The University of British Columbia Sustainable Seafood Project – Phase II:

An Assessment of the Sustainability of

Rainbow Trout and Steelhead

Purchasing at UBC

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December 2006

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INTRODUCTION

Global Fisheries and Aquaculture

Many of the world's fish stocks, which were once thought to be vast and inexhaustible, are imperilled by human activities and overfishing. The Food and Agriculture Organisation of the United Nations (FAO) estimates that 75% of the world's fish stocks are fully exploited, over-exploited, or depleted (FAO 2004). Overfishing has seriously impacted marine ecosystems throughout history, driving target species to ecological extinction and acting as a catalyst for large-scale ecological change (Jackson et al. 2001). With the rapid expansion of fisheries in the second half of the 20th century, several important fish stocks, such as the North Atlantic cod, have collapsed (Myers et al. 1997). Global fisheries landings have been declining since 1980 (Pauly et al. 2002); combined with a downward trend in bycatch, this suggests an even greater decline in total catch and significant decreases in overall fish abundance (Zeller and Pauly 2005). According to the Fishprint, a new tool developed to measure the ocean area required to sustain humanity's consumption of fish and shellfish, current fisheries production exceeds the ocean's biological capacity by 157% (Talberth et al. 2006). This indicates that current fisheries practices and harvest rates are unsustainable (Pauly et al. 1998, 2002).

Aquaculture production has increased significantly with the downward trend in wild fish stocks, raising ecological concerns related to its appropriation of marine resources and its effect on wild fish populations (Naylor et al. 2000). The industry has grown at an average annual rate of 8.9% since 1970 (FAO 2004). In its most recent global assessment of fisheries and aquaculture (2004), the Food and Agriculture Organisation of the United Nations (FAO) stated that over 25% of the fish and shellfish consumed directly by humans came from aquaculture, of which 57.7% was freshwater, 36.5% was marine, and 5.8% was brackish water by quantity (FAO 2004). Although there is a widespread belief that aquaculture has the potential to compensate for wild fish stock depletion (Brugère and Ridler 2004, Lubchenco 2003, Subasinghe 2001), many fisheries scientists reject this idea (Folke et al. 1998, Pauly et al. 2002). The aquaculture industry still relies on the marine environment both to provide resources, for example fish feed, and to assimilate wastes (Folke et al. 1998, Pauly et al. 2002). Other ecological problems include disease transmission to wild populations, pollution of the surrounding environment, and escapes of farmed fish (Naylor et al. 2000, Pauly et al. 2002).

Sustainable Seafood

With increasing public awareness of concerns related to overfishing and ecological impacts of aquaculture, sustainable seafood initiatives have emerged and gathered momentum on local to global scales. Sustainable seafood is defined by the Monterey Bay Aquarium (MBA) as coming "from sources, whether fished or farmed, that can maintain or increase production into the long-term without jeopardizing the structure or function of affected ecosystems" (MBA 2005). The UBC definition of sustainbility is broader, including social and economic aspects in addition to ecological concerns (www.sustain.ubc.ca).

Seafood initiatives take four approaches to promoting sustainable seafood, focusing on consumers, wholesalers, restaurants, or suppliers.

Seafood rating systems aimed at increasing consumer knowledge include MBA's Seafood Watch program (http://www.mbayaq.org/cr/seafoodwatch.asp) and the Blue Ocean Institute's (BOI) Guide to Ocean-Friendly Seafood (www.blueocean.org/Seafood) in the USA, as well as the SeaChoice program in Canada (www.seachoice.org). These programs provide consumers with information regarding the origin, population status, and side effects of harvesting or aquaculture of seafood items, and with a ranking system that classifies seafood items based on their ecological sustainability (Brownstein et al. 2003). This enables consumers to make informed decisions about their purchases (Brownstein et al. 2003). More details of the ranking schemes used by individual programs can be found in Table 1.

The New England Aquarium (NEA) works with seafood wholesalers through its ChoiceCatch Project (http://www.neaq.org/choicecatch/index.php). It has developed a partnership with Ahold USA, one of the largest seafood buyers in the country, to ensure that all seafood products sold in the company's supermarkets are caught or farmed in an environmentally responsible manner. Through the recommendations it makes to Ahold USA on whether to buy individual species, NEA is able to influence purchasing practices at a higher level than that of individual consumers.

Other programs, such as the Endangered Fish Alliance (www.endangeredfishalliance.org/) and Ocean Wise (www.vanaqua.org/conservation/oceanwise/), target restaurant chefs. They raise awareness of the ecological sustainability of certain fish products and ask restaurants to remove specific items from their menus.

The Marine Stewardship Council (MSC) takes a fourth approach, providing a certification system for recognising sustainable seafood (MSC 2002a). It harnesses consumer power to create a demand for sustainable seafood, yet also works with seafood suppliers. It is a voluntary system, in which seafood suppliers choose to have their practices assessed by an accredited certification body in order to be certified as well-managed and sustainable.

Seafood programs such as those described above have considerable potential to increase the sustainability of fisheries and aquaculture (Peterman 2002). They raise consumer awareness and empower consumers to "vote with their dollar" by choosing sustainable seafood options and avoiding unsustainable ones. This creates market pressure for changes to fishery and aquaculture practices, as exemplified by the dolphin-safe tuna campaign in the 1980s (Hall et al. 2000). Concerned by the high bycatch of dolphins in the tuna fishery, consumers avoided tuna products; in response, fishermen reduced dolphin bycatch from 133,000 (1986) to 1877 (1998) individuals and the USA introduced legislation to enforce dolphin-safe tuna (Hall et al. 2000, Kaiser and Edwards-Jones 2006). Similarly, the "Give Swordfish a Break" campaign, launched in 1998, which called for restaurant chefs to boycott swordfish, successfully led to reduced catch quotas (Brownstein et al. 2003). The boycott could be called off in 2000 when effective management practices, including reduced catch quotas and the protection of juvenile nursery habitats, were put in place; these practices allow for the continued recovery of swordfish to healthy population levels (Brownstein et al. 2003, Jacquet and Pauly 2006). Other successes of seafood programs include reduced albatross mortality in the Pacific halibut fishery due to market incentives provided by purchasing guidelines (Brownstein et al. 2003), and the increasing consumption of Tilapia, promoted as a sustainable seafood choice, in the USA (Cox 2005 in Jacquet and Pauly 2006)

Many of the existing sustainable seafood initiatives focus on the end of the seafood supply chain, either on consumers or restaurant chefs, relying on pressure from the bottom up in order to promote sustainable fishery and aquaculture practices. In order for them to be effective, consumers must already be aware of and concerned about the ecological impacts of fisheries. Along with awareness, consumer acceptance of the labelling scheme or purchasing guidelines is necessary (Wessells et al. 1999). The MSC acts as a bridge between the two ends of the supply chain, because although it relies on consumer demand to be successful, it also works with suppliers to increase the sustainability of their practices.

Initiatives that are driven by consumer demand are useful only if alternative products from suppliers using sustainable practices are available (Brownstein et al. 2003), or if consumers are willing to decrease their seafood consumption. The MSC system addresses this concern by identifying and clearly labelling products that come from ecologically-friendly operations, but not all seafood products currently have MSC-certified alternatives (MSC 2002b). Some organisations, such as the Seafood Choices Alliance, provide a database of ecologically-friendly suppliers on their website (Seafood Choices Alliance 2006).

The effectiveness of all current sustainable seafood programs, with the exception of the MSC, is limited by a focus solely on the harvesting or production stage in determining their sustainability recommendations. The MSC requires chain of custody certification to ensure traceability of certified products (MSC 2002c), but other programs are vulnerable to the mislabelling or misrepresentation of seafood products as more desirable alternatives (Jacquet and Pauly 2006). Without evaluation or analysis of the chain of custody, consumers cannot be sure of the origin or identity of the products they are consuming, detracting from efforts to choose sustainable options. For example, shrimp produced in Thailand may be labelled as wild-caught as opposed to farm-raised (Miller 1999), while fish labelled as “Snapper” may belong to one of more than 352 different species (J. Barnaby, in litt., 4 October 2006).

Current sustainability assessments have chosen to focus on ecological impacts, with little or no evaluation of social or economic concerns.

Table 1. Comparison of the ranking schemes of different seafood purchasing guidelines. Information was obtained from the respective organisation's websites: Monterey Bay Aquarium http://www.mbayaq.org/cr/seafoodwatch.asp, Blue Oceans Institute www.blueocean.org/Seafood, and SeaChoice www.seachoice.org.

	Monterey Bay Aquarium (MBA)	**Blue Oceans Institute (BOI)**	**SeaChoice**
Region of Focus	National (mainly the USA but also Canada), West Coast, Hawaii, Southeast, Northeast, Midwest	Mainly the USA	Canada
Rating System	(1) Best Choices: These seafood items are abundant in the wild and their production (capture fishery or aquaculture) is well-managed with minimal environmental impact. (2) Good Alternatives: These seafood items are acceptable alternatives when no "Best Choices" products are available, although there are concerns related to long-term sustainability. Production of these seafood items may raise concerns related to the status of wild populations or the environmental impact of production. (3) Avoid: These seafood items should be avoided. Wild populations may be overfished or the production of these items may have damaging ecological effects on surrounding ecosystems.	BOI uses a colour-coded ranking based on its gradient scale. The three basic categories (Best, Intermediate, and Avoid) are the same as those used by MBA, but BOI also includes additional intermediary categories along the colour gradient. (1) Dark green = Best (2) Light green = Best-Intermediate (3) Yellow = Intermediate (4) Orange = Avoid-Intermediate (5) Red = Avoid	SeaChoice uses the same rating system as MBA.
Method of Seafood Evaluation	MBA uses a multi-step framework to develop its seafood rankings.[1] 1. Identify seafood for review based on market information. 2. Gather and analyse information on the species biology and fishery/aquaculture practices. Information is obtained from literature (peer-reviewed scientific papers, government reports, industry reports, etc.) and from discussions with experts. 3. Create a seafood report that relates the information gathered to MBA's sustainability criteria. MBA uses the following sustainability criteria, each of which has specific factors to evaluate. For capture fisheries: a. Inherent vulnerability to fishing pressure. b. Status of wild stocks.	BOI uses a similar procedure to MBA in developing its recommendations. However, it has not established (or does not publish on its website) a clear multi-step framework like that of MBA. The key differences between MBA's and BOI's approaches are: 1. Sustainability criteria used. BOI uses the following criteria, each of which has, similarly to MBA's evaluation, specific questions to answer. For capture fisheries: a. Life history characteristics. b. Current level of abundance. c. Habitat quality. d. Management effectiveness.	SeaChoice uses the same evaluation method as MBA.

	c. Nature and extent of discarded bycatch. d. Effect of fishing practices on habitats and ecosystems. e. Effectiveness of the management regime. For aquaculture: a. Use of marine resources. b. Risk of escaped fish to wild stocks. c. Risk of disease and parasite transfer to wild stocks. d. Risk of pollution and habitat impacts. e. Effectiveness of the management regime. A score of low, moderate, or high conservation concern is assigned under each criterion. The overall combination of low, moderate, and high concerns is used to arrive at an overall seafood recommendation (Best Choices, Good Alternatives, or Avoid). In addition, certain criteria can also be assigned a rank of critical conservation concern; any critical conservation concern results in an automatic "Avoid" recommendation. 4. Review of the Seafood Report for scientific content and accuracy. Both internal and external reviews are done. 5. Final ranking sessions based on the completed report and its recommendations, to ensure internal consensus before a seafood ranking is published. 6. Ongoing monitoring and evaluation of the seafood status as new developments are made. Recommendations are updated at least once a year.	e. Bycatch. For aquaculture: a. On-site operations. b. Feed composition. c. Water quality. d. Biological effects. e. Ecological effects. 2. Method to arrive at overall sustainability recommendation. In BOI's evaluation method, species are given a score under each criterion. These scores are added together to generate an overall score for the species, which is converted to a colour-coded ranking for clarity. The species is listed in relation to other seafood already ranked along a continuous gradient. 3. BOI does not require peer review of its recommendations.	

[1.] MBA Seafood Watch 2005.

University of British Columbia (UBC)

The University of British Columbia (UBC) is committed to being a leader in campus sustainability (UBC Sustainability Office 2006b). It was the first university in Canada to adopt a sustainable development policy (1997) and to establish a campus sustainability office (1998) (UBC Sustainability Office 2006a). Since then, UBC has twice received Green Campus Recognition from the USA-based National Wildlife Federation (UBC Sustainability Office 2006a). UBC now claims to incorporate sustainability into 300 of its courses (UBC Sustainability Office 2006b), and has included sustainability in its official visioning document, “Trek 2010: A global journey”. UBC’s vision includes “[promoting] the values of a civil and sustainable society” and its mission specifically states that UBC graduates will “strive to secure a sustainable and equitable future for all” (UBC Trek 2005).

UBC Sustainable Seafood Project: Background

The UBC Sustainable Seafood Project brings together multiple stakeholders to analyse and improve the sustainability of seafood purchasing practices at the university. It involves six main project partners: Project Seahorse at the UBC Fisheries Centre, the Campus Sustainability Office, the Faculty of Land and Food Systems, AMS Food and Beverage, UBC Food Services, and Green College. AMS Food and Beverage and UBC Food Services are the two main food service providers at UBC, while Green College is a smaller, independent food service provider. The final food service provider, St. John’s College, has also expressed interest in collaborating with the Sustainable Seafood Project and is active in this domain already (Magera 2006).

The first phase of the Sustainable Seafood Project saw a preliminary analysis of the sustainability of the seafood purchasing practices of UBC Food Services and AMS Food and Beverage (Magera 2006). This evaluation was performed across all taxa; taxa of immediate concern were identified, and the food service providers committed to removing monkfish, wild caviar, imported swordfish, and internationally-sourced longline tuna from their menus. Challenges and potential obstacles to developing thorough assessments for other taxa were also identified, with one such concern being overgeneralization of seafood products.

UBC Sustainable Seafood Project: Current Research

The present study provides a more detailed assessment of the sustainability of steelhead and rainbow trout purchasing at UBC. Overgeneralization was identified as a concern for this category, with products reported as “steelhead/trout” or “salmon/trout” (Magera 2006). Steelhead and rainbow trout belong to the same species, *Oncorhynchus mykiss*, but display different life histories (e.g. Cowx 2006, Scott and Crossman 1973, Wooding 1994). Steelhead are marine fish as adults, migrating to the ocean as juveniles and returning to freshwater streams to spawn, while rainbow trout are entirely freshwater fish (e.g. Cowx 2006, Scott and Crossman 1973, Wooding 1994). This basic distinction is widely accepted, including, for example, by authorities such as Fisheries and Oceans Canada (DFO 2002) and the US Fish and Wildlife Service (Pauley et al. 1986). One would therefore expect it to be reflected in steelhead and rainbow trout products, yet some fish labelled as steelhead come from freshwater lakes. For example, fish that are stocked in the Great Lakes for recreational fishing are called steelhead (Scott and Crossman 1973) and aquaculture companies in Saskatchewan purportedly produce steelhead in freshwater lakes (DFO 2006b). This ambiguity in the labelling and sourcing of steelhead and rainbow trout products makes it difficult to assess their sustainability accurately. For this study, all fish obtained from fresh water are considered to be rainbow trout, while those obtained from marine or brackish water are considered to be steelhead.

This study focuses solely on aquaculture of steelhead and rainbow trout, because it is the primary production method used. Rainbow trout are produced exclusively through aquaculture, while a small commercial fishery for steelhead exists (BOI 2004c). Steelhead is native to the Pacific coast of North America from Alaska to Mexico, but its current distribution does not extend south of California

(Pauley et al. 1986, Scott and Crossman 1973, Wooding 1994). In Canada, the targeted commercial fishing of steelhead is prohibited (NCSA 2006). However, a pre-determined percentage of steelhead caught as bycatch in commercial salmon fisheries can be retained; this may represent as much as 20% of the total number of fish caught (NCSA 2006, A. Tautz, pers. comm., 26 Oct 2006). In the USA, commercial fishing is restricted to native Americans (BOI 2004c). Quantitative measurements of the contribution of this fishery to the total steelhead market were unavailable. All steelhead and rainbow trout products currently purchased by UBC are produced through aquaculture.

There is a significant recreational fishery for steelhead and rainbow trout. They are highly prized for the tremendous fight they offer, and are regarded as a favourite catch by many anglers (Gordon 1977, Scott and Crossman 1973, Wooding 1994). In Washington State, for example, an annual average of 100,000-150,000 steelhead individuals is caught by anglers (WDFW 2004). Rainbow trout have been introduced worldwide for recreational fisheries (Cowx 2006) and are considered to be among the top five sport fish in North America (Scott and Crossman 1973). Because of the incredible popularity of steelhead and rainbow trout as sport fish, hatchery programs have been established with twin objectives of stocking these fish for recreational fisheries and promoting their conservation and recovery (Busack et al. 2006). Sport fishing is often strictly limited to hatchery-raised fish or otherwise tightly regulated to protect wild stocks (DFO 2007).

Recreational and commercial fishing of steelhead is closely regulated or prohibited because of declining trends in wild populations. In Canada, 50% of steelhead populations are listed as being of conservation concern or of extreme conservation concern (MWLAP 2002), and in the USA 10 of 17 “distinct population segments” are endangered or threatened (NMFS 2006b). Large declines in the past few decades are a result of anthropogenic influences and climatic changes (NMFS 2006a); even with conservation efforts that include hatchery programs and stream rehabilitation, many populations continue to decrease (NMFS 2006b).

The goal of this study is to make recommendations to UBC food service providers regarding the sustainability of steelhead and rainbow trout purchasing practices. The underlying objectives are:

i) To understand the supply of steelhead and rainbow trout to UBC food service providers.

ii) To analyse the ecological impacts of steelhead and rainbow trout aquaculture.

iii) To analyse the social and economic impacts of steelhead and rainbow trout aquaculture

STEELHEAD AND RAINBOW TROUT ECOLOGY

As mentioned previously, steelhead and rainbow trout are different strains of the same species, *Oncorhynchus mykiss* (e.g. Cowx 2006, Scott and Crossman 1973, Wooding 1994). This species was formerly classified as *Salmo gairdneri*, but was subsequently found to be more similar to salmon than to trout, resulting in its reclassification as *O. mykiss* (Smith and Stearley 1989). It belongs to the family Salmonidae and subfamily Salmoninae (Wooding 1994).

Figure 1 shows the native distribution of *O. mykiss* along the Pacific coast of North America. Rainbow trout have been introduced throughout the world, to all continents except Antarctica, for sport fishing and aquaculture (Cowx 2006). Steelhead have also been introduced to other continents, including South America and Europe, for aquaculture (Cowx 2006).

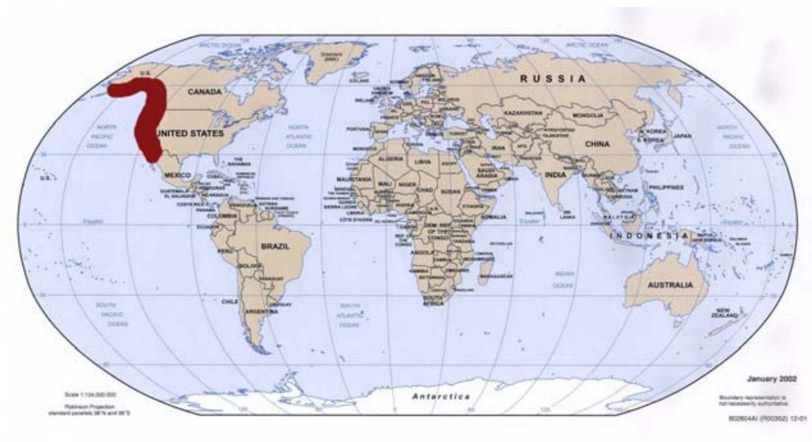

Figure 1. The native distribution of steelhead and rainbow trout along the Pacific coast and drainages of North America, from Alaska to Mexico.

Steelhead

The steelhead life cycle, shown in Figure 2, includes both freshwater and marine phases. Steelhead hatch in freshwater rivers or streams, remaining there for one to four years (Scott and Crossman 1973, Wooding 1994). They migrate to the ocean in spring and grow rapidly as they enter estuarine waters, doubling or tripling in size in approximately two weeks (Childerhose and Trim 1979). Steelhead spend two to three years in the ocean, yet little is known about this phase of their life cycle; they are regularly reported in Alaskan and Aleutian waters and may travel as far as Japan (Wooding 1994). For example, a steelhead caught in the Skagit River in northern Washington State had been tagged six months earlier in the Sea of Japan (Ball 2006). Two different types of steelhead are distinguished by the time at which they return to freshwater: winter run fish enter rivers and streams from November to May while summer run steelhead return between April and October (DFO 2002b, Wooding 1994). Both populations spawn in early spring (April to May), with eggs hatching four to seven weeks later (Scott and Crossman 1973, Wooding 1994). Unlike Pacific salmon, adult steelhead may return to the ocean after spawning and spawn multiple times; up to 20% of steelhead are repeat spawners (Wooding 1994).

Steelhead survival, which is currently low, is affected by factors acting at the freshwater and marine stages of the life cycle. The greatest mortality occurs at the freshwater stage, with a 0.77% average survival from egg to smolt; this is influenced by land use decisions and weather patterns that alter channel morphology, water temperature, food availability, and other stream features (Childerhose and Trim 1979, NMFS 2006a, T. Johnston, in litt., 13 December 2006). Marine survival varies from 13-15% when ocean conditions are favourable to 2-4% when they are unfavourable (T. Johnston, in litt., 13 December 2006). Changes in marine productivity caused by climatic events such as El Niño or decadal oscillations influence ocean survival; declining ocean productivity is associated with the current low marine survival of steelhead and several Pacific salmon species (Beamish et al. 2002, T. Johnston, in litt., 13 December 2006). Other factors that may impact ocean survival include predation by species such as salmon sharks (*Lamna ditropis*) and daggertooth (*Anotopterus nikparini*), which have increased in abundance in recent years (Nagasawa et al. 2002), viral diseases (Emmenegger et al. 2002), and environmental conditions such as sea surface temperature (Mueter et al. 2002).

A comparison of the life history characteristics of steelhead and rainbow trout is given in Table 2.

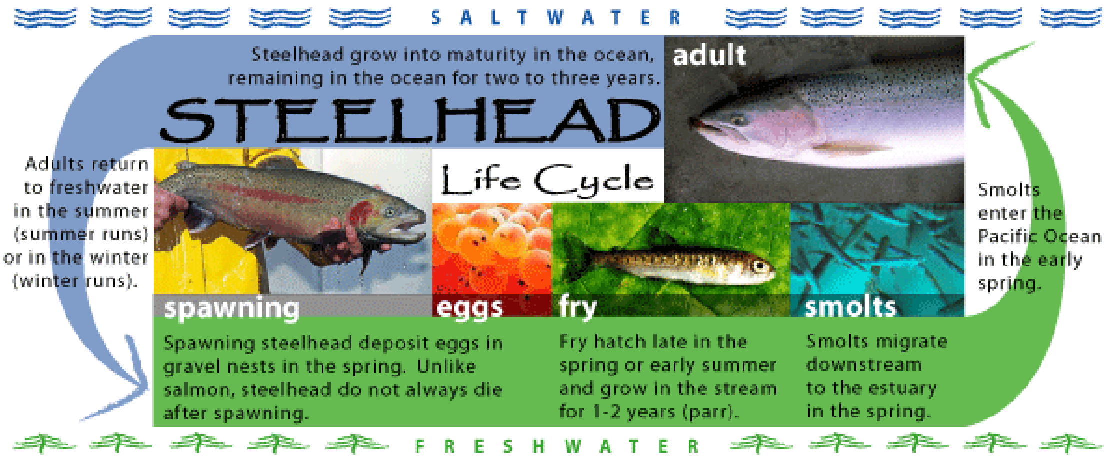

Figure 2. A typical steelhead life cycle. Freshwater residency varies from one to four years, while ocean residency is as indicated, varying from two to three years. From: BC Conservation Foundation 2006.

Rainbow Trout

The life cycle of rainbow trout, although confined to fresh water, is similar to that of steelhead, with lakes or large rivers replacing the ocean (Scott and Crossman 1973). Rainbow trout hatch in small tributary streams to large rivers or inlet or outlet streams of lakes (Scott and Crossman 1973). They may migrate to the adjacent lake or river immediately, but most remain in these streams for one to three years (Scott and Crossman 1973). Rainbow trout grow to adult size in their lakes or rivers, usually maturing at 3-4 years of age (Cowx 2006). They return to their natal streams to spawn in early spring (April to June) and eggs hatch after four to seven weeks (Scott and Crossman 1973, Wheeler 1985). Rainbow trout can spawn multiple times, to a maximum of five successive years, although repeat spawners may represent less than 10% of the population (Scott and Crossman 1973). The distance travelled by rainbow trout between natal streams and lakes or rivers is generally small compared to the ocean migration of steelhead, yet impressive journeys have been recorded: a rainbow trout tagged in Great Lakes rivers in Michigan was caught eight months later in Lake Ontario, having travelled a distance of 375 km (Scott and Crossman 1973).

I was unable to find information on survival rates of rainbow trout.

Table 2. Comparison of steelhead and rainbow trout life history characteristics.

	Steelhead	**Rainbow Trout**
Typical life span	6-8 years[1]	5-6 years[1,2,3,4]
Average length (cm)	50-75 cm[1]	30-45 cm[1,2,3,4]
Average weight (kg)	3.6-4.1 kg[1]	1.36-1.81 kg[1,2,3,4]
Maximum size attained under ideal conditions	Length 122 cm[1,5,6] Weight 16-17 kg[1,5,6]	Unable to obtain information
Largest recorded single fish	A single fish caught by a sports fisherman in southeast Alaska weighed 19.5 kg.[7] Fish up to 22.7 kg have been reported in First Nations tribal net fisheries.[7]	A single fish of the Gerrard strain, which feeds on kokanee, was recorded at 23.6 kg.[4]
Diet	Juvenile steelhead are planktivorous; as they mature, their diet shifts to insects and crustaceans and then to other fish.[1,4] In the ocean they eat greenling, squid, and amphipods.[4]	As they mature, rainbow trout shift from planktivorous feeding to a diet consisting of freshwater shrimp, their most important food source, as well as other invertebrates, crustaceans, insects, and fish eggs.[1,2,6] Some populations further shift to a piscivorous diet.[1]
Growth rate at optimal feeding and water conditions	6.8-10 kg in three years[2]	4.5 kg in three years[2]

1. Scott and Crossman 1973.

2. Cowx 2006.

3. Parkinson et al. 2004.

4. Wooding 1994.

5. Childerhose and Trim 1979.

6. Wheeler 1985.

7. Ball 2006

METHODS

A variety of information is required in order to analyse the sustainability of UBC's consumption of steelhead and rainbow trout. This includes information regarding:

i) the sources of "steelhead/trout" for UBC, including provenance (location of aquaculture and processing) and the aquaculture methods used;
ii) other potential sources of steelhead and rainbow trout;
iii) the ecological impacts of the aquaculture methods used; and
iv) the social and economic impacts of the aquaculture methods used.

I obtained information on the sources of "steelhead/trout" for UBC from Phase I of the UBC Sustainable Seafood Project (Magera 2006), as well as from minutes of meetings with the chefs at Green College and St. John's College. This provided a general overview of the source regions of "steelhead/trout". I then identified the aquaculture methods used in these regions by researching government ministry publications and websites, speaking to scientists in the BC Ministry of the Environment, and researching production methods of specific aquaculture companies. In this way I was able to simultaneously investigate other potential sources of steelhead/trout. I obtained specific information on the sources of steelhead and rainbow trout for UBC Food Services, AMS Food and Beverage, and Green College by contacting the wholesale seafood suppliers and their source companies.

I used a variety of sources to obtain information on the ecological, social, and economic impacts of different aquaculture methods. I obtained preliminary information from existing assessments of steelhead and/or rainbow trout and then used scientific literature, publications and websites of governmental bodies, and interviews with scientists in the BC Ministry of the Environment for further investigation. Unfortunately, I was unable to speak to First Nations representatives.

A major difficulty encountered in this project has been distinguishing between farming of rainbow trout and steelhead. Because they belong to the same species, the names steelhead and rainbow trout are sometimes used interchangeably. For example, the BC Ministry of Agriculture and Lands lists several aquaculture companies that are licensed to grow rainbow trout in marine operations (AGF 2005). Labelling ambiguity will continue to present a problem unless the method of production (marine vs. freshwater) is clearly identified.

CONSERVATION AND MANAGEMENT STATUS

Steelhead Aquaculture

Steelhead aquaculture is a growing industry worldwide. The main producing countries are Chile and Norway, where steelhead is farmed, mostly for the export market, by large multinational companies such as Marine Harvest (Cowx 2006, Marine Harvest 2006). In 2004, the industry produced 214,869 tonnes of steelhead for a market value of US$823.7 million globally, with Chile accounting for 58% of production by weight and 66% by value (FAO 2006). Farmed steelhead is also raised in the USA and Canada, but the industry is much smaller; Canada produced only 1150 tonnes valued at C$6.3 million in 2003 (Cowx 2006, DFO 2006b, O'Neill 2006). According to Fisheries and Oceans Canada, steelhead is farmed in BC, Saskatchewan, Nova Scotia, New Brunswick, and Newfoundland and Labrador (DFO 2006b). Production in Saskatchewan, however, comes from freshwater lakes; therefore it should be classified as rainbow trout instead (Seafood Canada 2006).

Steelhead are farmed in floating net-pens in coastal waters (Marine Harvest 2006, O'Neill 2006). Eggs, obtained from hatcheries or produced within the facility, are incubated in hatching troughs (Cowx 2006). Once fry have hatched they are transferred to circular tanks, where they are reared until they reach the fingerling stage (Cowx 2006). Fry are then transferred to the floating net-pens and grown to market size in six to nine months (Cowx 2006, DFO 2006b, Marine Harvest 2006). Due to fast growth rates in the marine environment, steelhead are well-suited to aquaculture (DFO 2006b, Gordon 1977, Marine Harvest 2006). In Canada, steelhead are harvested once a year, between September and December, while in Chile and Norway they are grown and harvested year-round (DFO 2006b, Marine Harvest 2006).

Management of steelhead aquaculture is restricted to general regulations and policy initiatives regarding salmonid aquaculture in coastal net-pens. An analysis of management practices across different countries found them to vary widely, although on the whole they were ineffective at reducing environmental impacts and preventing escapes of farmed fish (Naylor et al. 2005). BC, Washington State, and Maine have the strictest regulations, including specifications for facility design, prevention and response plans, and monitoring and enforcement to effectively manage the risks of escaped farm fish (Naylor et al. 2005). However, penalties and other deterrents are generally insignificant, undermining the potential success of these regulations (Naylor et al. 2005). Norway has weaker requirements for contingency plans and reporting of escapes, while no regulations exist in New Brunswick or Chile (Naylor et al. 2005).

Rainbow Trout Aquaculture

Rainbow trout aquaculture has been practised since 1874, but production greatly increased in the 1950s with the introduction of pelleted feeds, and has grown exponentially since then (Cowx 2006). In 2004, the industry produced 290,000 tonnes of fish for a market value of US$864 million (FAO 2006). Production is dominated by eight countries: France, Italy, Spain, Denmark, Germany, Iran, the USA and the UK (Cowx 2006). In the USA, rainbow trout aquaculture is the second largest finfish aquaculture industry, after channel catfish (Moffitt 2003, O’Neill 2006). Production, mainly for the domestic market, was nearly 25,000 tonnes in 2004, of which approximately 70% came from the Snake River region of Idaho (Moffitt 2003, O’Neill 2006). Canadian production of rainbow trout is significantly smaller, with 5661 tonnes produced in 2003 for a value of C$26.5 million (DFO 2005). Nevertheless, it is the largest freshwater aquaculture industry in Canada (DFO 2005). Rainbow trout is raised commercially across Canada, in BC, Alberta, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia and Prince Edward Island (DFO 2006a).

Rainbow trout are farmed in freshwater flow-through systems or floating freshwater cages (DFO 2006a, O’Neill 2006). Both methods are used in Canada, while in the USA all rainbow trout farming uses flow-through systems (DFO 2006a, O’Neill 2006). These systems consist of raceways, ponds, or circular tanks that have a continuous flow of freshwater, usually diverted from adjacent rivers, moving through the facility (Cowx 2006, NOAA 2006). Two typical layouts are shown in Figure 3. As with steelhead, the production cycle begins with incubation of eggs, obtained from hatcheries or produced within the facility, followed by rearing of fry in circular tanks (Cowx 2006). Fry are transferred to the raceways, ponds, or cages at sizes of 8-10cm (Cowx 2006). Rainbow trout typically attain market size of 30-40 cm within nine months, but may be grown to larger sizes depending on market demand (Cowx 2006).

Management of rainbow trout aquaculture is limited to universal regulations applying to all freshwater aquaculture practices; these regulations are country-specific. In both Canada and the USA, several agencies have some jurisdiction and control over rainbow trout aquaculture; in Canada these include provincial ministries such as the BC Ministry of the Environment and the BC Ministry of Agriculture and Lands and federal agencies such as Fisheries and Oceans Canada and the Canadian Food Inspection Agency (MOE 2006). Regulations and policies need to consider human health, water usage and pollution, rainbow trout feed, and other impacts of aquaculture facilities on the surrounding environment. Rainbow trout aquaculture is purportedly well-managed in the USA, with regular monitoring to ensure compliance with wastewater discharge regulations (EPA 1997). Furthermore, large operations with annual production greater than 45 tonnes (100,000 pounds) are required to develop best management practices (IDEQ 1997 in O’Neill 2006).

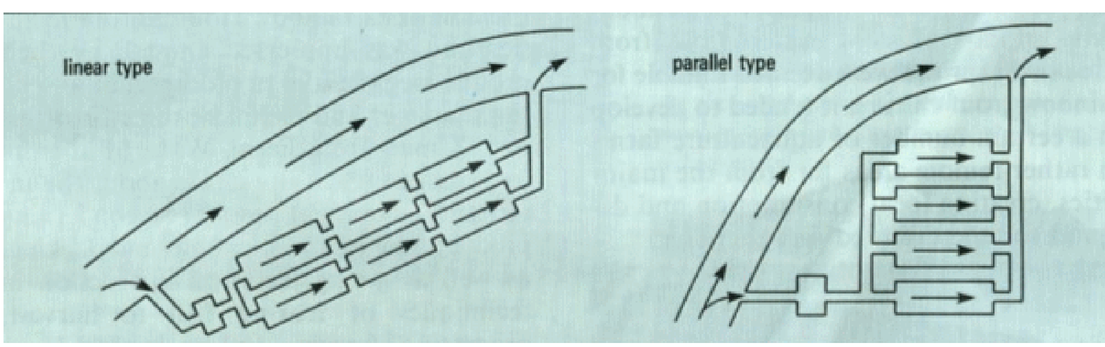

Figure 3. Two typical layouts of freshwater flow-through systems for rainbow trout aquaculture. Water is diverted from an adjacent river and flows through raceways or ponds in either a linear or parallel setup.

Conservation Issues Associated with Aquaculture

Potential conservation issues associated with steelhead and rainbow trout aquaculture include the source of broodstock, feed content, water pollution, transmission of pathogens to wild populations, escapes of farm fish, and the source of water. These concerns are summarised in Table 3.

Wild fish are not used as broodstock in steelhead and rainbow trout aquaculture. All broodstock is artificially cultured; facilities either maintain their own broodstock or purchase eggs from hatcheries which spawn hatchery-raised fish (e.g. Troutlodge 2006, Wild West Steelhead 2006, D. Foss, pers. comm., 13 December 2006, B. Lehmann, pers. comm., 13 December 2006).

Fish meal and fish oil used in steelhead and rainbow trout feed are derived from reduction fisheries. These are commercial fisheries that target small pelagic fish such as anchovy, herring, menhaden, and mackerel specifically for their conversion to fish meal and fish oil (i.e. for feed production for aquaculture and other industries) rather than for human consumption (Naylor et al. 2000, O'Neill 2006). Many of these fish stocks are already overfished and vulnerable to climatic fluctuations such as El Niño Southern Oscillation (ENSO) events (Naylor et al. 2000, O'Neill 2006). Replacement of fish meal and oil by alternative protein sources such as soy, wheat, maize, rapeseed, or linseed has resulted in a reduction to less than 50% fish meal in trout feed (Cowx 2006, Moffitt 2003, Papatryphon et al. 2004). However, the use of these protein sources may raise concerns regarding the indirect introduction of genetic modification into seafood products, since the vegetables and grains used as alternatives are often genetically modified. Rainbow trout are able to efficiently convert the energy in their feed to fish biomass, with a feed conversion ratio (FCR) of approximately 1:1 (Cowx 2006, O'Neill 2006); one unit of feed (dry weight) produces one unit of farmed fish (wet weight). Converting this to the ratio of wild to farmed fish, O'Neill (2006) found that 1.49 kg of wild fish were required to produce 1 kg of trout. No such data were available for steelhead feed conversion.

Floating Net-Pen and Cage Aquaculture

Water pollution, pathogen transmission, and escapes of farmed fish are significant concerns for floating net-pen or cage aquaculture of steelhead and rainbow trout.

Diffusion of excess phosphorus and nitrogen, feces, and suspended solids into the surrounding environment can cause increased growth of algae and phytoplankton and localised changes in benthic communities (Clark et al. 1998, Bostick et al. 2005 in BOI 2004b). Phosphorus is the main nutrient of concern for eutrophication in freshwater systems, while nitrogen is a greater threat in marine systems (O’Neill 2006, Sugiura et al. 1999). Studies of the effects of different diets on uptake of phosphorus in rainbow trout have successfully increased its retention (O’Neill 2006, Papatryphon et al. 2004, Satoh et al. 2003, Sugiura et al. 1999). No data were found for nitrogen retention in mariculture.

Spread of diseases and parasites to wild populations can occur through several routes, greatly increasing the risk of transmission (Naylor et al. 2005). Table 3 details possible transmission routes common to all salmonid net-pen aquaculture. Potential diseases and parasites include Whirling Disease, caused by the protozoan *Myxosoma cerebralis*, as well as several bacterial and viral diseases such as infectious pancreatic necrosis (Cowx 2006, O’Neill 2006, BOI 2004b). No data specific to disease and parasite transmission for steelhead or rainbow trout were found.

Potential risks associated with escaped fish include establishment of feral stocks, competition with wild populations for food, space, and mates, genetic interactions and possible depletion of the wild gene pool through interbreeding, and transmission of pathogens (Naylor et al. 2005, Schiermeier 2003). It has been argued that escaped steelhead are unlikely to establish feral populations because the reproductive success of hatchery-raised steelhead, measured as number of smolts produced per female, is much lower than that of wild adults (McLean et al. 2003). This is a result of differences in fecundity and genetics; hatchery-raised fish are less adapted to the local stream conditions than are wild populations because they have adapted to the hatchery environment over generations and they may be selected for traits, such as spawning time, that differ from those of the wild fish (McLean et al. 2003). Rainbow trout, however, have been documented to establish feral stocks, for example in a river in Newfoundland (CBC 2003); a population can be founded by very few fish

The risks of interactions between wild and farmed steelhead are based on risks common to all salmonids. Interactions might cause decreases in genetic diversity, productivity, and fitness of wild populations, potentially even leading to extirpation of local populations (Naylor et al. 2005). This is a serious concern as many steelhead populations are already threatened, and escapes from marine net-pens are common, with up to two million farmed Atlantic salmon estimated to escape in the North Atlantic each year (Schiermeier 2003). Escapes from freshwater cages are likely to be similar, yet their effects on wild rainbow trout populations are probably small in comparison to the large numbers of rainbow trout stocked worldwide for sport fishing (O’Neill 2006). However, escaped rainbow trout may also affect other wild fish; the feral population in Newfoundland, for example, is reducing the fitness of the already dwindling wild Atlantic salmon population through competition for food (CBC 2003).

Freshwater Flow-Through Aquaculture

Excess nutrients, feces, suspended solids, and pathogens can be transmitted to the natural environment in the effluent of freshwater flow-through systems. Effluent is treated using settling ponds or settling areas at the ends of raceways, from which fish are absent, to remove suspended particles (Cowx 2006, O’Neill 2006). Another possible treatment method, ozonation, is uncommon in rainbow trout aquaculture (B. Lehmann, pers. comm., 13 December 2006). Improved phosphorus retention, as mentioned previously, reduces the risk of eutrophication in freshwater systems (O’Neill 2006, Papatryphon et al. 2004, Satoh et al. 2003, Sugiura et al. 1999). However, decreases in the release of dissolved solids and organic matter will require improved treatment methods such as filtration systems (Papatryphon et al. 2004). Such systems are also necessary to decrease transmission of disease-causing microorganisms to wild populations, while parasite transmission can be prevented through proper facility design (Cowx 2006, BOI 2004b, O'Neill 2006). Filtration systems or other improved treatment methods are not currently used by the aquaculture industry (B. Lehmann, pers. comm., 13 December 2006).

Table 3. Summary of conservation concerns associated with different aquaculture production methods for steelhead and rainbow trout.

Conservation Concern	Steelhead	Rainbow Trout	
	Floating net-pens	**Floating cages**	**Flow-through systems**
Source of broodstock	No wild fish are used as broodstock. Facilities maintain their own broodstock or obtain eggs from hatcheries, which spawn hatchery fish.[e.g. 1,2,3,4]		
Feed content	Fish meal and fish oil are used in feeds.[5,6] These are increasingly being replaced by alternative protein sources such as soy, wheat, or linseed.[7,8,9]		
	No data on the efficiency of steelhead feed conversion were found.	Rainbow trout are efficient at converting food to biomass, with 1.49 kg of wild fish (in the form of fish meal and oil) required to produce 1 kg of rainbow trout.[6]	
Water pollution	Open exchange with the natural environment allows excess nutrients, feces, and suspended solids to freely diffuse into the ocean.[10] No information was found on the impacts of excess nitrogen or the efficiency of nitrogen retention.	Open exchange with the natural environment allows excess nutrients, feces, and suspended solids to freely diffuse into the lake.[10] Improvements in phosphorus retention have reduced discharge of excess phosphorus.[6,9,11,12]	Settling ponds are used to remove suspended solids from effluent.[6,7] Excess nutrients and other dissolved particles are not removed, but improvements in phosphorus retention have reduced discharge of excess phosphorus.[6,9,11,12]
Pathogen transmission	Open exchange with the natural environment allows diseases and parasites to be transmitted to wild populations when they swim near net-pens or cages containing infected individuals or through plumes carried by water currents.[13] Escaped farm fish can also directly transmit pathogens to wild populations.[13]		Diseases caused by microorganisms can be transmitted through the effluent. Increased prevalence of disease-causing microorganisms has been documented downstream of aquaculture facilities.[14] Infections by and transmission of parasites can be prevented by removing habitat for intermediate hosts such as worms or snails.[7,15]
Escapes	Escapes are common from net-pens. Many wild steelhead populations are threatened, and the impacts of escaped farm fish may lead to further declines. Interactions between farm and wild fish can decrease the productivity and fitness of wild	No information was found specifically on escapes from freshwater cages, but they are likely to be similar to those from net-pens. As rainbow trout have been stocked worldwide, the impacts of escaped fish from aquaculture may be small compared to those of stocking	There is no evidence of escapes from freshwater flow-through systems.[6]

	populations and potentially lead to extirpation of local stocks.[13] Interactions with farm fish can also cause the decline of other wild fish species.[e.g. 16]	programs.[6]	
Water source	Open to natural environment.	Open to natural environment. Require location with clean fresh water.	Require constant supply of clean water. This may become difficult to sustain as fresh water becomes increasingly scarce.

1. Troutlodge 2006.

2. Wild West Steelhead 2006.

3. D. Foss, pers. comm., 13 December 2006.

4. B. Lehmann, pers. comm., 13 December 2006.

5. Naylor et al. 2000.

6. O'Neill 2006.

7. Cowx 2006.

8. Moffitt 2003.

9. Papatryphon et al. 2004.

10. Clark et al. 1998.

11. Satoh et al. 2003.

12. Sugiura et al. 1999.

13. Naylor et al. 2005.

14. McAllister and Bebak 1997.

15. BOI 2004b.

16. CBC 2003.

STEELHEAD AND RAINBOW TROUT USE AT UBC

Consumption patterns at UBC

Steelhead and rainbow trout represent a small proportion of total seafood consumption at UBC. Both UBC Food Services and AMS Food and Beverage use “steelhead/trout” in limited amounts. It accounted for less than 2% of total seafood purchasing, by weight, for both food service providers over a 12-month period (Magera 2006). In a meeting with Anna Magera in August 2006, Green College chef Sherry Geraghty did not report any use of steelhead or trout, while in July 2006 St. John’s College head chef Clarence Tay reported that rainbow trout from the USA was commonly used. Green College is flexible in its food purchasing and would consider using steelhead or rainbow trout if they are considered sustainable options.

Purchasing trends at UBC

Table 4 provides a summary of steelhead and rainbow trout purchasing by UBC Food Services and AMS Food and Beverage, showing amount purchased, supplier, and source region, based on data from Phase 1 of the Sustainable Seafood Project (Magera 2006).

UBC Food Services purchased “steelhead/trout” from its main supplier, Albion Fisheries. Albion reports obtaining steelhead from Saskatchewan and Washington State (L. Donnelly, pers. comm., 15 November 2006). It is raised in floating freshwater cages in Saskatchewan (and should therefore be called rainbow trout) and in coastal net-pens in Washington State (A. Tautz, pers. comm., 26 Oct 2006, D. Foss, pers. comm., 13 December 2006). Albion reports obtaining rainbow trout from Sun Valley Trout Farm in Mission, BC and from aquaculture facilities in Idaho (L. Donnelly, pers. comm., 15 November 2006), both of which use freshwater raceways for production (D. Lehmann, pers. comm., 13 December 2006, O’Neill 2006). The lake in Saskatchewan from which “steelhead” is obtained was given as Logan Lake by Lee Donnelly of Albion Fisheries (L. Donnelly, pers. comm., 15 November 2006), yet according to Seafood Canada no aquaculture facilities exist there (Seafood Canada 2006). Donnelly also mentioned that the lake is named after a former prime minister (L. Donnelly, pers. comm., 15 November 2006). Since Wild West Steelhead raises “steelhead” in Lake Diefenbaker, Saskatchewan, which is near the community of Lucky Lake, I assumed that this company does in fact supply “steelhead” to Albion Fisheries. I will henceforth refer to these “steelhead” as rainbow trout. Unfortunately I was unable to determine specifically which of the above sources UBC’s steelhead and rainbow trout purchases come from.

“Steelhead/trout” was the fifth most purchased seafood item by AMS Food and Beverage over the 19-month period from July 2004 to January 2006 (Magera 2006). This accounted for 1.9% of its seafood purchasing by weight (Figure 4). Steelhead and rainbow trout were purchased from two suppliers, Sysco and Nishimoto. Attempts to determine the sources of these products from the suppliers were unsuccessful.

Information from the most recent purchasing records (May-November 2006) for AMS Food and Beverage are shown in Table 5. On November 1, 2006, it discontinued its purchasing relationship with Sysco, switching to Neptune GFS as its main supplier (N. Toogood, in litt., 21 November 2006). Due to time constraints, I was unable to obtain information on the provenance of steelhead and rainbow trout products for Neptune.

St. John’s College obtains its seafood from a variety of sources, including Albion, Deluxe Seafood, and Sysco (C. Tay, pers. comm. to A. Magera, 20 July 2006). It is unclear from which supplier rainbow trout is purchased, although according to head chef Clarence Tay (C. Tay, pers. comm. to A. Magera, 20 July 2006) it comes from the USA. All rainbow trout in the USA is farmed using freshwater flow-through systems (O’Neill 2006).

Green College obtains seafood from Blundell, Sysco, and Centennial Food Service (S. Geraghty, pers. comm. to A. Magera, 2 Aug 2006).

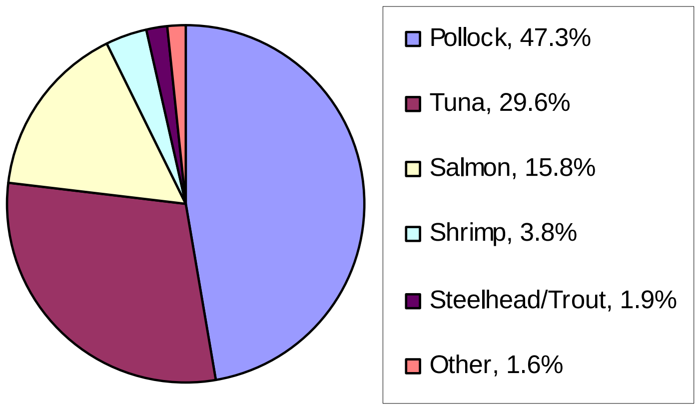

Figure 4. AMS Food and Beverage seafood purchasing, by weight, for the 19-month period from July 2004 to January 2006.

Table 4. Purchases of steelhead and rainbow trout by UBC Food Services and AMS Food and Beverage. Purchases for UBC Food Services are for the year 2005, while those for AMS Food and Beverage are for the period July 2004 to January 2006, with the 12 month estimate calculated according to the following equation: $12month(kg) = 19month(kg) \times {}^{12}\!/_{19}$. All information in this table was obtained from Magera (2006).

Product	Supplier	Supplier Codes	Amount (kg)	Time Period	Farmed/Wild	Source Region
UBC Food Services						
Steelhead/trout[1]	Albion		12.0	12 months	Farmed	Canada (BC, SK), USA (Washington, Idaho)
AMS Food and Beverage						
Salmon/trout[1]	Nishimoto	90691	60.0 *37.9*	19 months *12 month estimate*	Farmed	unable to obtain information
Smoked steelhead/trout[1]	Sysco	71701, 71710	203.6 *128.6*	19 months *12 month estimate*	Farmed	Chile, USA, Canada

1. As recorded in Magera (2006).

Table 5. Purchases of steelhead and rainbow trout by AMS Food and Beverage from May to November 2006.

Product	Supplier	Supplier Codes	Amount (kg)	Time Period	Farmed/Wild	Source Region
Smoked steelhead	Sysco	71701	7.98	May-October	Farmed	unable to obtain information
Salmon side smoked steelhead sliced	Neptune	3177807	8.25	November	Farmed	unable to obtain information

SUSTAINABILITY OF UBC'S USE

The sustainability of UBC's current purchasing practices for steelhead and rainbow trout depends on the source region and aquaculture methods used. Seafood assessments under existing programs are only available for farmed US rainbow trout, with the exception of BOI's assessment for the Native American fisheries of steelhead in the USA (BOI 2004c). These assessments are based on the production method used, namely freshwater flow-through systems, and therefore also apply to rainbow trout produced using such systems in Canada and other countries.

Rainbow trout farmed using freshwater flow-through systems receive a rating of "Best Choice" from MBA and a yellow rating from BOI (see Table 1 for details of the respective ranking schemes) (O'Neill 2006, BOI 2004b). MBA awards a "Best Choice" rating, despite the moderate risk of disease or parasite transfer, because of the low impact on the surrounding environment - there is no evidence of escaped fish and wastes that are retained in settling ponds are used as fertilizer or compost - and effective management practices (O'Neill 2006). In BOI's ranking, the ecological effects of rainbow trout aquaculture facility sites and the risks posed by potential escapes or disease transmission are considered to be high; however, low inherent operational risks and concerns related to feed production result in an overall intermediate rating (BOI 2004b).

The rainbow trout purchased by UBC that are farmed in freshwater flow-through systems are currently of intermediate sustainability, as considerable concerns related to effluent treatment in these systems still exist. Companies that supply UBC's rainbow trout, including Sun Valley Trout Farm and aquaculture facilities in Idaho, use settling ponds (B. Lehmann, pers. comm., 13 December 2006, EPA 2007, O'Neill 2006). This treatment method only has limited efficacy in reducing or preventing water pollution and disease transmission. Other potential treatment methods, for example ozonation or filtration of effluent, would be more effective.

No assessment has yet been performed for rainbow trout raised in floating freshwater cages. This includes those fish labelled as “steelhead” that are farmed in lakes. Freshwater cages pose the same qualitative threats as marine net-pens, yet the magnitude of these risks is currently unknown. As a result of the high uncertainty related to concerns of escaped fish, water pollution, and pathogen transmission, and their potentially high impacts on the surrounding environment, this production method is considered unsustainable.

Although no assessment of steelhead produced in marine net-pens currently exists, this product would most likely receive an “Avoid” rating under existing methodologies. Atlantic salmon are farmed in the same manner and are ecologically very similar to steelhead (E. Parkinson, pers. comm., 26 Oct 2006). They are usually rated as “Avoid” on sustainable seafood guides, such as those published by MBA and BOI, because of the risks of escaped fish, disease transfer, and water pollution (Mazurek and Elliott 2004, BOI 2004a). In its Atlantic salmon rating, MBA lists the risk of escaped fish, which are often non-indigenous in the areas in which they are farmed, as a critical concern that automatically results in an “Avoid” rating (Mazurek and Elliott 2004). Steelhead are farmed both in areas to which they are not native, for example Chile and Norway, and within their native range. Escaped fish pose a significant risk within their native range, where more than 50% of wild steelhead populations are threatened, and in other areas of the world where they may establish feral populations that can negatively impact native fish species (NMFS 2006b, MWLAP 2002). Combined with concerns of water pollution and disease transmission to wild fish stocks, this implies that steelhead aquaculture is unsustainable.

DISCUSSION

Summary of Steelhead and Rainbow Trout Exploitation

Rainbow trout farming in freshwater flow-through systems is currently the most sustainable method, while aquaculture of steelhead or rainbow trout in floating cages or net-pens is unsustainable. Concerns still exist with all forms of steelhead and rainbow trout aquaculture, however, for example the appropriation of marine resources for feed and the potential transfer of pathogens to wild populations. These concerns place limitations on further expansion of production, yet they also provide opportunities to improve the sustainability of steelhead and rainbow trout aquaculture by addressing them successfully.

Integrated culture provides one of the most promising opportunities for the continued expansion of steelhead aquaculture. In these systems, steelhead is raised together with algae such as *Gracilaria*, *Laminaria*, or *Nereocystis*, with the wastes from steelhead culture being used as resources for the production of seaweed (Buschmann et al. 1996, Chopin et al. 2001, Petrell and Alie 1996); this coupling results in improvements in water quality that can counter all or most of the water pollution from steelhead aquaculture (Folke et al. 1998, Neori et al. 2004). Despite the possibilities this presents in terms of decreased ecological impacts and increased total revenue through product diversification, there is a common view that intensive monoculture systems are necessary for economic viability (Cowx 2006). This perspective provides a barrier to realizing the potential of integrated culture. Neori et al. (2004) suggest that the production of integrated polyculture systems can be increased to the level of monoculture systems by connecting monocultures through water transfer rather than placing the different species, for example steelhead and algae, in direct contact . Many experimental integrated culture systems have been set up and studied worldwide in the past 30 years (Neori et al. 2004). The technology is now at the point of being economically viable and becoming a commercial reality; in Israel, for example, SeaOr Marine Enterprises has established an intensive integrated mariculture farm that grows marine fish (gilthead seabream *Sparus aurata*), seaweed (*Ulva* and *Gracilaria*) and Japanese abalone (*Haliotis discus hannai*) (Neori et al. 2004).

Rainbow trout aquaculture can be integrated with irrigation systems for traditional agriculture to reduce its ecological impacts and water use. The increasing scarcity of freshwater may become a barrier to rainbow trout aquaculture in the future, as freshwater flow-through systems depend on a constant supply of clean, well-aerated water near the optimum growing temperature (Cowx 2006, Naylor et al. 2000). Integration of aquaculture and irrigation systems would reduce overall water usage (Moffitt 2003).

Feed production for steelhead and rainbow trout aquaculture is a concern for further development, yet it also presents opportunities through decreased use of fish meal and oil. Reduction in the proportion of fish meal and oil in feed is both ecologically and economically beneficial (Folke et al. 1998, Naylor et al. 2000). Feed represents the largest single production cost for aquaculture (Naylor et al. 2000). The increasing price of fish meal is an economic concern for aquaculture operations; decreasing the percentage of fish meal is thus a priority, as it will result in more stable prices and better product consistency, and much research has been devoted to alternate sources of protein (Cowx 2006, Moffitt 2003, Naylor et al. 2000, Papatryphon et al. 2004). However, despite projected reductions to 25% fish meal in trout feed by 2010, the inclusion of fish meal is still an order of magnitude higher than in poultry and swine feeds (Hardy 2001c in Moffitt 2003, Naylor et al. 2000). Because of this, the aquaculture industry still uses a large percentage of annual global fish meal production (32% in 2000) even though the conversion from fish feed to animal biomass is two to three times more efficient in fish than in poultry and swine (Moffitt 2003).

Concern about the long-term viability of farming carnivorous fish, with its dependence on fish protein derived from wild capture fisheries, is increasing pressure to shift towards production of herbivorous fish (Naylor et al. 2000). Despite reductions in the amount of fish meal and oil used in trout feed, the demand for fish meal by the aquaculture industry is growing rapidly, placing greater pressure on marine ecosystems and pelagic fish stocks (Moffitt 2003, Naylor et al. 2000). Herbivorous or omnivorous fish aquaculture, in contrast, does not rely on fish protein for its feed. It can also more easily be integrated into systems that use wastes from fisheries, households, and agriculture as feed; therefore, this sector has the greatest potential for expansion to meet human food demands (Cowx 2006, Folke et al. 1998, Naylor et al. 2000)

Continued growth of the steelhead and rainbow trout aquaculture industry will provide new, local employment opportunities. Aquaculture facilities are especially important in rural communities (DFO 2002a). Fisheries and Oceans Canada recognizes the opportunities for rural and coastal communities as a key feature in developing the Canadian aquaculture industry (DFO 2002a).

Increasing public awareness and concern about the ecological impacts of aquaculture practices presents an obstacle to continued expansion of steelhead farming (Government of Canada 2001). The use of net-pens in coastal waters has drawn considerable public attention and criticism, especially with publicity of escaped Atlantic salmon and sea lice spread to wild Pacific salmon stocks along the BC coast (Naylor et al. 2005). Management policies to effectively reduce or mitigate such risks will be necessary to improve the ecological sustainability of aquaculture and thus gain consumer confidence (Naylor et al. 2005).

The use of genetically-modified organisms (GMOs) in aquaculture will likely increase in the future, raising concerns about consumers' reactions and effects on fish, human, and ecosystem health. Vegetable sources of protein used in feeds, such as soy or canola meal, are often genetically modified and may raise concerns related to the indirect introduction of GMOs into fish products. Furthermore, the aquaculture industry is exploring possibilities of using genetic modification in broodstock and farm fish to increase production and/or minimize biological risks to wild populations (Cowx 2006, Lewis 2001). However, many questions, such as the possible interactions between escaped transgenic fish and wild stocks, remain; these must be answered before the sustainability of such techniques can be evaluated (Lewis 2001). Consumer wariness of GMOs in foods, due to potential human health effects, environmental impacts, and ethical concerns, also needs to be addressed (Lewis 2001).

Recommendations to UBC

Based on the sustainability analysis of UBC's consumption, the best alternative is rainbow trout farmed in freshwater flow-through systems. This includes all US-farmed rainbow trout and some rainbow trout from Canada. UBC should avoid any steelhead products, as well as rainbow trout raised in freshwater cages. In order to distinguish between rainbow trout products from freshwater cages and flow-through systems, UBC needs to work with its seafood suppliers to establish a chain of custody for steelhead and rainbow trout products.

UBC should attempt to support local aquaculture operations where possible, as this stimulates the local economy and also provides opportunities for employment in rural communities. Sun Valley Trout Farm in Mission, BC, one of the suppliers to Albion Fisheries, is a good, local option. However, the local industry may be too small to provide UBC with a consistent, year-round supply.

In addition, UBC should encourage the use of better effluent treatment methods and re-circulating systems for rainbow trout aquaculture. Re-circulating systems are completely closed and have no wastewater discharge, alleviating concerns related to water pollution and pathogen transmission. As such, they are a sustainable option for rainbow trout aquaculture. Although UBC food service providers purchase only small amounts of rainbow trout, their overall seafood consumption is large. Therefore, UBC has considerable lobbying power with its suppliers to promote more sustainable aquaculture practices.

Further research

There is little information available regarding steelhead aquaculture in marine net-pens and its associated conservation issues. The sustainability analysis in this report is based largely on similarities with Atlantic salmon farming; however, further research specific to the risks posed by steelhead aquaculture to the surrounding environment and wild fish populations is necessary in order to develop species-specific sustainability recommendations. Since steelhead aquaculture is increasing globally and steelhead is seen as a potential alternative to farmed Atlantic salmon, such an assessment is important even though this fish currently does not constitute a large portion of the seafood market.

Similarly, little research has been executed on the impacts of floating freshwater cages such as those used for rainbow trout culture in Canada. As with steelhead net-pens, additional information regarding ecological effects on the lake community and on native fish populations in adjacent streams is needed in order to more rigorously assess the sustainability of these practices. Fisheries and Oceans Canada is currently conducting a study of freshwater floating cage aquaculture in the Experimental Lakes Area near Kenora, Ontario, to determine effects on the lake environment and native species (Mactaggart 2006). This research will be instrumental in establishing regulations for floating freshwater farms (Mactaggart 2006).

With increasing concern regarding the ecological footprint of intensive monoculture operations, an important area for further research is the possibility of shifting to semi-intensive or extensive aquaculture or using integrated culture systems. Intensive monoculture practices such as floating net-pen or cage systems require an area more than 10,000 to 50,000 times greater than the area of the cages for food production and waste assimilation (Folke et al. 1998). The area required to sustain aquaculture operations decreases from intensive to extensive systems (Folke et al. 1998). Integration of steelhead and rainbow trout aquaculture with other processes provides significant opportunities to decrease its ecological impact (Chopin et al. 2001, Folke et al. 1998). For example, waste products from agriculture can be used in feeds for both rainbow trout and steelhead, and excess nutrients from steelhead aquaculture can be used to grow algae (Chopin et al. 2001, Folke et al. 1998). Expansion of integrated culture systems and extensive aquaculture methods would significantly reduce the conservation issues associated with steelhead and rainbow trout aquaculture. Integration of fish and algae aquaculture has been investigated in floating net-pen and land-based aquaculture systems in Canada, Chile, Norway, the USA, and Sweden, among others (Chopin et al. 2001). Further evaluation of the feasibility of these systems both globally and locally in BC is an important avenue for future research.

CONCLUSION

This study identified ambiguity of labeling of steelhead and rainbow trout products as a major concern. Because of confusion in the labeling of steelhead, which is a marine fish, and rainbow trout, a freshwater fish, traceability of these products is necessary for accurate sustainability analyses. Detailed research into the chain of custody of steelhead and rainbow trout purchased by UBC was required in order to determine the aquaculture methods used and evaluate their ecological sustainability. This analysis showed that rainbow trout produced in freshwater flow-through systems is the best alternative, although impacts on the surrounding environment can be reduced with improvements in effluent treatment methods. Steelhead are raised in marine net-pens and should be avoided due to risks associated with escaped fish, water pollution, and disease transfer to wild populations. Similarly, rainbow trout grown in freshwater cages should be avoided. UBC has the opportunity to improve the sustainability of rainbow trout production by encouraging its suppliers to adopt better effluent treatment methods or shift to re-circulating systems. An important possibility for steelhead aquaculture is its integration with seaweed production. Moreover, this report has identified several areas for additional research to improve the sustainability of steelhead and rainbow trout aquaculture.

ACKNOWLEDGEMENTS

This project could not have been completed without the assistance and support of the UBC Sustainable Seafood Project partners. Jade Barnaby was the project coordinator and organized meetings, provided direction for this project, and facilitated communication between the Sustainable Seafood Project partners. Fisher Scientific kindly provided funding for her position. Dr. Amanda Vincent gave valuable advice and feedback throughout the project and provided insight into fisheries and aquaculture. Office space was donated by Project Seahorse at the UBC Fisheries Centre. Brenda Sawada, manager of the SEEDS program at the UBC Campus Sustainability Office, helped to coordinate and facilitate communication between project partners, and provided insight into sustainability at UBC. Dr. Brent Skura from the Faculty of Land and Food Systems gave suggestions that helped direct research. The UBC food service providers were extremely cooperative and helpful; thank you to Nancy Toogood of AMS Food and Beverage, Andrew Parr, Dorothy Yip, and Piyush Sahay of UBC Food Services, and Sherry Geraghty of Green College for providing information on their purchasing practices and being open to making changes to improve the sustainability of seafood purchasing at UBC. The UBC food service providers' suppliers were also instrumental in providing information on their products and helping to trace the chain of custody of steelhead and rainbow trout products. Lee Donnelly and Mark Blouin at Albion Fisheries, Randy Phillips at Sysco Vancouver, Allan Li at Blundell Seafoods, Dean Foss at Wild West Steelhead, and Bernie Lehmann at Sun Valley Trout Farm all provided valuable assistance. Finally, Art Tautz, Eric Parkinson, and Tom Johnston from the BC Ministry of the Environment provided information on steelhead and rainbow trout in BC, while Mike Jones at the UBC Fisheries Centre helped to clarify the steelhead and rainbow trout labeling ambiguity.

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