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THE SALMON AQUACULTURE INDUSTRY IN THE MARITIME PROVINCES

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Abstract

The salmon farming industry of the Maritime Provinces began in the late 1970s when 6 t of Atlantic salmon were produced by a research project located near Deer Island, New Brunswick. In 1998, about 8.6 million smolts for aquaculture were produced by 31 freshwater hatcheries in the Maritimes. In New Brunswick, only St. John River stock salmon are allowed in aquaculture, while in Nova Scotia the industry uses mostly St. John River stock, plus some local stocks. Growout takes place in floating net cages located in protected, nearshore marine sites. Harvested production in the Maritimes in 1997 was estimated at 19,700 t, worth $145 million. Ninety-four percent of this production was from 80 marine sites in southwestern New Brunswick and the remaining 6% was from 11 marine sites in Nova Scotia. In 1998, in response to an outbreak of the viral disease Infectious Salmon Anemia (ISA) in southwestern New Brunswick, several growout sites were completely harvested and fallowed, while some new sites were approved in order to accommodate the 1998 hatchery-produced smolts that were to have been transferred to the fallowed sites. There is a lack of good data on the numbers and causes of escapes from salmon cages. Various federal and provincial laws have relevance to aquaculture, most notably the federal Fisheries and Oceans Acts, the New Brunswick Aquaculture Act, and the Nova Scotia Fisheries and Coastal Resources Act. Memoranda of Understanding on aquaculture development have been signed between Canada and New Brunswick and Nova Scotia. These give these provinces the right to issue and administer licenses and leases for aquaculture operations within their boundaries. The federal government continues its role in monitoring, diagnosis, prevention, and control of fish diseases in cultured and wild stocks.

Résumé

C'est au début des années 1970 que l'industrie salmonicole a débuté dans les provinces maritimes, lorsque 6 t de saumon de l'Atlantique ont été produites dans le cadre d'un projet de recherche mené aux environs de Dear Island, au Nouveau-Brunswick. En 1998, 31 piscicultures des Maritimes on produit quelque 8,6 millions de saumoneaux pour l'aquaculture. Au Nouveau Brunswick, le seul stock de saumon autorisé à cette fin est celui de la rivière St. John. Il constitue également la source principale pour l'industrie salmonicole de la Nouvelle-Écosse, qui a recours, en plus, à des stocks locaux. L'engraissement se déroule dans des cages flottantes en filet, disposées dans des zones marines côtières protégées. La récolte de 1997 pour les Maritimes a été estimée à 19 700 t, et sa valeur, à 145 M$. De cette production marine, 94% provenait de 80 élevages au sud ouest du Nouveau-Brunswick, et l'autre 6%, de 11 élevages en Nouvelle-Écosse. À la suite d'un accès d'anémie infectieuse du saumon (AIS), qui a frappé plusieurs emplacements aquacoles marins au sud-ouest du Nouveau-Brunswick, une récolte complète a été effectuée suivie de la suspension des activités d'engraissement dans ces lieux. La production de saumoneaux de 1998 qui devait y être acheminée sera accueillie plutôt dans de nouveaux emplacements approuvés à cette fin. Il y a un manque de données fiables sur le nombre et les causes d'évasions de poissons d'élevage. Un certain nombre de lois fédérales et provinciales régissent l'aquaculture, dont les principales sont les lois du ministère des Pêches et des Océans, la *Loi sur l'aquaculture* du Nouveau-Brunswick et la *Fisheries and Coastal Ressources Act* de la Nouvelle-Écosse. De plus, le Canada, le Nouveau-Brunswick et la Nouvelle-Écosse ont signé des protocoles d'entente sur le développement de l'aquaculture. Ceux-ci autorisent les provinces à délivrer et à administrer les permis et les baux relatifs aux activités aquacoles qui se déroulent à l'intérieur de leurs limites territoriales. Le gouvernement fédéral continue pour sa part d'assumer la responsabilité de surveillance, de diagnostique, da prévention et de la lutte contre les maladies des stocks de poissons d'élevage et sauvages.

Introduction

Farming of Atlantic salmon (*Salmo salar*) in floating sea cages began in Norway in 1969. Preliminary research in the Maritimes suggested that winter water temperatures were too cold for this type of salmon aquaculture. However, a research project begun in 1978 involving Fisheries and Oceans Canada, the New Brunswick Department of Fisheries, and a private company, Marine Research Associates, showed that commercial salmon farming was feasible in southwestern New Brunswick (Sutterlin *et al.* 1991). This research project, conducted at Lords Cove, Deer Island, produced the first harvest of farmed salmon in Atlantic Canada: 6 t in 1979. A comprehensive review of the development of the Atlantic salmon aquaculture industry in the Maritime Provinces up to 1993 can be found in Saunders (1995).

Current Aquaculture Production in the Maritimes

The salmon aquaculture industry in the Maritimes currently includes 31 freshwater hatcheries (Fig. 1) and over 90 marine growout sites (Fig. 2). The 1997 harvest was estimated as 19,700 t, worth $145 million. While the volume of farmed salmon is relatively small in comparison to harvest fisheries landings, in terms of value, farmed salmon has become one of the most important fisheries industries in the Maritime Provinces (Table 1). In New Brunswick, the value of farmed salmon production is almost equal to the value of all harvest fisheries landings.

In 1997, southwestern New Brunswick produced 94% (18,600 t) of the total farmed Atlantic salmon harvest in the Maritimes, at 80 marine growout sites, plus 5 brackish water sites for smolt acclimation, occupying a total of approximately 900 ha (data from New Brunswick Department of Fisheries and Aquaculture). Nova Scotia produced the remaining 6% (1,100 t) of farmed salmon at 11 marine growout sites (data from Nova Scotia Department of Fisheries and Aquaculture). There are currently no marine salmon growout sites on Prince Edward Island.

Newfoundland produced 610 t of farmed Atlantic salmon in 1997, all from Bay d'Espoir (data from Fisheries and Oceans Canada). British Columbia, which is currently the largest producer of farmed Atlantic salmon in Canada (Fig. 3), produced 30,800 t in 1997 (data from British Columbia Ministry of Fisheries). While salmon farming has become extremely important to the economy in the Maritimes, the total east coast production represents only 3% of the total world production of farmed salmon (Fig. 4).

Baum (1998) reports that Maine produced 12,140 t of farmed Atlantic salmon in 1997. Most of the Maine production sites are located near the New Brunswick border (Fig. 2).

Life Cycles of Wild and Farmed Salmon

The typical life cycle of wild Atlantic salmon consists of a freshwater stage lasting generally 2 to 3 years in rivers and streams, followed by one to 3 years of growout at sea (Fig. 5). The age of wild adult salmon returning to rivers in the Maritimes is generally 4 to 6 years (Saunders 1995). In salmon farming, the freshwater stages generally occur in hatcheries, while the marine growout takes place in floating net cages located in nearshore marine sites. Under culture conditions, market size (usually 3.5-4.5 kg) can be achieved in less than 3 years after hatching (Fig. 5). See Saunders (1995) for details on the life cycle of farmed salmon.

Hatchery Smolt Production

Saunders (1995) described the main requirements for hatchery sites:

- continuous supply of surface or groundwater at appropriate volume (some recirculation may be used)
- high water quality
- suitable water temperature (6-10°C for incubation, 14-18°C for juvenile growth); heating or cooling may be required, but is costly
- absence of disease organisms
- availability of land for building the hatchery facility
- proximity to marine growout sites

In the early years of salmon farming, the main supplier of smolts was the Mactaquac hatchery (operated by Fisheries and Oceans Canada), whose main purpose was to produce juveniles for enhancement of the St. John River salmon run. Only juveniles considered surplus to the enhancement function were allocated for aquaculture. The limited supply of smolts restricted the early development of the salmon farming industry in the Maritimes (Saunders 1995).

Private hatcheries for aquaculture began operating in New Brunswick in the mid-1980s. There are now 31 hatcheries in the Maritimes, producing about 8.6 million Atlantic salmon smolts for the aquaculture industry (estimates from New Brunswick Department of Fisheries and Aquaculture and Nova Scotia Department of Fisheries and Aquaculture). These include 23 hatcheries in New Brunswick (producing about 7.1 million smolts) and 6 in Nova Scotia (producing about 1.5 million smolts). There is also one hatchery on Prince Edward Island which produces eggs and fry for growout to smolt stage at other hatcheries. In some years, smolts have been transferred from hatcheries in Maine for growout in the Maritimes and some smolts produced in hatcheries in the Maritimes have been sent to Maine for growout. There are 5 salmon aquaculture hatcheries in Maine and one in New Hampshire (Baum 1998; J. McGonigle, personal communication).

Lake rearing of juveniles in cages is practised in other salmon growing areas such as Scotland, Norway, Chile, and British Columbia, but is not practised in the Maritimes, due to unsuitable thermal conditions (Saunders 1995). However, there is some smolt production in small, man-made ponds near Minto, in south-central New Brunswick (B. Glebe, personal communication).

There are also a few brackish water sites which have been used for smolt acclimation (see Fig. 8 and 9).

Initially, most smolts produced in hatcheries were 2+ smolts. As a result of research on the manipulation of temperature and photoperiod in hatcheries, most smolts produced in the Maritimes for aquaculture are now 1+ smolts (14-16 months after hatching), less than 5% are 2+ smolts, and about 10% are 0+ fall smolts which can be put into sea cages in November or December of their first year (S. McGeachy, personal communication).

All salmon hatcheries producing for the salmon farming industry in New Brunswick are using salmon of St. John River stock origin (R. Henry, personal communication). Nova Scotia hatcheries also are using mostly St. John River stock, as well as some local Nova Scotia stocks such as the LaHave River and River Philip (J. Ritter, personal communication). A selection and breeding program, the Salmon Genetics Research Program (now called the Atlantic Salmon Broodstock Development Program), located near St. Andrews, has produced strains with traits better suited for aquaculture than the original St. John River stock (Friars *et al.* 1997; Glebe 1998). The local salmon farming industry has requested the importation of the Landcatch strain, which is of Norwegian origin, because the industry believes that the use of this and other non-indigenous strains could improve yields. Some scientists argue, however, that indigenous strains should be better adapted to local conditions (Saunders 1995). The Landcatch strain is one of three stocks currently being used in sea cages in adjacent waters of Maine, the others being Penobscot River and St. John River stocks (Baum 1998). Current legislation restricts importations of smolt from Maine into New Brunswick to smolts of St. John River origin (R. Henry, personal communication). It should be noted that protocols adopted by the North American Commission (which includes both Canada and the United States) of the North Atlantic Salmon Conservation Organization (NASCO) do not permit the use of reproductively viable European strains in western Atlantic waters (Porter *et al.* 1998). However, these protocols are not legally binding and the use of Landcatch salmon in Maine waters indicates that the protocols have not been implemented in a consistent manner.

Marine Growout

Saunders (1995) and Hill (1992) described the main requirements for suitable marine growout sites for Atlantic salmon:

- protection from rough water and weather conditions
- minimum water temperature -0.7 to -0.8°C; maximum 16°C
- adequate water exchange to maintain dissolved oxygen levels and remove wastes
- high salinity
- adequate depth
- absence of flow ice

In the Maritimes, these requirements are best met in southwestern New Brunswick, near the mouth of the Bay of Fundy (Saunders 1995). In addition to the above conditions, the site allocation process must take into account possible conflicts with navigation, wharves, traditional fisheries, other aquaculture operations, and other activities. In New Brunswick there is a minimum 300 m separation distance between adjacent aquaculture sites, lobster pounds, herring weirs and wharves.

Smolts transferred to sea cages can attain market size in 16 to 24 months. However, the marine growout period may be extended to 2.5 years or more, for marketing reasons.

Preliminary analyses from a study of 20 salmon farms in southwestern New Brunswick from 1995 to 1997 indicate that the average mortality rates in sea cages (from the time of smolt transfer into cages until harvest) are 10 to 15% (R.H. Peterson, personal communication). However, mortality rates at some growout sites in New Brunswick have been elevated in recent years, due to an outbreak of the viral disease Infectious Salmon Anemia (ISA) which began in late summer 1996.

Smolts are grown out to market size in sea cage systems, consisting of floating collars, bag-shaped net pens for holding fish, and mooring systems consisting of anchors, floats, and lines. Most sites also use predator nets to prevent attacks by seals, otters, mink, and birds. At some sites, the Canadian Coast Guard may require navigation aids. Table 2 provides information on some of the common cage types that have been used in the Maritimes. Because there is such a wide range of cage volumes, the number of cages on a site does not provide an accurate indication of the number of fish on the site.

The most common cages used in the early years of salmon farming in the Maritimes had wooden octagonal collars (Malloch cages); these were a modification of a common cage type then in use in Norway (Saunders 1995). Later, cages with steel square collars became more common. Some sites continue to use octagonal and square cages, but the trend now is toward using larger cages with plastic circular collars. It is estimated that about 50% of the cages now in use in New Brunswick have 70 m circumference plastic circular collars (B. Hill, personal communication). Some newer cage designs have been developed to withstand more severe conditions and thus may allow siting of fish farms in more exposed or offshore locations.

The octagonal and square cages are usually moored in clusters of connected cages. Initially, the plastic circular cages were also moored in clusters, but the larger plastic cages are now usually moored with a separation of several metres between cages.

Up until recently, most marine growout sites stocked smolts every year. This meant that most sites would have 2, and often 3, year classes simultaneously. Recently, however, outbreaks of sea lice and ISA have led to increasing use of single year class sites, with fallowing of sites between harvesting of one year class and the next stocking of smolts. It is believed that these husbandry practices are important for the management and control of diseases and parasites and they are widely practised in other salmon growing areas (Stewart 1998).

Increased separation between sites has also been suggested as a way of controlling disease and parasite outbreaks. Other salmon growing areas generally use separation distances of 1-3 km between sites (as compared to 300 m in New Brunswick), but there is no evidence that these greater separation distances are effective barriers against disease and parasite outbreaks (Stewart 1998).

The Development of Salmon Farming in the Maritime Provinces

The first harvest of farmed salmon in southwestern New Brunswick was 6 t from one site in 1979. As shown in Fig. 6, the production in New Brunswick has steadily grown over the past 20 years, reaching an estimated 18,600 t in 1997. This growth has resulted from an increase in the number of growout sites (to 80 sites in 1997) and from increased average production at each site (Fig. 7). The sizes of marine growout sites in New Brunswick now range from 60,000 to 340,000 fish permitted on site at any one time (information provided by the New Brunswick Department of Fisheries and Aquaculture).

Fig. 8 shows how the industry in New Brunswick has spread since its inception. The first site, at Lords Cove, Deer Island, began operating in 1978. The second site was established in Dark Harbour, Grand Manan Island in 1980. By 1985, the industry had become centred in the Lime Kiln Bay/Bliss Harbour area, with additional sites off Deer and Campobello Islands. In the 1990s, new sites were permitted in these areas and also in Passamaquoddy Bay and off Grand Manan Island. In addition, site expansions were permitted at most of the existing sites.

The locations of marine salmon farm sites in southwestern New Brunswick in 1998 are shown in Fig. 9. As a result of the outbreak of ISA, the provincial government ordered total harvesting by June 1998 of all 21 growout sites in the 3 bays which were initially affected: Lime Kiln Bay, Bliss Harbour, and Seal Cove (Grand Manan Island). These bays will be fallowed until spring 1999, when smolts will again be stocked, although there will probably be fewer sites and fewer total fish than previously. As a result of the detection of ISA in Back Bay in early 1998, it was determined that no 1998 smolts would be stocked in the 7 sites in this bay and all fish at these sites would be harvested by January 1999 to allow a fallow period before stocking with 1999 smolts. In order to provide growout sites for the 1998 hatchery smolt production that was intended for the fallowed sites, 5 new growout sites were approved: one temporary site (one year class only) in northern Passamaquoddy Bay, 2 in southern Passamaquoddy Bay, one in Foleys Cove (near Beaver Harbour), and one in Long Pond Bay (Grand Manan Island). In addition, temporary production level increases were authorized for some existing sites. Also as part of the ISA management plan, the New Brunswick Department of Fisheries and Aquaculture has prohibited the transfer of smolts from brackish water acclimation sites to marine growout sites (R. Henry, personal communication). As a result, the future of these brackish water sites is in doubt, although one of them is now being used for growout of steelhead.

The Nova Scotia salmon aquaculture industry has grown more slowly than in New Brunswick (see Fig. 6). The first harvest of farmed salmon in Nova Scotia was 5 t from one site in 1984. In 1997, production reached 1,100 t. There were 11 active marine growout sites in Nova Scotia in 1998 (Fig. 10): 4 sites in the Annapolis Basin, 2 in Shelburne Harbour, one at Aspotogan (St. Margarets Bay), and 4 on Cape Breton Island (information from Nova Scotia Department of Fisheries and Aquaculture).

Potential Impacts of Farmed Atlantic Salmon on Wild Atlantic Salmon

The potential interactions between wild and farmed Atlantic salmon have been the subject of two recent symposia, in Norway in 1990 (Hansen *et al.* 1991) and in England in 1997 (Hutchinson 1997). The types of impacts can be divided into spreading of diseases and parasites, behavioral-ecological interactions, and genetic impacts (Saunders 1991; Hansen *et al.* 1997). These issues will be dealt with in detail by other speakers at this workshop, so they will be only briefly discussed here. While the presence of salmon in cages can have some impacts on wild salmon in the vicinity, the impacts are generally thought to be greater when farmed salmon escape from hatcheries or sea cages (Hansen *et al.* 1997).

If we assume an average harvest size of 4 kg, then the total production figure of 19,700 t for the Maritimes in 1997 would represent about 5 million market-size salmon in cages during that year. In comparison, the total stock size of wild and hatchery-origin Atlantic salmon adults returning to Maritime rivers is estimated as 115,000 to 229,000 (Chaput 1998).

Bailey (1998) described the main reasons for farmed salmon escapes and provides suggestions for reducing the risk of escape. Salmon may escape from sea cages as a result of deliberate release of culls, equipment failure, operator error, vandalism, predation, collisions, and weather. In order to assist in the reduction of farmed salmon escapees, Fisheries and Oceans Canada (DFO) produced a draft *Code of Practice for the Containment of Non-local Strains of Salmonids in Sea Cage Culture in the Atlantic Provinces* (April 1997), which included equipment standards, handling standards, contingency measures, and reporting of escapes; however this draft code of practice has not been finalized. A similar *Code of Practice for the Responsible Containment of Farmed Atlantic Salmon in Maine Waters* (October 1998) has been adopted by salmon farms in Maine. A protocol has been developed by the Nova Scotia Department of Fisheries and Aquaculture and DFO on the immediate recapture plans following a massive escapee event. This protocol would give the fish farmer the first opportunity to recover the escaped fish within a prescribed perimeter of the lease (R. Cook, personal communication).

Improved cage systems, including stronger predator nets, could reduce the number of escapees. Other methods suggested for reducing escapees include using totally enclosed bags or tanks in the marine environment or using on-land tanks; however, to date these types of cage systems have not been shown to be commercially viable. The use of sterile salmon for aquaculture would be a way of reducing genetic impacts of escaped farmed salmon on wild salmon. Currently, the only method for large scale production of sterile salmon is through induced triploidy. Trials with triploid salmon indicate that they do not perform as well as diploids and show higher rates of deformities, so they are not, at present, an economically viable option for the industry (Benfey 1998). There are also significant market-related concerns with the use of triploid salmon (R. Cook, personal communication).

There is little published data available on the number of salmon that do escape from sea cages in the Maritimes. It was reported that in September 1994, an estimated 20,000 salmon escaped from a damaged sea cage in Passamaquoddy Bay (Carr, Lacroix *et al.* 1997). It is also reported that in the Magaguadavic River, which is located near the centre of salmon farming activity in southwestern New Brunswick, the majority of returning adult salmon are escaped fish from sea cages (Carr, Anderson *et al.* 1997). Preliminary analyses in the previously mentioned study of 20 salmon farms in southwestern New Brunswick from 1995 to 1997 indicate that the rates of escape from sea cages (from the time of smolt transfer into sea cages until harvest) are less than 2% (R.H. Peterson, personal communication). This estimate is similar to recent estimates of escape rates of 1-2% in British Columbia (Alverson and Ruggerone 1997) and 1.6% in Norway (Bailey 1998). One to two percent of the estimated 8.6 million smolts produced and presumably transferred to sea cages in the Maritimes in 1998 would represent 86,000 to 170,000 escapees from this group of fish between the time of transfer to cages until harvest.

Smolts can also escape from hatcheries. Smolts escaping from 3 hatcheries located on the Magaguadavic River may constitute more than 50% of the total smolt output of that river (Stokesbury and Lacroix 1997).

It should also be noted that salmon farming has the potential to be of benefit to wild stocks. By supplying the market with fresh salmon, the aquaculture industry can reduce or eliminate the need for a commercial fishery (Anderson 1988), which should help the recovery of wild stocks. Aquaculture escapees may also be able to contribute to the recreational fishery (Phillips *et al.* 1985). It has also been suggested that escaped farmed salmon which interbreed with wild salmon could have beneficial impacts on the fitness of wild stocks in some circumstances, as a result of the introduction of genetic variation for fitness, although it is more probable that interbreeding would have negative impacts on wild stocks (Saunders 1991; Peterson 1993; Alverson and Ruggerone 1997; Verspoor 1997).

Potential Impacts of Farming of Other Finfish Species on Wild Salmon

Farming of other finfish species could have similar impacts on wild salmon stocks as does Atlantic salmon culture, except that direct genetic impacts from interbreeding could not occur. The degree of risk would also depend on the farming methods, with a lower probability of escapees expected from land-based tank farms, as compared to net cages.

In the Maritimes, Atlantic salmon currently represents 97% of the total marine finfish aquaculture production. The remaining 3% is from sea cage farming of steelhead (*Oncorhynchus mykiss*, anadromous form). Most of this production is from Nova Scotia, which had a production of 590 t in 1997 from 9 growout sites (Fig. 10). There were at least two marine sites in southwestern New Brunswick farming steelhead in 1998 (Fig. 9). There had also been some sea cage farming of *O. mykiss* in the early years of the New Brunswick salmon industry when there was an insufficient supply of Atlantic salmon smolts. There is also some freshwater production of farmed rainbow trout (*O. mykiss*, freshwater form) in the Maritimes. The farming of *O. mykiss* in the Maritimes means that there is some potential for interspecific interactions between escapees of this non-indigenous salmonid species and wild Atlantic salmon stocks. New Brunswick is currently phasing in a policy requiring the use of sterile, triploid *O. mykiss*. This policy should eliminate the possibility that aquaculture escapees of this species could establish self-sustaining populations in the Maritimes. This policy is to be reviewed in 1999 (R. Henry, personal communication).

In addition to rainbow trout, other freshwater salmonids being farmed in the Maritimes include brook trout (*Salvelinus fontinalis*), and Arctic char (*Salvelinus alpinus*). Estimated production of freshwater salmonids in the Maritimes in 1997 was 680 t (primarily rainbow and brook trout).

There is also interest in aquaculture of non-salmonid species in the Maritimes. There are 3 operations (2 in New Brunswick and 1 in Nova Scotia) which raise wild-caught American eel elvers to the juvenile or market stages. All 3 are land-based operations using freshwater recirculation technology. There are 2 small operations in the Maritimes producing striped bass in excavated ponds (1 in New Brunswick and 1 in Nova Scotia). Research is on-going in the Maritimes to develop aquaculture of other finfish species, including halibut, haddock, flounders, and sturgeon. Since it is not yet certain what methods will be used to culture these species on a commercial basis, it is difficult to estimate the potential impacts that farming of these species could have on wild Atlantic salmon.

Legislative and Administrative Roles

Cook and Simpson (1995) described the regulatory framework for aquaculture in Atlantic Canada. There have, however, been some legislative changes since the date of that report (see Porter *et al.* 1998). Several federal and provincial laws have relevance to aquaculture. The most important are the federal Fisheries and Oceans Acts, the New Brunswick Aquaculture Act, and the Nova Scotia Fisheries and Coastal Resources Act (which incorporates the aquaculture provisions in the former Nova Scotia Aquaculture Act). In addition, Memoranda of Understanding (MOUs) on aquaculture development have been signed between the federal government and New Brunswick and Nova Scotia. These MOUs give New Brunswick and Nova Scotia certain powers with respect to licensing and leasing of aquaculture operations:

- the province issues and administers licenses and leases for aquaculture facilities and operations, in accordance with relevant provincial and federal acts and regulations.
- the province must refer all aquaculture applications to the federal government for comment.
- Canada and the provinces shall cooperate in the establishment of aquaculture site allocation criteria.
- Canada and the provinces will undertake ongoing inspection of aquaculture facilities in accordance with relevant legislation.

In New Brunswick, applications for hatcheries and growout sites are reviewed internally by the Department of Fisheries and Aquaculture and are referred to various federal and provincial agencies via a formal referral system. In addition, the Aquaculture Site Evaluation Committee (ASEC) has been established to discuss and make recommendations on applications for marine sites. This committee is co-chaired by the New Brunswick Department of Fisheries and Aquaculture and Fisheries and Oceans Canada (DFO) and includes representatives of these and other federal and provincial agencies. This committee makes recommendations to the New

Brunswick Registrar of Aquaculture, who then forwards the information to the Minister of Fisheries and Aquaculture for approval or rejection of the application. The review process for marine site application in New Brunswick is shown in Fig. 11. License conditions include exact location and boundaries of the site, while lease conditions include species and strain(s), optimum stocking density, maximum production level, and other conditions. The New Brunswick marine aquaculture site allocation policy is currently under review. The proposed new policy includes the use of bay management areas and single year-class sites.

In Nova Scotia, applications for aquaculture operations are reviewed internally by the Department of Fisheries and Aquaculture and are referred to various federal and provincial agencies via a formal referral system. In addition, Regional Aquaculture Development Advisory Committees (RADACs) have been established in some areas as a means to allow local community input into decisions. Where there is no RADAC, public hearings may be held. The information from the review processes are forwarded to the Minister of Fisheries and Aquaculture, who then approves or rejects the application. Nova Scotia does not place limits on production levels at finfish farms, but does require annual reporting of production levels. License conditions include location, site boundaries, species, and culture method.

In Prince Edward Island, under a federal-provincial agreement for commercial aquaculture development, the federal government issues licenses and leases for aquaculture facilities and operations. Applications are referred to the province for comment.

Freshwater facilities, including hatcheries, require water use permits and must meet environmental standards of provincial government agencies, under the New Brunswick Clean Water Act (administered by the New Brunswick Department of Environment), the Nova Scotia Environment Act (administered by the Nova Scotia Department of Environment), and the Prince Edward Island Environmental Protection Act (administered by the Prince Edward Island Department of Technology and Environment).

In all 3 Maritime Provinces, the federal government has the lead role in monitoring, diagnosis, prevention, and control of fish diseases in cultured and wild stocks. The federal authority is via 3 legislative components pertaining to introductions and transfers of fish or eggs: the Fisheries Act; Fish Health Protection Regulations; and Fisheries (General) Regulations (see Cook and Simpson 1995). Import Permits are required to allow movement of fish or eggs into Canada or between provinces. These permits are issued only when the importation will not result in the introduction of disease. In order to obtain an Import Permit, a production facility must receive certification from DFO, based on fish health standards. A license is required to transfer fish to any rearing facility or to release fish into fish habitat. Licenses are issued only if the transfer or release will not adversely affect the management, health, size or genetics of fish or fish stocks. Applications for licenses are reviewed by federal-provincial Introductions and Transfers Committees (chaired by DFO) in each province. The federal Regional Fish Health Policy for the Maritimes includes guidelines for intra-provincial fish transfers, with respect to furunculosis, enteric redmouth disease, and bacterial kidney disease.

Provincial regulations pertaining to intra-provincial fish movement and fish health have been enacted in New Brunswick and Nova Scotia. Under the authority of these regulations, provincial agencies conduct monitoring and diagnosis of fish diseases in aquaculture.

DFO has the lead role in resource management issues related to aquaculture, under the authority of Fisheries Regulations under the Fisheries Act. These issues include broodstock collection from wild stocks and harvesting of aquaculture animals which would be undersize or out-of-season if harvested in the traditional fisheries.

Habitat concerns are jointly enforced by federal and provincial governments. Federal legislation is through the habitat components of the Fisheries Act and the new Oceans Act. There are also habitat components in provincial legislation relevant to aquaculture. The use of pesticides (such as those used for controlling sea lice), drugs, biologics (such as vaccines), and chemicals used in aquaculture are regulated under various federal acts (Pest Control Products Act; Food and Drug Act; Health of Animals Act; Canadian Environmental Protection Act).

Navigation concerns related to siting of aquaculture growout sites are addressed in the federal Navigable Waters Protection Act, which is administered by the Canadian Coast Guard (DFO).

Product health and safety issues are handled by the Canadian Food Inspection Agency, through various legal authorities, including the Fish Inspection Act, various regulations under the Fisheries Act, and the Food and Drug Act. There is also provincial fish inspection legislation in each Maritime Province.

Canada also has international obligations which have relevance to aquaculture, through the North Atlantic Salmon Conservation Organization and other international organizations and agreements (Porter *et al.* 1998).

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Literature Cited

Alverson, D.L. and G.T. Ruggerone. 1997. Escaped farm salmon: environmental and ecological concerns. *In* Salmon aquaculture review, vol. 3: Technical Advisory Team Discussion Paper B. British Columbia Environmental Assessment Office, Victoria, BC.

Anderson, J.M. 1988. Effects of aquaculture on salmon management. p.83-92. *In* R.H. Stroud (ed.) Present and future Atlantic salmon management: measuring progress toward international cooperation. Twelfth annual marine recreational fisheries symposium, Portland, ME, 27-29 October 1987. Atlantic Salmon Federation, Ipswich, MA and National Coalition for Marine Conservation, Inc., Savannah, GA.

Bailey, J. 1998. Options for containment of farmed Atlantic salmon. DFO Can. Stock Assess. Secretariat Res. Doc. 98/165.

Baum, E.T. 1998. History and description of the Atlantic salmon aquaculture industry in Maine. DFO Can. Stock Assess. Secretariat Res. Doc. 98/152.

Benfey, T.J. 1998. Use of triploid Atlantic salmon (*Salmo salar*) for aquaculture. DFO Can. Stock Assess. Secretariat Res. Doc. 98/166.

Carr, J.W., J.M. Anderson, F.G. Whoriskey, and T. Dilworth. 1997. The occurrence and spawning of cultured Atlantic salmon (*Salmo salar*) in a Canadian river. ICES J. Mar. Sci. 54: 1064-1073.

Carr, J.W., G.L. Lacroix, J.M. Anderson, and T. Dilworth. 1997. Movements of non-maturing cultured Atlantic salmon (*Salmo salar*) in a Canadian river. ICES J. Mar. Sci. 54: 1082-1085.

Chaput, G. 1998. Status of wild Atlantic salmon (*Salmo salar*) stocks in the Maritime Provinces. DFO Can. Stock Assess. Secretariat Res. Doc. 98/153.

Cook, R.H. and F.J. Simpson. 1995. Roles of government agencies in aquaculture development in Atlantic Canada: regulations and incentives. p. 501-536. *In* A. Boghen (ed.) Cold-water aquaculture in Atlantic Canada, 2nd ed. Canadian Institute for Research on Regional Development, Moncton, NB.

Friars, G.W., J.K. Bailey, and F.M. O'Flynn. 1997. Realized genetic gains in economic traits of Atlantic salmon (*Salmo salar*). Aquacul. Assoc. Can. Spec. Publ. 2: 69-73.

Glebe, B.D. 1998. East coast salmon aquaculture breeding programs: history and future. DFO Can. Stock Assess. Secretariat Res. Doc. 98/157.

Hansen, L.P., T. Håstein, G. Nævdal, R.L. Saunders, and J.E. Thorpe (ed.). 1991. Interactions between cultured and wild Atlantic salmon. Proc. of symposium hosted by Directorate for Nature Management and Norwegian Institute for Nature Research, Loen, Norway, 23-26 April 1990. Aquaculture 98: 1-324.

Hansen, L.P., M.L. Windsor, and A.F. Youngson. 1997. Interactions between salmon culture and wild stocks of Atlantic salmon: the scientific and management issues. ICES J. Mar. Sci. 54: 963-964.

Hill, M. 1992. Atlantic salmon (marine) aquaculture development plan. Nova Scotia Dept. of Fisheries, Tech. Rep. 92-02: 29 p.

Hutchinson, P. (ed.). 1997. Interactions between salmon culture and wild stocks of Atlantic salmon: the scientific and management issues. Proc. ICES/NASCO symposium, Bath, England, 18-22 April 1997. ICES J. Mar. Sci. 54: 963-1227.

Peterson, R. 1993. When farm fish escape: what is the genetic impact on wild stocks? Northern Aquaculture 9(5): 23-26.

Phillips, M.J., M.C.M. Beveridge, and L.G. Ross. 1985. The environmental impact of salmonid cage culture on inland fisheries: present status and future trends. J. Fish. Biol. 27 (Suppl. A): 123-137.

Porter, R., T. Carey and D. Harris. 1998. A review of existing conventions, regulations, and policies pertaining to the control and minimization of negative impacts from aquaculture on wild salmonid stocks. DFO Can. Stock Assess. Secretariat Res. Doc. 98/164.

Saunders, R.L. 1991. Potential interaction between cultured and wild Atlantic salmon. Aquaculture 98: 51-60.

Saunders, R.L. 1995. Salmon aquaculture: present status and prospects for the future. p. 36-81 *In* A. Boghen (ed.) Cold-water aquaculture in Atlantic Canada, 2nd ed. Canadian Institute for Research on Regional Development, Moncton, NB.

Stewart, J.E. 1998. Sharing the waters: an evaluation of site fallowing, year class separation and distances between sites for fish health purposes on Atlantic salmon farms. Can. Tech. Rep. Fish. Aquat. Sci. 2218: vii + 56 p.

Stokesbury, M.J. and G.L. Lacroix. 1997. High incidence of hatchery origin Atlantic salmon in the smolt output of a Canadian river. ICES J. Mar. Sci. 54: 1074-1081.

Sutterlin, A.M., E.B. Henderson, S.P. Merrill, R.L. Saunders, and A.A. MacKay. 1981. Salmonid rearing trials at Deer Island, New Brunswick, with some projections on economic viability. Can. Tech. Rep. Fish. Aquat. Sci. 1011: iv + 28 p.

Verspoor, E. 1997. Genetic diversity among Atlantic salmon (*Salmo salar* L.) populations. ICES J. Mar. Sci. 54: 965-973.

Table 1. Marine harvest fisheries landings and mariculture production in the Maritime Provinces, 1997 (preliminary figures). Source: Fisheries and Oceans Canada.

	1997 landings/production (t)			
	NS	NB	PEI	Totals
Marine harvest fisheries landings				
Groundfish	69 192	2 171	1 153	72 516
Pelagics & other finfish	84 748	70 681	23 117	178 546
Shellfish	101 329	26 986	25 631	153 946
Other	15 226	5 362	8 152	28 740
Total landings	270 495	105 200	58 053	433 748
Mariculture production				
Atlantic salmon	1 112	18 585	0	19 697
Steelhead	591	0	0	591
Shellfish	895	402	11 429	12 726
Total mariculture production	2 598	18 987	11 429	33 014

	1997 value $ (thousands)			
	NS	NB	PEI	Totals
Marine harvest fisheries landings				
Groundfish	79 921	2 683	1 023	83 627
Pelagics & other finfish	38 270	14 549	7 751	60 570
Shellfish	353 766	123 454	102 441	579 661
Other	982	709	1 457	3 148
Total landings	472 938	141 396	112 671	727 005
Mariculture production				
Atlantic salmon	6 356	139 016	0	145 372
Steelhead	2 683	0	0	2 683
Shellfish	1 924	675	15 277	17 876
Total mariculture production	10 963	139 691	15 277	165 931

Table 2. Dimensions of some cage types used for marine growout of farmed salmon in the Maritime Provinces. Source: New Brunswick Department of Fisheries and Aquaculture.

Collar type	Collar size	Net depth (m)	Net volume (m^3)	Number of fish per cage*
octagonal (wood)	10 m diameter	6	470	2 100
square (steel)	12 m width	6	860	3 900
square (steel)	15 m width	6	1 350	6 100
circular (plastic)	22 m diam. (70 m circum.)	8	3 040	13 700
circular (plastic)	32 m diam. (100 m circum.)	8	6 430	28 900

* number of 4 kg adults at the recommended stocking density of 18kg/m^3.

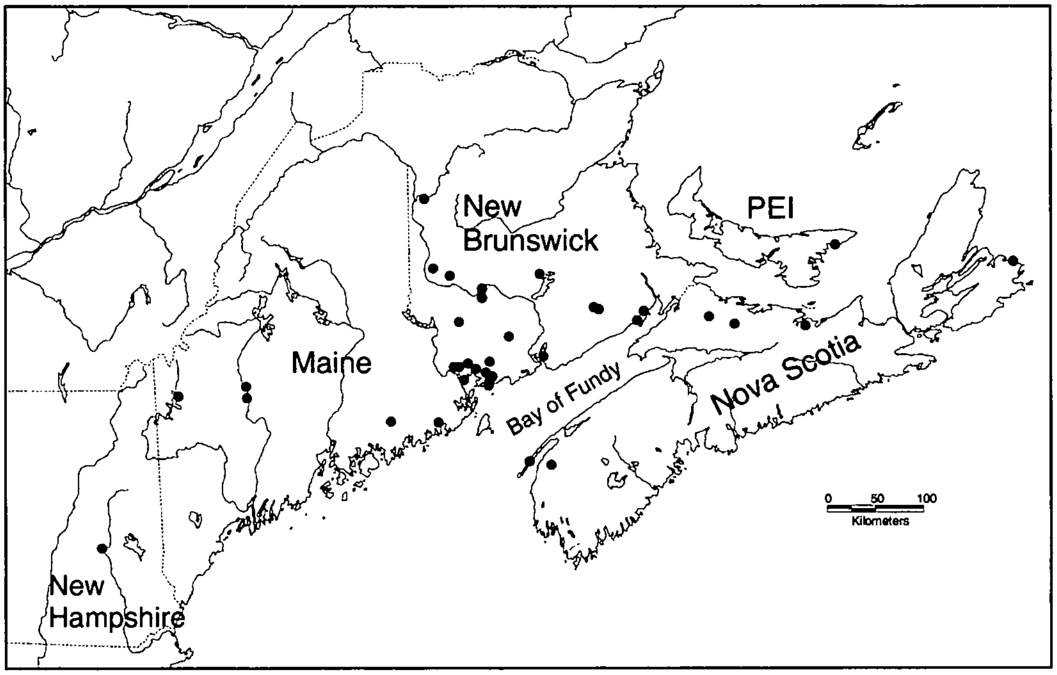

Fig. 1. Locations of hatcheries (●) producing Atlantic salmon for aquaculture in the Maritime Provinces and New England, 1998. Data sources: New Brunswick Department of Fisheries and Aquaculture; Nova Scotia Department of Fisheries and Aquaculture; PEI Department of Fisheries and Tourism; J. McGonigle, personal communication.

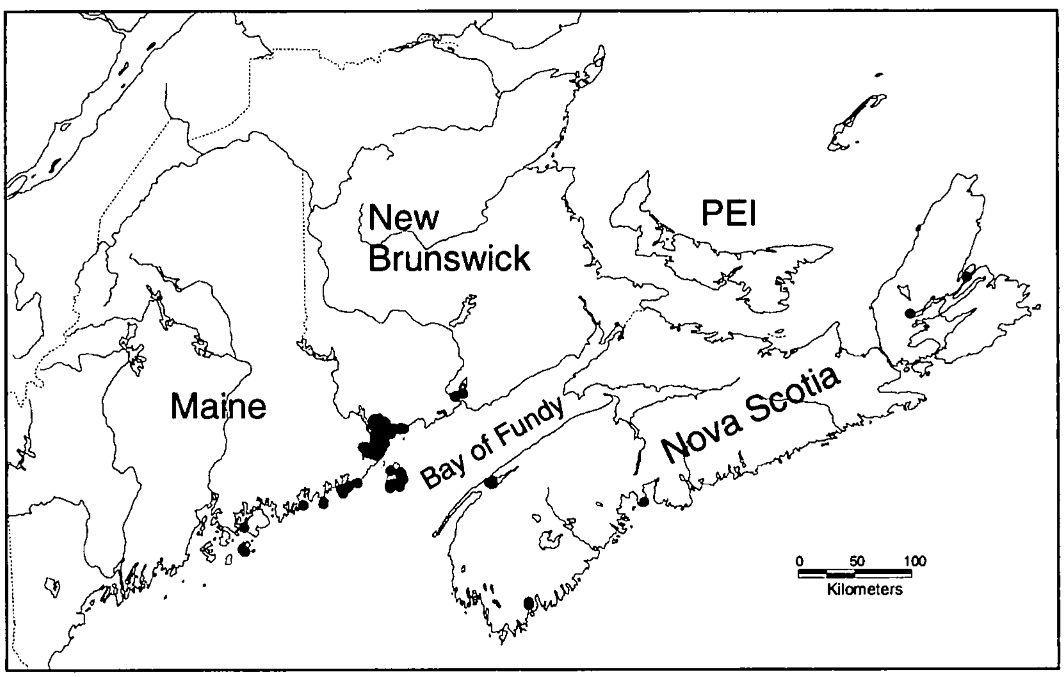

Fig. 2. Atlantic salmon marine and brackish water aquaculture sites (●) in the Maritime Provinces and Maine in 1998. Data sources: New Brunswick Department of Fisheries and Aquaculture; Nova Scotia Department of Fisheries and Aquaculture; Baum 1998.

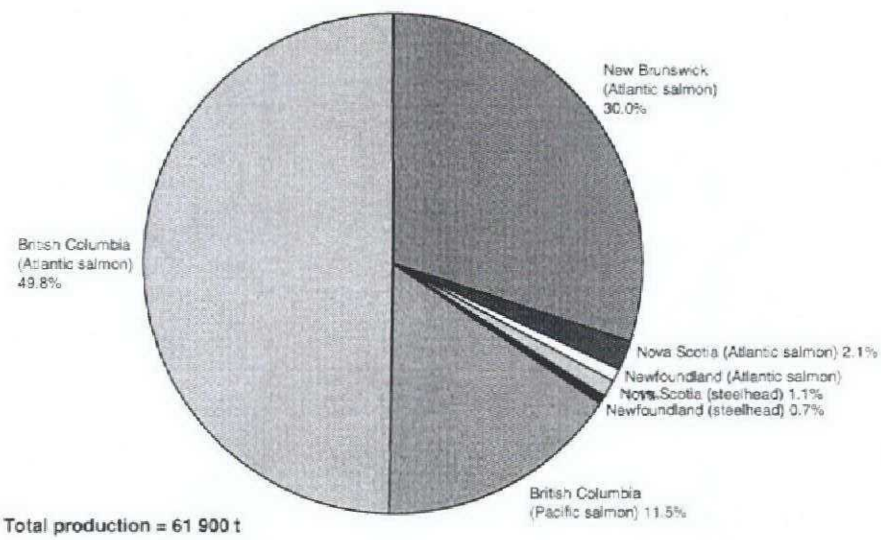

Fig. 3. Distribution of Canadian farmed salmonid mariculture production by Province, 1997 estimates. Data sources: British Columbia Ministry of Fisheries; New Brunswick Department of Fisheries and Aquaculture; Nova Scotia Department of Fisheries and Aquaculture; Fisheries and Oceans Canada.

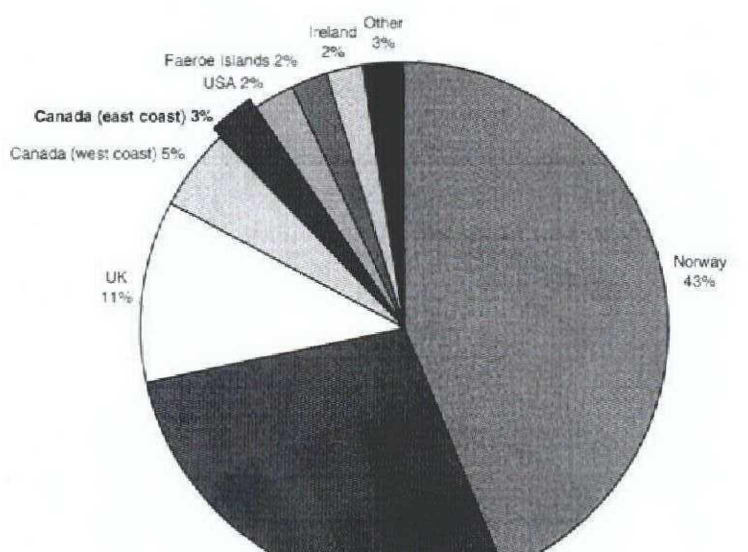

Fig. 4. Distribution of world farmed salmonid production (marine) by country, 1997 estimates. Approximately 73% of the total production was Atlantic salmon, 16% marine trout, and 11% Pacific salmon. Data sources: Norwegian Fish Farmers Association (http://www.fiskeoppdrett.no); Fisheries and Oceans Canada.

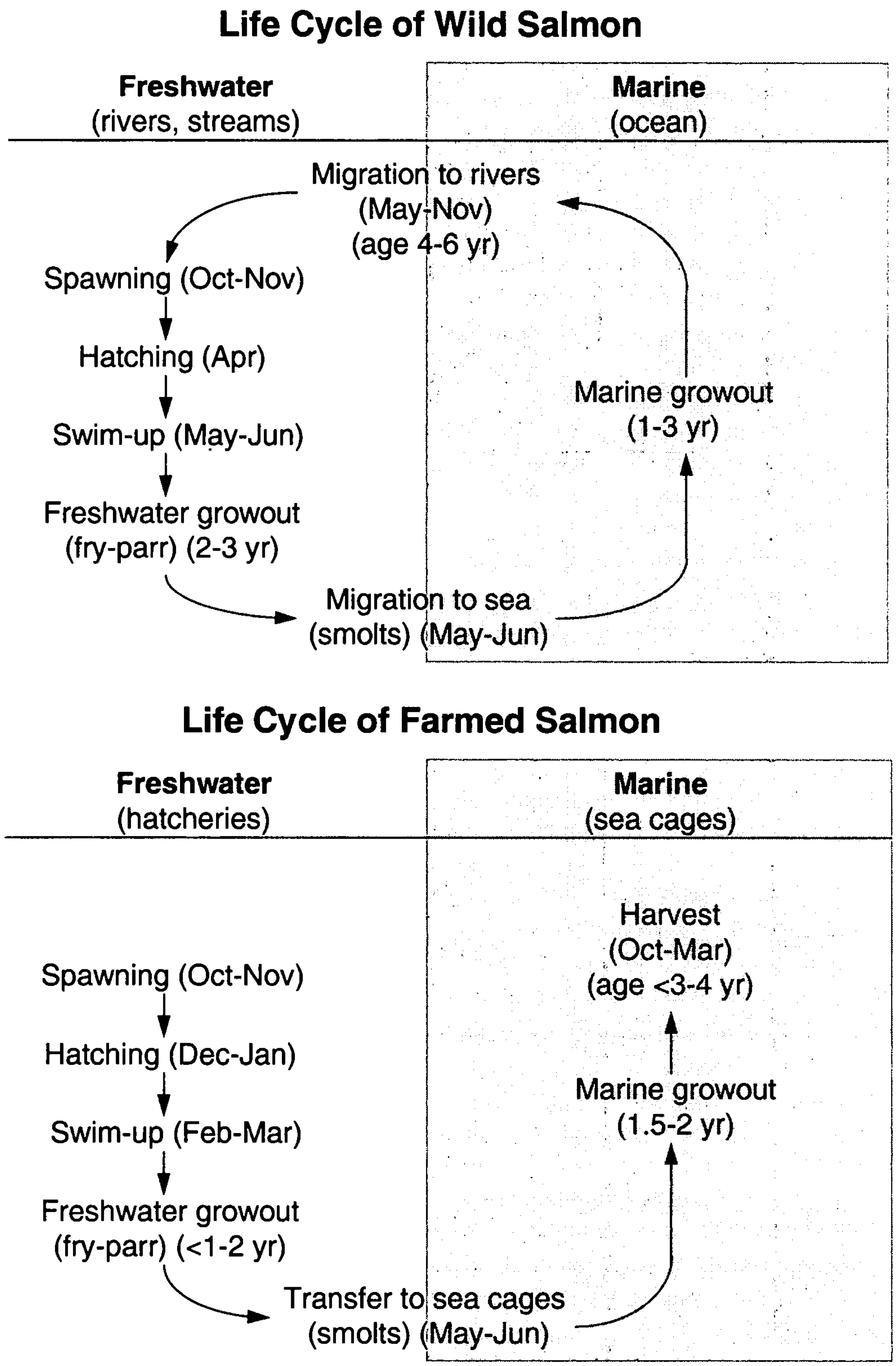

Fig. 5. Typical life cycles of wild (top) and farmed (bottom) Atlantic salmon in the Maritime Provinces. Based on information in Saunders (1995).

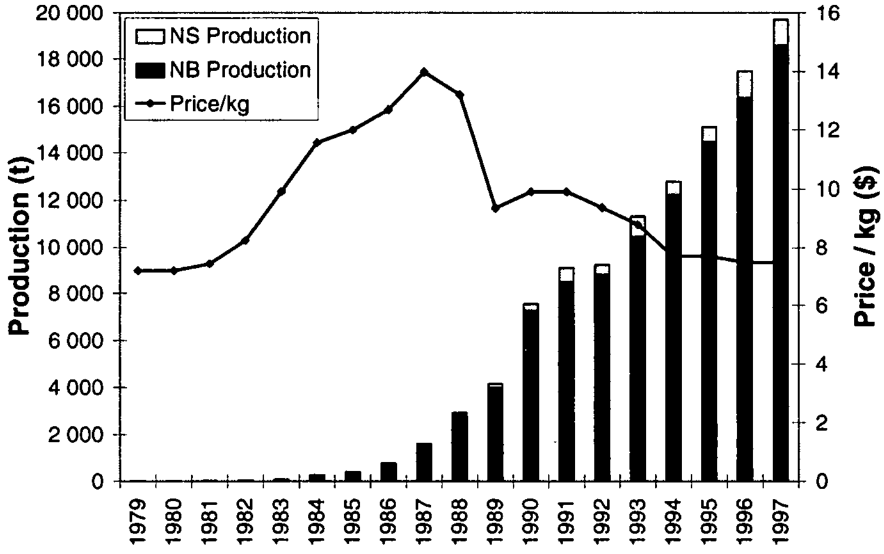

Fig. 6. Farmed Atlantic salmon production and prices in the Maritime Provinces, 1979-1997. Data sources: New Brunswick Department of Fisheries and Aquaculture; Nova Scotia Department of Fisheries and Aquaculture.

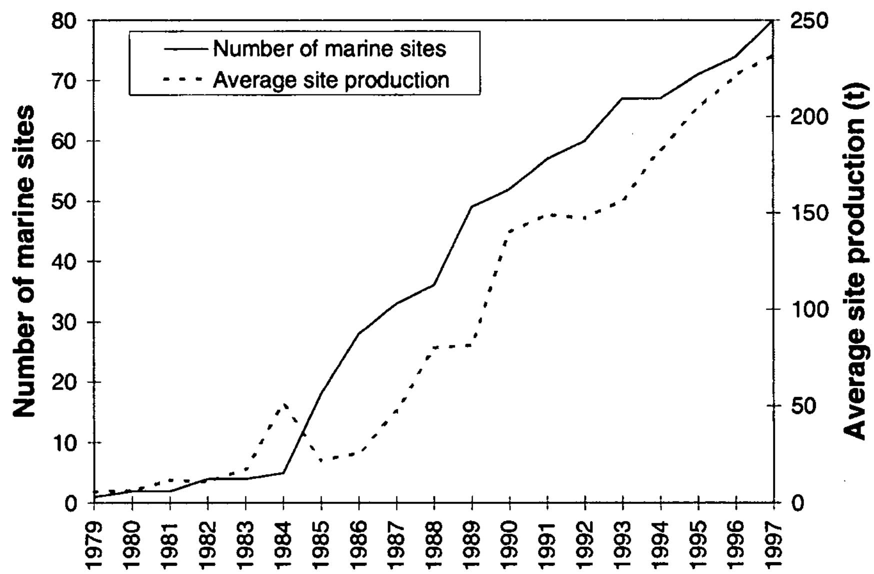

Fig. 7. Growth in number of marine growout sites and average site production in southwestern New Brunswick, 1979-1997. Average site production was calculated as the total annual production divided by the number of licensed sites. Data source: New Brunswick Department of Fisheries and Aquaculture.

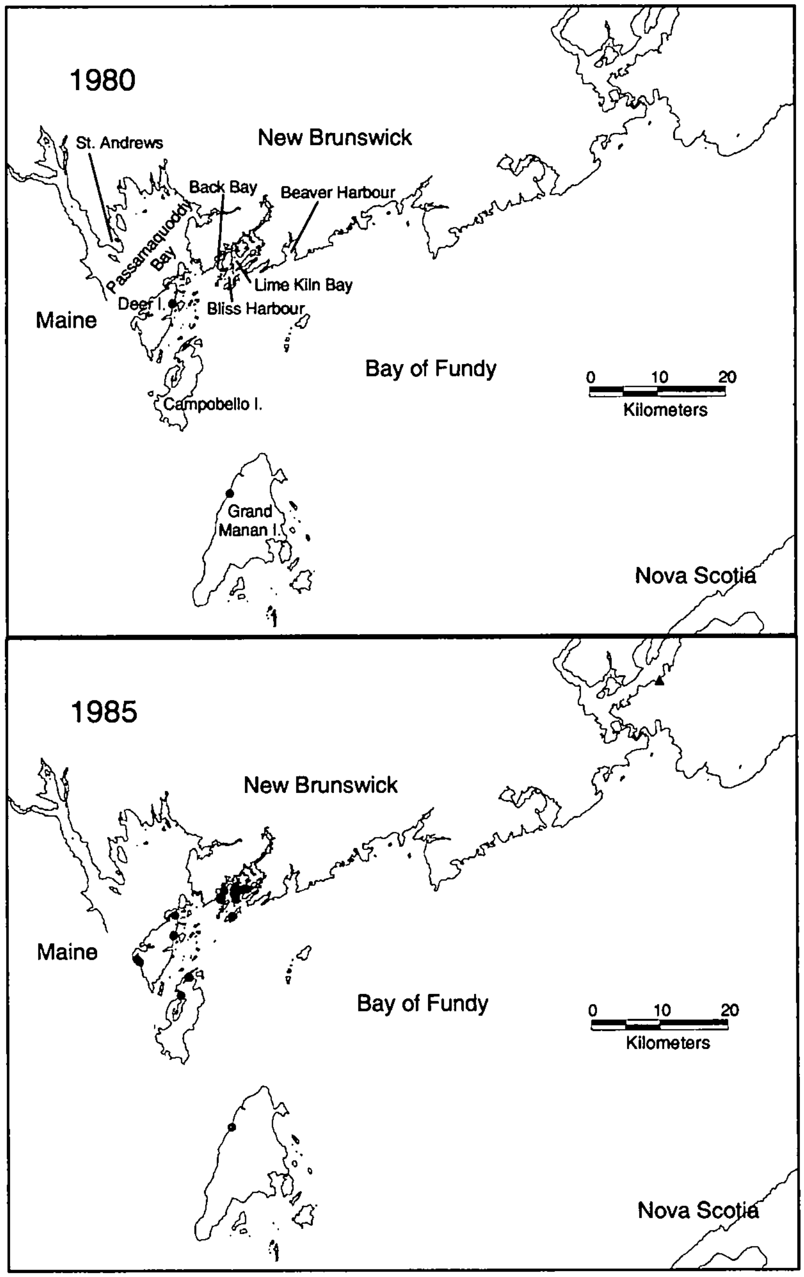

Fig. 8a (top) and 8b (bottom). Marine Atlantic salmon aquaculture sites in southwestern New Brunswick, 1980 and 1985. (●) growout sites; (▲) brackish water sites (smolt acclimation). Data source: New Brunswick Department of Fisheries and Aquaculture.

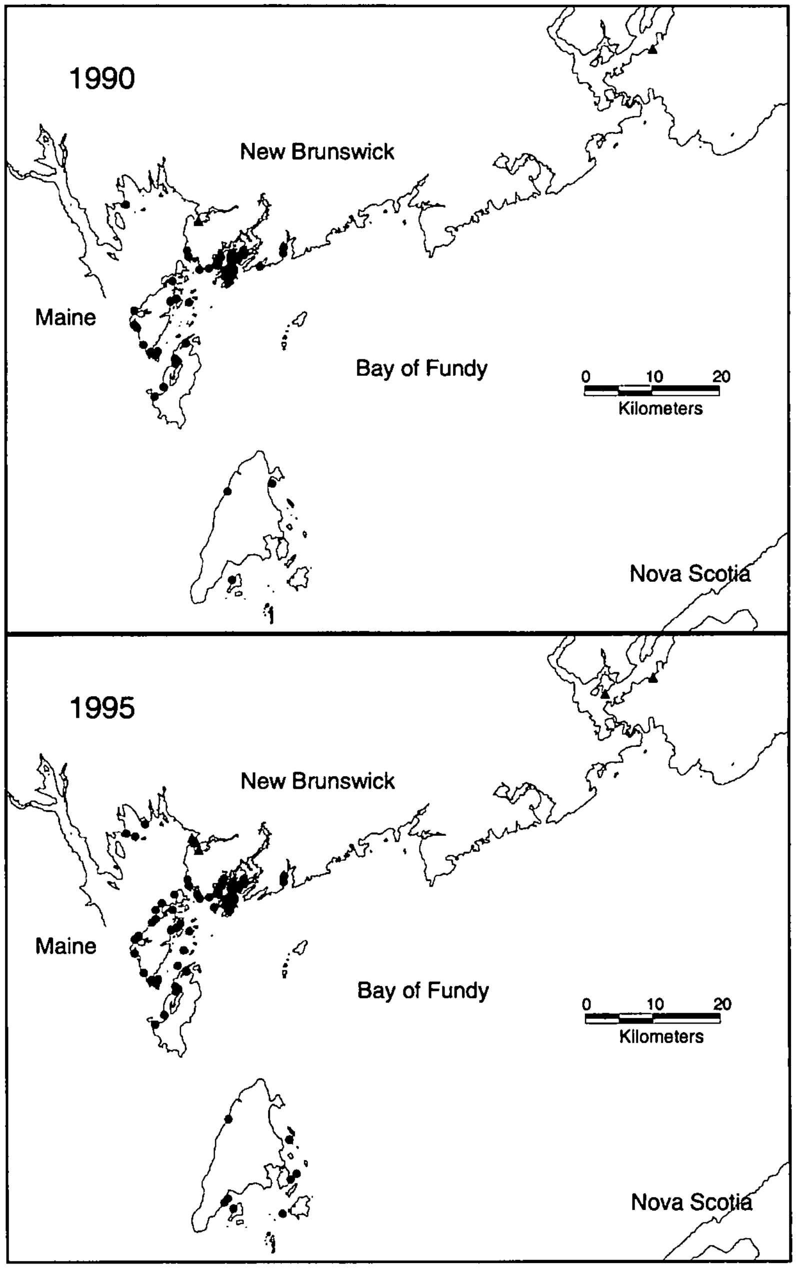

Fig. 8c (top) and 8d (bottom). Marine Atlantic salmon aquaculture sites in southwestern New Brunswick, 1990 and 1995. (●) growout sites; (▲) brackish water sites (smolt acclimation). Data source: New Brunswick Department of Fisheries and Aquaculture.

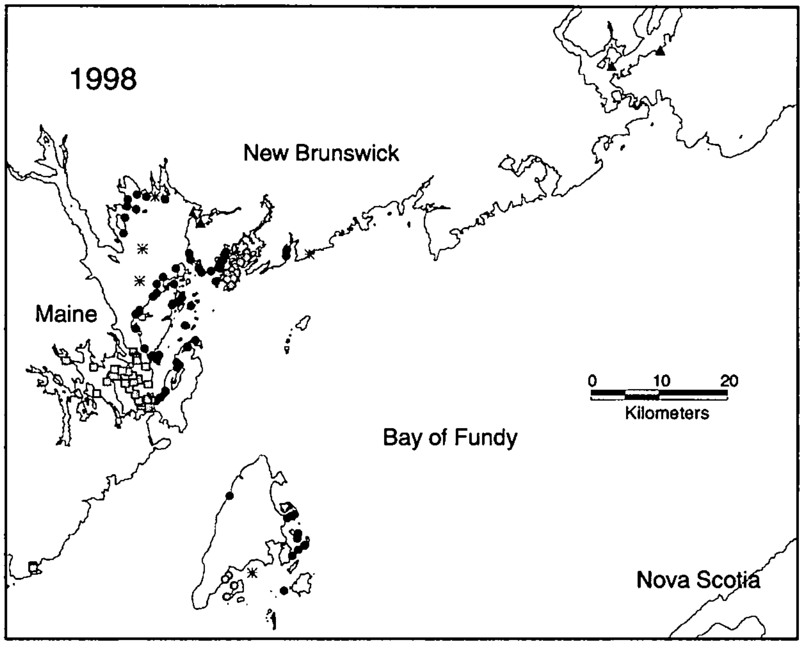

Fig. 9. Marine Atlantic salmon aquaculture sites in southwestern New Brunswick, 1998. (●) active growout sites approved before 1998; (▲) brackish water sites (smolt acclimation); (○) fallowed sites in 1998; (✳) new sites approved in 1998; (▽) steelhead (marine trout) sites; (□) adjacent sites in Maine. Data sources: New Brunswick Department of Fisheries and Aquaculture; Baum 1998.

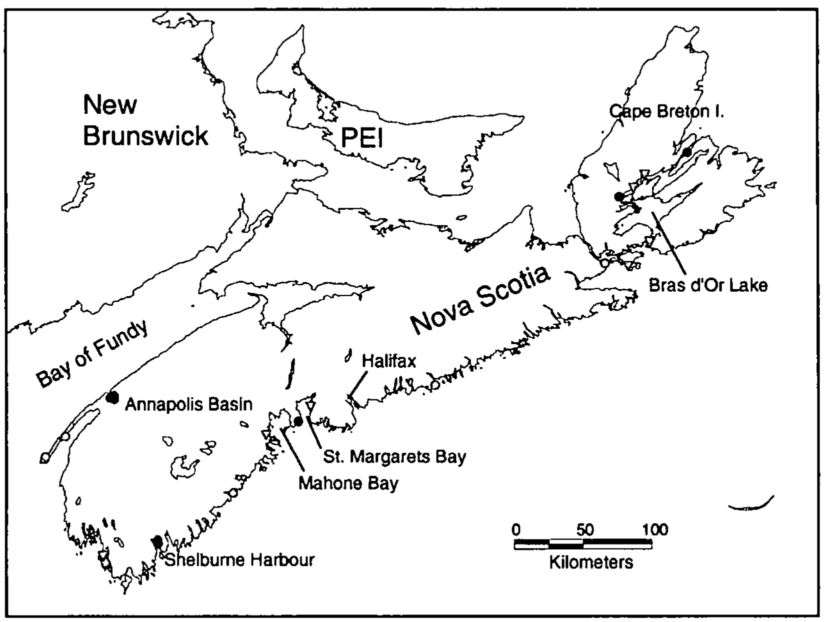

Fig. 10. Marine Atlantic salmon and steelhead aquaculture sites in Nova Scotia, 1998. (●) Atlantic salmon; (▽) steelhead; (○) inactive sites. Data source: Nova Scotia Department of Fisheries and Aquaculture.

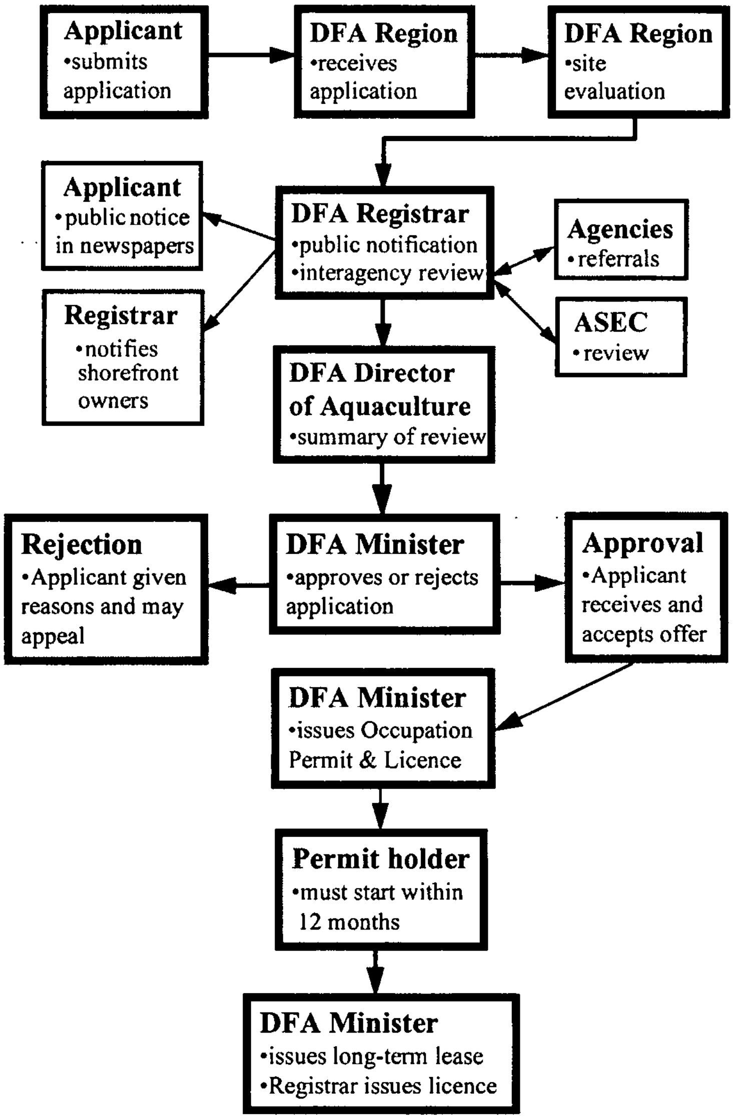

Fig. 11. The site review process for marine aquaculture sites in New Brunswick. DFA = New Brunswick Department of Fisheries and Aquaculture; ASEC = Aquaculture Site Evaluation Committee. See text for more information. Source: New Brunswick Department of Fisheries and Aquaculture.