Characteristics of current international trade of live salmonid eggs

M. JANSEN and R. McLEARY *

Summary: World trade in live salmonid embryos (eyed eggs) has grown in response to increased global salmon production, particularly in South America, and parallels international trade in farmed salmonid products. Rainbow trout (Oncorhynchus mykiss), Atlantic salmon (Salmo salar) and coho salmon (O. kisutch) are the most commercially important species. In 1992, the Food and Agriculture Organization of the United Nations estimated world production of rainbow trout at 300,000 tonnes, while the production of Atlantic salmon was estimated at 250,000 tonnes and coho salmon at 50,000 tonnes. One can estimate that roughly 3 billion, 150 million and 30 million eggs, respectively, were required to produce this yield. Broodstock are cultivated world-wide, using a wide variety of water sources, including the marine environment, riverine water containing anadromous fish, and ground water free of migrating fish. As many as 70% of all coho eggs are derived from feral fish. Approximately 50% of all commercial salmonid eyed eggs are produced in Europe, and approximately 15% are produced in the state of Washington, United States of America.

Conditions which are ideal for commercial salmonid grow-out are not necessarily ideal for the cultivation of salmonid broodstock; this is one reason why international egg trade is necessary. The trend of current salmonid health regulations is towards facilitating egg commerce on a regional level, in an attempt to control disease transmission. Regulations controlling egg importation often include pathogens which are not vertically transmitted. This serves only to increase egg prices, in compensation for the costs of laboratory tests.

Genetic improvements have been the cornerstone of increasing commercial production of all agricultural commodities. Fish health regulations are sometimes instituted in an effort to protect the local industry, but in fact they act more often to restrict the flow of genetic material and may actually serve to reduce industry productivity and profitability.

KEYWORDS: International trade – Live salmonid eggs – Salmonids.

INTRODUCTION

World trade in live, fertilized salmonid embryos (eyed eggs) has increased in recent years, primarily in response to increased global production of harvestable product. Traditional sources of eggs are private farms or other local sources, e.g. government resource enhancement facilities. Production efficiency may be improved by obtaining

* Troutlodge, Inc., P.O. Box 1290, Sumner, WA 98390, United States of America.
seedstock of proven performance potential and uniformity throughout the year. This economic incentive is further enhanced by the corresponding decrease in the cost of farm labour required to care for broodstock and incubating eggs.

GLOBAL FARMED SALMONID PRODUCTION

Although many species of salmonids are raised world-wide, the three most commercially important farmed species are rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo salar*) and coho salmon (*O. kisutch*). The Food and Agriculture Organization of the United Nations (FAO) estimated global production of rainbow trout in 1992 at 300,000 tonnes, while the production of Atlantic salmon was estimated at 250,000 tonnes and coho salmon at 50,000 tonnes (8). Global production by species in 1986 and 1992 is shown in Table I. There has been a dramatic increase in the volume of production for all three species.

Table I


<table>
<thead>
<tr>
<th>Continent</th>
<th>Rainbow trout</th>
<th>Atlantic salmon</th>
<th>Coho salmon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>787</td>
<td>1,332</td>
<td>-</td>
</tr>
<tr>
<td>Asia</td>
<td>20,005</td>
<td>19,894</td>
<td>-</td>
</tr>
<tr>
<td>Australia</td>
<td>570</td>
<td>1,914</td>
<td>10</td>
</tr>
<tr>
<td>Europe</td>
<td>151,904</td>
<td>219,191</td>
<td>59,123</td>
</tr>
<tr>
<td>North America</td>
<td>30,925</td>
<td>33,758</td>
<td>700</td>
</tr>
<tr>
<td>South America</td>
<td>2,428</td>
<td>21,802</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>206,619</td>
<td>297,891</td>
<td>59,833</td>
</tr>
</tbody>
</table>

Rainbow trout

Rainbow trout are raised in both freshwater and salt water facilities. In general, freshwater production is geared towards the portion-sized market (200-350 g). A larger fish is harvested from salt water. Seven countries – namely France, Italy, Germany, Denmark, Spain, the United States of America (Idaho) and Chile – accounted for 65% of world production in 1992 (Table II). Approximately three-quarters of rainbow trout are cultured in Europe (Table I). The majority of fish reared in Europe are harvested for the portion-sized market. It is estimated that production in France, Italy and Spain will increase by at least 10%, as a result of improved husbandry (improved nutrition, use of injected oxygen, and disease prophylaxis via the use of vaccines), rather than through site expansion. Declines in Danish and German production are primarily due to restrictions on water use in these countries. Another possible source of growth is Eastern Europe. In the early 1980s, there was an increase in trout production in the
**TABLE II**

*Industry trends for farmed rainbow trout (Oncorhynchus mykiss)*

*in the principal producing countries*

Figures are rounded to nearest 1,000 tonnes; numbers in brackets correspond to the references (where no reference is given, 1994 figures have been estimated by the authors)

<table>
<thead>
<tr>
<th>Continent</th>
<th>Location</th>
<th>1986 (8)</th>
<th>1992 (8)</th>
<th>1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>Denmark</td>
<td>24,000</td>
<td>41,000</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>29,000</td>
<td>41,000</td>
<td>50,000</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>21,000</td>
<td>26,000</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>Italy</td>
<td>25,000</td>
<td>35,000</td>
<td>42,000 (1)</td>
</tr>
<tr>
<td></td>
<td>Spain</td>
<td>14,000</td>
<td>18,000</td>
<td>22,000</td>
</tr>
<tr>
<td>North America</td>
<td>Idaho</td>
<td>20,000</td>
<td>20,000</td>
<td>20,000 *</td>
</tr>
<tr>
<td>South America</td>
<td>Chile</td>
<td>1,000</td>
<td>16,000</td>
<td>23,000 (13)</td>
</tr>
<tr>
<td>World total**</td>
<td></td>
<td>200,000</td>
<td>300,000</td>
<td>350,000</td>
</tr>
</tbody>
</table>

* E. Brannon, personal communication

** these figures are not the sum of the above values, due to production from other countries and/or rounding-up errors

former Soviet bloc. Salmonid aquaculture has been reduced in this area, however, due to scarcity of hard currency to purchase eggs, feed, etc.

The North American industry is also geared towards the portion-sized market, and two-thirds of the fish are raised in the state of Idaho (14). The trout industry has been rather static in North America over the past few years, as environmental issues have restricted the use of available water resources. Only marginal increases are expected in the future, reflecting slow expansion mainly in the Canadian industry.

There has been a remarkable increase in rainbow trout culture in Chile, which accounts for almost three-quarters of production in South America. Many of these fish are raised in sea cages, are pigmented, and are harvested at 3.0 kg to substitute for wild sockeye (or kokanee) salmon (*O. nerka*) on the Japanese market (12). The rainbow trout harvest in Chile was expected to reach 25,000 tonnes in 1995 (13).

**Atlantic salmon**

Industry trends for the largest Atlantic salmon producers are illustrated in Table III. In 1993, 98.6 percent of Atlantic salmon (valued at US$ 1.2 billion) consumed were farm-raised (8).

More than half of the world production of farmed salmon is cultured in Norway, where the industry began. Salmon culture has experienced considerable growth in both Ireland and the Faeroe Islands over the past eight years. Scottish and Norwegian production was expected to increase in 1994, mirroring an increase in the survival of fish from egg to harvest, due to improved fish health management. Development and utilization of effective *Hitra* and *furunculosis* vaccines, separation of age classes, and
TABLE III

Industry trends for principal countries producing farmed Atlantic salmon (Salmo salar)

Figures over 10,000 tonnes are rounded to the nearest 1,000 tonnes; numbers in brackets correspond to the references

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>Norway</td>
<td>–</td>
<td>127,000</td>
<td>210,000 (20)</td>
</tr>
<tr>
<td></td>
<td>Scotland</td>
<td>10,000</td>
<td>36,000</td>
<td>64,000 (5)</td>
</tr>
<tr>
<td></td>
<td>Faeroe Islands</td>
<td>1,400</td>
<td>18,000</td>
<td>15,000</td>
</tr>
<tr>
<td></td>
<td>Ireland</td>
<td>1,200</td>
<td>10,000</td>
<td>14,000</td>
</tr>
<tr>
<td>North America</td>
<td>Canada</td>
<td>600</td>
<td>10,000</td>
<td>23,000 (15)</td>
</tr>
<tr>
<td></td>
<td>United States</td>
<td>8</td>
<td>10,000</td>
<td>12,000 (15)</td>
</tr>
<tr>
<td>South America</td>
<td>Chile</td>
<td>0</td>
<td>24,000</td>
<td>26,000 (13)</td>
</tr>
<tr>
<td>World total*</td>
<td></td>
<td>60,000</td>
<td>240,000</td>
<td>360,000 (3)</td>
</tr>
</tbody>
</table>

* these figures are not the sum of the above values, due to production from other countries and/or rounding-up errors

fallowing of sites have contributed to a rise in production to a greater extent than the increase in smolt entry (4).

In 1986, virtually all North American Atlantic salmon were raised in Canada. In 1992, production was divided between the United States of America (USA) and Canada, and between the East and West coasts of North America. Much of the increased harvest over the eight-year period was due to the replacement of chinook (or Pacific) salmon (O. tshawytscha) and coho salmon with Atlantic salmon in the net pens of British Columbia, rather than through industry expansion. Due to various concerns related to land use and other environmental issues, Atlantic salmon production is not expected to increase substantially in North America (15).

Chile has become firmly established as a high-quality, low-cost producer of salmon and trout. The low costs result from cheap labour and the local availability of low-cost fish meal. In addition, growing conditions are ideal. As in other sectors of the Chilean aquaculture industry, the only real constraint on further expansion of the Atlantic salmon industry is the condition of the market for the harvestable product (17).

Coho salmon

Japan and Chile account for 98% of the world production of farmed coho salmon (Table IV), and Japan is the most important consumer of this species of fish. Since 1992, Japanese production has declined due to poor climatic conditions. The 1995 Japanese harvest was predicted to be 14,000 tonnes (P. Heggelund, personal communication). Rickettsial disease has limited coho production in Chile (12). No substantial expansion in the world production of this species is anticipated over the next few years.
TABLE IV
Industry trends for the principal producers of farmed coho salmon
(Oncorhynchus kisutch)
Figures are rounded to the nearest 1,000 tonnes; numbers in brackets correspond to the references

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>1,000</td>
<td>22,000</td>
<td>25,000  (13)</td>
</tr>
<tr>
<td>Japan</td>
<td>8,000</td>
<td>26,000</td>
<td>20,000 *</td>
</tr>
<tr>
<td>World total*</td>
<td>10,000</td>
<td>48,000</td>
<td>46,000 *</td>
</tr>
</tbody>
</table>

* P. Heggelund, personal communication
** these figures are not the sum of the above values, due to production from other countries and/or rounding-up errors

CHARACTERISTICS OF THE PRODUCT

In many senses, salmonid seedstock are not very different from the seedstock of other livestock industries, but some salient differences do exist. One is that the product is perishable and once processed for shipping, it has a shelf life of only a few days. Unlike poultry eggs, salmonid eggs must arrive in the same condition as they were when packed. If the eggs hatch in transit, the product is no longer viable as it is shipped on ice and not in water.

From a commercial standpoint, the most important feature of this industry is that, although most orders are confirmed at least one week prior to shipping, approximately 25% of orders are confirmed, placed or delayed — or order size is changed — on the evening prior to shipping. Uncertainty is thus a permanent feature of this trade (2), since the arrival of eggs is usually dependent on some climatic occurrence, such as the presence or absence of rainfall and/or a change in temperature. Very often, a new order is filled using eggs from a delayed order. For this reason, it is a constraint on the egg producer and the receiving farmer to state the number of eggs on a health certificate or other document which must be pre-endorsed prior to the day of shipment. Small changes in the number of eggs actually shipped require that the health certificate be re-endorsed, while the actual health status of the product is, of course, unchanged. Shipment size is best stated on the bill of lading or on some other separate document.

CHARACTERISTICS OF THE WORLD EYED-EGG MARKET

Unlike rainbow trout and Atlantic salmon, the eggs of which are virtually all obtained from domesticated stocks, as many as 70% of farmed coho salmon eggs are derived from feral fish. Approximately half of the world-wide production of salmonid eggs occurs in Europe. Roughly 15% of all commercial salmonid eggs are produced in the state of Washington. One can estimate that roughly 3 billion (6), 150 million and
30 million eggs, respectively, were required to produce this yield. It is estimated that purchasing eggs represents between 1% and 5% of production costs (E. Brannon, personal communication). Although global production is expected to increase, the egg market is expected to increase less rapidly. Fish are being harvested at a larger market size and management practices have favoured fish survival; thus, less eggs are required to produce a marketable product.

One distinctive feature of the salmonid egg industry – as opposed to the production of other fish eggs – is the amount of regulatory attention ‘enjoyed’ by salmonids. In fact, many of the current world regulations are aimed at facilitating egg commerce on a regional level, thereby reducing international transport and distribution in an attempt to control disease transmission. This is unfortunate and displays a lack of understanding regarding the dynamics of international trade in these unique live products. Some reasons for supporting international trade are given below.

**LACK OF ENVIRONMENTAL CONDITIONS**

Conditions which are ideal for grow-out do not necessarily favour the cultivation of broodstock, and some regions are not suited for egg production, e.g. Southern Europe, southern Idaho, parts of Asia and parts of South America. These regions therefore rely on imported eggs. Many of these areas import heavily from the Pacific northwest of North America. Interestingly, the state of Washington is within the native geographical range of both rainbow trout and chinook salmon (11), and is thus optimal for broodstock culture.

**HEALTH CONCERNS**

Broodstock are cultivated world-wide using a wide variety of water sources (10) which include sea water, surface water containing anadromous fish, and ground water which is free of migrating fish. As previously stated, the majority of coho eggs are spawned from wild fish. Many producers seek to obtain eggs from isolated and controlled water sources, in order to decrease the possibility of disease transmission. One such source is the Pacific northwest, where private egg hatcheries are supplied by first-use spring water or well-water.

**INCREASED FARMING PRODUCTIVITY**

Probably the most important reason for supporting international trade is that this may lead to increased productivity. As the salmonid industry matures and becomes more competitive, the need to increase efficiency is paramount. Broodfish are typically cultured at low densities. This reduces production capacity which could be utilised to rear fish for food.

**Year-round egg availability**

In nature, salmonids are seasonal spawners. The trend on farms is towards reducing the seasonality of eyed egg availability, by making marketable fish available.
throughout the year. This has been achieved for rainbow trout by some broodstock producers. The period of egg availability is being expanded through genetic selection, manipulation of the photoperiod ('day': 'night' ratio) for broodstock, and temperature manipulation of the eggs (for coho and Atlantic salmon). Another method of decreasing the seasonality of egg availability is by obtaining eggs from the opposite hemisphere during the off season.

**Genetic manipulation**

There is great interest in suppressing sexual maturation of marketable rainbow trout as a means of reducing the number of precocious males and also to aid the production of larger market fish (> 400 g). The demand for late-maturing strains, and for triploid and all-female rainbow trout eggs, has been steadily increasing over the past five years. In addition, limited amounts of all-female and all-female triploid Atlantic salmon eggs are available commercially. The commercial demand for late-maturing, all-female or all-female triploid eggs has been directed partly towards ameliorating the grilse (early maturation) problem and — perhaps even more significantly — by environmental concerns, including genetic interactions of farmed and wild fish.

**Obtaining uniform seedstock**

Production efficiency can be enhanced by ensuring uniformity and predictability of the product. Many large farms require the acquisition of more than one million eggs per month to sustain year-round production. This goal is better served by acquiring eggs from a known source which houses a large amount of related broodstock which are spawned on the same day and incubated at the same temperature, rather than from co-operative sources supplied by pooled eggs from a number of smaller farms.

**Genetic improvements**

Probably the most important feature in increasing productivity is the use of genetic improvements. Some attention has been paid recently to the development of disease-resistant strains (16), but most selection is centered around growth and related performance criteria. The results of a selection programme can be significant. For example, the Norwegian National Breeding Programme for rainbow trout reported an annual growth increase of 4.3% in genetically-selected rainbow trout (9). Genetic improvements are progressive, and the progeny of selected broodstock spawned in 1986 will therefore lag behind those taken from the same programme in 1990. For this reason, it is difficult to understand the rationale of some countries (Australia and certain Canadian provinces) which have allowed or continue to allow the importation of foreign eggs in only small quantities and for a limited time period. Industries in these countries thus fail to benefit from continual genetic advances.

The development of broodstock programmes requires large amounts of broodstock, special equipment and facilities (photoperiod control buildings, chillers, pressure vessels, access to methyl testosterone), increased expertise and the presence of designated, educated personnel. The economic health of the salmonid industry is best served by maintaining a small number of large farms (10). This parallels the situation in other livestock industries.
INDUSTRY CODES OF PRACTICE

In promoting the sustainability and growth of the salmonid industry, the risk of transmission of diseases must be minimized, without restricting the access of the industry to quality seedstock. One should be reminded that screening for pathogens often requires lethal sampling, is costly, and adds substantially to the price of the product. To enhance this important trade, the following observations and suggestions have been made:

a) Farmed fish and their products, such as eyed eggs, should be recognized as an agricultural commodity and not as a wild resource.

b) Eggs should be governed by a separate code of practice, distinct from those used for live fish. Attention should focus only on vertically-transmitted diseases of economic importance, particularly those for which no treatment is available.

c) Regulations should not include local endemic diseases.

d) Regulations should not be a form of non-tariff trade barriers, e.g. situations where the health standards for the imported product are more stringent than those for the national product, or where slight differences in laboratory methodology (without any difference in sensitivity or specificity) are used by the importing country to disqualify the results of testing performed in the exporting country.

e) Technology dictates that the identification of potential new pathogens will precede both the evaluation of their pathogenicity and the development of effective methods of treatment and control. Sanctions should not be introduced on a presumptive basis, and should only be used if there is scientific justification and if the economic consequences of such actions have been considered. For example, infectious pancreatic necrosis (IPN) is endemic in most of Europe and can be transmitted both vertically and horizontally. Recent advances in serotyping have enabled the fish health community to institute more effective preventive measures. For example, Spanish farmers who import salmonid eggs from North America have been able to trace clinical outbreaks on their farms to a virus strain of European rather than North American origin (18). The farmer can then concentrate on controlling horizontal transmission to prevent clinical disease, rather than focus on restricting egg imports, as vertical transmission does not seem to be an issue in this instance. After considering the scientific data, the European Union has chosen not to include IPN in either of its lists of ‘certifiable’ diseases.

f) The economic consequences of any pathogen should be considered prior to instituting regulations. For example, in the USA, far more fish have died as a consequence of whirling disease regulations than will probably ever succumb to the disease itself.

g) Determining and monitoring the specific pathogen-free status of the farm (i.e. health history, water source and management practices) is a more practical and cost-effective means of establishing risk of disease transmission than surveying an entire geographical zone.

h) Alternative forms of fish health management (e.g. improved husbandry, vaccination and rearing of resistant strains of fish) should also be used to prevent clinical disease. As an example, improved husbandry has led to a decrease in the prevalence of bacterial kidney disease despite the ubiquitous distribution of the causative agent, *Renibacterium salmoninarum* (19). For this reason, *R. salmoninarum* has been dropped from lists of ‘certifiable’ diseases in import regulations in the USA and Canada.
CONCLUSION

In conclusion, it should be remembered that genetic improvements have been the cornerstone of increases in the commercial production and profitability of all agricultural commodities. Although fish health regulations have sometimes been instituted in an effort to protect the industry, they more frequently act to restrict the flow of genetic material and actually serve to reduce the efficiency and profitability of the industry. Although clinical disease can decrease the profitability and productivity of the industry, it is not the only factor. In fact, clinical health is really only one element of a more important consideration, the economic health of the fish. The authors take exception to the view that the only safe fish to import is a dead fish (7), favouring a more balanced approach – as outlined above – towards regulations governing international commerce in eyed eggs, and thereby promoting the economic health of the industry.

ACKNOWLEDGEMENTS

The authors would like to thank J. Lindbergh, P. Heggelund and Dr R. Middleton for critically reviewing this manuscript.
Les améliorations génétiques ont été la pierre angulaire de l’accroissement de la production commerciale de toutes les denrées agricoles. Les réglementations sanitaires appliquées aux poissons, parfois mises en place pour protéger l’industrie locale, restreignent souvent les échanges de matériel génétique et peuvent, en fait, réduire la productivité et la rentabilité de ce secteur.

MOTS-CLÉS : Commerce international – Œufs de salmonidés vivants – Salmonidés.

* * *

CARACTERÍSTICAS ACTUALES DEL COMERCIO INTERNACIONAL DE HUEVOS VIVOS DE SALMÓNIDO. – M. Jansen y R. McLeary.

Resumen: El comercio internacional de huevos embrionados vivos de salmónido ha crecido en respuesta a la mayor producción global de salmones, especialmente en Sudamérica, y corre parejo al mayor comercio internacional de salmónidos de vivero. La trucha arco iris (Oncorhynchus mykiss), el salmón del Atlántico (Salmo salar) y el salmón coho (O. kisutch) son las especies más importantes desde un punto de vista comercial. En 1992, la Organización de las Naciones Unidas para la Agricultura y la Alimentación estimó la producción mundial de trucha arco iris en 300.000 toneladas métricas (tm), la de salmón del Atlántico en 250.000 tm y la de salmón coho en 50.000 tm; cabe estimar que se requirieron alrededor de 3.000 millones, 150 millones y 30 millones de huevos respectivamente para obtener una tal producción. La cría de estas especies se practica en el mundo entero, con utilización de una gran diversidad de tipos de agua (desde un entorno marino hasta aguas de origen fluvial con presencia de peces anádromos, pasando por aguas subterráneas libres de peces migratorios). Hasta un 70% del total de huevos de coho derivan de individuos salvajes. Un 50% de todos los huevos embrionados de salmónido que se comercializan han sido producidos en Europa, y aproximadamente un 15% en el estado de Washington, Estados Unidos de América.

Las condiciones idóneas para la producción comercial de salmónidos adultos no son necesariamente las mismas que se requieren en los criaderos. Esta es una de las razones por las que es necesario el comercio internacional de huevos. Hoy en día, las regulaciones sanitarias relativas a los salmónidos tienden a privilegiar el comercio a nivel regional, en un intento por limitar la transmisión de enfermedades. Las normativas que se aplican a la importación de huevos suelen incluir a los patógenos cuya transmisión no es vertical. Ello redunda tan sólo en un aumento del precio de los huevos en compensación por el coste de las pruebas de laboratorio.

La mejora genética ha constituido la piedra angular de la creciente producción comercial de todos los productos agrícolas. Las normas sanitarias relativas a los peces se dictan a veces con el objetivo de proteger a la industria local; sin embargo, actúan a menudo como un freno al flujo de material genético y, en realidad, tal vez provoquen una reducción de la productividad y la rentabilidad del sector.

PALABRAS CLAVE: Comercio internacional – Huevos vivos de salmónido – Salmónidos.
REFERENCES