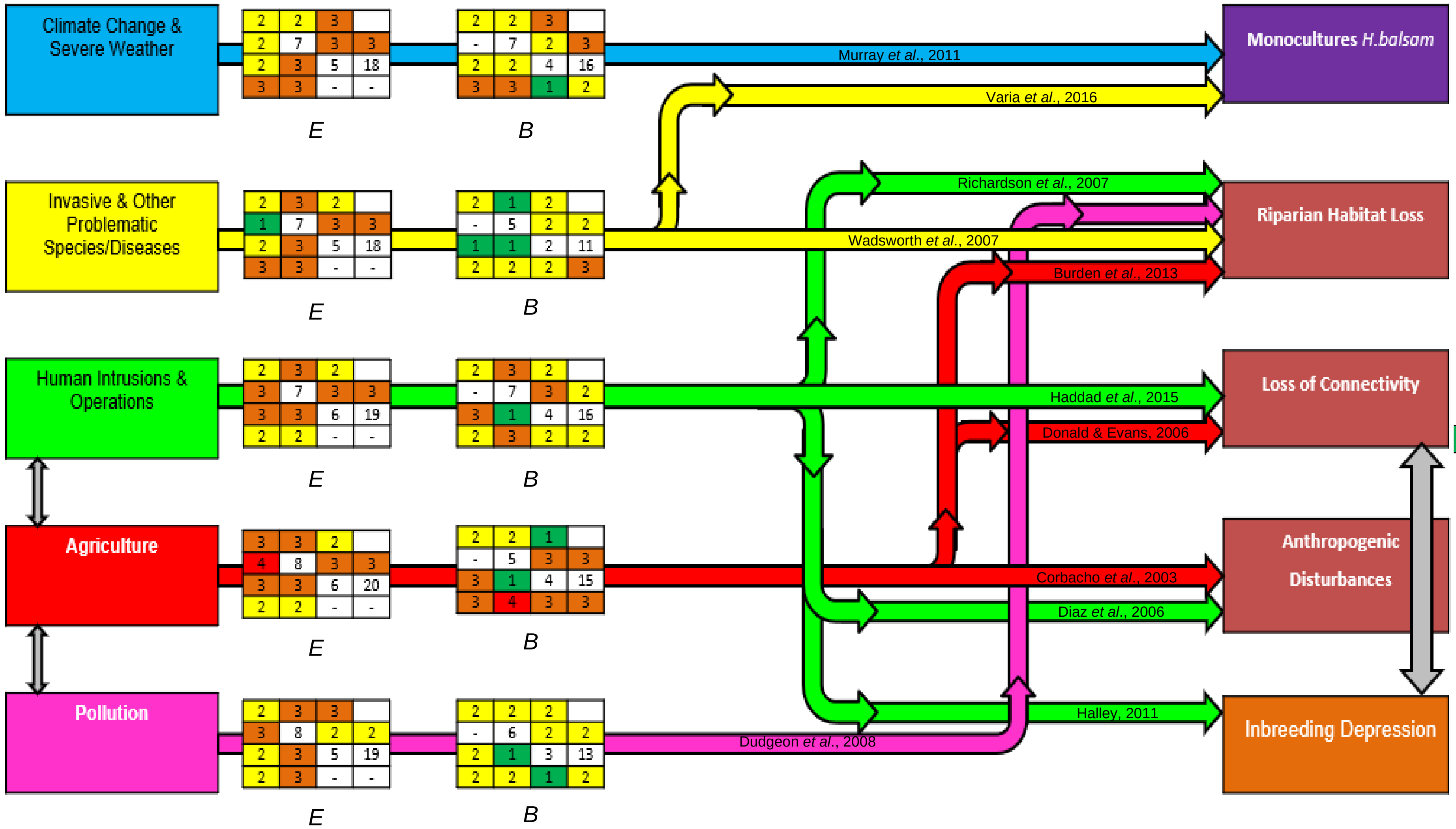


Table 50. MARISCO Threats Scorecard

| Threat | | | | |
|---|---|---|---|---|
| | 1. Criticality – Scope | 2. Criticality – Severity | 3.Criticality - Irreversibility | MARISCO |
| | 4. Past Criticality (-20yrs) | 5. Current Criticality (1+2+3) | 6. Trend of Change (of current criticality) | 7. Future Criticality (+20yrs) |
| | 8. Systemic Activity (level of Activity) | 9. Systemic Activity (no. of influenced elements) | 10. Systemic Activity (8+9) | 11. Strategic Relevance (5+6+7+10) |
| | 12. Manageability | 13. Knowledge | 14. Chance of Conflict (Human Beaver) | 15. Management Intervention |

Table 51. Impact Rating

| | | | |
|---|---|---|---|
| 1 – very low | 2- reasonably low | 3- reasonably high | 4- very high |

**Legend**

Relationship (any colour)

Ecosystem Impacts Scorecard – *E*

Beaver Impacts Scorecard – *B*

Figure 44. MARISCO Conceptual Model Threats & Stresses Relationships. Risk and threat places a wide range of stresses on ecosystems. Resulting from the assessments of stresses and threats, key relationships could be constructed with the assistance of peer reviewed scientific literature for confirmation. Climate change can facilitate invasive riparian plant species in a number of ways such as through the alteration of flow regimes which can influence seed dispersal allowing further distribution (Murray *et al*., 2011). Invasive species such as *Impatiens glandulifera* will outcompete native riparian plant species creating monocultures which will die off in Autumn months exposing bare banksides prone to accelerated erosion (Wadsworth *et al*., 2002; Varia *et al*., 2016). This was recorded on the River Otter. Human intrusions and operations are a key direct and indirect driver of negative impacts on the system such as riparian habitat loss (Diaz *et al*., 2006; Richardson *et al*., 2007). Such loss of habitat results in fragmentation with a loss of area, more exposure to human land-uses and operations and increase in isolation can initiate long-term challenges to structure and function of lasting fragments (Haddad *et al*., 2015). Further resulting from human loss of connectivity and isolation of beaver populations, risks of inbreeding depression may become an issue, previously recorded as a result of historic human persecution and isolation of Eurasian beaver (Halley, 2011). Due to the homogenous landscape character of the River Otter region, there a key relationships between stresses and agricultural operations that dominate land-usage. Many of the threats to freshwater river systems stem from such operations, such as the relationship with anthropogenic disturbances (Corbacho *et al*., 2003) and connectivity loss (Donald & Evans, 2006). Of the 594 kilometers watercourse in the catchment, 22% - 27% of the land within a 30m buffer of the river is used for agriculture and could also impact beavers (DWT, 2016b).Other impacts include suitable habitat removal (riparian habitat loss), the alteration of flow regimes, and the input of diffuse pollutants and increased sedimentation (Dudgeon *et al*., 2006; Burden *et al*., 2013). There can be feedbacks between threats and stresses respectively, such as the threat of agriculture leading to human intrusions and operations and pollution, and the stress of connectivity loss leading to potential inbreeding depression. Table 50. is a MARISCO scorecard for threats and table 51. is the impact rating applied when scoring.

*8.6 Contributing Factors Analysis Results*

Formulation and identification of contributing factors completes the MARISCO situation analysis and conceptual model.

Table 52. *Climate change & Weather Extremes*

| | | | | |
|---|---|---|---|---|
| Climate Change & Weather Extremes | 1. Criticality – Scope 2 | 2. Criticality – Severity 2 | 3.Criticality - Irreversibility 3 | MARISCO |
| | 4. Past Criticality (-20yrs) 1 | 5. Current Criticality (1+2+3) 7 | 6. Trend of Change (of current criticality) 2 | 7. Future Criticality (+20yrs) 4 |
| | 8. Systemic Activity (level of Activity) 2 | 9. Systemic Activity (no. of influenced elements) 2 | 10. Systemic Activity (8+9) 4 | 11. Strategic Relevance (5+6+7+10) 16 |
| | 12. Manageability 3 | 13. Knowledge 2 | Chance of Conflict (Human Beaver) n/a | Management Intervention n/a |

Accelerated Climate Change is far beyond natural variability and set to continue well into the future (Karl & Trenberth 2003). Mitigation and management of the widespread impacts can be problematic as for future uncertainties (*ibid*). Extreme weather is occurring more frequently globally, accelerated by climate change (IPCC, 2001). A wide range of threats can be triggered by extended periods of drought or major storm events (*ibid*). Devon and the south-west of England are under high risk of flooding (DATA.GOV.UK, 2017). It has also been documented that climate change can facilitate invasive species (Murray *et al.*, 2011)

Table 53. *Habitat Loss/ Fragmentation & Land-Use Change*

| | | | | |
|---|---|---|---|---|
| Habitat Loss/ Fragmentation & Land-Use Change | 1. Criticality – Scope 3 | 2. Criticality – Severity 3 | 3.Criticality - Irreversibility 2 | MARISCO |
| | 4. Past Criticality (-20yrs) 2 | 5. Current Criticality (1+2+3) 8 | 6. Trend of Change (of current criticality) 3 | 7. Future Criticality (+20yrs) 3 |
| | 8. Systemic Activity (level of Activity) 3 | 9. Systemic Activity (no. of influenced elements) 3 | 10. Systemic Activity (8+9) 6 | 11. Strategic Relevance (5+6+7+10) 20 |
| | 12. Manageability 3 | 13. Knowledge 3 | Chance of Conflict (Human Beaver) 2 | Management Intervention 3 |

Fragmentation and loss of habitat is a key driver and contributor of biodiversity decline (Newbold *et al*., 2015; Liu *et al*., 2018). In the past long stretches of riparian habitat have been lost and fragmented on the River Otter (Google earth, 2017). With continued restoration efforts such as that of the ROBT there appears to be continued development to improve habitat quality and connectivity. The conversion of land for urban environments and agricultural practices is also a key driver of rapid environmental change (Newbold *et al*., 2015). These environments have been recorded as sources of various pollutants that can have adverse impacts on many terrestrial and aquatic ecosystems (Chapin *et al*., 2000; CBD, 2014). The River Otter Valley is dominated by agricultural land-usage. *Strategic Relevance = 20.*

Table 54. *Agricultural Intensification*

| | | | | |
|---|---|---|---|---|
| Agricultural Intensification | 1. Criticality – Scope 2 | 2. Criticality – Severity 2 | 3.Criticality - Irreversibility 2 | MARISCO |
| | 4. Past Criticality (-20yrs) 3 | 5. Current Criticality (1+2+3) 6 | 6. Trend of Change (of current criticality) 3 | 7. Future Criticality (+20yrs) 3 |
| | 8. Systemic Activity (level of Activity) 2 | 9. Systemic Activity (no. of influenced elements) 3 | 10. Systemic Activity (8+9) 5 | 11. Strategic Relevance (5+6+7+10) 17 |
| | 12. Manageability 2 | 13. Knowledge 3 | Chance of Conflict (Human Beaver) 2 | Management Intervention 2 |

Intensive agriculture can raise the impacts of threats and stresses can become more widespread (Tilman *et al*., 2011). There is a strong relationship with economic factors and increased product demands which can result in maximizing land productivity (*ibid*). *Strategic Relevance = 17.*

Table 55. *Economic Factors, Infrastructure & Development*

| | | | | |
|---|---|---|---|---|
| Economic Factors, Infrastructure & Development | 1. Criticality – Scope 3 | 2. Criticality – Severity 2 | 3.Criticality - Irreversibility 3 | MARISCO |
| | 4. Past Criticality (-20yrs) 3 | 5. Current Criticality (1+2+3) 8 | 6. Trend of Change (of current criticality) 2 | 7. Future Criticality (+20yrs) 2 |
| | 8. Systemic Activity (level of Activity) 2 | 9. Systemic Activity (no. of influenced elements) 3 | 10. Systemic Activity (8+9) 5 | 11. Strategic Relevance (5+6+7+10) 17 |
| | 12. Manageability 2 | 13. Knowledge 2 | Chance of Conflict (Human Beaver) 1 | Management Intervention 3 |

Economic factors appear to play a complex role in the generation of risk and threat. It is interrelated with maximization of productivity of the landscape (Tilman *et al*., 2011), and may play a key role in conflict issues surrounding *Castor fiber*. There is tendency for landowners and managers to have concerns of flooding of land and drainage ditches by beaver damming which fundamentally is concern of loss of earnings from lost crops (Campbell-Palmer *et al*., 2015). However, there is potential for an increase in local economy through tourism and landowners may benefit from aspects such as increased ecosystem pollination services as a result of beaver colonization (Gurnell *et al*., 2009). Infrastructure and development can contribute to a range of pressures on the ecosystem such as connectivity loss and fragmentation (MEA, 2005). It can also impact the beavers as road incidents can be a mortality factor, recorded throughout regions where the species have colonized human dominated landscapes (Gurnell *et al*., 2009; Campbell-Palmer *et al*., 2015; DWT, 2016a). *Strategic Relevance = 20.*

Table 56. *Landowners & Local Businesses*

| Land Owners & Local Businesses | 1. Criticality – Scope 2 | 2. Criticality – Severity 2 | 3.Criticality - Irreversibility 3 | MARISCO |
|---|---|---|---|---|
| | 4. Past Criticality (-20yrs) 3 | 5. Current Criticality (1+2+3) 7 | 6. Trend of Change (of current criticality) 3 | 7. Future Criticality (+20yrs) 2 |
| | 8. Systemic Activity (level of Activity) 2 | 9. Systemic Activity (no. of influenced elements) 2 | 10. Systemic Activity (8+9) 4 | 11. Strategic Relevance (5+6+7+10) 16 |
| | 12. Manageability 3 | 13. Knowledge 2 | Chance of Conflict (Human Beaver) 2 | Management Intervention 3 |

Landowner's ethics and values are an integral element to conservation management (Ibisch & Hobson, 2014). Mis-management of land can result in widespread negative impacts on the surrounding environment. With any restoration or reintroduction program the relationships between managers and stakeholders may be a significant challenge and vital for future prosperity (Halley *et al*., 2009). There appears to be a strong alliance between the ROBT management and stakeholders that may influence the River Otter ecosystem enhancing probabilities of success. The area surrounding the river ecosystem appears to have many valued local businesses reliant, and relied on by public trade, tourism and surrounding infrastructure. Therefore they may play a role on contributing to vulnerability of the ecosystem. However, much of this is indirect and challenging to manage. The local businesses are important to the region economically and may assist in aspects such as promotion and education of the ROBT. These businesses may well profit from increased tourism brought from wildlife tourists visiting to see the beavers (DWT, 2016a). *Strategic Relevance = 14.*

Table 57. *Human Population Increase, increased Product Demands, Food Consumption*

| | | | | |
|---|---|---|---|---|
| Human Population Increase, Increased Product Demand, Food Consumption | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>2 | 3.Criticality - Irreversibility<br>3 | |
| | 4. Past Criticality (-20yrs)<br>1 | 5. Current Criticality (1+2+3)<br>7 | 6. Trend of Change (of current criticality)<br>3 | 7. Future Criticality (+20yrs)<br>3 |
| | 8. Systemic Activity (level of Activity)<br>2 | 9. Systemic Activity (no. of influenced elements)<br>2 | 10. Systemic Activity (8+9)<br>4 | 11. Strategic Relevance (5+6+7+10)<br>16 |
| | 12. Manageability<br>2 | 13. Knowledge<br>2 | Chance of Conflict (Human Beaver)<br>n/a | Management Intervention<br>n/a |

Human population increase is occurring on a global scale and may be related to many of the threats facing ecosystems and the natural environment (CBD, 2014). With the human population increasing demands for ecosystem services and products are rising steadily (MEA, 2005). Sustainability is a central pillar of the CBD (1992) and is a key aspect in reducing impacts taking place worldwide (CBD, 2014). The consumption of food sources such as arable crops or livestock by humans underpins the widespread agricultural economy of the east Devon region. The demand for food has risen on a global scale correlating with a rise in environmental impacts derived from this (Tilman *et al*., 2011). *Strategic Relevance = 18*

Table 58. *Members of the Public, Holiday Makers/Tourism, Leisure/Recreation*

| | | | | |
|---|---|---|---|---|
| Members of the Public, Holiday Makers/Tourism, Leisure & Recreation | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>3 | 3.Criticality - Irreversibility<br>2 | |
| | 4. Past Criticality (-20yrs)<br>3 | 5. Current Criticality (1+2+3)<br>7 | 6. Trend of Change (of current criticality)<br>3 | 7. Future Criticality (+20yrs)<br>3 |
| | 8. Systemic Activity (level of Activity)<br>3 | 9. Systemic Activity (no. of influenced elements)<br>2 | 10. Systemic Activity (8+9)<br>5 | 11. Strategic Relevance (5+6+7+10)<br>18 |
| | 12. Manageability<br>2 | 13. Knowledge<br>3 | Chance of Conflict (Human Beaver)<br>3 | Management Intervention<br>3 |

The general public can contribute in various ways to threats on the ecosystem. People have to be considered as part of any natural system (Ibisch & Hobson, 2014), and aspects such as rights of way and recreation are considered in the ROBT management strategy (DWT, 2016a). Anthropogenic disturbances and pollution such as litter and garbage can become more frequent. However, support from the general public is required for future enhanced probabilities of success (IUCN/SSC, 2013), and can assist with aspects such as funding (DWT, 2016). Holiday makers and tourists are clearly economically important to the region. Wildlife tourism appears to have increased following news such as that from media outlets has become more frequent and knowledge of the ROBT has spread (DWT, 2018a). As a result this can play a greater role in contributing to threats derived from anthropogenic disturbances (DWT, 2016a). However, it is thought that over time increased visitor numbers will stabilize as projects such as the ROBT are more widely recognized by the general public (Gurnell *et al.*, 2009). The recreational use of the River Otter can provide a range of socio-cultural ecosystem services for people in the region. It is integrated into the ROBT management strategy (DWT, 2016a) to raise awareness of the beavers on the river and how to minimize any impact or threat deriving from this contributing factor. *Strategic Relevance = 18.*

Table 59. *Anthropogenic Influences & Cultural Traditions*

| | | | | |
|---|---|---|---|---|
| Anthropogenic Influences & Cultural Traditions | 1. Criticality – Scope<br>2 | 2. Criticality – Severity<br>3 | 3.Criticality - Irreversibility<br>2 | MARISCO |
| | 4. Past Criticality (-20yrs)<br>3 | 5. Current Criticality (1+2+3)<br>7 | 6. Trend of Change (of current criticality)<br>2 | 7. Future Criticality (+20yrs)<br>2 |
| | 8. Systemic Activity (level of Activity)<br>3 | 9. Systemic Activity (no. of influenced elements)<br>2 | 10. Systemic Activity (8+9)<br>5 | 11. Strategic Relevance (5+6+7+10)<br>16 |
| | 12. Manageability<br>2 | 13. Knowledge<br>2 | Chance of Conflict (Human Beaver)<br>2 | Management Intervention<br>3 |

Anthropogenic influences are more holistic and have been thought as like aspects such as a will for economic growth or prosperity and are linked to contributing factors such as agricultural intensification. These factors are mostly socio-cultural issues and could potentially be minimized by education of the many positive outcomes of beaver reintroduction (Campbell-Palmer *et al*., 2015). Cultural tradition appears close to people across the region. Traditional farming practices may be popular and small local businesses look to have thrived for generations. As a result of *Castor fiber* colonizing many parts of the species former range it has been documented that some human communities, organizations and land-users have had cultural difficulties in coming to terms with reintroduction programs (Campbell-Palmer *et al*., 2015). *Strategic Relevance = 16.*

Table 60. MARISCO Contributing Factors

| **Contributing Factors** MARISCO | *Strategic Relevance* |
|---|---|
| Climate Change & Weather Extremes | 16 |
| Habitat Loss/ Fragmentation & Land-Use Change | 20 |
| Agricultural Intensification | 17 |
| Economic Factors, Infrastructure & Development | 17 |
| Landowners & Local Businesses | 16 |
| Human Population Increase, increased Product Demands, Food Consumption | 16 |
| Members of the Public, Holiday Makers/Tourism, Leisure/Recreation | 18 |
| Anthropogenic Influences & Cultural Traditions | 16 |

The results from the contributing factors analysis highlight significant root causes of the threats in the River Otter ecosystem. Habitat loss, fragmentation and land-use change appear to be a key driver of threat. Other key factors include agricultural intensification, economics, infrastructure and development, members of the public, tourists, leisure and recreation and anthropogenic influences and cultural traditions.

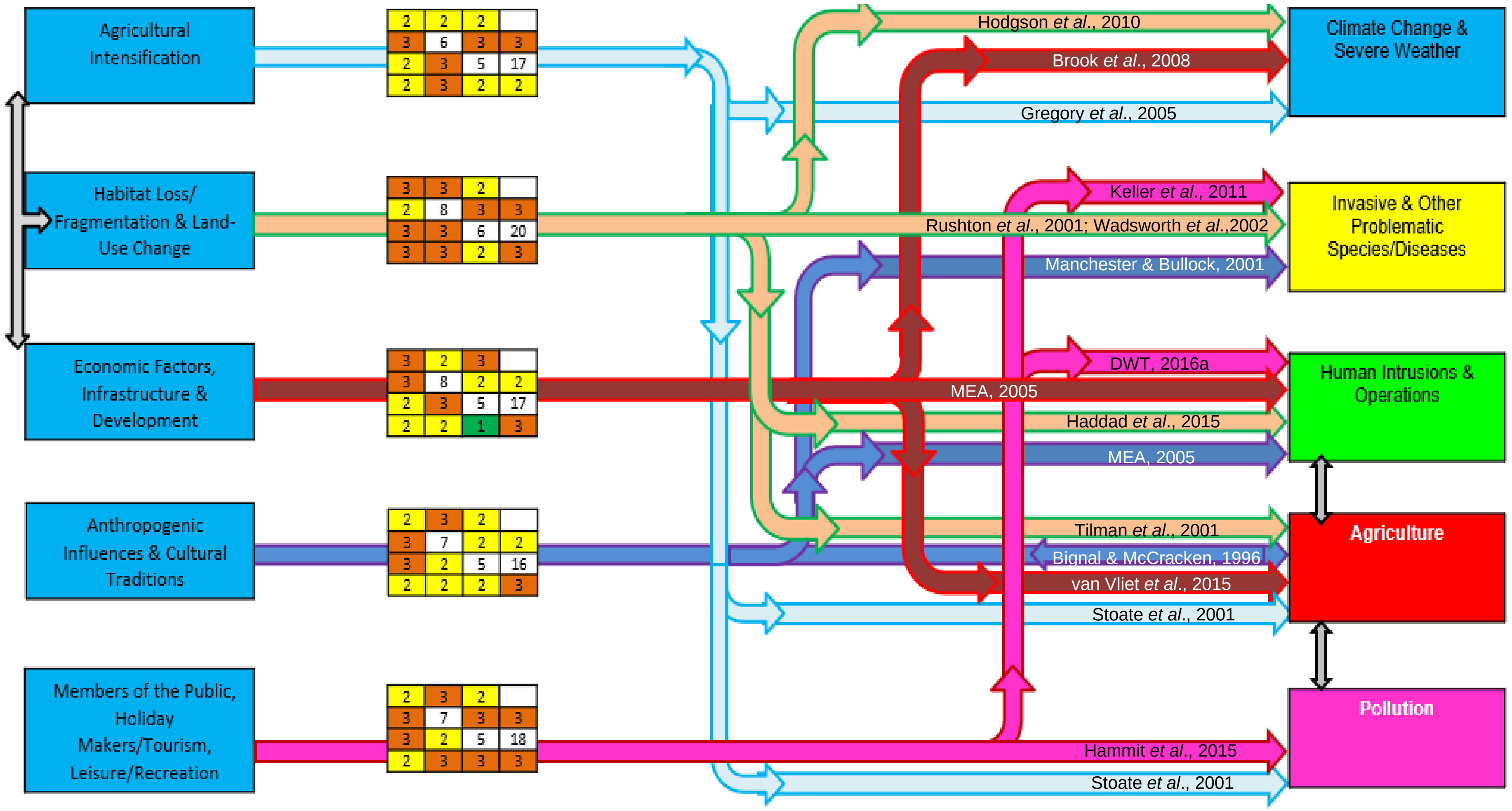


Table 61. MARISCO Contributing Factors Scorecard

| Contributing Factor | | | | |
|---|---|---|---|---|
| | 1. Criticality – Scope | 2. Criticality – Severity | 3.Criticality - Irreversibility | MARISCO |
| | 4. Past Criticality (-20yrs) | 5. Current Criticality (1+2+3) | 6. Trend of Change (of current criticality) | 7. Future Criticality (+20yrs) |
| | 8. Systemic Activity (level of Activity) | 9. Systemic Activity (no. of influenced elements) | 10. Systemic Activity (8+9) | 11. Strategic Relevance (5+6+7+10) |
| | 12. Manageability | 13. Knowledge | Chance of Conflict (Human Beaver) | Management Intervention |

Table 62. MARISCO Contributing Factors Scorecard

| | | | |
|---|---|---|---|
| 1 – very low | 2- reasonably low | 3- reasonably high | 4- very high |

**Legend**

Relationship (any colour)

Relationship Feedback (any colour)

Ecosystem Impacts Scorecard - *E*

Beaver Impacts Scorecard - *B*

Figure 45. MARISCO Conceptual Model Contributing Factors of Threats. Following the assessment of contributing factors key relationships were highlighted for there impact and influence on the River Otter Ecosystem. Observations made during the EDA combined with a review of literature assisted in determination of relationships. There can be intricate relationships between individual contributing factors and the threats generated in an ecosystem (Ibisch & Hobson, 2014). An example is of economic factors and development driving historic intensification of agriculture (Gregory *et al*., 2005; van Vliet *et al*., 2015), leading to habitat fragmentation and land-use change and a key driver of accelerated climate change (Brook *et al*., 2008; Haddad *et al*., 2015). The intensification of agricultural operations can be a leading driver of a range of threats being associated with loss of non-crop habitat, reductions of plant and animal communities and altering food chains and trophic interactions (Stoate *et al*., 2001). Such intensification has also led to deterioration of soils from compaction, erosion, organic matter loss and pollutant contamination from pesticides (*ibid*). This also has implications for associated watercourses resulting in connectivity losses (Donald & Evans, 2006), and pollution from run-off and increased sedimentation (Stoate *et al*., 2001). During the EDA it was recorded that intensive agro-industry farming may be taking place on adjacent land uses with large arable fields and livestock pasture. In the East Devon region agriculture appears to hold significant importance to culture and tradition, which may influence land-use in the area. However, historic, traditional farming practices can be of a lower intensity and have greater ecological sustainability (Bignal & McCracken, 1996). Habitat fragmentation and land-use change can also influence negative processes in the system. The larger the area size of habitat, with good connectivity, can provide source populations for species, territories to naturally colonise and adds resilience of species to adapt to accelerated climate change (Hodgson *et al*., 2010). In riparian ecosystems fragmentation can play a role alongside invasive species such as the case for the endangered water vole in Britain and the invasive American mink which have contributed significantly to the species decline (Rushton *et al*., 2001). In other cases land-use change and fragmentation can facilitate invasive species (Wadsworth *et al*., 2002). The spread of invasive species such as Himalayan balsam, recorded in many places on the River Otter, can be contributed to significantly by anthropogenic influences, the movement of people, members of the public and tourists alike (Manchester & Bullock, 2001; Keller *et al*., 2011). At the River Otter, tourism is said to increase due to the presence of *Castor fiber* which may potentially lead to increased pollution (Hammit *et al*., 2015), and a higher level of human intrusion and disturbance (DWT, 2016a). Table 61. is an example of the scorecard for contributing factors and table 62. is the impact rating of scores for each factor.

## 9 *Rural Participatory Appraisal RPA: Questionnaire Analysis*

There was a total of 14 male participants and 12 female participants of which 17 lived locally to the River Otter and 9 were not local. 12 participants inhabited rural villages while 10 inhabited towns or town fringes, 2 lived in a city and 1 participant occupied a local farmstead. Out of the 26 people who took part in the survey 12 were dog owners. Participants were asked why they use the river and its footpaths, more than one option could be answered for this question.

Table 63. River usage by participants

| ***'Which of the following best describes how you use the river?'*** | **No. of Participants** |
|---|---|
| Rambling/Walking | 10 |
| Dog Walking | 9 |
| Tourist Recreation | 5 |
| Local Recreation | 7 |
| Angler | - |
| Exercise | 10 |
| Wildlife Watcher | 10 |

Participant river usage (Frampton, 2018). The most popular usages of the river by participants were rambling/walking 10, exercise 10, and wildlife watching 10. Closely followed by dog walking 9, local recreation 7, and tourist recreation 5.

Following river usage participants were questioned on how regularly they visit the river or others, table 7.1 This may assist in determining cultural value of the river.

Table 64. Frequency

| ***'How often do you visit the River Otter or other rivers local to you?'*** | **No. of Participants** |
|---|---|
| Regularly, Daily or few times weekly | 3 |
| Fairly regular, weekly | 10 |
| Once, twice monthly | 7 |
| Rarely | 6 |

10 people used the river on a fairly regular, weekly basis. Only 3 participants used the river on a daily basis or few times weekly. 7 visited the river once or twice monthly and 6 people rarely visited the river or other rivers local to them.

A large proportion of people who took part in the questionnaire had knowledge of the Eurasian beavers present on the River Otter, 22/26.

When asked how the knowledge was obtained, word of mouth featured most 11, followed by local media coverage 9, in-field beaver signs 6, interpretation signage/boards 5, and national media coverage 2. A further 2 had been approached or consulted by Devon Wildlife Trusts. Participants were again able to answer more than one answer for this question.

Table 65. Nature of Eurasian beaver impacts: Participants Perspective

| ***'Which of the following best describes the nature of beaver impacts?'*** | **No. of Participants (18/26)** |
|---|---|
| Very Positive | 5 |
| Quite Positive | 6 |
| Neither Negative or Positive | 4 |
| Quite Negative | 2 |
| Very Negative | 1 |

Nature of beaver impacts (Frampton, 2018). When participants were questioned of awareness of impacts of beaver colonization, 18 individuals answered they were aware while 8 were not aware. Of the 18 people aware of beaver impacts when asked what the nature of the impacts were 5 answered 'very positive', 6 answered 'quite positive', 4 answered 'neither negative or positive', 2 answered 'quite negative' and 1 participant answered 'very negative',

Table 66. Overall attitudes to beavers living on the River Otter

| ***'Which of the following best describes you're attitude to beavers living on the River Otter?'*** | **No. of Participants** |
|---|---|
| Strongly Agree | 9 |
| Agree | 9 |
| Neither Disagree or Agree | 5 |
| Disagree | 2 |
| Strongly Disagree | 1 |

Attitude towards beavers on the River Otter (Frampton, 2018). All participants were asked their individual attitudes to beavers present on the River Otter. 9 answered 'strongly agree', 9 'agree', 5 'neither disagree or agree', 2 'disagree', and 1 participant answered 'strongly disagree', figure 9.2.

Table 67. Perspective of potential economic value

| ***'What economic value do you think the beavers could bring to the River Otter and Otter Valley region through aspects such as tourism?'*** | **No. of Participants** |
|---|---|
| Lots | 3 |
| Some | 16 |
| Little | 6 |
| None | 1 |

Economic value of beavers ( Frampton, 2018). Questionnaire participants were asked what economic value the beavers could bring to the local region. 16 answered 'some', 6 'little', 3 'lots' and 1 person answered 'none'.

Table 68. Perspective of ecological value

| ***'What ecological value do you think the beavers could bring to the River Otter and the ecosystem?'*** | **No. of Participants** |
|---|---|
| Contribute significantly to the nature of the river | 6 |
| Bring some benefits to the natural environment | 11 |
| Bring little benefit to existing nature of the river | 5 |
| Disrupt the balance of nature | 4 |

Ecological value of beavers (Frampton, 2018). When questioned on what ecological value participants think beavers could bring to the river, 11 answered 'would bring some benefits', 6 marked 'would contribute significantly', 5 'would bring little benefit', and 4 answered 'would disrupt the balance of nature'.

Table 69. Perspective of aesthetic value

| ***'What aesthetic value do you think the beavers could contribute to the River Otter?'*** | **No. of Participants** |
|---|---|
| Would contribute significantly to the aesthetic appeal | 3 |
| Would raise the aesthetic appeal | 10 |
| Would offer little contribution to the aesthetic appeal | 9 |
| Would make no contribution to the aesthetic appeal | 4 |

Perspective of aesthetic appeal of beavers ( Frampton, 2018). Participants were asked for their views on aesthetic value beavers would contribute to the river ecosystem. 10 answered 'would raise the aesthetic appeal', 9 marked 'would offer little contribution', 4 'would make no contribution', and only 3 answered 'would contribute significantly'.

Table 70. Perspective of beaver reintroduction to other suitable UK rivers

| ***'Which of the following best describes how you feel about reintroducing beavers to other suitable rivers in the UK?'*** | **No. of Participants** |
|---|---|
| Very Positive | 8 |
| Positive | 10 |
| Neither Negative or Positive | 5 |
| Negative | 2 |
| Very Negative | 1 |

Perspective of beaver reintroduction to other UK rivers (Frampton, 2018). When trying to capture how participants thought about beaver reintroductions to other rivers in the UK, 10 answered 'positive', 8 'very positive', 5 'neither negative or positive', 2 'negative', and 1 answered 'very negative'.

Table 71. Overall perspective of beavers on the River Otter and other British rivers

| ***Score /10*** | **No. of Participants** |
|---|---|
| 1 | 1 |
| 2 | - |
| 3 | 3 |
| 4 | - |
| 5 | 3 |
| 6 | 2 |
| 7 | 6 |
| 8 | 3 |
| 9 | 4 |
| 10 | 5 |

The 26 volunteers for the questionnaire were asked to indicate a score from 1-10 on their views on beavers on the River Otter and other UK rivers from 1, very negative to 10, very positive. 6 answered 7/10, 5 gave a full 10/10, 4 said 9/10, 3 marked 8/10 and 5/10 respectively, 2 answered 6/10 and 3/10 respectively and 1 answered 1/10.

The RPA and questionnaire was concluded by 2 open questions for participants to state key words they may feel, surrounding the ROBT. The first of these questions asks '*which aspects of the ROBT do you most like?*', and the second '*which aspects of the ROBT do you least like?*'. Table 7, positive and negative comments have been separated from the answers. Key words have been grouped as certain words were repeated by different participants.

Table 72. Attitudes towards ROBT

| ***Positive*** | ***No. of participants*** | ***Negative*** | ***No. of Participants*** |
|---|---|---|---|
| Seeing beavers | 5 | Excessive people/tourists | 5 |
| Signs of healthy environment | 4 | Unknown impacts | 3 |
| People gaining knowledge and interest | 2 | Anti-dog, want to stop dogs | 2 |
| Good for area | 2 | More litter from visitors | 2 |
| Good for biodiversity | 2 | Safety for river users/children | 1 |
| ***Total:*** | ***15*** | ***Total:*** | ***13*** |

A total of 10 participants either did not answer 'N/A', or answered 'don't know'.

# 10 *Discussion*

Accelerated environmental change has placed a wide range of pressures on ecosystems and biodiversity, challenging the longevity of the services provided for the wellbeing of humanity (MEA, 2005; CBD, 2014; Perring *et al*., 2015). Anthropogenic operations have been determined to be a leading driver of such change predominantly due to the rapidly increasing demands for, and exploitation of natural resources (MEA, 2005; Ibisch & Hobson, 2014). Post the evidence that had been produced at the landmark Convention on Biological Diversity (CBD) (1992), and the Millennium Ecosystem Assessment (MEA) (2005), new pathways in conservation management and strategy were created putting emphasis on trans-system management, an ecosystem approach and adaption in times of environmental unpredictability (Ibisch & Hobson, 2014). The importance of the state of functionality within ecosystems has been highlighted as for providing resilience to negative environmental change and adaptive capacity, energy dissipation and ecosystem service provisioning (Fraudenberger *et al*., 2012). Ecological research studies and the birth of systems theory have made a significant contribution to current ecosystem understanding (Ibisch & Hobson, 2014).

Ecosystem and ecological restoration has become a prevalent tool in attempting to repair and replenish the systems degraded by anthropogenic influences (Hobbs, 2007; Perring *et al*., 2015). One approach to ecosystem restoration is the use of species reintroductions in order of restoring trophic levels, functions and services previously cascaded, diminished or collapsed as a result of human operations (Smith *et al*., 2015; Svenning *et al*., 2016). In many cases, keystone species and apex predator populations which have declined or become extinct in their distributional ranges, are being attempted to be restored (Ritchie *et al*., 2012). The Eurasian beaver is a keystone species with the ability of modifying and manipulating processes within freshwater ecosystems having positive effects on functionality and resilience (Rosell *et al*., 2005; Campbell-Palmer *et al*., 2015; Law *et al*., 2017). The species had historically faced heavy persecution and was made extinct or faced heavy declines from vast areas of its historical distribution (Halley *et al*., 2012; Batbold *et al*., 2016). With global negative trends and degradation to aquatic freshwater systems (MEA, 2005a; Finlayson *et al*., 2017), it is now emerging that reintroduction of Eurasian beaver can play a key role in assisting with ecosystem restoration and conservation actions (Campbell-Palmer *et al*., 2016; Law *et al*., 2017; Puttock *et al*., 2017).

Today there are a number of initiatives and projects involving Eurasian beaver in Britain with the River Otter Beaver Trial ROBT being at the forefront of current knowledge and research into the species role in the ecosystem and society (DWT, 2016; Elliott *et al*., 2017). Assessment techniques to monitor the species role in the ecosystem include feasibility studies prior reintroduction (Gurnell, 2009), to strict monitoring guidelines set out by IUCN post reintroduction (IUCN/SSC, 2013).

A MARISCO situation and vulnerability analysis was carried out to display a whole system, adaptive approach to assessment of Eurasian beaver reintroduction with focus on risk and vulnerability dynamics to the ecosystem and beaver population. Key objectives were providing context to the situation of the River Otter Beaver Trial, clarification of the current state and character of the ecosystem, the determination of any risk, threat and vulnerability to the River Otter ecosystem and beaver population and finally to gather an insight into the socio-cultural dynamics of the ROBT and public perception.

A review of scientific published literature was carried out prior to the site assessment in order of gaining a knowledge base of ecosystem vulnerability with focus on risk, threat and trends to freshwater systems and British lowland river systems. The literature review also predominantly focused on Eurasian beaver ecology giving an insight into the dynamic behavioral traits of the species and any immediate vulnerability and issues that may arise such as human-beaver conflict. An example is the risk of the parasitic zoonoses *Echinococcus multilocularis* which can cause significant health concerns to beavers and other hosts (Gottstein *et al*., 2014). However, *E.multilocularis* is currently not present in the British landscape (Campbell-Palmer *et al*., 2015b). This highlights the importance of quarantine measures of any translocated individuals to minimize the risk of introduction to areas which are free of the parasite.  In addition to the ecological perspective, a scope of the situation of Eurasian beavers present in Britain explained the species presence in Scotland, and the site for this study the River Otter, Devon, England (ROBT). This assisted and contributed to meeting the aims of providing context to the River Otter Beaver Trial and began determination of risk threat and vulnerability to the species.

The MARISCO assessment commenced with an ecosystem diagnostics analysis (EDA). EDA has two essential elements, a desktop study including spatial analysis, and a ground-truthing exercise for investigation in-situ (Ibisch & Hobson, 2014). Results from the desktop study indicated the homogenous character of the landscape at both regional and local scales with the use of satellite imagery. This was further supported with ground-truthing being carried out. Agricultural practices dominate land usage despite a reasonably wide topographical range with much of the River Otter floodplain under management for arable and livestock. Also evident through historical imagery (Google earth, 2017) was the incision and removal of reasonably large stretches of the rivers riparian habitat which has been vastly improved and developed in more recent times. However, there are areas that remain patchy, without riparian habitat as a result of erosion, incision, or urban sprawl, recorded when ground-truthing which can lead to increased run-off diffuse pollution and increased sedimentation (Burden *et al*., 2013). The same historic images also highlighted the long-term flood risk attached to the region with flood damage being prevalent, correlating with Environment Agency data mapping of flood risk (DATA.GOV.UK, 2017). Devon Wildlife Trusts (2016) have produced a range of maps as part of the ROBT management plan that included a 2016 beaver activity map and connectivity mapping. Recorded in-situ, beaver activity could be observed in many places, sign-posting areas where potential human-beaver conflicts may occur. Connectivity may be seen as a future issue for *Castor fiber* management with restrictions in place for the duration of the ROBT (2015-2020) with any individual beavers leaving the catchment being retrieved (DWT, 2016a).. This is a restriction in place from the licensing body Natural England whilst the trial commences and data is recorded of the species impact in the landscape both ecologically and socio-culturally (*ibid*). However DWT connectivity mapping displays many areas and tributaries where the species can disperse allowing species permeability in the future should restrictions be lifted (Elliott *et al*., 2017). Further environmental data mapping (DATA.GOV.UK), highlighted the region and catchment as a nitrate vulnerable zone (NVZ) possibly as a result of intensive agricultural operations (Macgregor & Warren, 2015). A Key objective of this research was to provide context to and characterize the River Otter ecosystem which has been captured by the EDA. The MARISCO step has also contributed to the objective of highlighting risk, threat and vulnerability to the ecosystem and beaver population. It has further contributed to the understanding and clarifying of the current state of the ecosystem and possible risk and vulnerability to the beaver.

Following comprising a list of biodiversity objects and habitat typologies, recorded during the EDA, an assessment of ecological attributes began a more comprehensive analysis of risk and threat. With emphasis on a whole-system approach, the identification of attributes that if absent or altered will result in loss or improper functioning of the system is a key step in understanding risk and threat (Ibisch & Hobson, 2014; Schlik *et al*., 2019). Once identified, to measure the state of the ecosystem indicators were formed that were attached to measure the status of ecological attributes. It was determined that Riparian habitat and ditches scored ¾ gaining 'reasonably poor' status as for indicators such as pollutant signs, connectivity, invasive species retention and species composition. However, referring to literature on beaver foraging behavior (Rosell *et al*., 2005; Campbell-Palmer *et al*., 2016) there is potential for the species to have a positive relationship creating mosaics and diverse habitat structures adding quality to riparian zones and ditches. There can be potential for the species to dam drainage ditches potentially conflicting with land-use practices which may require consultation and mitigation using flow devices (Gurnell, 2009; Campbell-Palmer *et al*., 2016).

Resulting from the assessment the MARISCO conceptual model could be constructed to determine the key relationships with the biodiversity objects and habitat typologies of the River Otter ecosystem. Peer-reviewed scientific literature associated with the ecological attributes was assessed to confirm relationships. Backed up by the EDA, it was determined the key relationships between connectivity, species composition, and seed dispersal and pollination with riparian habitat and ditch lines may be most significant. Riparian habitat was observed as fragmented and patchy in areas as were many associated ditch lines, where in others monocultures of the invasive weed *Impatiens glandulifera* had established, resulting in alteration of native species composition and seed dispersal or pollination services. This assessment adds further contribution to the objectives of clarifying the state and character of the ecosystem and the determination of risk, threat and vulnerability to the River Otter ecosystem in a cause-effect, situation concept model.

This step has contributed to the objective of clarifying ecosystem state and character and assisted in other key objectives of determining risk, threat and vulnerability to the ecosystem. To carry out this process it may be required that the observer has a knowledge base of the ecosystems habitat typologies if acting alone, in order of some determination of which ecological attributes underpin them (Ibisch & Hobson, 2014). This may potentially be seen as a weakness or limitation to the process with a degree of subjectivity as data may differ between observers. MARISCO attempts to embrace this factor as ideally the process can be carried out as a team made up of managers, stakeholders and members of the public, and/or can be carried out on a reoccurring basis by individuals with the goal of identifying any blindspots which may initially be missed (*ibid*). This may also be the case when measuring indicators and scores for the attributes where again blindspots may be identified and averages taken when scores differ. This can also add transparency to the process when carried out as a group as all members can participate despite non-knowledge of complex ecosystem dynamics (Ibisch & Hobson, 2014).

An assessment of stresses continued the MARISCO process identifying the symptoms or pressures on the ecological attributes following selected criteria. When selected each stress was scored for a range of vulnerabilities applying a MARISCO stresses scorecard and impact rating. This was done for stresses to the ecosystem and the River Otter beaver population. Anthropogenic disturbances had the most significant impact rating and *strategic relevance* for both the ecosystem and Eurasian beaver. For the ecosystem, stresses of connectivity loss and monocultures *I. glandulifera* closely followed. Inbreeding depression and connectivity loss were found to be other potential issues for Eurasian beaver dependent on the situation, post-ROBT and the level of future required management intervention. These findings appear to correlate with sources of scientific literature as it is stated that human operations are a significant and direct and indirect driver of freshwater, river ecosystem degradation (MEA, 2005a; Aronsen & Alexander, 2013). Human influences also can be held accountable for the historic persecution of beavers (Campbell-Palmer *et al*., 2015), and the species modifications conflicting with land management practices are said to be the greatest risk to the species today (*ibid*). Connectivity loss in an ecosystem can play a key role in the alteration of ecological attributes (Wohl, 2017) and the isolation of beaver territories (Campbell-Palmer *et al*., 2016). The River Otter beaver population was recorded as being closely genetically related following health screening and inbreeding depression declared a factor (DWT, 2016a). The ROBT mitigated against this by releasing new individuals to widen the gene pool (*ibid*). However, Eurasian beaver modifications can also significantly promote riparian and floodplain connectivity (Hood & Larson, 2014) adding a potential feedback into the system . The MEA (2005a) synthesis report on aquatic freshwater environments highlighted invasive species as another key driver of ecosystem degradation. There is continued work to attempt to reduce and tackle the spread of Himalayan balsam *I.glandulifera* from the River Otter riparian zones (OVA, 2018). Despite actions from local organisations and volunteers, monoculture patches and swards of the invasive species were recorded sporadically occurring. This MARISCO step has further added to the fundamental objectives of understanding and determination of risk, threat and vulnerability to the River Otter ecosystem and beaver population.

Following recording the Stresses to the ecosystem and Eurasian beaver population the second part of the MARISCO conceptual model was created to highlight the key relationships between the stresses and the impacted ecological attributes. The integration of peer-reviewed scientific literature and observations made during the EDA assisted in the determination of relationships and any feedbacks that occur. Key relationships highlighted are that of anthropogenic disturbances with invasive species retention, ecosystem functionality and Eurasian beaver. Human changes in the environment have been found to facilitate the spread of invasive species

(Manchester & Bullock, 2001), and other alterations have impacted ecosystem function through losses in biodiversity, productivity and stability (Hautier *et al*., 2015). Other significant relationships between stresses and ecological attributes include connectivity loss with functional diversity (Staddon *et al*., 2010), and the potential relationship feedback with Eurasian beaver. *Castor fiber* may face isolation and an increased risk of inbreeding depression (Gaywood *et al*., 2017), however, the species dynamic modifications can lead to significant increases in channel and floodplain connectivity (Hood & Larson, 2014).

The assessment of stresses added greater depth to combatting the key objectives of determining risk, threat and vulnerability to the River Otter system and beaver population, and further clarified the state, character and nature of vulnerability in the River Otter ecosystem..

The risk and threat assessment dynamic of MARISCO proceeded applying IUCN risk/threat categories (IUCN, 2018) to recorded threat. Threats were grouped in their broader categories selected by IUCN following being recorded impacting the River Otter ecosystem or Eurasian beaver population. The assessment of threats commenced with threat mapping of the four areas selected for the EDA. During the desktop study and ground-truthing exercise approximate GPS locations of categorised threats were taken and integrated spatially onto Google earth (2018) satellite imagery. This displayed the homogenous character of the landscape and threats associated, mainly stemming from agriculture, pollution and flood risk. Invasive Himalayan balsam could also be observed occurring more frequently heading down river potentially as a result of hydrochory, seed dispersal through water (Love *et al*., 2013). This provided further insight to risk and threat generation in the system.

Threats were scored for different complexities including *severity*, *irreversibility* and *current criticality* to provide an overall, final score of *strategic relevance*. Threats from the category of agriculture were recorded as the most significant threat to the ecosystem including impacts from harvesting annual and perennial non-timber crops, shifting agriculture, agro-industry farming and agro-industry livestock farming which is characterised by the region. Other significant threats are that of pollution, which appear to be generated from agricultural practices such as nutrient run-off and diffuse pollution and increased sedimentation. Other stresses of significance to the ecosystem are human intrusions and disturbance as the River Otter appears to be a hub for local recreation, tourism and local industry. Risk and threat to potentially impact Eurasian beaver also include human intrusions and operations, and agriculture. It has been reported of an aggressive encounter between a domestic dog and a beaver on the River Otter (Elliott *et al*., 2017) and interpretation signage has been installed by the ROBT warning of best practice around beaver territory for safety of both the public and beavers. Eurasian beavers may face additional pressure from increased wildlife tourism as onlookers try to view the species (DWT, 2016a). Agriculture may not directly impact the Eurasian beavers inhabiting the river however, it is thought that beaver modifications such as dams are most likely to conflict with land management in these areas and be the greatest risk in modern Britain to the species (Campbell-Palmer *et al*., 2015). This is a crucial step in completing the objective of determining risk, threat and vulnerability to the Eurasian beavers and River Otter ecosystem.

To complete the threat analysis the MARISCO conceptual model was constructed to highlight key relationships between threats and the stresses that are produced. Once again referral to the EDA supported by peer-reviewed literature confirmed any relationships present. Key relationships of note involve further distribution of riparian invasive species through altered flow regimes which can be facilitated through climate change (Murray *et al*., 2011). Due to the establishment of monocultures of Himalayan balsam, native riparian plant species are being outcompeted leading to riparian habitat loss (Wadsworth *et al*., 2002; Varia *et al*., 2016). Human intrusions, disturbance and operations can have a range of relationships with stresses in the ecosystem, driving riparian habitat loss (Diaz *et al*., 2006; Richardson *et al*., 2007) and a loss of connectivity (Haddad *et al*., 2015) in the ecosystem. Potentially synergistic impacts can occur from such habitat loss as this may lead to pollution from adjacent land-uses creating more exposure, allowing for agricultural run-off, nutrient loads and increased sedimentation (Dudgeon *et al*., 2006; Burden *et al*., 2013).

For the completion of the MARISCO risk, threat and vulnerability dynamic, an assessment of contributing factors determined sources and causes of threats within the River Otter ecosystem. This final phase of analysis will complete the key objectives of clarifying the current state and character of the ecosystem, determine any risk, threat and vulnerability to the River Otter ecosystem, and determine any risk, threat and vulnerability to the River Otter beaver population. Contributing factors are mainly human induced and root causes of threat, stress and vulnerability (Ibisch & Hobson, 2014). Threats will, in many cases have numerous contributing factors that may have a synergistic impact (*ibid*). With a combination of in-field observations, information obtained during the EDA and peer-reviewed scientific literature a list of contributing factors to threats derived. Each individual factor was then scored with the application of a MARISCO contributing factors scorecard and impact rating, identical to that of threats. Factors that scored the highest *'strategic relevance'* were deemed to be the key contributing factors to draw relationships from in the final step of the MARISCO conceptual model. Habitat loss, fragmentation and land-use change had the greatest *strategic relevance* as a result of landscape character, fragmented riparian habitat and its impacts on the river ecosystem. A mosaic of agricultural fields homogenous in character has fragmented any semi-natural habitats. The riparian zone is patchy in areas due to habitat loss from aspects such as accelerated erosion and incision. Such fragmentation can be influenced by other key contributing factors such as agricultural intensification and economic factors (Gregory *et al*., 2005; van Vliet *et al*., 2015), which also scored high *strategic relevance*. The final key factor contributing to threat is members of the public, holiday makers and tourism and leisure and recreation. This factor is linked to human disturbance levels as the river is a popular destination for local and tourist recreation. This may have impacts on the Eurasian beavers and their behavior and installation of interpretation signage warns river users of best practice around beaver territory (DWT, 2016a).

The final part of the MARISCO conceptual model provided an overview of key relationships between contributing factors and the threats generated. There can be a wide range of intricate relationships and feedbacks and some may act synergistically (Ibisch & Hobson, 2014). Key relationships for this research consist of fragmentation, habitat loss and land-use change on a range of threats in the system. Many human influences can influence aquatic, hydrologic and riparian fragmentation including flow regulation, water extraction and water diversion (Pringle, 2001). Nutrient run-off, pollution impacts, and the facilitation of invasive non-native species are perpetuated by fragmentation and habitat loss and may be exacerbated by alterations in river ecosystem connectivity (Pringle, 2001). It has been stated that these actions can be a driver of accelerated climate change (Brook *et al*., 2008; Haddad *et al*., 2015) mainly stemming from agricultural operations and specifically intensive farming practices (Tillman *et al*., 2001; Gregory *et al*., 2005). Further relationships between individual contributing factors may be involved such as economic factors, infrastructure and development and the intensification of farming methods (Gregory *et al*., 2005; van Vliet *et al*., 2015). It was also considered that for anthropogenic influences and cultural traditions, may be strongly linked to the agricultural character and industry of the region. Anthropogenic influences such as the movement of people, members of the public and tourists can facilitate the spread of invasive species (Manchester & Bullock, 2001; Keller *et al*., 2011). It has been suggested that tourism may increase as a result of the beavers presence (DWT, 2016a), potentially resulting in higher levels of intrusion, disturbance and pollutants. The final MARSCO conceptual model has finalised clarification of the current state and character of the ecosystem, and the determination of risk, threat and vulnerability to the River Otter ecosystem.

In order of combatting the final key objective of gathering an insight into the socio-cultural dynamics of the ROBT and public perception, the rural participatory appraisal questionnaire was carried out with 26 voluntary participants in and around the study area.

It has been highlighted that the socio-cultural perspective of Eurasian beaver reintroductions may require the most attention (Halley *et al*., 2009; Campbell-Palmer *et al*., 2015). When it was first confirmed that beavers were inhabiting the River Otter government agencies took the step to capture the individuals present, to restate political and ecological order (Crowley *et al*., 2017). However, key stakeholders and members of the public refused to brand the species as a biological threat, alien and illegal (Buller, 2008, as cited in Crowley *et al*., 2017). The key actors opposition prompted calls for the beavers to return with support suggesting the species belonged on the river (Crowley *et al*., 2017). Although there is a documented alliance between the Devon Wildlife Trusts and associated stakeholders such as Clinton Devon Estates (DWT, 2016), The National Farmers

Union (NFU) initially opposed the ROBT (NFU, 2015). Following further consultation a range of parameters were set for the trial to commence, (i) legal status and framework had to be made clear, (ii) clear exit strategies must be presented resulting from any negative impact from beavers, and (iii) and transparent consultation of the management plan, legalities and license agreement set by Natural England (*ibid*). These aspects are also integrated into IUCN reintroduction guidelines to enhance probability of success (IUCN/SSC, 2013).

The questionnaire data highlighted that there was broad support for the ROBT. There was a minority that did not show full support for the reintroduction. Evidence from Scotland also displays similar trends of public support (Gaywood *et al*., 2008). There appeared to be some confusion amongst participants of the RPA questionnaire regarding the ecological and aesthetical impacts of beavers. This may support the belief that the return of the species to Britain will challenge how the public positively view uniform woodlands and manufactured waterways, as a degree of irregularity and geomorphology will result from beaver modifications (Campbell-Palmer *et al*., 2015). This further highlights that one of the potential risks to the beaver population is that of anthropogenic influences. This may suggest that greater public knowledge of potential outcomes of beaver reintroduction could have a positive impact on decreasing the risk and vulnerability to the species from conflicting with human land use operations.

Gurnell *et al.,* (2009) further supported that reintroduction plans should include extensive public relations ensuring that information regarding the management and likely environmental impacts are made clear. The need for public consultation was also highlighted when the National Farmers Union (NFU) initially opposed the ROBT (NFU, 2015). Following further consultation with the NFU a range of parameters were set for the trial to commence. The parameters that were agreed included: (i) legal status and framework had to be made clear, (ii) clear exit strategies must be presented resulting from any negative impact from beavers, and (iii) and transparent consultation of the management plan, legalities and license agreement set by Natural England (*ibid*). These aspects were are also integrated into IUCN reintroduction guidelines to enhance probability of success (IUCN/SSC, 2013). There has also been research undertaken across Britain in which approximately 2,750 participants have expressed their perception which is under review and due for publication (*ibid*). The Devon wildlife trusts and the University of Exeter have also commissioned a new 2018 PhD study to further investigate socio-economic impacts of the River Otter beavers (DWT, 2018a). The results of this on-going research may contribute to the understanding of the impact of public perception on the ROBT.

It is recommended that the MARISCO methodology should be fully integrated into the management of the project with the full inclusion of stakeholders, managers and members of the public to collectively carry out the assessment. This can be beneficial as a more holistic approach can be undertaken to the process and management of reintroduced beavers in the ecosystem. A limitation of this research was that this was unable to be carried out as the ROBT had already commenced and there is an understandable high degree of sensitivity with stakeholder relationships which are integral to the projects probabilities of success. However, the methodology can be carried out as an individual (Ibisch & Hobson, 2014). Carrying out the MARISCO process as an individual may also lead to a degree of subjectivity, which may be viewed as a limitation. MARISCO attempts to embrace subjectivity and the use of non-knowledge as it can allow for the identification of potential blindspots and knowledge gaps when carried out by different individuals (Ibisch & Hobson, 2012, 2014). The RPA questionnaire on public perception of the ROBT was intended to gather a brief scope of attitudes however, the relatively low number of participants may have impacted the validity and reliability of the results.

Overall the findings of this research show a range of risk, threat and vulnerability to the River Otter ecosystem that appears to be contributing to degradation of ecosystem function, production and resilience. There are also a number of threats that can potentially impact the Eurasian beaver population, however, predominantly low risk levels were recorded without the inclusion of humans and their operations. The findings also suggest that beaver can have a positive impact and relationship with risk, threat and vulnerability to the ecosystem in a range of ways, contributing to ecosystem restoration. This suggests that there may be minimal risk in reintroduction of Eurasian beaver, and this may significantly contribute to ecosystem restoration projects in British, lowland agricultural river systems.

The political status of *Castor fiber* in Britain appears to be changing in Britain. During this research, Scotland has placed legal protection on the Knapdale trial population and Tayside population of beavers allowing them to naturally expand and become resident again in the Scottish environment (Gaywood, 2017; ScottishWildlifeTrusts, 2017). The River Otter Beaver Trial has become at the forefront on providing consultation to government bodies which has led to greater evidence to other reintroduction trial projects commencing in the U.K (DWT, 2018a), such as the Forest of Dean trial project (GOV.UK, 2018).

Due to the RPA social-dynamic of this project being limited it is recommended that further research should investigate public perception at a broader scale throughout the catchment. Gaining widespread public and stakeholder support of the ROBT is a fundamental aim of the project that may impact conclusions of the trial in 2020.

# 11 *References*


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# 12 *Appendices*

## 12.1 *Ground-Truthing Risk Assessment*

College

**RISK ASSESSMENT**

| | | |
|---|---|---|
| **Document Ref No:** | **Date:** 4/2/17 | |
| **Activity: Location:** GROUND-TRUTHING / WALKING, River Otter, Devon, England<br>**Persons at risk:**<br>Researcher: Thomas Frampton<br>Assistance: Kelsey O'Donohoe | | |
| **Assessment carried out by:** Thomas Frampton | | |
| **Risk Rating: H = high, M = medium, L = low** | **Without Controls** | **With Controls** |
| **Hazards:** Uneven surfaces, falling in river, Tick bites, | High | Low |
| **Specific Risk:** Slips, trips, falls, drowning, Lymes disease | Medium | Low |
| **Control Measures:** Stick to public footpaths, stay away from water and unstable banksides, keep close distance between one another, keep mobile phones on, let others know of location, check for ticks upon completion. | | |
| **Is risk adequately controlled?** If NO then specify measures below: | **YES** | **NO** |
| **Additional control measures required:**<br>N/A | **Action Taken** | **By Whom** |
| **Relevant Legislation and Sources of Information:** *(use Accepted Codes of Practice (ACoPS) or guidance)*<br>keep to public rights of way (footpaths) | | |
| **Training Requirements:**<br>N/A | | |
| **Personal Protective Equipment:** Good stable walking boots. | | |

Student's signature: T.A. Frampton Supervisor's acceptance: John E. May

Review Date: 4/2/17

SF019 Aug17

## 12.2 *RPA Questionnaire ethics approval*

Writtle University College

~~FOR REFERENCE ONLY – UNDERGRADUATE STUDENTS TO COMPLETE FORM ONLINE~~

**ETHICS FORM EC2 – Research Involving People**

Name of student: Thomas Anthony Frampton
Name of module or dissertation title: A MARISCO Situation & Vulnerability Analysis for Eurasian Beavers on the River Otter, Devon, England.
Name of tutor or supervisor: Prof. Peter Hobson

**PLEASE ANSWER ALL QUESTIONS**

*Write "n/a" if not applicable - and give details where appropriate.*

1. How do you intend to carry out your research involving people?
   ***Please tick appropriate box or boxes.***

   by questionnaire ☒ *please attach a copy quoting the Data Protection statement found on Form EC1*

   by interview ☐

   by other means ☐(please state)

2. Will the subjects be informed they are being questioned as part of an academic study?

   **Yes** ☒

   **No** ☐ *If "no" please give your reasons* ……

3. Describe what steps you have taken/will take to ensure the anonymity of the replies you receive: No personal details were taken as part of the questionnaire. Each participant was read a statement regarding their anonymity.

   *If Q3 is not applicable please state why not:* ……

4. What precautions have you taken to minimise inconvenience and/or emotional stress in your subjects? Each participant was made aware they can terminate the questionnaire at any time. All participants were volunteers.

5. Are you receiving or giving any financial reward or inducement for the thesis or project?

   **No** ☒
   **Yes** ☐ *If "yes", please give details* ……

6. Are minors (under 18 years of age) of vulnerable adults likely to be the subject of the research (directly or indirectly)?

   **No** ☒

   **Yes** ☐ *If "yes" please give details. Please include the steps you have taken to inform any responsible adults:* ……

7. Does your study involve issues of gender, race, religion or sexual orientation?

   **No** ☒
   **Yes** ☐ *If "yes" please give details*

8. Are there any other issues of an ethical nature you wish to make known to your supervisor or the University College authorities?

   **No** ☒
   **Yes** ☐ *If "yes" please give details* ……

9. Please attach your research protocol (the description of how you will carry out the research) the research information sheet (the information for potential respondents that will allow them to decide whether to take part), the consent form that you will be using (if this is applicable, e.g., for interviews, focus groups), and your draft questionnaire (if applicable).

I agree that the information in this form is accurate to the best of my knowledge.
Signature of student: T.A. Frampton Date: 20/4/17

When completed please pass this form to your Supervisor

Writtle University College

I agree with the answers given in this form, approve the questionnaire (copy attached) and support the methodology being adopted.

Signature of supervisor: John E. Mayo Date: 20/4/17

## 12.3 *RPA questionnaire*

Writttle University College

**Public Perception of beavers on the River Otter:**

**Questionnaire by Thomas Frampton Bsc**

As part of MSc by research at Writtle University College & University of Essex.

Disclaimer: you are not obliged to take part in this questionnaire. You are free to withdraw from this at any time without giving reasons why. All data will be analysed and written up anonymously. Should you have any questions please ask.

Male: Female:

| | | |
|---|---|---|
| 1 | 18-25 | |
| 2 | 26-30 | |
| 3 | 31-50 | |
| 4 | 51-65 | |
| 5 | 65+ | |

Do you live locally (East Devon region) to the River Otter? Yes/No

What best describes where you currently live?

| | | |
|---|---|---|
| 1 | City | |
| 2 | Provincial Town | |
| 3 | City/Town Fringe | |
| 4 | Rural Village | |
| 5 | Farmstead/Open Countryside | |
| 6 | Other (please state) | |

Dog owner?

Which of the following best describes how you use the river?

| | | |
|---|---|---|
| 1 | Rambling/Walking | |
| 2 | Dog Walker | |
| 3 | Tourist recreation | |
| 4 | Local recreation | |
| 5 | Angler | |
| 6 | Exercise | |
| 7 | Wildlife Watcher | |
| 8 | Other (please state) | |

How often do you visit the River Otter or other rivers local to you?

| | | |
|---|---|---|
| 1 | Rarely/once, twice annually | |
| 2 | Sometimes/once, twice monthly | |
| 3 | Fairly regularly, weekly | |
| 4 | Regularly, daily, few times weekly | |

Are you aware of the Eurasian Beaver population living on the River Otter? Yes/No

If yes, how did you become aware?

| | | |
|---|---|---|
| 1 | In-field signs | |
| 2 | Word-of-mouth | |
| 3 | Local media coverage | |
| 4 | National media coverage | |
| 5 | Interpretation signage/boards | |
| 6 | Information leaflets | |
| 7 | Approached or consulted by Devon Wildlife Trusts | |
| 8 | Other (please state) | |

Are you aware of potential impacts to the river as a result of beaver colonisation? Yes/No

If so which of the following best describes the nature of these impacts?

| | | |
|---|---|---|
| 1 | Very Negative | |
| 2 | Quite Negative | |
| 3 | Neither Negative or Positive | |
| 4 | Quite Positive | |
| 5 | Very Positive | |

Which of the following best describes your attitude to beavers living on the River Otter?

| | | |
|---|---|---|
| 1 | Strongly disagree | |
| 2 | Disagree | |
| 3 | Neither disagree or agree | |
| 4 | Agree | |
| 5 | Strongly agree | |

What economic value do you think the beavers could bring to the River Otter and Otter Valley region through aspects such as tourism?

| | | |
|---|---|---|
| 1 | None | |
| 2 | Little | |
| 3 | Some | |
| 4 | Lots | |

What ecological value do you think the beavers could bring to the River Otter and its ecosystems?

| | | |
|---|---|---|
| 1 | Disrupt the existing balance of nature | |
| 2 | Bring little benefit to existing nature of the river | |
| 3 | Would bring some benefits to the natural environment | |
| 4 | Would contribute significantly to the nature of the river | |

What aesthetic value do you think the beavers could contribute to the River Otter?

| | |
|---|---|
| 1 | Would make no contribution to the aesthetic appeal of the river |
| 2 | Would offer little contribution to the aesthetic appeal of the river |
| 3 | Would raise the aesthetic appeal of the river |
| 4 | Would contribute significantly to the aesthetic appeal of the river |

Which of the following best describes how you feel about reintroducing beavers to other suitable rivers in the UK?

| | | |
|---|---|---|
| 1 | Very Negative | |
| 2 | Negative | |
| 3 | Neither Negative or positive | |
| 4 | Positive | |
| 5 | Very Positive | |

Overall, indicate a score from 1-10 on your views of beavers on the River Otter and other British rivers for the long-term? 1= very negative 10= very positive

Which aspects of the River Otter Beaver Trial do you most like?

Which aspects of the River Otter Beaver Trial do you least like?

## *12.4 IUCN Risk & threat categories*

**1 Residential & commercial development**

- 1.1 Housing & urban areas
- 1.2 Commercial & industrial areas
- 1.3 Tourism & recreation areas

**2 Agriculture & aquaculture**

- 2.1 Annual & perennial non-timber crops
  - 2.1.1 Shifting agriculture
  - 2.1.2 Small-holder farming
  - 2.1.3 Agro-industry farming
  - 2.1.4 Scale Unknown/Unrecorded
- 2.2 Wood & pulp plantations
  - 2.2.1 Small-holder plantations
  - 2.2.2 Agro-industry plantations
  - 2.2.3 Scale Unknown/Unrecorded
- 2.3 Livestock farming & ranching
  - 2.3.1 Nomadic grazing
  - 2.3.2 Small-holder grazing, ranching or farming
  - 2.3.3 Agro-industry grazing, ranching or farming
  - 2.3.4 Scale Unknown/Unrecorded
- 2.4 Marine & freshwater aquaculture
  - 2.4.1 Subsistence/artisinal aquaculture
  - 2.4.2 Industrial aquaculture
  - 2.4.3 Scale Unknown/Unrecorded

**3 Energy production & mining**

- 3.1 Oil & gas drilling
- 3.2 Mining & quarrying
- 3.3 Renewable energy

**4 Transportation & service corridors**

- 4.1 Roads & railroads
- 4.2 Utility & service lines
- 4.3 Shipping lanes
- 4.4 Flight paths

**5 Biological resource use**

- 5.1 Hunting & collecting terrestrial animals
  - 5.1.1 Intentional use (species being assessed is the target)
  - 5.1.2 Unintentional effects (species being assessed is not the target)
  - 5.1.3 Persecution/control
  - 5.1.4 Motivation Unknown/Unrecorded
- 5.2 Gathering terrestrial plants
  - 5.2.1 Intentional use (species being assessed is the target)
  - 5.2.2 Unintentional effects (species being assessed is not the target)
  - 5.2.3 Persecution/control
  - 5.2.4 Motivation Unknown/Unrecorded
- 5.3 Logging & wood harvesting
  - 5.3.1 Intentional use: subsistence/small scale (species being assessed is the target) [harvest]
  - 5.3.2 Intentional use: large scale (species being assessed is the target) [harvest]
  - 5.3.3 Unintentional effects: subsistence/small scale (species being assessed is not the target) [harvest]

    - 5.3.4 Unintentional effects: large scale (species being assessed is not the target) [harvest]
    - 5.3.5 Motivation Unknown/Unrecorded
- 5.4 Fishing & harvesting aquatic resources
    - 5.4.1 Intentional use: subsistence/small scale (species being assessed is the target) [harvest]
    - 5.4.2 Intentional use: large scale (species being assessed is the target) [harvest]
    - 5.4.3 Unintentional effects: subsistence/small scale (species being assessed is not the target) [harvest]
    - 5.4.4 Unintentional effects: large scale (species being assessed is not the target) [harvest]
    - 5.4.5 Persecution/control
    - 5.4.6 Motivation Unknown/Unrecorded

**6 Human intrusions & disturbance**

- 6.1 Recreational activities
- 6.2 War, civil unrest & military exercises
- 6.3 Work & other activities

**7 Natural system modifications**

- 7.1 Fire & fire suppression
    - 7.1.1 Increase in fire frequency/intensity
    - 7.1.2 Suppression in fire frequency/intensity
    - 7.1.3 Trend Unknown/Unrecorded
- 7.2 Dams & water management/use
    - 7.2.1 Abstraction of surface water (domestic use)
    - 7.2.2 Abstraction of surface water (commercial use)
    - 7.2.3 Abstraction of surface water (agricultural use)
    - 7.2.4 Abstraction of surface water (unknown use)
    - 7.2.5 Abstraction of ground water (domestic use)
    - 7.2.6 Abstraction of ground water (commercial use)
    - 7.2.7 Abstraction of ground water (agricultural use)
    - 7.2.8 Abstraction of ground water (unknown use)
    - 7.2.9 Small dams
    - 7.2.10 Large dams
    - 7.2.11 Dams (size unknown)
- 7.3 Other ecosystem modifications

**8 Invasive & other problematic species, genes & diseases**

- 8.1 Invasive non-native/alien species/diseases
    - 8.1.1 Unspecified species
    - 8.1.2 Named species
- 8.2 Problematic native species/diseases
    - 8.2.1 Unspecified species
    - 8.2.2 Named species
- 8.3 Introduced genetic material
- 8.4 Problematic species/diseases of unknown origin
    - 8.4.1 Unspecified species
    - 8.4.2 Named species
- 8.5 Viral/prion-induced diseases
    - 8.5.1 Unspecified "species" (disease)
    - 8.5.2 Named "species" (disease)
- 8.6 Diseases of unknown cause

**9 Pollution**

- 9.1 Domestic & urban waste water
    - 9.1.1 Sewage
    - 9.1.2 Run-off

    - 9.1.3 Type Unknown/Unrecorded
- 9.2 Industrial & military effluents
    - 9.2.1 Oil spills
    - 9.2.2 Seepage from mining
    - 9.2.3 Type Unknown/Unrecorded
- 9.3 Agricultural & forestry effluents
    - 9.3.1 Nutrient loads
    - 9.3.2 Soil erosion, sedimentation
    - 9.3.3 Herbicides and pesticides
    - 9.3.4 Type Unknown/Unrecorded
- 9.4 Garbage & solid waste
- 9.5 Air-borne pollutants
    - 9.5.1 Acid rain
    - 9.5.2 Smog
    - 9.5.3 Ozone
    - 9.5.4 Type Unknown/Unrecorded
- 9.6 Excess energy
    - 9.6.1 Light pollution
    - 9.6.2 Thermal pollution
    - 9.6.3 Noise pollution
    - 9.6.4 Type Unknown/Unrecorded

**10 Geological events**

- 10.1 Volcanoes
- 10.2 Earthquakes/tsunamis
- 10.3 Avalanches/landslides

**11 Climate change & severe weather**

- 11.1 Habitat shifting & alteration
- 11.2 Droughts
- 11.3 Temperature extremes
- 11.4 Storms & flooding
- 11.5 Other impacts

**12 Other options**

- 12.1 Other threat

12.5 *ROBT Management Strategy Mitigation Flow Chart*