21 An Overview Assessment of Compensation and Mitigation Techniques Used to Assist Fish Habitat Management in British Columbia Estuaries

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Abstract.—A comprehensive fisheries management strategy to ensure sustainability of salmon and steelhead needs to arrest and reverse the ongoing and piecemeal loss of estuarine fish habitat in the northeast Pacific. Prevention, mitigation, compensation, and restoration are techniques used by Canadian fisheries agencies when managing estuarine fish habitat for no net loss of productive capacity. In the context of the Department of Fisheries and Oceans habitat management policy, mitigation includes prevention, alternate siting, modification of proposals, ecological zoning, or other techniques used for avoiding site-specific damage. Mitigation by alternate siting and ecological zoning has been used extensively in the Fraser River estuary, where a comprehensive, large scale database was developed to determine the fisheries values of specific sites. In the Fraser River estuary and other British Columbia estuaries there have been more than 100 situations where compensation has been applied in efforts to recover productive capacity due to losses. Vegetation transplanting, channelization, construction of intertidal islands, creation of artificial reefs, and lowering the elevation of terrestrial habitat were some of the techniques used. The success of the compensation projects has been mixed. Some major shortcomings are the lack of performance criteria and remedial action where projects have failed. Habitat restoration is also being used as a strategy to achieve net gain in productive capacity, but few projects have been adequately evaluated. Better design criteria, long-term monitoring and use of the basic principles of adaptive management are needed to improve the success rate of both compensation and restoration projects. It will be very difficult to achieve sustainability of estuarine habitats because of the lack of comprehensive followup studies to assess performance of the projects and the ongoing disruption of small habitat areas.

INTRODUCTION

In response to industrial and urban development in coastal British Columbia (B.C.), habitat managers and scientists with the Canadian Department of Fisheries and Oceans (DFO) have developed methods and policies to minimize loss of productive fish habitat in estuaries. This chapter provides a brief summary of some of the contemporary methods used and problems encountered, with particular reference to the Fraser River estuary, near the City of Vancouver (population approximately 1.2 million).

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Estuaries in B.C. are considered critical habitat for salmon as these fish are adapted to migrate through the mouth of the river twice, once as juveniles heading to sea and again as adults moving into the rivers to spawn. In addition, certain stocks of chinook salmon *Oncorhynchus tshawtyscha* and chum salmon *O. keta* use the estuaries as nursery areas and are, therefore, dependent on estuarine habitat for feeding and as refuge from predation (e.g., Levings et al. 1989). Estuaries and their associated uplands are also critical for human settlements and transportation facilities. Resources from inland areas, such as coal and wood products, are moved from railways to ships in the estuaries. Fish habitats such as marshes, sand and mud flats, and seagrass beds can be adversely affected by such industrial activity.

POLICY CONTEXT

There are several aspects of the Canadian fish habitat policy that are particularly relevant to estuary management. The 1986 Policy on Fish Habitat Management (DFO 1986) gave the following working definitions for mitigation and compensation, which will be followed in this chapter:

*mitigation**—actions taken during the planning, design, construction, and operation of works and undertakings to alleviate potential adverse effects on the productive capacity of fish habitats, including rejection of development proposals at a particular site.

compensation for loss—the replacement of natural habitat, increase in the productivity of existing habitat, or maintenance of fish production by artificial means in circumstances dictated by social and economic conditions, where mitigation techniques and other measures are not adequate to maintain habitats.

More recent policy items include guidance pertinent to Section 35(2) under the Canadian Fisheries Act, which prohibits harmful alteration, disruption, and destruction of fish habitat unless authorized. If an authorization to alter or destroy fish habitat is permitted, then compensation must be provided (Metikosh 1997). The January 1997 passage of the Oceans Act calls for management of the coastal zone, including estuaries, on an ecosystem basis.

TYPES OF DISRUPTION

About 25 years ago, Odum (1970) described the insidious loss of estuarine habitat in North America. Loss was occurring in many small inconspicuous or unnoticeable areas through waste disposal and small scale disruption. This type of loss has also been prevalent in B.C. estuaries for the past two decades and is an ongoing problem that must be addressed. However, most fish habitat loss in B.C. estuaries has occurred as a result of diking and filling of intertidal and flood plain areas for agriculture and/or urban development, particularly in the late 19th century. In the Fraser River estuary, 70 to 90% of this type of habitat has been lost since European settlement began, with accompanying decreases in carbon supply to the ecosystem (Healey and Richardson 1996). There has also been substantial habitat loss from port construction, especially ferry terminals and bulk loading facilities (Levings and Thom 1994). Some lower reaches of rivers are prone to erosion from currents at high discharge. Riprap revetment has been placed at these areas to protect land, which leads to secondary loss of shoreline habitat. Changes in flow patterns in the estuaries have also occurred as training walls and causeways have been built to constrain flow in shipping channels (Levings 1980).

* Note the difference in meaning relative to U.S. policy language, where mitigation is similar to the Canadian terminology for compensation (see also Metikosh 1997)

METHODS FOR PREVENTION AND MITIGATION

In British Columbia, development proposals are reviewed through a referral system, which uses inference based on available information to make decisions. The referral method involves the exchange of information about a proposal among a variety of resource and planning agencies that are invited to provide comments. The shared information is then used to reach a joint consensus decision concerning the project in question. If permission is obtained for the development to proceed, the shared information is also used to specify the procedures needed to avoid unacceptable impacts.

Locating an industrial development on a shoreline characterized by habitat of lower value than other areas is a zoning technique that is routinely used in the Fraser River estuary. The Fraser estuary is perhaps the most intensively managed estuary in Canada because of its major fish stocks and rapidly growing human populations. To help decide where development will have less impact, an inventory of fish habitat along the entire shoreline (about 538 km) has been developed by the Fraser River Estuary Management Program (FREMP). The data are available on 1:2,500 scale maps and are currently being entered in a geographic information system. The shoreline is color coded, so that red zones are areas of high habitat value (including all compensation sites), yellow areas are intermediate value, and green areas are of low value. The data were originally gathered in the 1980s and have been updated recently (Kistritz et al. 1992). In other estuaries, where detailed data are not available or an estuary management plan not in place, a site-specific survey is conducted before a decision is made on habitat alteration.

There have also been some innovative methods developed to mitigate estuarine habitat loss. For example, a project was proposed where construction of a conveyor system was needed to move a product from a factory to a ship loading facility on the riverfront. To avoid disrupting the estuarine marsh between the factory and the loading facility, a suspended conveyor system was built on posts, with minimal impact on the marsh.

METHODS USED FOR COMPENSATION: SUCCESSES AND PROBLEMS

Several methods have been used to compensate for habitat loss in B.C. estuaries, but unfortunately very few follow-up studies have been conducted to evaluate their effectiveness. Therefore, in most cases, we do not know whether the compensation project was successful from a fisheries viewpoint or not. A brief review of some of the available evidence is given below.

Vegetation Transplanting

The importance of estuarine marsh vegetation in fish food webs and as refuge from predation has been demonstrated in numerous studies (e.g., Sibert et al. 1977; Gregory and Levings 1996). Therefore, transplanting of marsh vegetation has been identified as an important tool for compensating habitat loss. Sedges, especially Lyngbyei's sedge *Carex lyngbyei*, have been used extensively in this application. In a long-term study at the Campbell River estuary, for example, sedges have survived 14 years after transplanting in 1982 on four intertidal artificial islands (Levings and Macdonald 1991; Levings, unpublished 1996 observations). Low wave energy, intermediate salinity, and stable substrates may be factors that have led to the relative success of this particular project. Other transplant projects elsewhere in the region have shown mixed success. For example, in the Fraser River estuary, a transplanted marsh developed on a dredged sand platform was buried by sand moving in from the adjacent river channel (Williams 1993). Another technique, used successfully in the Fraser estuary, is the construction of marsh benches. These structures are constructed at the appropriate elevation on the outside of the riprap revetment, which characterizes about 30% of the shoreline in the Fraser River estuary. Fine sediment is placed on the benches and then planted with cores of sedge rhizomes. Submergence and stability of all the transplant areas is a key factor affecting success since these physical variables influence whether or not fish can access the transplanted habitat. In a subsample of transplanted and natural marshes in the Fraser River estuary, some transplanted marshes showed more variability in submergence relative to natural sites (Levings and Nishimura 1996). In some instances higher elevations of the transplanted marshes resulted in reduced submergence time relative to natural sites, which meant the former locations would be flooded by water for relatively less time.

In view of the risk involved in developing successful compensation marshes, and the time required for them to approach the productive capacity of natural marshes, habitat managers apply safety factors to the particular areas involved. For example, a 2:1 factor is required for new marshes—that is, for each unit lost, two need to be transplanted (Levings 1991).

There have been eight compensation projects where the eelgrass *Zostera marina* has been transplanted in the Strait of Georgia. There are few published data on survival of transplanted eelgrass in British Columbia. Kistritz and Gollner (1995) reviewed seven transplant projects and found it difficult to draw conclusions about the success of the projects because monitoring data were sparse. In Puget Sound, techniques for transplanting this species have generally been unsuccessful (Thom 1990). Light availability, carbon reserves, and timing may be some of the determining factors for survival of the transplants (Zimmerman et al. 1995).

Pickleweed *Salicornia virginica* is a salt marsh plant which has been transplanted in an experiment at the Fraser River estuary (Pomeroy, et al. 1981) and a compensation project at an estuary on the east coast of Vancouver Island. Preliminary results at the latter site showed this species may be suitable for transplanting if conditions at the compensation site match those where the species occurs naturally.

Channelization and Lowering of Terrestrial Habitat

Because of extensive loss of intertidal and shallow subtidal habitat due to filling in estuaries, compensation projects have often involved lowering of land to create embayments or channels. There is an obvious and immediate advantage for fish as newly created productive capacity or living space becomes available for fish. An example is a project in the Fraser estuary where compensation was provided for habitat lost when supports for a highway bridge were built in the intertidal zone. An embayment of approximately 0.5 ha with a depth of about –2 m below chart datum was dug out of forested habitat. Sedge was then planted around the perimeter of the embayment. Unfortunately, the created shoreline was steep and unstable and the sedge transplants did not survive—ultimately colonization did occur from adjacent natural areas (Levings and Nishimura 1996). However, the habitat was definitely useable by fish even before marsh colonization was complete. Investigations of fish behavior showed that juvenile chinook salmon resided in the embayment about the same length of time relative to natural habitats (Hvidsten et al. 1996).

Lowering of terrestrial habitat to create an intertidal marine foreshore was used as a compensation measure in eight projects on the south coast of B.C., including Victoria and Nanaimo harbors, Menzies Bay, and sites in Knight Inlet (DFO, unpublished data). A study conducted on the northeast coast of Vancouver Island showed creation of intertidal lagoons could provide habitat for some stocks of juvenile coho salmon *O. kisutch* (Atagi 1994).

Fish are often adapted to feed on the edges or perimeters of habitats and, therefore, habitats that maximize shoreline length can also maximize productive capacity. The intertidal islands constructed at the Campbell River estuary, for example, were provided with channels and bays to increase their shape complexity (Levings and Macdonald 1991). Since they were constructed 14 years ago, some infilling of sediment has occurred, showing that maintenance of some aspects of the islands is necessary. In the Fraser River estuary, a system of freshwater tidal creeks about 2 km long was dug through riparian habitat as a habitat improvement measure. This technique was also used as a restoration measure at the Squamish River estuary, when tidal creeks were reconnected after a planned port development blocked flow (Ryall and Levings 1987).

Artificial Reefs

Development of subtidal artificial reefs was initially attempted in our region in 1983 as a measure to compensate for sand and mudflat fish habitat lost to port construction at Roberts Bank on the Fraser River estuary. Since then, the technique has been applied at about eight other sites, including Nanaimo (Armstrong 1993) and Sidney harbors, Discovery Passage, Port Hardy, and in Seymour Inlet (DFO, unpublished data). Natural rock was usually used as a substrate but in some cases concrete blocks or large diameter concrete pipes were used. However, it should be noted there are difficulties determining whether fish use of these structures actually represents an increase in productive capacity or whether fish observed near the reefs are being attracted to it from adjacent habitats (Levings 1995).

Habitat Banks

Another emerging strategy is the construction of habitat banks, which are habitats created in anticipation of loss. In the Fraser River estuary, habitat managers and harbor authorities have developed about 3.5 ha of marsh habitat for use as a bank from which withdrawals can be made if industrial activity requires the loss of habitat in the future. The artificial reef in Nanaimo harbor was created to bank habitat toward future fill projects (DFO, unpublished). Some authors are of the opinion that mitigation banks, as they are called in the U.S., could be a very useful technique in estuarine management (e.g., Etchart 1995). However, this is more or less an unproven technique that tends to focus on the creation of a large amount of habitat in a particular reach of the estuary. In natural estuaries, habitat is more evenly distributed or has a pattern of patchiness that may be important for fish and wildlife. Research in estuaries from a landscape ecology perspective would help answer some of these questions and could perhaps be conducted by habitat fragmentation analyses, as used in forestry studies.

SUMMARY AND RECOMMENDATIONS

Because of the lack of comprehensive monitoring and follow-up studies to assess the results of habitat management in the estuaries, it is difficult to make general statements about how effective the programs described above have been in achieving sustainability of salmon habitat in British Columbia estuaries. Fiscal constraints have prevented assessment in the dozens of B.C. estuaries where habitat managers have practiced their trade. At the Fraser River estuary, it appears that estuarine habitat loss may have slowed. Kistritz (1996) determined that, since about 1985, there had been a "net gain" of 6 ha of brackish marsh habitat, at the expense of sand and mud flat habitat that had been planted with marsh vegetation. On the other hand, as Levings and Nishimura (1996) have shown, it is not clear whether all the created marshes will perform as planned. In addition, Hutchinson (1982) and Hutchinson et al. (1989) showed that expansion of brackish marsh was occurring fairly rapidly at certain areas on the Fraser estuary owing to natural sedimentation and colonization. Unfortunately, these gains have never been quantified, but need to be added to the area of created habitat identified by Kistritz (1996).

It is also unclear whether sufficient critical fish habitat remains to provide functions for the current anadromous fish populations that use the estuary. At any rate, estuarine fish habitat function should not be viewed in isolation from freshwater and marine influences (Bradford and Levings 1997). Major fish populations which are thought to be reliant on the Fraser River estuary as rearing habitat, such as chinook in the Harrison River, a lower Fraser tributary, have recently shown significant interannual variability in survival (Schubert et al. 1994), likely owing to the interactive levels of survival in their three primary habitats (freshwater, estuary, and ocean). On the other hand, non-anadromous fish, such as cyprinids, show relatively stable populations in the lower river and estuary (Healey and Richardson 1996) when data from recent surveys were compared with those obtained two decades ago.

Many estuaries around the world are in poor health and require rejuvenation. Many B.C. estuaries could also benefit from restoration, another strategy which may help. When humans suffer heart problems, we often can be revived using cardiopulmonary resuscitation (CPR). Estuarine ecosystems need ecological CPR: Conservation, Preservation, and Restoration. Because of the uncertain success of several of the compensation measures discussed above, fish habitat managers should strive to manage for total prevention of habitat loss, and ideally, net gain of habitat through restoration. Mitigation and prevention should be used to avoid habitat loss, in keeping with the precautionary principle. If compensation is to be used, as a last resort, performance criteria need to be established before the compensatory habitat is built. The basic principles of adaptive management should be followed. While safety factors are routinely applied in compensation projects, there are very few projects where fisheries-oriented performance criteria have been applied. Performance bonds may be needed at high risk areas to ensure that funds are in place to repair compensation works that may degrade over time or simply do not work as anticipated.

The cumulative loss of numerous small areas (range 10 to 1000 m^2), especially in small estuaries, will continue to be a major problem unless overall management plans are developed and implemented. These estuary plans require the involvement and commitment of the many community stakeholders in addition to fisheries agencies.

As estuaries begin to be managed on an ecosystem basis, as called for in the new Oceans Act, estuary management plans should be developed for all the major estuaries on the B.C. coast, providing an ideal opportunity for integrating the restoration assessments with other ecological projects in the coastal zone.

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REFERENCES

Armstrong, J. W. 1993. A biological survey of an artificial reef at Newcastle Island, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2212.

Atagi, D. Y. 1994. Estuarine use by juvenile coho salmon *Oncorhynchus kisutch*: is it a viable life history strategy? Master's thesis, University of British Columbia, Vancouver.

Bradford, M. J., and C. D. Levings. 1997. Report on the Workgroup "Partitioning Survival." Pages 279–282 *in* R. L. Emmett and M. H. Schiewe, editors. Proceedings of the workshop on estuarine and ocean survival of Northeastern Pacific salmon. NOAA Technical Memorandum NMFS-NWFSC-29.

DFO (Department of Fisheries and Oceans). 1986. The Department of Fisheries and Oceans Policy for the Management of Fish Habitat. DFO, Ottawa, Ontario.

Etchart, G. 1995. Mitigation banks: a strategy for sustainable development. Coastal Management 23:223–237.

Gregory, R. S., and C. D. Levings. 1996. The effects of turbidity and vegetation on the risk of juvenile salmon (*Oncorhynchus* spp.) to predation by adult trout (*O. clarkii*). Environmental Biology of Fishes 47:279–288.

Healey, M. C., and J. S. Richardson, 1996. Changes in the productivity base and fish populations of the lower Fraser River (Canada) associated with historical changes in human occupation. Archive Hydrobiologie (Supplement) 113 (Large Rivers 10) (1–4):279–290.

Hutchinson, I. 1982. Vegetation-environment relations in a brackish marsh, Lulu Island. Canadian Journal of Botany 60:452–462.

Hutchinson, I., A. C. Prentice, and G. Bradfield. 1989. Aquatic plant resources of the Strait of Georgia. Pages 50–60 *in* K. Vermeer and R. Butler, editors. The ecology and status of marine and shoreline birds in the Strait of Georgia, British Columbia. Special Publication, Canadian Wildlife Service. Catalogue Number CW66-98/1987E.

Hvidsten, N. A., C. D. Levings, and J. Grout. 1996. A preliminary study of hatchery chinook salmon smolts migrating in the lower Fraser River, determined by radiotagging. Canadian Technical Report of Fisheries and Aquatic Sciences 2085.

Kistritz, R. U. 1996. Habitat compensation, restoration, and creation in the Fraser River estuary: are we achieving a no net loss of fish habitat? Canadian Manuscript Report of Fisheries and Aquatic Sciences 2349.

Kistritz, R., G. Williams, and J. Scott. 1992. Inspection of red-coded habitat, Fraser River estuary, summer of 1992. Prepared for Fraser River Estuary Management Program. Burnaby, British Columbia.

Kistritz, R., and M. Gollner. 1995. Review and assessment of eelgrass *Zostera marina* transplanting projects in coastal British Columbia. Report prepared for Department of Fisheries and Oceans, West Vancouver Laboratory. West Vancouver, British Columbia.

Levings, C. D. 1980. Consequences of training walls and jetties for aquatic habitats at two British Columbia estuaries. Coastal Engineering 4:111–136.

Levings, C. D. 1991. Strategies for restoration and development of fish habitat in the Strait of Georgia—Puget Sound Inland Sea, northeast Pacific Ocean. Marine Pollution Bulletin 23:417–422.

Levings, C. D. 1995. Natural factors to be considered in restoration of marine and estuarine ecosystems supporting fisheries. Pages 47–50 *in* Murata, B., editor. Proceedings of the Osaka-Wan Symposium. Osaka, Japan.

Levings, C. D., and five coauthors. 1989. Chinook salmon and estuarine habitat: A transfer experiment can help evaluate estuary dependency. Pages 116–122 *in* C. D. Levings, L. B. Holtby, and M. A. Henderson, editors. Proceedings of the national workshop on the effects of habitat alteration on salmonid stocks. Canadian Special Publication of Fisheries and Aquatic Sciences 105.

Levings, C. D., and J. S. Macdonald. 1991. Rehabilitation of estuarine fish habitat at Campbell River, British Columbia. Pages 176–190 *in* J. Colt and R. J. White, editors. Proceedings of the fisheries bioengineering symposium. American Fisheries Society Symposium 10. Bethesda, Maryland.

Levings, C. D., and R. M. Thom. 1994. Habitat changes in Georgia Basin: implications for resource management and restoration. Pages 330–351 *in* R. C. H. Wilson, R. J. Beamish, F. Aitkens, and J. Bell, editors. Review of the marine environment and biota of Strait of Georgia, Puget Sound, and Juan de Fuca Strait. Canadian Technical Report of Fisheries and Aquatic Sciences 1948.

Levings, C. D., and D. J. H. Nishimura, editors. 1996. Created and restored sedge marshes in the lower Fraser River and estuary: An evaluation of their functioning as fish habitat. Canadian Technical Report of Fisheries and Aquatic Sciences 2126.

Metikosh, S. 1997. No net loss in the "real" world. Pages 9–17 *in* C. D. Levings, C. K Minns, and F. Aitkens, editors. Proceedings of the DFO workshop on research priorities to improve methods for assessing productive capacity for fish habitat management and impact assessment. Canadian Technical Report of Fisheries and Aquatic Sciences 2147.

Odum, W. E. 1970. Insidious alteration of the estuarine environment. Transactions of the American Fisheries Society 99:836–847.

Pomeroy, W. M., D. K. Gordon, and C. D. Levings. 1981. Experimental transplants of brackish and salt marsh species in the Fraser River estuary. Canadian Technical Report of Fisheries and Aquatic Sciences 1067.

Ryall, R., and C. D. Levings. 1987. Juvenile salmon utilization of rejuvenated tidal channels in the Squamish estuary, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1904.

Schubert, N., Farwell, M. K., and L. W. Kalnin, 1994. Enumeration of the 1993 Harrison River chinook salmon escapement. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2242.

Sibert, J., T. J. Brown, M. C. Healey, B. A. Kask, and R. J. Naiman. 1977. Detritus-based food webs: exploitation by juvenile chum salmon *Oncorhynchus keta*. Science 196:649–650.

Thom, R. M. 1990. A review of eelgrass *Zostera marina* transplant projects in the Pacific Northwest. Northwest Environmental Journal 6:121–137.

Williams, G. L. 1993. Mitchell Island marsh compensation project: Monitoring results and implications for estuarine management. Pages 415–425 *in* Proceedings of the 1993 Canadian coastal conference. National Research Council of Canada, Ottawa, Ontario.

Zimmerman, R. C., J. L. Reguzzoni, and R. S. Alberte. 1995. Eelgrass *Zostera marina* transplants in San Francisco Bay: Role of light availability on metabolism, growth, and survival. Aquatic Botany 51:67–86.