Multi-Jurisdiction Review of Fisheries Management Strategies for Illegally Introduced Non-native Sport Fish

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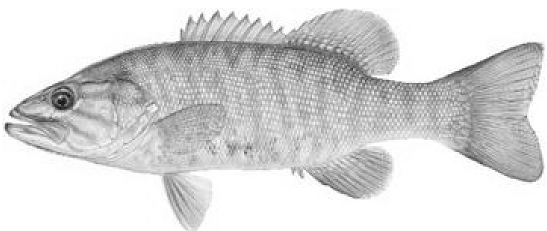

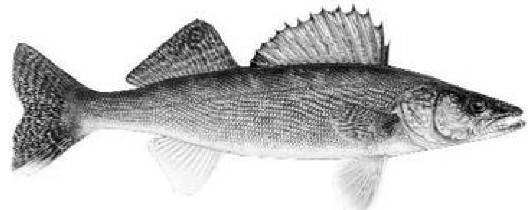

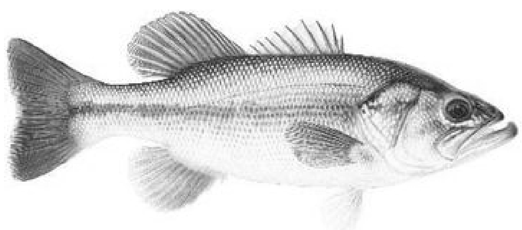

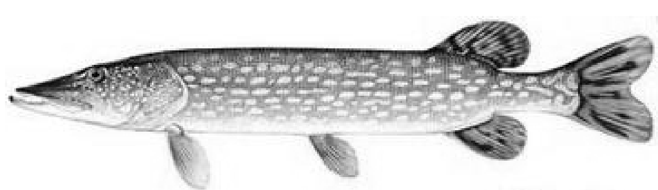

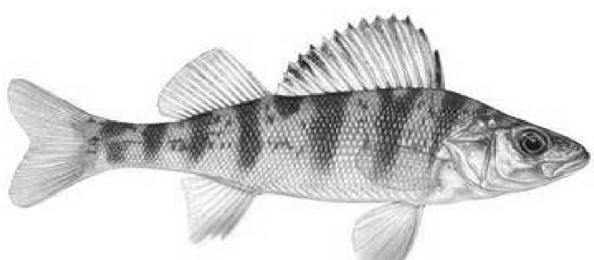

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Executive Summary

Introduction and Project Objectives

Wild fish are an important component of healthy aquatic ecosystems and the foundation of significant benefits to the province of BC. Conserving wild salmonid species and their associated fisheries, as well as those of traditional hatchery stocks, is becoming increasingly complicated by illegal introductions of non-native fisheries species. The BC Fisheries Program is developing a policy and management plan to address illegal introductions of non-native sport fish species. While the scope of the Fisheries Program policy and management plan may encompass a wide variety of non-native fish species, the present project focuses only on non-native fisheries species including: smallmouth bass (Micropterus dolomieui), largemouth bass (M. salmoides), yellow perch (Perca flavescens), black crappie (Pomoxis nigromaculatus), walleye (Stizostedion vitreum) , and northern pike (Esox lucius). The present project provides background for the new management policy and management plan and provides a toolbox of strategies to:

1. Manage existing non-native fisheries;
2. Control non-native fish stocks where possible and necessary; and,
3. Prevent illegal introductions of non-native fisheries species.

Approach

I developed approaches to meet the project objectives based on information provided in almost 200 peer-reviewed studies and the experience and guidance provided through interviews I conducted with fisheries managers from more than 20 North American jurisdictions. I divided these recommendations into several sections encompassing: fisheries management techniques including regulations; fish removal and control using techniques such as piscicides and mechanical methods; and fish movement prevention strategies including legislation and internal and external communication strategies.

Management and Control of Non-native Fisheries Species

Regulations

Fish harvest can be restricted by regulating angling seasons, hours, areas and methods, and the species, number and size of fish that may be kept. I found examples of regulations used to manage the non-native species of concern and although the objectives in most of these cases was to usually to protect, maintain or enhance fisheries, the effects of these strategies may be of some assistance to fisheries mangers seeking to control or manage these stocks in this province. For example, harvest regulations including liberal limits can be used to:

- Provide angling opportunities for smallmouth and largemouth bass prior to implementing other control methods;

- Enhance opportunities for junior anglers for yellow perch and black crappie;
- Control numbers of small fish in walleye fisheries.

Minimum length and slot length limits can be used to:

- Produce trophy fisheries for smallmouth and largemouth bass and potentially yellow perch and black crappie;
- Increase numbers of large fish to control stocks such as yellow perch that are naturally regulated by cannibalism;
- Produce larger walleye to control levels of other non-native prey including yellow perch.

Mixed Native-Non-native Fisheries Management

In those situations where the objective is to manage non-native fisheries, and existing policies allow, managers can:

1. Manage for quality or trophy fisheries for bass, and basic yield fisheries by:
    - Improving the potential for stocked trout survival by changing/improving stocking sites and stocking larger sizes;
    - Improving bass habitat;
    - Discontinuing/limiting commercial crayfish fisheries;
    - Introducing regulations to improve bass fisheries including slot limits and closures;
    - Providing shore access/sites for anglers and promoting fisheries;
    - Establishing non-native fisheries management working groups with angler groups.

2. Manage for native and non-native fisheries in large lakes with a diversity of habitats by:
    - Improving native fish habitat to improve stocked trout survival;
    - Improving trout growth in low productivity areas through nutrient addition;
    - Managing non-native prey to ensure forage for non-native predators;
    - Stocking trout strains suited for survival in mixed stock lakes;
    - Stocking larger trout (yearlings) in deeper water;
    - Introducing regulations to balance non-native fisheries stock levels.

3. Manage for native fisheries in small lakes with no opportunity for spatial segregation between native and non-native stocks by:
    - Introducing LWD at stocking sites and in-shore areas to improve stocked trout survival;
    - Addressing trout habitat limitations identified in lake assessments;
    - Adjusting stocking timing/stock strains to maximize trout survival;
    - Removing restrictions on non-native species;
    - Supporting derbies for non-native stocks;
    - Chemically/mechanically removing non-native fish.

Controlling Non-native Fisheries Species

Chemical Removal

Approximately 41% of the almost 170 piscicide projects I reviewed were effective at achieving their objective whether that be eradicating the target stock entirely or reducing levels to provide some relief to native stocks. According to both the literature and fisheries managers from other jurisdictions, chemical fish removal projects can be ineffective because of:

- Incomplete distribution of the piscicide;
- In ability to concentrate piscicides in heavy vegetation or areas where fish can hide;
- Water quality parameters that inhibit chemical effectiveness; and
- Not accounting for different susceptibilities of target species.

According to discussions with fisheries managers from other jurisdictions, piscicide project success can be improved by ensuring projects meet the following criteria:

- The target stock is new in the system (i.e. no multiple generations);
- Native fish can be re-stocked from hatcheries or neighbouring waters;
- The system does not contain threatened (Red- or Blue-Listed) species;
- The system is isolated and small (<1 km deep and <15 hectares in area);
- There are no beaver dams or heavy vegetation that cannot be removed;
- Project cost <10 days effort and <$5,000; and,
- Ensuring funds are available to implement repeat projects and monitoring for a minimum of 3 years.

Mechanical Removal

Mechanical removal techniques I reviewed included: angling; bounties; commercial fishing; electrofishing; explosives; netting; and trapping. Overall, these projects were approximately 40% successful at removing unwanted species, although some techniques such as netting and trapping were more successful than others such as angling. The effectiveness of mechanical removals strategies is highest when:

- Implemented in small areas (e.g. lakes <3 ha in area and <10 m in depth);
- Implemented in lakes with limited spawning habitat;
- There are no self-sustaining fish populations in inlets/outlets;
- Fisheries managers tailor the method(s) to the microhabitat and movements of target species;
- Projects are repeated and effectiveness is monitored over multiple years.

Biological Control

Biological control includes the introduction of native and non-native piscivors to control unwanted species. Fisheries managers in some jurisdictions also use this technique to create new fisheries for the introduced predator. Biological control strategies have various levels of success and there can be ecological impacts associated with this technique including the introduction of diseases associated with the piscivor. Prior to introducing a new predator, fisheries managers must:

- Determine the habitat suitability for the introduced predator;
- Establish control measures that may be necessary for the predator;
- Evaluate potential impacts including hybridization or competition/predation on other (non-fishery) native, threatened or endangered species.

Where there is the additional objective of creating a fishery, managers must also:

- Determine if the predator will be a desirable sport species; and,
- Establish how the new fishery will be maintained if the stock is not available locally.

Habitat Alteration

Habitat can be altered to make it more hospitable for the native species, less hospitable for the non-native species, or to exclude non-native species once they have been removed. Habitat alteration strategies include: the creation of non-native-free zones; water body drawdown; temperature alteration; vegetation removal; barrier creation to exclude non-native fish; and barrier removal to improve/expand native fish habitat. While habitat alteration projects were the most consistently effective of all the control strategies I reviewed, the objectives of most of these projects were usually to control or exclude non-native species for a short time, not eradicate these stocks over the long term.

Overall Effectiveness of Fish Management and Control Strategies

There are no quick-fixes when a non-native species is introduced into a new habitat and overall the literature I reviewed and interviews I conducted revealed that fish control and management strategies have <40% chance of success even when implemented over multiple years. According to fisheries staff I spoke to, the effectiveness of fish control and management projects can be increased when fisheries managers:

- Identify and address the specific problem affecting the native fish or fishery;
- Assess the ecology and biology of the non-native species;
- Identify the appropriate technique(s) required for the species and/or life history phase;
- Consider the technical requirements of the technique(s);
- Implement projects and monitoring programs over multiple years; and,
- Address the potential for illegal re-introductions by also implementing surveillance programs, angler-agency non-native species management committees and general public education and involvement projects.

<u>Preventing Non-native Fish Introductions</u>

Legislation, and Internal and External Communication

Although current federal and provincial legislation addresses the illegal introduction/movement of non-native species, in BC, only approximately 1% of the total warnings and tickets issued over the past 20 years have been under statutes related to the illegal movement of fish. Fisheries managers and Conservation Officers from a variety of jurisdictions say it is difficult to enforce legislation because of: problems apprehending perpetrators; ineffective and outdated statutes and inadequate penalties; the time delay between fish introduction and discovery; and systemic problems including the failure of agencies to communicate to staff priorities regarding illegal non-native fish movements. I suggest several approaches to address these limitations including:

- Reviewing and strengthening provincial legislation and associated penalties;
- Communicating to staff agency priorities regarding non-native species;
- Improving internal understanding and communication of agency concerns by implementing information programs and workshops for both staff and managers; and establishing or expanding related working committees to address legal, policy and program issues regarding illegal fish movement; and,
- Improving external communication by implementing angler involvement projects, consulting with client groups and establishing joint agency-angler non-native fish management committees; and implementing general public awareness projects and Community Watch surveillance programs.

Rapid Response

Understanding clients and the current distribution of non-native fish stocks is critical to predicting the potential movements, both natural and human-assisted, of non-native species. I suggest developing regional GIS-linked databases identifying existing non-native species distribution and potential distribution and expansion pathways to improve the effectiveness of agency surveillance, Community Watch programs and rapid response plans.

Non-native Fishery Species Management, Control and Introduction Prevention Summary

According to Shafland (1986), once non-native fisheries species are discovered or established in a new system, all efforts should be made to assess, manage and, if possible, utilize them in a beneficial manner. To that end, decisions regarding the selection of strategies to eliminate, control or manage non-native fisheries species, and prevent their illegal re-introduction will be most effective when fisheries managers consider:

1. The specific problem affecting the native stock and/or fishery and whether it is as a result of the non-native species;
2. The ecology and biology of the target non-native stock;
3. The technical requirements of the management and/or control technique(s);
4. The operational requirements of the project and whether the agency can support these over multiple years;
5. What the public and clients will accept; and,
6. The possibility of illegal re-introduction and methods to curtail this over the long-term including changes to legislation and penalties and the implementation of staff, angler and public involvement and awareness programs.

Multi-Jurisdiction Review of Fisheries Management Strategies for Illegally Introduced Non-native Sport Fish

1.0 Introduction and Project Objectives

Wild fish are an important component of healthy aquatic ecosystems and the foundation of significant benefits to the province of BC. Balancing native fish stocks, while providing consumptive and recreational opportunities is complex even in the most uncomplicated of systems. Unfortunately, this becomes even more difficult when non-native fish, some of which may compete or prey upon native species, are introduced into freshwater systems that support popular, traditional native species fisheries.

The BC Fisheries Program is developing policy and procedures to address the illegal introduction of non-native sport fish species into provincial waters. While the scope of the Fisheries Program policy and management plan may encompass a wide variety of non-native fish species, the present project focuses only on non-native fisheries species including: smallmouth bass (<u>Micropterus dolomieui</u>), largemouth bass (<u>M. salmoides</u>), yellow perch (<u>Perca flavescens</u>), black crappie (<u>Pomoxis nigromaculatus</u>), walleye (<u>Stizostedion vitreum</u>) , and northern pike (<u>Esox lucius</u>). The present project provides background information to support the development of management policy and procedures and provides strategies to:

1. Manage existing non-native fisheries where appropriate;
2. Control non-native fish stocks where possible and necessary; and,
3. Prevent illegal introductions of non-native fisheries species.

2.0 Methods

I tallied the number of small and large lakes by region with confirmed reports of the non-native species of interest to determine the extent of non-native fisheries species in BC. I then summarized the results of the National Sportfish Survey to determine the contribution of those species to provincial fisheries over the past two decades. I spoke to biologists, fisheries management and Conservation Officer staff from BC to determine current legislation and policies regarding non-native fisheries species management, and summarized provincial technical reports to document all research, control and management endeavours involving non-native fisheries species fisheries to date in this province (**Appendix 1, Appendix 2**).

I also interviewed fisheries managers from Alberta, California, Florida, Idaho, Manitoba, Montana, Nevada, Ontario, Oregon, Utah and Washington State to document agency policies and field-level strategies used to manage non-native and illegally-introduced sport fish in those jurisdictions (**Appendix 1, Appendix 2**). I developed my contact list based on information provided in past studies (e.g., Govindarajulu, 2006) and from information provided by Sue Pollard (Aquatic Species at Risk Specialist) and Miles Stratholt (Fish Policy Analyst), both of the Environmental Stewardship Division of the Ministry of Environment. I devised a list of questions focused on addressing the objectives of this paper, then interviewed one or more representative(s) from each jurisdiction. I documented all answers in Excel spreadsheets for the appendices, and summarized this information for the body of the report.

I conducted on-line literature searches through the American Fisheries Society, the UBC Library, the Ministry of Forests Library and the Ministry of Environment Ecocat System, and at the Pacific Biological Station, Malaspina College in Nanaimo, and the University of Victoria, to compile additional information on non-native fish and fisheries management (**Appendix 3**). I gathered information on specific studies focused on impacts to native stocks and habitats as a result of the introduction of non-native fisheries species, the legislation and fisheries management strategies used in North America, and preventative measures such as education used to address illegal fish movement. Where possible, I concentrated on the species which are the focus of this paper, however, I also used information on other similar, or closely related species where applicable.

I classified the effectiveness of all non-native species management and control projects I had reviewed to develop the toolbox of fish control and management strategies and prevention measures. I considered projects effective if they met the objectives as noted by authors of the papers I reviewed or the fisheries managers I interviewed. I discussed the effectiveness of each technique within the respective sections in the body of the report, and developed several flow charts to guide the decision-making process regarding what control or management techniques to use depending on the situation or species.

3.0 Non-Native Species and Fisheries in North America

BC is not alone in grappling with complexities of controlling and managing non-native species. Almost 40% of the fisheries managers I spoke to from other regions estimated that non-native fisheries species were present in more than half of their water bodies, and >50% of those interviewed also said the problem of illegal introductions was increasing (**Table 1, Appendix 2**).

Table 1. Summary of non-native fisheries species, percent of lakes affected and status of introductions in 13 North American jurisdictions.

Jurisdiction	Non-native species*	Percent of Water Bodies Affected*	Status
Alaska	yellow perch, northern pike	>50%	stable
Alberta	yellow perch, walleye (in non-native drainages)	unknown	unknown
California	smallmouth bass, northern pike	>50%	increasing
Colorado	smallmouth bass, largemouth bass, yellow perch, walleye	unknown	unknown
Florida	largemouth bass	>50%	stable
Idaho	smallmouth bass, largemouth bass, yellow perch, northern pike walleye	50% >50% 50%	stable stable increasing
Montana	bass	<50%	increasing
Nevada	northern pike	<50%	increasing
Nova Scotia	smallmouth bass	<50%	increasing
Ontario	smallmouth bass, black crappie	unknown	increasing
Oregon	bass, yellow perch, walleye	unknown	increasing
Utah	smallmouth bass, yellow perch	<50%	stable
Washington	bass, yellow perch, black crappie, northern pike walleye	>50%	stable

*estimated by Fisheries Biologists and Fisheries Managers participating in the telephone interview conducted as part of this study. Please see Appendix 1 for contact names and Appendix 2 for responses to specific interview questions.

3.1 Non-native Fisheries Species and Fisheries in BC

The first introduction of a non-native fishery species in BC likely dates back to at least 1908 when the Dominion government transplanted bass into Christina and Moyle lakes (Field and Dickie, 1987). Since then, a variety of freshwater fisheries species has been introduced by agencies and anglers into provincial lakes and there have been non-native fishery stocks documented in various regions of the province for, in some cases, >50 years (**Table 2**).

Table 2. Dates of first recorded collection by Fisheries Branch staff or contractors of black crappie, smallmouth bass, largemouth bass, walleye and yellow perch in British Columbia. (Source: Warburton, P. 1998; Field and Dickie, 1987).

Region 1 - Vancouver Island		**Region 5 - Cariboo**	
Smallmouth Bass	1952	Smallmouth Bass	2006
Yellow Perch	1997	**Region 7 - Peace**	
Region 2 - Lower Mainland		Walleye	1968
Black Crappie	1947	**Region 8 - Okanagan**	
Largemouth Bass	1998	Black Crappie	1987
Yellow Perch	1997	Largemouth Bass	1920[1]
Region 3 - Thompson-Nicola		Smallmouth Bass	1954
Smallmouth Bass	1963	Walleye	1969
Region 4 - Kootenay		Yellow Perch	1951
Largemouth Bass	1953		
Smallmouth Bass	1958		

Yellow Perch	1956		

Despite the long-term presence of non-native species in the province, only approximately 1% of provincial waters are currently inhabited by non-native fishery species. However, most of the concentration of those species exists in only four regions: Region 1 (Vancouver Island), Region 2 (Lower Mainland); Region 4 (Kootenays), and Region 8 (Okanagan) (**Table 3**).

Table 3. Total number of BC lakes with smallmouth bass, largemouth bass, walleye, northern pike, yellow perch and black crappie. (Source: Sally Bertram, Integrated Land Management Branch, Ministry of Environment, Nanaimo - 2006; and FISS Database, Ministry of Environment).

Region	**Area**	**Total number of lakes***	**Total number of lakes with non-native species**	**Percent of lakes with non-native species**
1	Vancouver Island	1543	57	3.7
2	Lower Mainland	970	84	8.7
3	Thompson-Nicola	1686	6	0.4
4	Kootenay	902	56	6.2
5	Cariboo	4583	0	0.0
6	Skeena	7530	1	0.0
7	Omineca	3587	1	0.0
8	Okanagan	410	39	9.5
9	Peace	2966	32	1.1
Total		24177	276	1.1

*includes small (<5 and >1,000 ha) and large (>1,000 ha) lakes

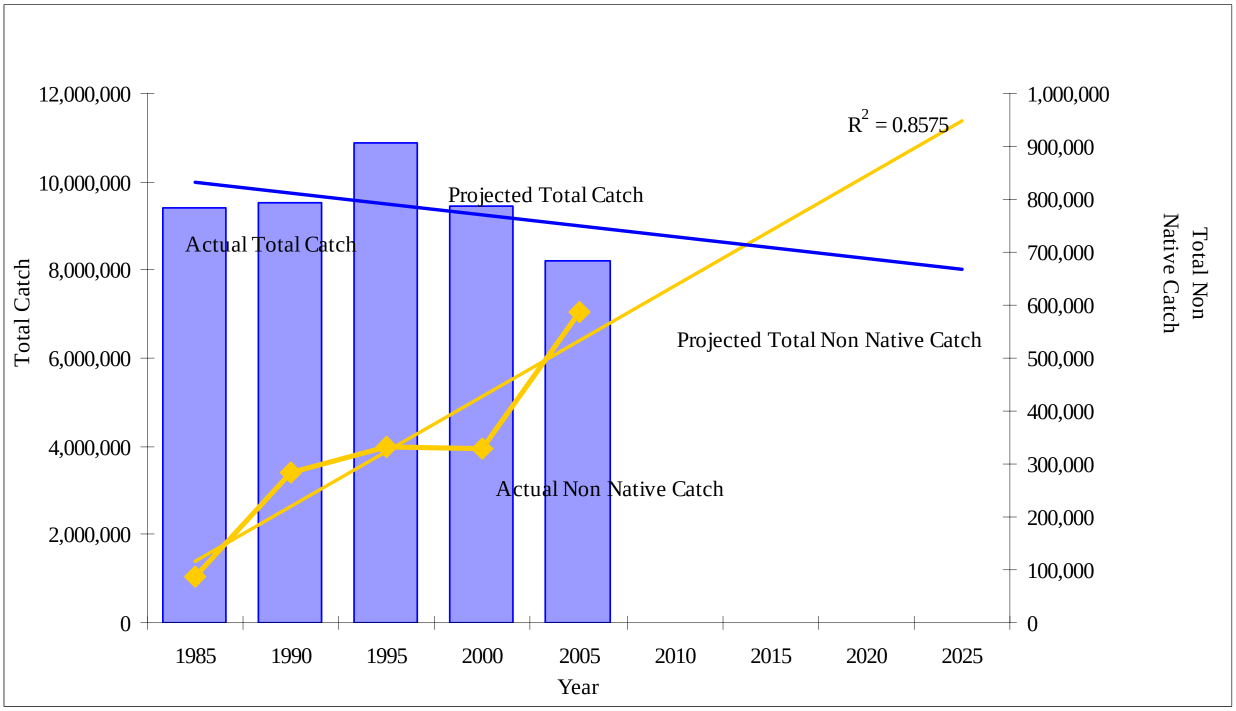
Regardless of the small concentration of non-native species overall, some of these stocks are spreading and supporting an increasing proportion of our fisheries. In 2005 for example, the catch of non-native species accounted for 20% of the total catch in Region 8 (Okanangan), and >16% in Region 4 (Kootenays) (**Table 4**). If present trends continue, I estimate that non-native species could, within the next decade, comprise up to 10% of provincial fisheries (**Figure 1)**.

Table 4. Percent catch of yellow perch, bass, northern pike and walleye caught by region in BC 1985-2005. (Source: Levey, and Williams, 2003; Brickley, K. pers. com., 2007).

Region	Percent non-native catch				
	1985	1990	1995	2000	2005
Region 1 - Vancouver Island	—	2.5	3.2	9.2	9.0
Region 2 - Lower Mainland	1.3	—	0.8	0.2	0.3
Region 3 - Thompson Nicola	—	—	—	1.8	4.1
Region 4 - Kootenay	2.2	13.4	11.2	7.0	16.4
Region 5 - Cariboo	—	—	—	0.06	0.08
Region 6 - Skeena*	0.05	—	—	0.2	0
Region 7 - Omineca	3.8	2.2	4.6	0.2	0
Region 8 - Okanagan	0.7	2.5	3.9	7.7	20.0
Region 9 - Peace**	2.2	3.9	2.0	2.4	12.2
Total Non-native Catch (BC)	88,498	285,180	332,423	328,400	585,883
Total Catch (BC)	9,395,215	9,506,068	10,869,636	9,428,643	8,204,705
Percent non-native (BC)	0.9	3.0	3.0	3.4	7.1

* Does not include northern pike which are native in this region.
** Does not include walleye or northern pike which are native in this region.

Figure 1. Total and projected catch of bass, yellow perch, walleye, and northern pike to total and projected catch of rainbow trout, cutthroat trout, steelhead, brook trout, Dolly Varden/bull trout, kokanee, salmon, walleye, arctic grayling, whitefish, perch, bass, northern pike, and other fish in BC 1985-2005 and projected to 2015. (Source: Levey, and Williams, 2003; Brickley, K. pers. com., 2007). NOTE: Incidental reports of non-native species in new lakes are reported to regional staff on an ongoing basis, however, these reports are not included in the projected trends because trends shown are based on fisheries reported as part of the National Sportfish Survey.



4.0 Management and Control of Non-Native Fishery Species

Agencies throughout North America have attempted to manage, for the purposes of creating and maintaining fisheries, and control introduced fish using a variety of methods. The techniques chosen depend on the ecology of the target species, the conservation goals for the native species, the characteristics of the landscape, the regulatory framework, public opinion, and budgetary constraints (Govindarajulu, 2006) (**Table 5**). Over 50% of the fisheries managers I spoke to, or studies I examined used regulations to manage non-native species, while just under 50% implemented measures including mechanical removal to control these species (**Table 5)** (**Appendix 3**). Of the agencies that implemented control measures, approximately 40% have used piscicides, 21% have tried biomanipulation, and 25% have altered habitat.

Table 5. Summary of non-native species control and management strategies used by 32 North American Fish and Wildlife management agencies.

Jurisdiction	Chemical Removal	Mechanical Removal					Biological Control	Regs*	Habitat Alteration	
		Traps	Nets	E.fishing	Angling	Explosives			Barriers	Drawdown
Alaska	✓									
Alberta; Fish and Wildlife				✓	✓	✓		✓		
Alberta; Parks Canada			✓	✓						
Australia		✓								
British Columbia	✓								✓	
California	✓		✓	✓		✓				
Colorado		✓						✓		
Delaware								✓		
Florida	✓						✓	✓		✓
Georgia								✓		
Idaho	✓		✓	✓	✓		✓		✓	✓
Iowa								✓		
Kentucky								✓		
Manitoba										
Michigan	✓							✓		
Minnesota		✓							✓	
Missouri								✓		
Montana	✓		✓	✓					✓	✓
Nevada	✓								✓	
New Brunswick	✓									
New Zealand		✓					✓			
Nova Scotia			✓				✓			✓
Oklahoma								✓		
Ontario	✓				✓			✓		
Oregon	✓		✓	✓			✓	✓		
Quebec; Parks Canada	✓									
South Dakota								✓		
Texas								✓		✓
Utah	✓		✓				✓	✓		
Washington	✓		✓		✓		✓	✓		
Wisconsin								✓		
Wyoming		✓								
Total	**14**	**5**	**8**	**6**	**4**	**2**	**7**	**17**	**5**	**5**
Percent of Total Jurisdictions Surveyed	**44**	**16**	**25**	**19**	**13**	**6**	**22**	**53**	**16**	**16**

*regulations designed for control and fisheries management depending on the objectives of the agency.

5.0 Fisheries Management

Because anglers can be such effective predators (Magnuson, 1991), it follows that harvest regulations could be powerful management tools, and that their efficacy could extend beyond manipulating target populations to manipulating whole ecosystems (Johnson and Martinez, 1995). Unfortunately, only a few examples exist where sport fishing regulations have been used to accomplish community, food web, or ecosystem goals (Johnson and Martinez, 1995). Nonetheless, many jurisdictions have implemented regulations to attempt to control non-native fisheries stocks.

5.1 Regulations

Fish harvest can be restricted by regulating angling seasons, hours, areas, and methods, and the species, number and size of fish that may be kept. I found examples of harvest regulations primarily for bass, walleye, yellow perch and crappie, and length limits for the management of bass and walleye. Note, however, the objectives in most of these situations were usually to protect, maintain or enhance, rather than control or eradicate those species. I summarized the information regarding management strategies using regulations in the following section, and have presented the details of my interviews and literature searches in **Appendix 4**.

(a) Harvest Regulations

(i) Liberal Limits Regulations – General

- Largemouth Bass

Due to their slow growth, largemouth bass are susceptible to over harvest (Idaho Department of Fish and Game, 2007). Regardless, however, harvest rates for largemouth bass are generally low because they are difficult to catch, and most bass anglers practice catch-and-release (Daily et al. 1999). These factors impact the effectiveness of liberal regulations in controlling this species. Estimates based on modeling in Oregon suggest that the highest harvest rate for bass that could be achieved by removing regulations at the most popular bass lake in this state is 18% (Daily et al. 1999). Based on this level of exploitation, a population model predicted a reduction in predator-size bass (>8 inches) by only 16%, which fisheries managers believed would be insufficient to have any measurable effect on the production of native salmonid stocks (Daily et al. 1999).

- Smallmouth Bass

Studies in Oregon suggest that the level of angler exploitation and the presence of strong bass year classes would alter the efficacy of liberal angling regulations rendering them effective only sporadically (Daily et al. 1999). For example, Tabor et al. (1993) reported that the exploitation of smallmouth bass was so low that changing creel limits would have little effect on the population, while in 1990, Beamesderfer et al. (1991) found that these regulations did have some limited effects on the target stock. In addition, there is disagreement on the size of smallmouth bass that produces the bulk of salmonid predation (Daily et al. 1999). Connolly and Rieman (1988) suggest that most of the predation on salmonid smolts was by smallmouth bass too small to be harvested by anglers. Since most bass in a population are small, i.e., there are more young than old bass at any given time, liberalizing regulations on large bass would likely have little impact on the native prey stock, especially given that the minimum acceptable size of smallmouth bass for anglers appears to be approximately 8 inches (Nigro et al. 1985). Furthermore, bass anglers are conservative. Studies have found this client group regularly implements voluntary catch-and-release practices, and that few bass anglers keep their bag limit (Daily et al. 1999). In fact, public input received during a program review in Oregon showed bass anglers strongly supported more restrictive harvest regulations to improve the quality of bass fisheries (Daily et al. 1999).

On the surface, liberal limits may appear to be a logical method for controlling or eliminating non-native stocks, however this method allows anglers to harvest the largest fish first, leaving only small fish available for the fishery. Eventually, therefore, this regulation will fail if the objective is to control or eliminate stocks because the exploitation rate on smaller fish will likely be insufficient to affect the target population. Moreover, the regulation may even fail to suppress the larger fish in fisheries where there is insufficient exploitation.

(ii) Bass Spawning/Nesting Season

Like other centrarchids, male largemouth and smallmouth bass excavate nests in the littoral zones of lakes and rivers, typically in late spring, and once spawning is complete, the male remains alone at the nest site to provide sole parental care for the developing brood (Breder, 1936). If a nesting male largemouth or smallmouth bass is removed from his nest, his brood is left defenceless against predators (Neves, 1975), and if that male is harvested, rapid and total brood loss is a likely outcome (Suski and Philipp, 2004). For both smallmouth and largemouth bass, increases in the size of the nesting male results in a significant increase in brood size (Suski and Philipp, 2004). According to Suski and Philipp (2004), the largest males have the largest brood sizes, and it is these males that are the most likely to be caught as they defend their nests. These large males are not only the most valuable for the fishery, but they also invest the most in the defence and care of their offspring and, as such, are the ones with the greatest potential to contribute to annual recruitment (Suski and Philipp, 2004).

While relaxing regulations on spawning and nesting bass may impact bass population size, it may also negatively alter the population structure. In Ontario, for example, anglers often do not comply with regulations which prohibit angling for bass until the last Saturday in June (Kubacki et al. 2002), and this illegal angling reduces both individual and population-level reproductive success (Philipp et al. 1997), which in turn may reduce annual recruitment (Svec, 2000). If anglers target nesting bass, the individual bass caught will not be a random selection; the largest most aggressive males with the largest broods will be captured preferentially. Consequently, over time, harvest angling for nest-guarding bass is likely to select smaller, less aggressive males with reduced ability to provide parental care to their offspring (Suski and Philipp, 2004).

Given the popularity of bass fishing in some areas of the province, attempting to eradicate or control these stocks by targeting fish when they are most vulnerable may not be popular with anglers, and could result in angler non-compliance and reduced exploitation. This action would render the regulation ineffective, or worse, result in redoubled efforts by anglers to establish bass fisheries elsewhere. The only areas where this approach might be supported is where new non-native stocks have recently become established, and associated fisheries have not yet gained in popularity. However, it is unlikely a new fishery would have the exploitation rate required to control or eradicate the stock.

- Yellow Perch

A common problem in panfish populations, which includes yellow perch and black crappie, is poor size structure due to the lack of large fish in the population. In their study, Beard et al. 1997, noted that some stunting may be caused by excessive exploitation of large parental males and this leads to decreases in age and size at maturity of remaining males. Opening panfish fisheries and allowing anglers to harvest larger fish will likely backfire because large cannibalistic adults would be removed leaving numerous small fish of little interest to anglers. As the numbers of small fish increase, growth rates often decrease and, while anglers enjoy high catch rates, the harvest potential is limited (Eder, 1984). Furthermore, even where anglers are able to harvest more small fish, they may not because even in fisheries with regulations limiting exploitation, anglers do not regularly harvest their bag limits (Noble and Jones, 1999).

- Black Crappie

Increased harvesting or thinning has been recommended to increase utilization and improve crappie quality (Goodson, 1966), however, the potential effects of high exploitation include reduced density, lower survival and smaller average size (Larson et al. 1991). Colvin 1991 notes that while creel limits have been successful for crappies, when growth slows, creel limits become ineffective and Larson, et al. (1991) note that concomitant changes that might buffer the effects of exploitation include improved growth and condition, compensatory reductions in natural mortality, younger age-at-maturity, and increased fecundity. Consequently, high exploitation rates encouraged through liberal regulations (e.g., >65%) (Espegren et al. 1990) could backfire if remaining fish are smaller and, therefore, unattractive to anglers, and if remaining fish exhibit the concomitant changes noted by Larson et al. (1991).

- Walleye

In some cases, the biology of the species confounds the efforts to reduce predation through relaxation or elimination of restrictive regulations. For example, the large walleye sought by anglers are not the predators consuming the bulk of the salmonids (Daily et al. 1999). In fact, as walleye get larger, they tend to eat larger prey rather than more small prey. In a study conducted below a reservoir dam in Oregon, salmonids were the most important prey item of walleye <12 inches in length, but were of secondary importance for larger walleye (Daily et al. 1999). As a result, walleye <12 inches were found to consume the largest majority of the salmonids eaten by the species, consequently, relaxing harvest regulations on large walleye leaves unaddressed the fact that it is the juvenile walleye consuming the largest portion of salmonids, at least in this particular riverine-set study. In the case of this species, then, it may be more prudent to lift limits on small walleye, while still keeping restrictive limits on larger trophy-sized fish. The effectiveness of this measure will then depend on there being sufficient angler pressure on smaller fish.

- Northern Pike

Northern pike provide considerable recreational value, in part because of their vulnerability to anglers, consequently this species can be affected by angling regulations even at low effort (Paukert et al. 2001). In a study of the St. Lawrence River, Dunning et al. (1982) found that a higher minimum limit on northern pike reduced yield because the harvest of older fish caused a decrease in egg production in the population. In 2006, the Idaho Department of Fish and Game went to no-limit on northern pike, not to control populations per se, but to discourage illegal introductions into other waters (Idaho Department of Fish and Game, 2006).

Liberal bag limits are often intended to promote harvest of small fish. As with panfish, however, liberal bag limits may be ineffective in reducing numbers of small northern pike because anglers typically do not remove enough small fish of this species to increase growth rates and increase the proportion of large fish in the population (Goeman et al. 1993). In this fishery, anglers tend to selectively harvest single large fish, therefore, for liberalized bag limits to work effectively on this species, anglers must be willing to harvest more small fish (Goeman et al. 1993, Paukert et al. 2001).

Rather than controlling northern pike with regulations, fisheries managers may want to consider controlling their non-native prey. Northern pike may consume other large predatory non-native species including largemouth bass and yellow perch (Soupir et al. 2000). Consequently, implementing regulations to increase the size structure of northern pike to facilitate predation on other non-native prey species may both control those prey species, and bolster northern pike fisheries.

(iii) Liberal Limits - Fishing Derbies

One situation where liberal regulations could be implemented, if not to control stocks of non-native species but to foster non-native species fisheries, is by encouraging fishing derbies, particularly for juvenile anglers. An assessment of the warm water fishery of Lake Stevens in Washington State by Mueller (undated) found superabundant yellow perch, the growth of which was below average suggesting inter-and intraspecific competition caused by crowding. Mueller suggested reducing stocks by implementing juvenile fishing derbies which, he pointed out, may not exert significant control of these prolific fishes, but would provide excellent opportunities for increased angler awareness and recruitment. A similar approach has been implemented in California where the Lake Pillsbury/Upper Eel River Coordinated Resource Management Planning Group holds an annual California Pike Derby to increase awareness of this species and eliminate as many pike as possible in one day (Govindarajulu, 2006). In 2003, the total catch in this derby was close to 100 kg. In Idaho, the Department of Fish and Game manages illegally-introduced walleye by allowing unrestricted harvest, or by permitting fishing tournaments (Idaho Department of Fish and Game, 2007). And, while fisheries managers recognize that these strategies may not control walleye stocks, agency personnel in this jurisdiction maintain this approach sends a message to anglers that unauthorized introductions will not be managed to improve or sustain fisheries (Partridge, F., pers. com. 2006).

It is the policy of the BC Ministry of Environment to oppose fishing derbies where commercial and competitive aspects are emphasized to the detriment of fish or the fishing experience (Ministry of Environment, 1984). One of the reasons for this policy is that fishing derbies are not always compatible with encouraging angling ethics, especially when associated with species or stocks whose numbers are relatively scarce (Ministry of Environment, 1984). However, this is not the case with non-native species and, as a result, the Ministry may consider developing a separate policy to enable fishing derbies specifically for non-native fisheries species, or in specific bodies of water.

(b) Length Limit Regulations

(i) Minimum Length Limits - General

Length limits are among the most widely used and valuable tools available to fishery managers for the protection and manipulation of freshwater game fishes (Wilde, 1997). There are two types of length limits: minimum-length limits, and slot-length limits. Minimum-length limits require that fish below a minimum size be released while allowing larger fish to be harvested. In general, minimum-length limits could be used to increase the individual size of non-native fish to encourage or increase a fishery and, therefore increase exploitation rate over time or, as with some species like yellow perch where populations are kept in check by cannibalism, to increase the size and number of predatory adults.

Length limits are also recommended for fish populations characterized by low rates of recruitment and natural morality, good growth rates, and high fishing mortality (Anderson, 1980). In the case of northern pike, length limits can be effective because exploitation of this species can be size-selective. The effects of the regulation, however, can take numerous years to realize. In addition, physical characteristics of lakes may exert strong influences on northern pike population dynamics and influence the effectiveness of size regulations. Consequently, regulations need to be tailored to the inherent productivity of a water body and its fish population (Paukert et al. 2001), fishery pressure, and angler compliance.

(ii) Slot Length Limits

With slot limits, fish within a protected size range, or slot, must be released, while fish smaller than the lower limit of the protected size range, or larger than the upper limit, may be kept. Slot limits are recommended for populations with high recruitment and low growth rates, and are expected to result in increased numbers of protected-size fish, promote growth of smaller fish by reducing intraspecific competition through angler harvest, and increase production of trophy fish (Anderson, 1976). Slot length limits also offer a means for manipulating prey fish populations, and can be used to reduce the number of fish and thereby increase the growth rates of abundant, stunted individuals. Ideally, slot limits should be geared toward lake-specific management that takes into consideration varying growth rates and fecundity (Brousseau and Armstrong, 1987).

Eder (1984) found mean lengths of largemouth bass were significantly higher, and there was a gradual but dramatic shift in the length distribution of largemouth bass after a slot limit was implemented. The benefits to anglers were obvious: the slot length limit promoted substantial harvests of largemouth bass compared to suspected limited yields under a former minimum length limit. However, Eder (1984) also noted that harvest rates in largemouth bass populations needed to approach 70% before slot limits were effective and growth rates increased.

Like Eder, Martin (1995) found that slot limits failed to restructure largemouth bass populations when harvest rates were low. In addition, Martin (1995) also found that although they were initially supportive of the slot limits, ultimately anglers did not cooperate with the regulations and released high numbers of their catch despite the implementation of a substantial angler-awareness program. Even a small degree of non-compliance can seriously compromise the success of a length limit (Gigliotti and Taylor, 1990), and Martin (1995) notes that the concept of catch-and-release fishing for largemouth bass appears to be the rule rather than the exception. Promoting angler cooperation through awareness programs appears to be the key to the success of this technique.

- Smallmouth Bass

Slot limits are a common approach to overcoming reduced bass growth rate under a minimum-length limit because these limits will redirect some angler harvest toward surplus sizes of bass (Dean and Wright, 1992). In theory, the consequently-lower abundance of smaller bass results in greater availability of prey for each remaining bass and allows increased bass growth. Again, however, exploitation rate and angler compliance are key to the effectiveness of this regulation. In their study on the Shenandoah River, Smith and Kauffman (1991) found slot limits ineffective at increasing the growth rates of smallmouth bass because anglers harvested only 36% of the stock-to-quality–size fish. Angler attitudes of not keeping small fish, and the relatively large size of the smallest fish they keep, likely limits the harvest of fish below the protective slot limit and prevents possible increases in growth (Buynak and Mitchell 2002).

- Walleye

Slot limits in walleye fisheries are usually used to increase the quality of a fishery that has good natural production (Brousseau and Armstrong, 1987). Again, however, angler awareness and support of the effects of this regulation are central to its success. For example, lack of angler cooperation resulted in the failure and subsequent rescinding of a slot limit in a walleye fishery in Wisconsin even though the regulation ultimately would have produced a better fishery (Brousseau and Armstrong, 1987). An evaluation of walleye length limits in western Minnesota provided no direct evidence to indicate that adult walleye abundance, size structure or age structure changed after implementation of length limits, or that the regulations reduced annual variation in size structure common in walleye populations (Isermann, 2007). In this case, Isermann (2007) notes that improvements in fishery-related metrics such as size structure of harvested fish may merely reflect changes in angler behaviour rather than actual improvements in the population.

(c) Summary of Effectiveness of Harvest and Length Limit Regulations

The evidence from other jurisdictions suggests that regulations are inconsistent in their effectiveness at affecting stock levels of the non-native species of concern. In fact, I found only two (10%) examples where harvest regulations were effective at achieving management goals for these species (**Table 6**). Moreover, some regulations, such as liberal limits, may even work to the detriment of some species, for example, by facilitating stunting in populations such as yellow perch that are regulated by cannibalism. In addition, even if liberal limits were a mechanism to control non-native fisheries stocks, there are few harvest restrictions now in place in BC, yet the incidental evidence presented by regional fisheries biologists is that these stocks are increasing, suggesting that this particular approach does little to control stocks.

Table 6. Summary of effectiveness of regulations implemented or studied by North American fisheries management agencies (Source: note Appendix 3; Appendix 4).

Regulation	Type	Outcome			Species
		Effective	Ineffective	Undetermined	
Harvest	Liberal	1	3	2	Largemouth bass, smallmouth bass, yellow perch, walleye
	Restrictive	1	2	3	Largemouth bass, crappie, walleye
Length	Minimum	3	1		Largemouth bass, smallmouth bass, walleye
	Slot	2	2		Largemouth bass, smallmouth bass
Total		7	8	5	

Rather than implementing regulations to eradicate non-native species, regulations can be used to maintain or enhance angling opportunities to help control stock levels and size structure. For example, I found five (55%) examples where length regulations were effective in meeting management objectives focused on improving fisheries for bass (**Table 6, Table 7**). Note, however, that angler exploitation rate must be sufficient to create a response in the target stock, therefore, this approach would likely only be effective in a limited number of lakes and in regions with the most established and popular non-native fisheries.

Table 7. Effects of regulations on fish population, fish length and angler catch based on a review of 21 evaluations of regulation papers.

Harvest Regulations – Liberal Limits

	Effect of Regulation			Recommended to Maintain/Enhance Existing Angling Opportunity?	Recommended to Control Non Native Stocks?
	Fish Size	**Population Size**	**Angler Catch***		
Largemouth Bass	No change	Stable	Stable	Yes - liberal regulations for bass can be used to provide angling opportunities prior to implementation of other control methods.	No-will likely negatively restructure bass stocks to produce more smaller males if implemented during spawning/nesting; likely limited support/compliance**.
Smallmouth Bass	No change	Stable	Stable		
Yellow Perch	Decreased	Increased	Increased	Yes –if ministry develops separate policy for non-native species derbies to promote angling, especially with juveniles.	No-will likely reduce cannibalism in perch and crappie stocks and, therefore, produce increased numbers of stunted individuals.
Black Crappie	Decreased	Increased	Increased		
Walleye	Decreased	Stable	Stable	No	Possible–but only for small fish if angler exploitation is sufficient
Northern Pike	Decreased	Stable	Stable	No	Possible-if exploitation sufficient could result in increase size of large pike which would increase predation on other non-native species

Length Limit Regulations – Minimum Length

	Effect of Regulation			Recommended to Maintain/Enhance Existing Angling Opportunity?	Recommended to Control Non Native Stocks?
	Fish Size	**Population Size**	**Angler Catch***		
Largemouth Bass	Increased	Stable	Stable	Yes-will produce larger fish if angler exploitation rate is sufficient	No
Smallmouth Bass	Increased	Stable	Stable		
Yellow Perch	Decreased	Increased	Increased	Yes-if exploitation rate sufficient and larger fish produced may be more attractive to new anglers*.	Possible-if exploitation sufficient may increase large fish and, therefore, increase cannibalism of smaller fish.
Black Crappie	Decreased	Increased	Increased		
Walleye	Increased	Stable	Stable	Yes-if exploitation rate sufficient, larger fish produced likely more attractive to anglers.	Yes-could be used to increase size of large pike to control non-native prey species such as yellow perch.
Northern Pike	Increased	Stable	Stable	Yes-if exploitation rate sufficient, larger fish more attractive to .anglers.	

Length Limit Regulations – Slot Limit

	Effect of Regulation			Recommended to Maintain/Enhance Existing Angling Opportunity?	Recommended to Control Non Native Stocks?
	Fish Size	**Population Size**	**Angler Catch***		
Largemouth Bass	Increased	Increased	Increased	Yes-if exploitation sufficient would produce larger fish more attractive to anglers.	No
Smallmouth Bass	Increased	Increased	Increased		
Yellow Perch	Decreased	Increased	Increased	Yes-if exploitation sufficient would produce larger fish more attractive to anglers.	Possible-if exploitation sufficient may increase large fish and, therefore, increase cannibalism of smaller fish.
Black Crappie	Decreased	Increased	Increased		
Walleye	Increased	Stable	Stable	Yes-if exploitation rate sufficient, larger fish produced likely more attractive to new anglers produced may be more attractive to new anglers.	Yes-could be used to increase size of large pike to control non-native prey species such as yellow perch.
Northern Pike	Increased	Stable	Stable		

* Note: some authors noted an exploitation rate of 70% sustained over at least one generation would be required to reduce the population and angler catch. Creel surveys in South Dakota found that high percentages of anglers reported preferences for catching or harvesting fewer, larger yellow perch rather than catching or harvesting more but smaller fish (Isermann, et al 2005).

** Angler cooperation was a problem for all regulations - e.g., bass anglers began practicing Catch-and-Release to conserve stocks making regulations unreliable as a method to reduce populations.

5.2 Mixed Species Fisheries Management

Many US state agencies actively stock, manage, and promote non-native recreational fisheries because as Clarkson et al. (2005) point out, the states derive monetary benefit from these programs via licence sales and subsidies. Yet the same state agencies that manage non-native fisheries are simultaneously charged with the protection and recovery of native fishes and the management of associated fisheries. This is the case in BC where the Fisheries Program is responsible for both the protection of native fish and fisheries, and the provision of diverse angling opportunities (Ministry of Environment, 2006). Moreover, our agency has also been charged with increasing angling licence sales by 30% (Ministry of Environment, 2006). Clearly, non-native fisheries will be an important consideration in meeting that objective, consequently, it will be important in some situations for fisheries managers to identify opportunities to both protect native fish and fisheries, and maintain or create non-native fisheries.

(a) Native-Non-native Fisheries Species Interactions

In BC, there are concerns that non-native species may compromise native fish stocks and attendant fisheries. However, I reviewed a number of studies investigating the predator:prey interactions between non-native fishery species and salmonids and found that, in general, direct predation on salmonids by introduced species was not significant. For example, with respect to suspected predation by smallmouth bass on salmonids, a number of studies found only minimal predation and only when concentrations of smallmouth bass and salmonids overlapped significantly in time and space (**Table 8**) (Warner, 1972; Pflug and Pauley, 1983). Moreover, in their investigation of predation by smallmouth bass on sockeye smolts, Fayram and Sibley (2000) found that bass have limited consumption of sockeye during February-April when the salmon fry enter the lake because the low water temperature severely limits smallmouth bass feeding (Scott and Crossman, 1973). In effect, migrating juvenile sockeye salmon have a thermal refuge from bass predation (Fayram and Sibley, 2000). In addition, in their study of predation by smallmouth bass on riverine hatchery and wild salmonids in Washington, Fritts and Pearsons (2004) found that smallmouth bass also seem to switch in June from a diet composed of fish, to a diet composed of a higher percentage of invertebrates and crayfish.

Yellow perch are usually viewed as generalists (Keast, 1979) with insects constituting the majority of prey items identified in most of the studies I reviewed (eg. Marsden and Robillard, 2004; Guy and Willis, 1991; Galbraith, 1967; Echo, 1955; Langford and Martin, 1941; Moffett and Hunt, 1945). In addition, a study on the effects of prey size, abundance and population structure on piscivory by yellow perch by Paszkowski and Tonn (1994) found that even when prey such as fathead minnows and other fishes are continually available, piscivory by perch is a relatively uncommon event.

In contrast to findings regarding piscivory by yellow perch, I did find an example of moderate impacts by northern pike on prey including cutthroat trout (**Table 8**). The introduction of this species in particular creates concern because although few studies have documented the effects of northern pike, pike piscivory has the potential to impose large-scale changes in fish communities (He and Kitchell, 1990; Vashro, 1990). Nonetheless, while northern pike introduced into small lakes in Montana have been found to stunt once their prey was depleted (McMahon and Bennett, 1996), some researchers (e.g., Jones, 1990, DosSantos, 1991) have found that in general, this species does not pose a serious predation threat to existing fish communities because of their specialized habitat requirements which results in their limited distribution. Similarly with walleye, managers have not observed prey depletions and harm to salmonids in all cases (McMahon and Bennett, 1996). Again, different habitat requirements between walleye and salmonids appear to result in little spatial overlap in areas where there is sufficient opportunity for spatial segregation (MacLean and Magnuson, 1977, Colby and Hunter, 1989).

Table 8. Literature review of 22 studies investigating the predator: prey interactions between smallmouth and largemouth bass, walleye, yellow perch, black crappie, and northern pike on rainbow and steelhead trout, cutthroat trout and salmon.

Salmonids Non-native fish	Rainbow trout	Steelhead	Cutthroat trout	Salmon
Smallmouth bass	Small*	Small**	Small*	Small**
Largemouth bass	Small*	No data	Small*	Small***
Yellow Perch	Small****	No data	No data	Small****
Black Crappie	No data	No data	No data	Small*****
Walleye	Small: shoals	Small**	No data	Small******
Northern pike	Small: shoals	No data	Moderate	No data

* May impact fry in shoal areas before fry disperse.

** Studies of smallmouth bass-salmonid interactions have generally shown minimal predation on juvenile salmonid populations (Warner, 1972; Grey et al 1984, Poe et al 1991; Shively et al 1991). Predation by smallmouth bass may occur when bass and concentrations of juvenile salmonids overlap significantly in time and space (Pflug and Pauley, 1983; Tablor et al 1993). Impacts of smallmouth bass in shallow systems may be greater because of habitat overlap between that species and slamonids (Bonar et al., 2005).

*** In shallow lakes, largemouth bass were the most important predators of coho salmon, but although rapidly growing largemouth bass juveniles typically require higher food rations, coho salmon were a small component of their diet (Bonar et al, 2005).

**** Competition for food was the only type of interaction that followed the introduction of perch; there was no evidence that planted salmonids were eaten by perch and it is also unlikely that yellow perch have a substantial impact on juvenile salmonids because juvenile salmonids make up a very small portion of their diet (Costa 1979).

***** A study on coho salmon and introduced fishes by Bonar et al. (2005) found very few coho salmon eaten by black crappie.

****** Once walleye reach 300 mm, they prey mainly on Cyprinidae, Catastomidae and Cottidae species.

In addition to predator:prey interactions, I also reviewed studies investigating general interactions between trout and non-native species including bass and yellow perch, and found little diet overlap, except in one study in a lake in Ontario where the establishment of yellow perch resulted in a change in the food habits of planted salmonids and a reduction in their growth rates (**Table 8**). In fact, rather than having a negative impact on salmonids, observations on Vancouver Island suggest that bass predation on sunfish may have resulted in increased numbers of trout (**Table 9**) (Cassin and Silvestri, 2002(a); Cassin and Silvestri, 2002(c). Studies by the Oregon Department of Fish and Wildlife similarly found that direct impacts of bass on trout were reduced or eliminated by thermal segregation of bass and trout habitat, and the presence of bass may even have benefits offsetting any suspected negative impacts on salmonids. In this case, avian predation, which is a significant mortality factor for trout, was thought to be reduced because of buffering by bass which are behaviourally more vulnerable to avian predators (Shrader, 1993).

Table 9. Summary of 17 studies investigating interactions between native and non-native fishery species in North America.

Species	Location	Study Findings	Source
Largemouth bass and hatchery trout	Oregon	Diet overlap of rainbow trout and largemouth bass not biologically significant	Shrader and Moody, 1997
Bass	Oregon	Vulnerability of prey varies according to the size of bass and prey	Lewis and Helms, 1964
Yellow perch and other game fish species	Oregon, Montana	Generalist/opportunist feeding behaviour of rainbow trout decreased dietary overlap with yellow perch-both species rely on Daphnia as prey items, however, rainbow have more plasticity in feeding behaviour and more flexibility in the niches it can occupy. Little diet overlap or competition between yellow perch and cutthroat trout. In a lake inhabited by yellow perch and cutthroat, the food of perch was largely immature aquatic insects and plankton and that of trout was mostly mature insects and small perch.	Shrader, 2000; Wang et al. 1996; Galbraith, 1967; Echo, 1955; Swynnerton and Worthington, 1940.
Smallmouth bass	Various	Smallmouth bass have broad, generalist diets and feed on a mix of prey fish, crayfish, and other zoobenthos with zooplankton, amphibians	VanderZanden and Rasmussen, 2002; Schindler et al. 1997; Hodgson et al. 1991; Hodgson and Kitchell 1987
Largemouth bass and trophy (>10 lb) rainbow trout	Oregon	Rate of bass predation on stocked trout not consistent across reservoir; peak predation coincided with stocking and was highest at locations with no structural complexity/trout refugia. In spite of trout and largemouth bass often being found in the same habitat, hatchery trout not a dominant food item in the diet of largemouth bass and trout consumed by bass translated into approximately a 6% reduction in trout harvest in exchange for the recreation associated with catching >29,000 largemouth bass and production of trophy bass (>4 pounds).	Shrader and Moody, 1997
Bass and trout	Oregon	Thermal segregation of habitat of both species reduced interactions; vulnerability of bass to avian predation may reduce predation on trout.	Shrader, 1993
Bass and hatchery fingerling and yearling cutthroat	BC-Vancouver Island	No difference in performance of cutthroat stocked as fingerlings vs. yearlings	Fosker and Philip, 2004(c),
Bass and stocked rainbow trout	BC-Vancouver Island	In lakes with sunfish, bass control sunfish which allows increase in number of trout; length-frequency distribution, length at age and condition factor of rainbow trout as expected in both bass and non bass lakes	Cassin and Silvestri, 2002(a); Cassin and Silvestri, 2002(c).
Largemouth bass and hatchery rainbow trout	Oregon	Hatchery trout initially naïve but quickly learn to incorporate predation risk from bass into their behavioural strategies	Shrader and Moody, 1997; Nyberg, 1971

Table 9. Summary of 17 studies investigating interactions between native and non-native fishery species in North America. con't.

Species	Location	Study Findings	Source
Largemouth bass and coho salmon	Washington	Coho salmon were not growth limited in lakes with non-native species (largemouth bass) and although food competition with introduced fishes is possible, it is probably unimportant in contributing to mortality of juvenile coho salmon	Bonar et al., 2005
Rainbow trout and warm water species		Rainbow trout took advantage of cover to reduce predation risk by warm water species.	Dill et al., 1981

In addition to concerns regarding interactions between native and non-native species, there are also often questions regarding impacts to salmonid fisheries when non-native species are discovered. For example, the trout fishery at Crane Prairie Reservoir in Oregon was historically very productive and popular, and the introduction of largemouth bass into this reservoir raised concern about reductions in the quality of the trout fishery (Shrader, 1993). Subsequent studies including creel surveys did not substantiate those concerns however, and today both species support successful fisheries at this, and other reservoirs in the state (Shrader, 1993). There are similar experiences on Vancouver Island where observations found no difference in the returns to the creels for trout in lakes with, and without smallmouth bass (Reid, G. pers. com. 2007).

(b) Mixed Stocked Trout and Non-native Species Management

To maximize the production of one stock of fish, managers should manage that stock to the exclusion of all others. However, as pointed out by Beamesderfer and Nigro (1989), the greatest net gain to fisheries occurs if biologists manage for more than one species because each species uses resources that are not available to the others. For example, managers might manage for salmon and walleye, foregoing some salmonid production but gaining the benefit of a resident recreational fishery that lasts much of the year, and provides a fishery in an area where historical recreational fisheries for salmonids either no longer exist (Beamesderfer and Nigro, 1989) or are declining. In other cases, introduced species are better able to survive in areas either historically or more recently less habitable for native species. For example, in Nova Scotia, introduced bass are better able to survive than native trout in the increasingly eutrophic conditions created as a result of urban development and, as a result, bass are providing important fisheries in and around population centres (LeBlanc, J. pers. com. 2007).

(c) Maximizing Mixed Native and Non-native Fisheries

Large bodies of water often exhibit patches of distinct habitats with different assemblages of fish (Hayes et al. 1996) and, therefore, the morphometrics or trophic status of some lakes will naturally lend themselves to mixed species management. For example, American Lake in Washington was historically managed as a salmonid-only fishery, and was rehabilitated in the late 1950s to eliminate warm-water species such as largemouth bass and yellow perch (Mueller and Downen, 1999). Yellow perch soon reappeared and began dominating areas not inhabited by salmonids however, which prompted fisheries managers to recognize this lake as well-suited for mixed species management, and to implement two-story fisheries management strategies to increase the use of all available lentic habitat (Shrader, 1997).

Although they did not specify reasons why, managers in Idaho note that costs to maintain a trout fishery through stocking are increased when-warm water species are abundant (Idaho Department of Fish and Game, 2007). If this is the case, there may be strains or practices which may offset costs where managers choose to facilitate both stocked trout and non-native fisheries. Between 1988 - 1990, Tsumura and Godin (1991) evaluated rainbow trout strains in small course (native or non-native non-trout) fish lakes in BC to identify wild rainbow trout strains that may be pre-adapted to these types of environments. In general, these researchers found that rainbow trout strains originating from coarse fish environments grow faster and are larger in the first year after stocking into small coarse fish lakes, and that coarse fish trout strains become piscivorous at than earlier age and grow more rapidly than other non-coarse fish lake stocks (Tsumura and Godin, 1991). In addition to identifying differences between trout strains which may be beneficial in mixed-species management, Tsumura and Godin (1991) also suggest that release site, hour of release, and lake temperature could be factors related to the survival of stocked trout into lakes with piscivorous predators. In **Figure 2**, I've outlined some suggestions when considering implementing mixed stock management for lakes where both native and non-native species are present and can contribute to fisheries. I've based my suggestions on the results of techniques implemented in other jurisdictions outlined during telephone interviews with fisheries managers from other jurisdictions, and information provided through cited published studies.

Figure 2. Suggested mixed species management plan for lakes with stocked trout and introduced non-native small mouth and largemouth bass, yellow perch, northern pike and walleye.

Assessment/ Surveys

Lake Assessment: lake location, size and morphometry, habitat availability and limitations for both native and non-native species.

Creel Survey: composition and timing of native and non-native fisheries species; native and non-native species stock characteristics.

Lake Characteristics

Lake close to population center.

Lake size and morphometry provide diverse habitat types and sufficient size to allow spatial segregation between native/non-native species.
Spawning and rearing habitat available for both native and non-native species.
Non-native stock population healthy, i.e., not stunted.

Lake small – no opportunity for spatial segregation and/or non-native stock stunted.

Management Approach

Manage for quality or trophy fisheries for bass.
Manage for basic yield fisheries for trout.

Habitat: improve bass habitat by installing reefs; improve stocked trout survival by introducing cover at stocking sites.
Forage: discontinue or limit commercial crayfish fisheries.
Stocking stock larger trout (yearlings) in areas of deeper water; stock during the spring when bass are spawning in shoal areas.
Fishery: introduce regulations to improve bass fisheries – e.g., Slot limits for trophy fisheries and closures during spawning nesting. Provide shore access/sites including handicapped access, promote fisheries.
Monitor: implement netting surveys to monitor fish stocks and creel surveys to monitor fisheries and adjust regulations as required, establish working group with representation from local bass club(s) and Fish and Game affiliate(s) to provide recommendations for management of both fisheries.

Manage for Native and Non-native Fisheries.

Habitat: improve stocked trout survival by introducing LWD cover at stocking sites and in-shore areas.
Forage: investigate nutrient additions to improve trout growth in low productivity/nutrient regions and provide prey species for trout/yellow perch; manage yellow perch stocks to ensure forage for walleye/largemouth bass.
Stocking: investigate alternative trout stock suited for survival in mixed stock lakes; stock larger (yearlings) in areas of deeper water; stock in fall in areas with walleye (spring-stocked trout vulnerable to post-spawning walleye).
Fishery: introduce harvest and size limits to protect large walleye/Northern pike and balance yellow perch populations. Consider closures during walleye spawning.
Monitor: implement netting surveys to monitor fish stocks and creel surveys to monitor fisheries and adjust regulations as required, monitor adjacent water bodies to ensure no non-native fish movement/introduction.

Manage for Native Fisheries.

Habitat: improve stocked trout survival by introducing LWD cover at stocking sites and in-shore areas; address trout habitat limitations identified in initial lake assessment.
Stocking: adjust stocking timing/stock strains to maximize survival.
Fishery: remove all restrictions on non-native species; support derbies for non-native stocks in accordance with new Ministry policy (see suggested approaches in this document); manage for trophy trout where possible.
Non-native Management: chemically or mechanically remove non-native fish where possible.
Monitor: implement netting surveys to monitor fish stocks and creel surveys to monitor fisheries and adjust regulations as required, monitor adjacent water bodies to ensure no non-native fish movement.

6.0 Controlling Non-native Fisheries Species

In areas where mixed species management is not appropriate, or where there are concerns regarding impacts to biodiversity, fisheries managers may choose to implement strategies to control or eliminate non-native species. In the following section, I've outlined the variety and effectiveness of a number of management techniques used in various jurisdictions including BC to control fish stocks.

6.1 Chemical Removal

As many as 30 piscicides have been used for fisheries management in the United States and Canada, but only 4 are currently registered for use, and of these, rotenone and its commonly used substitute, antimycin, are by far the most commonly applied (McClay, 2000).

Both rotenone and antimycin are effective piscicides and have a number of advantages in fish removal projects due to their high toxicity to fish and low toxicity to non-aquatic organisms (Govindarajulu, 2006) (**Table 10**). Antimycin, which has few, if any impacts on invertebrates (Cerreto et al. 2003), has become more environmentally acceptable than rotenone, however there have been problems with registration and the discovery of a number of ineffective lots, which has curtailed its use in recent years (Shepard, B. pers. com. 2007).

Table 10. Summary of advantages and limitations of rotenone and antimycin as chemical fish removal agents. (Sources: Govindarajulu, 2006, Finlayson et al. 2000, Ling, 2003, Cerreto et al. 2003, Tredger et al. 1989).

Factor	Rotenone	Antimycin
Cost	Low cost	Cost higher than rotenone but dose required is lower making it comparable in cost
Biodegradable	Degrades rapidly; does not accumulate	Biodegrades rapidly and naturally in the environment
Toxicity	Extremely high but varies between species with coarse fish commonly less sensitive than trout; controls all post-embryonic life stages of fish	Used and mainly for eradication of trout; does not kill fish eggs until the shell ruptures at hatching; controls all post-embryonic fish life stages, can be selective by species
Water Chemistry	Absorbs strongly to sediments which reduces effectiveness in turbid waters	Not effective at high pH (>8.5); effectiveness affected by turbulence and turbidity
Fish Avoidance	Some fish can physically avoid and recover from rotenone	Not usually avoided by fish
Stability	Chemically unstable and degrades rapidly on exposure to light and air	Toxicity and behaviour in the environment less predictable than rotenone
Impacts to Potable/Recreational Water	Temporary loss of potable water and recreational opportunities; diesel taste in fish reported as much as 7 years following some treatments in BC lakes	Temporary loss of potable water and recreational opportunities

Table 10. Summary of advantages and limitations of rotenone and antimycin as chemical fish removal agents. con't.

Factor	Rotenone	Antimycin
Impacts to Other Species	Can dramatically affect invertebrates and cause massive drift within a few minutes of application; temporary effects on .zooplankton and newts	Little to no effect on invertebrates but highly toxic to amphibians; temporary effects on zooplankton
Limitations	Does not kill fish eggs until shell ruptures at hatching	
Registration/Other	May require registration	Limited availability - may not be registered; difficult to get now and batches must be tested by the purchasing agency
Effectiveness	Rapid results; most effective of all piscicides but varies by temperature and turbidity	Rapid results; effective at shorter exposures than rotenone; remains effective at lower temperatures than rotenone
Toxicity to Wildlife and Humans	Low	Low
Source	Naturally derived	No information
Solubility	Low solubility and complete dispersal through water may not be easily achieved; liquid formulation more effectively dispersed but produces noticeable tastes/odours and easily detected/avoided by fish	No information
Other	Can be applied to achieve spatially selective eradication; can be used in large river systems	Monitoring is difficult using dye so sentinel fish required

(a) Effectiveness of Chemical Removal Projects

Finlayson et al. (2000) note that with the exception of complete and prolonged dewatering, piscicide application is the only method that can completely eradicate undesirable fish communities. However, a study by Meronek et al. (1996) found <50% of 140 chemical removal projects using rotenone or antimycin were successful, and I found a success rate of 30% in the 25 projects I reviewed (**Table 11**). Eleven of the piscicide projects I reviewed were implemented in BC, and of these, only 1 (<10%) was documented as effective at removing the target stock (Ministry of Environment, 2000; **Appendix 5**).

Table 11. Summary of the effectiveness of 165 chemical removal projects implemented between 1935 – 2006 including the percentage of effective projects.

	Present Study			Meronek et al. 1996			Combined		
	Total Projects	Total Effective	Percent Effective	Total Projects	Total Effective	Percent Effective	Total Projects	Total Effective	Percent Effective
Panfish	2	1	50	68	32	47	70	33	47
Game Fish	8	5	63	4	3	75	12	8	67
Rough Fish	10	1	10	51	25	49	61	26	43
Mixed	6		0	17	0	2	22	0	2
Total	26	8	30	140	61	43	166	69	41

Note: panfish includes black crappie (Pomoxis nigromaculatus); yellow perch (Perca flavescens); game fish includes: northern pike (Esox lucius); smallmouth bass (Micropterus dolomieu); largemouth bass (M. salmoides) and walleye (Stizostedion vitreum); rough fish includes species such as carp (Cyprinus spp.); catfish (Ictalurus spp.); and suckers (Catostomus spp.).

(b) Reasons for Failure of Chemical Fish Removal Projects

There are a number of reasons why chemical removal projects may not be successful, among these, incomplete distribution of the piscicide due to biophysical characteristics of the water body, heavy vegetation or the presence of beaver dams or other areas where fish can hide, or water quality parameters that inhibit piscicide effectiveness. In addition, as noted in Meronek et al (1996), different species have different susceptibilities to piscicides which can compromise project success. As with all removal projects, if the fish kill is incomplete, there can be founder effects or compensatory responses to either decrease natural mortality, or increase growth by the remaining individuals, thereby causing a rebound of the stock and rendering the project ineffective over the long term. After treatment with rotenone in a number of lakes in Massachusetts, for example, growth rates of remaining yellow perch and largemouth bass were found to be more rapid than under natural conditions and in some cases growth rates in these situations exceeded those recorded in the literature (Grice, 1959).

(c) Criteria for Successful Chemical Fish Removal Projects

Although most chemical fish removal projects I reviewed were unsuccessful, there were some that achieved their objectives. Fisheries managers I spoke to from jurisdictions with successful projects were similar in that >80% had specific criteria under which they implemented chemical removal projects (**Table 12**). A number of these criteria were common between jurisdictions, including ensuring the non-native stock is newly introduced, the water body to be treated is small and isolated, the project is fiscally practical, and several chemical applications can be implemented over a several (i.e., $\geq$3-5) year period.

Table 12. Summary of criteria for piscicide programs used by five North American jurisdictions implementing successful chemical removal projects.

Jurisdiction	Contact	Criteria for Chemical Removal Projects
California	Brian Finlayson; Fish Toxicants Expert; California Department of Fish and Game Roger Blume; Invasive Species Specialist; California Department of Fish and Game	• project objective is to bring back native species. • unwanted stock is new. • unwanted stock is harmful (e.g., white bass, northern pike). • system is isolated.
Florida	Paul Shafland; Fish Eradication Biologist; Florida Fish and Wildlife Conservation Commission	• small isolated ponds. • <10 days effort and <$5,000 total project cost; and, in large lakes <5m deep and <30 acres. • unwanted species is ecologically or economically harmful (e.g., piranha).
Idaho	Dale Allen; Fisheries Biologist; Idaho Fish and Game Fred Partridge; Warmwater Fisheries Biologist; Idaho Fish and Game	• unwanted stock is new. • water is isolated. • removal is fiscally practical.

Table 12. Summary of criteria for piscicide programs used by five North American jurisdictions implementing successful chemical removal projects. con't.

Jurisdiction	Contact	Criteria for Chemical Removal Projects
Montana	Brad Shepard; Fisheries Biologist; Montana Fish, Wildlife and Parks Jim Vashrow; Fisheries Biologist; Montana Fish, Wildlife and Parks	• projects are planned and budgeted over several years. • no beaver dams or heavy vegetation.
Washington	Steve Jackson; Fisheries Biologist; Washington Department of Fish and Wildlife	• projects are long term and ongoing. • only hatchery lakes are treated. • no valuable stocks present.

In addition to the guidelines and common practices in successful jurisdictions, Finlayson et al.,(2000) note that water quality parameters, including temperature, pH, alkalinity, algae, organic content, and sunlight penetration influence the toxicity and rate of natural degradation of rotenone, therefore, these are also important considerations when developing a chemical treatment project. In addition, in BC, chemical removal projects must comply with the Ministry of Environment policy which requires that piscicides only be used to control or eradicate populations of undesirable species, when the project is necessary to meet Fisheries Program goals and objectives, when the risks to regional and provincial biodiversity and the environment are proven to be minimal, and when the project is in accordance with all provincial and federal statues, regulation and safe use practices (Ministry of Environment, 1993). I've used both the provincial requirements and the criteria from successful piscicide projects from other jurisdictions to develop the following suggested criteria to guide when to implement piscicide projects:

(i) Suggested criteria for chemical fish removal projects in BC

1. Non-native stock predaceous (e.g. northern pike, walleye).
2. Non-native stock is newly discovered in system.
3. Existing native fishery>potential non-native fishery.
4. Native fish can be re-stocked from hatcheries or neighbouring waters.
5. System contains no Red- or Blue-Listed species.
6. System is isolated and small (<1 km deep and <15 hectares in area).
7. System has no beaver dams or heavy vegetation that cannot be completely removed.
8. System water quality parameters are within the range specified for effective piscicide projects (Finlayson et al. 2000).
9. Project is in accordance with all provincial and federal statues, regulations and safe use practices as outlined in Ministry policy and procedures.
10. Project cost <10 days effort and <$5,000 total project cost and similar funds are likely available in base budget for at least the following 3 years.
11. System and donor stock monitoring planned and budgeted in staff work plan for following 2-3 years.

(d) Public Consultation and Chemical Fish Removal Projects

One final consideration before embarking on a chemical fish removal program is the extensive amount of public consultation which must accompany these types of projects. According to Finlayson et al. (2000), public acceptance and understanding of piscicide projects is perhaps one of the most important considerations when planning fish removal using chemicals. Furthermore, McClay (2000) notes that while the majority of rotenone treatments implemented through time have occurred without incident, a number of projects have generated widespread public controversy that could have been avoided had there been more public input and support of the project prior to treatment. Finlayson et al. (2000) suggest that an agency be prepared for the most probable public issues, and deal with those quickly, openly and before the project is implemented, and that any project that does not have a high degree of public support be re-evaluated. A complete summary of controversial issues identified by Fish and Wildlife agencies using rotenone in the past 10 years can be found in McClay (2000), while an example of a public involvement plan which should accompany chemical fish removal projects can be found in Finalyson et al. (2000).

In **Figure 3**, I’ve outlined an operational plan that can be used to guide management decisions and activities including the preplanning and public awareness components necessary for chemical fish removal projects. In addition, Finlayson et al. (2000) provide complete details regarding administrative and field-level procedures for rotenone projects, and the American Fisheries Society hosts annual workshops focused on planning and executing successful piscicide projects (American Fisheries Society, 2007).

Figure 3. Proposed chemical fish removal project operational plan. (Adapted from Finlayson et al. 2000 and Ministry of Environment Procedure: Use of Piscicides in Fisheries Management (Ministry of Environment, 1993).

Non-native stock is predaceous (black crappie, yellow perch, Northern pike, walleye); and Non-native stock is newly discovered in system.

Initial Lake, Fish and Fishery Surveys

Year 1

Mandatory Criteria: Stock is new (i.e., no multiple year classes); and Red- or Blue-Listed species absent; and Native species can be restocked; and Existing native fishery>potential non-native fishery; and System isolated and <1 km deep and <15 hectares in area; and, System without beaver dams/heavy vegetation; and Water quality parameters within the required range for chemical projects.

No to any one criterion

Implement Alternate Removal and/or Management Strategies

Yes to all criteria

Project and Long-Term Budget Assessment
Project adheres to Ministry policy and procedures; Project cost <10 days effort and <$5K; Matching funds likely in base budget or other funding source (HCTF) for following 2-3 years; Staff available for following 2-3 years.

Public Consultation and Involvement
Internal Communication – advise Fisheries/CO staff of situation and chemical treatment plans.
External Communication – develop communication plan including identifying client groups (local Federation clubs), general public, Native bands, landowners, press and other interested parties to be notified; identify list of potential concerns (e.g., collection/disposal of dead fish, impact of chemical, other animal welfare, piscicide residues, liability/property damage, etc. (Finlayson et al, 2000); develop plans/procedures for long-term communication (i.e., yearly feed-back to public).
Develop Public/Angler Involvement Project Component – establish steering committee with angler/client involvement to assist with project implementation (e.g., assist with pre-treatment procedures including system dewatering where possible, mechanical removal including angling opportunities etc.) and representatives to act as community liaison.

Year 2 (Project Implementation) Funding Proposal: Identify funding sources outside of base budget if required; solicit approval from project steering committee to proceed; develop/submit proposal

Staff Training: Pesticide certificates, AFS rotenone course etc.

Permit Applications

Implementation Plan: Steering Committee develops plan including: work timing, agency/volunteer responsibilities, Fish rescue and salvage piscicide application, Site safety and security, fish removal/disposal, spill contingency/emergency response, site neutralization, ongoing internal/external communication including public meetings, long term monitoring, restocking, records maintenance/data summaries and report preparation.

Implement Project

Years 2-5

Monitor: Implement 3-year fish netting sampling program to ensure chemical treatment successful; monitor native stocks to determine impacts/recovery, modify and adapt project as required.

6.2 Mechanical Removal

(a) Summary of Mechanical Removal Strategies

(i) Angling

Because fisheries often have the most significant impact on fish stocks, angling appears to be a logical method to remove unwanted fish. In addition, because the manpower required for this type of program can be volunteer, this approach also appears fiscally attractive. Moreover, if volunteer anglers are used, this technique allows fisheries managers to build partnerships with clients and, in the process, to communicate information regarding the harmful effects of illegal fish introductions.

Unfortunately, in addition to having limited effectiveness, this approach has other limitations including inconsistent participation and angler ability, particularly with respect to fish identification (Stelfox et al., undated) (**Table 13**, **Appendix 6**). As a result, fisheries managers must incorporate ongoing volunteer management and coordination, and educational components in these types of programs. In addition to the human limitations associated with volunteer angling projects, researchers must also consider the catchability and susceptibility of target and native fish to angling. For example, in their study using anglers to reduce non-native brook trout in Quirk Creek, Paul et al. (2003) found that hooking mortality for native trout was a concern given their high catchability and low growth rate. These attributes, coupled with the resiliency of brook trout to angling because of their ability to mature at small sizes and early ages, contributed to the ineffectiveness of angling as a control measure for that species. In fact, the resilience of the target species to angling coupled with the susceptibility of the native fish to that same technique is thought to have further depressed the native trout (Paul et al. 2003).

<u>Best Use:</u> Where the susceptibility of native fish to angling is not a concern these projects provide anglers with new opportunities and fisheries managers with an avenue for communicating the harmful effects of non-native fish introduction. Rather than being used for control, this technique is probably best used to create opportunities and educate clients about non-native fisheries species before other removal methods are implemented.

(ii) Bounties

Bounty programs were ineffective at totally removing the target species in the limited number of studies available for eview. In fact, while an angler reward/bounty program for pike minnow has been used in the Lower Columbia and Snake Rivers in Oregon since the 1990s, the Department of Fish and Wildlife has not recommend expanding this program to any other areas because of questions regarding its effectiveness (Daily et al. 1999). In addition, this type of project could require significant funding to compensate participants. In Oregon, for example, bounties exceeding US$1 Million have been paid on the approximately 240,000 northern pike minnow harvested over the 10 year life of that program (Daily et al. 1999).

Best Use: Overall these projects are likely to be ineffective and expensive. Because of the obvious lack of restrictions, however, bounty programs do offer managers an opportunity to demonstrate that introduced species will not be managed to create sustainable fisheries.

(iii) Commercial Fisheries

Commercial-scale removal of introduced fishes could effectively reduce their abundance to the benefit of native fishes if the fishery successfully avoids impacting the native species, and large enough markets can be found to entice operators. However, as noted by Grinstead (1975), most inland commercial fisheries do not remove enough of the undesirable species to benefit game fisheries. Moreover, continually fishing any commercially undesirable species is economically unstable, and complete elimination of any species by fishing is unlikely given the exponential increase in effort required as catch-per-unit-effort declines (Ling, 2003, Wydoski and Wiley, 1999).

On the other hand, in BC, and particularly in Region 1 (Vancouver Island), commercial harvest of crayfish, which are primary prey species for smallmouth bass (Wydoski and Whitney, 1999), may be a viable option for keeping this non-native in check especially considering the consistent interest from individuals regarding commercial crayfish opportunities within the region. This may also be an option in Region 8 (Okanangan), given that Field and Dickie (1987) suggest that the disappearance of crayfish from Osoyoos Lake could be one reason for the apparent decline of smallmouth bass in that area. In either region, financial incentives for start-up costs for operators might be required, and suitable markets would have to be located. In addition, as Daily et al. (1999) note, a number of other concerns would have to be evaluated including: a review of the significance of benefits compared to possible impacts on non-target native species of concern, potential impacts on angling opportunities, and public acceptance.

Best Use: Commercial harvest of bass prey species such as crayfish may be used to control bass stocks in Region 1 (Vancouver Island) and Region 8 (Okanangan) should operators be located and commercial markets and start-up costs be available. Fisheries managers must also ensure that impacts to native stocks and fisheries do not offset the benefits of the commercial endeavour, and that clients and the public are receptive to this strategy.

(iv) Electrofishing

Electrofishing is one of the most common methods for removing non-native stream-dwelling salmonids (Meyer et al. 2006) and this method appears to be a viable alternative to using piscicides, especially where extant populations of native fish exist in sympatry (Shepard and Nelson, 2004). The effectiveness of these projects appears to be contingent, not only on channel characteristics and the ability of operators to access the habitat, but also on the repeated implementation of the project over multiple years if complete eradication is the goal. Shepard et al. (2000) continued one project for eight years before achieving apparent eradication because as these researchers point out, even one missed breeding pair can reset all eradication efforts and juveniles will be difficult to capture the following year because smaller fish are less vulnerable to this technique. Consequently, while it is more environmentally acceptable than some methods such as chemical removal, electrofishing has the disincentive of being labour intensive. Finally, these projects should include the construction of barriers to ensure that no re-colonization by the non-native stock occurs during, or following electrofishing removals.

I found 2 examples of electrofishing used to remove lake stocks of bass. In one case, the objective to eliminate bass completely was not achieved, however, operators were able to reduce stocks by 90% (**Table 13**). In the other case, 99.5% of the bass population was removed by boat electrofishing and the remaining fish were removed by gillnetting and angling (Weidel et al, 2007). In this particular study, electrofishing accounted for an average catch of almost 300 bass/trip compared to approximately10 fish/trip for either gillnetting or angling.

Best Use: Electrofishing can be used to eradicate non-native stocks in small (<5 m wide) streams with limited habitat complexity, where long-term resources are available and chemical treatment is not an option. Fish removal via electrofishing can also provide short-term relief to native stocks in small (e.g., <3 ha <10 m depth) lakes with accessible, poorly-vegetated shoals, and/or limited habitat complexity and at times when non-native species such as bass, yellow perch and crappie are congregated, for example, during spawning.

(v) Explosives

Explosions produce seismic waves and, if the blasts are strong enough, the resulting pressure and mechanical shock can kill adult fish by rupturing their swim bladders. This technique also damages or kills incubating eggs particularly during the final stages of development (Faulkner et al., 2006, Govindarajulu, 2006, Fitzsimons, 1994). The effectiveness of the detonating cord increases at depths >3 meters, and this method is usually effective in killing fish and amphibians within a 6 mile radius (Govindarajulu, 2006).

The healthier an ecosystem is, the more capable it is of resisting invasions, therefore any management activity such as the use of explosives that damages habitat must also include a restoration component (Canadian Council of Fisheries and Aquaculture Ministers, 2002). This is particularly important given that a damaged ecosystem will not always be able to regenerate to its previous state and, as a result, can be more susceptible to subsequent invasion by non-native species. Therefore, in addition to restoring blasting sites, this strategy should incorporate habitat restoration projects that address damages from this technique and any previously existing spawning and rearing habitat limitations. In addition, in Canada, the use of explosives to hunt or kill fish or marine animals is prohibited under section 28 of the *Fisheries Act.* However, section 32 of the *Act* allows the Minister of Fisheries or Governor in Council to authorize the destruction of fish by means other than fishing. This would include the use of explosives if the activity is warranted, and no other option is available (Heusen, R. pers. com. 2007).

Best Use: This technique is best used in small areas to control non-native stocks when they are congregated on-shore, such as during spawning or, for example, to destroy redds and eggs. There must also be adequate resources available to implement native fish habitat restoration projects both to address any pre-exiting habitat limitations, and to restore the destroyed areas. This method is not appropriate in habitats with Red- and/or Blue-listed amphibians, and authorization from Fisheries and Oceans Canada is required.

(vi) Netting

Netting and trapping is one of the least invasive methods of controlling fish and, according to Meronek et al., (1996), the success rate of this technique varies from approximately 30-60%. This method has been used effectively in lake habitats in a number of jurisdictions with little or no apparent impact on the abundance of native fish. Some authors also note that the efficiency of removing a stock is increased when different types of nets are used to target different life history stages, for example, using gillnets to capture large fish or adults, and fyke nets to capture smaller fish. Gillnets placed along known migration routes or spawning grounds increases the rate of capture, and net sets conducted weeks apart may remove fish more quickly than continuous netting. Like other techniques, netting is most successful when conducted over a several-year period. In addition, although nets can be set to fish for long periods of time, some researchers note that frequent net-tending increases catch (Blume, R. pers. com. 2006).

Parker et al. (2001) and Knapp and Matthews (1998) suggest that this method is most effective in lakes <3 ha in area and <10 m in depth; in lakes with limited spawning habitat; and where there are no self-sustaining populations in inlets and outlets. In addition, fisheries managers in Florida and California note that the efficacy of netting is enhanced when managers understand the microhabitat selection and patterns of diel movement and activity of the target species as this enables better net placement and timing (Blume, R. pers. com. 2006, Shafland, P. pers. com. 2006).

One drawback to this method is that it is difficult to net in shoal habitats, and catch efficiency decreases with increasing pond or lake size and/or increased habitat heterogeneity (Ludgate and Closs, 2003). In addition, netting does not work well on species including bass that do not school. For example, Meronek et. al. (1996) found between 60-67% netting success for species including yellow perch and crappie, but 0% success for species including northern pike, smallmouth and largemouth bass, and walleye (**Table 13**).

<u>Best Use:</u> Netting can be used to control or eradicate non-native stocks in small (<3 ha; <10 m depth) lentic habitats with limited habitat diversity, and where the presence of native stocks is a concern. The effectiveness of this method is highest when fisheries managers understand the habitat use and movement of the target species, and can repeat the project over a 2-3 year period. Although this is one of the most successful techniques overall, this method is only effective for schooling species.

(vii) Trapping

Like netting, trapping is not invasive and in some cases this technique can substantially reduce fish populations, however the benefits realized depend on the vulnerability of the species to being caught. According to Daily et al. (1999), both the predictability of the response of the target species and the physical implementation of a trapping project can be challenging.

To increase the effectiveness this method, some researchers have attracted fish to traps using other means, for example with phermones in the case of brook trout (Young, undated), and lights in the case of larval and juvenile northern pike (Pierce et al. 2006, Kelso and Rutherford, 1996). Given that bass are usually caught only incidentally in traps (Daily et al. 1999), lights may also be useful for this species as well as for yellow perch given that members of both the Centrarchidae and Percidae families are positively phototactic (Pierce et al. 2006). Weirs have also been used to guide migrating or spawning fish into traps and electricity has been used to repel fish at hydroelectrical facilities (Wydoski and Wiley, 1999), consequently these methods may also increase trapping success.

Best Use: Trapping can be used to control specific life history stages of non-native stocks in small habitats with limited habitat diversity, and where impacts to native fish or biodiversity are a concern. The effectiveness of this technique may be increased by using supplementary methods such as lights or weirs to guide target fish to traps.

(b) Effectiveness of Mechanical Removal Techniques

Almost 50% of the fisheries managers I interviewed and projects I reviewed used mechanical means including electrofishing, netting and trapping and explosives to remove unwanted fish (**Appendix, 2, Appendix 3, Appendix 6**). Twelve of 34 (35%) mechanical removal projects I reviewed were effective, while 29 (43%) of mechanical removal projects investigated by Meronek et al (1996) were successful at depressing or eliminating unwanted stock (**Table 13**). I found that gillnetting was the most common method used to remove unwanted fish, and together with additional unspecified types of netting were the most successful mechanical techniques at either reducing or eliminating the target stock. Electrofishing in streams was also effective when projects extended over a several-year period.

Table 13. Summary of results of 102 non-native fish management studies regarding the success of fish control strategies including total number and percent of projects defined as successful/effective.

Management Strategy	Literature searches conducted by Meronek et al. 1996*: Projects Reviewed	Literature searches conducted by Meronek et al. 1996*: Number Successful/ Effective**	Literature searches and interviews conducted by Michalski: Projects Reviewed	Literature searches and interviews conducted by Michalski: Number Successful/ Effective	Total Projects Reviewed	Total Successful/ Effective	Percent Successful/ Effective
Mechanical Removal							
General	68	29			68	29	43
Mechanical Removal							
Angling			1	0	1	0	0
Bounties			3	0	3	0	0
Commercial Fishing			1	1	1	1	100
Electrofishing-Boat			2	1	2	1	50
Electrofishing-Stream			8	3	8	3	38
Explosives			4	0	4	0	0
Gillnetting			10	6	10	6	60
Nets and Seines			3	0	3	0	0
Traps			3	2	3	2	67
Total	68	29	35	13	103	42	40

* The project occurred on water bodies ranging from 0.2 – 55, 752 ha and were located in 36 states and 3 countries. Success was judged by changes in standing stock, growth, proportional stock density, relative weight values, catch or harvest rates, and other benefits, such as angler satisfaction.

** The definition of success or effectiveness relates to whether the study met its objective. For example, if the objective of the study was to reduce the target stock for a short period of time, and the authors found that had been accomplished, then I classified that study as effective. If the objective was to eliminate the target stock completely and the researchers found that the method had only reduced the numbers of the target stock then I classified that study as not effective at meeting its objective.

6.3 Biological Control

Biological control methods can be grouped into three categories: (1) the use of pathogens such as viruses, bacteria and fungi; (2) biomanipulation; and (3) predation by piscivorous animals including fishes (Wydoski and Wiley 1999). The use of pathogens for fish control is risky and generally not used in aquatic environments, and biomanipulation, which is the deliberate adjustment of the biota and habitat is applicable mostly to shallow lakes where piscivorous fish are stocked to control undesirable benthic-feeding planktivors (Reynolds 1994). In contrast, the introduction of predator species to control forage fish has wider application, and Wydoski and Wiley (1999) note that because it can establish balanced predator:prey relationships, this strategy is one of the most promising biological methods for managing non-game forage-fish populations.

Meronek et. al. (1996) reviewed the success of introducing predaceous species (ictalurids) to control species including yellow perch and crappie, but found only a 25% success rate in the four projects they reviewed. In contrast, I reviewed five (71%) projects which both controlled the target species, and created fisheries (**Table 14, Appendix 7**). Apart from the fact that this practice further contributes to the problem of non-native introductions however, this technique is not without its ecological problems as is currently being experienced by agencies importing tiger muskellunge. These fish have recently been found to carry viral hemorrhagic septicaemia (VHS), and a moratorium has been placed on importing eggs which has forced some western states to begin investigating implementing their own hatchery programs to support biocontrol programs and the fisheries they created (Jackson, S. pers. com. 2006).

Rather than introducing non-native predators, the stocking of native piscivores may be a better alternative to control non-native species. In Utah, for example, fisheries managers use highly predaceous native Bear Lake/Bonneville cutthroat trout to control chub, while in the Laurentian Great Lakes an intensive native predator stocking program increased the consumption of exotic prey fishes which eventually led to decreased abundances of exotic rainbow smelt and alewife (Kitchell and Crowder, 1986) (**Table 14, Appendix 7**).

Prior to considering the introduction of any predaceous species, whether native or non-native, fisheries managers must implement an extensive pre-stocking assessment to identify the habitat suitability for the predator; the desirability of the predator as a sport species; the predicted angler harvest of the stocked fish and its control if necessary; and other possible impacts, including hybridization and competition or predation on other native fish species, especially those already threatened or endangered (Wydoski and Wiley, 1999).

Table 14. Summary of results of seven biocontrol studies and projects including total number of successful/effective projects.

Predator	Prey	Number of Projects/Studies	Number Effective	Fisheries Created
Butterfly peacock	Various exotic species	1	1	1
Tiger muskellunge	Northern pike, brook trout, walleye, perch, bass	2	1	2
Native piscivorous trout	chub	2	1	2
Yellow perch (large, cannibalistic adults)	Yellow perch	1	Unknown	0
Bass	Goldfish	1	Unknown	Unknown
Total		7	3 (43%)	5 (71%)

6.4 Habitat Alteration

Habitat can be altered to make it more hospitable for the native species, less hospitable for the non-native species, or to exclude non-native species once they have been removed. Of the 17 habitat alteration projects I reviewed, 5 concentrated on excluding non-native species, 10 on creating habitat less hospitable for non-native fish, and 2 on restoring habitat for native species (**Appendix 8**).

(a) Habitat Alteration to Exclude Non-native Stocks

(i) Barrier Construction

Maintaining and creating fish passage barriers to prevent colonization or re-colonization by non-native species once they have been removed is among the most common and effective tools for conserving native fish. In fact, Clarkson et al. (2005) suggest that to begin the recovery process for native fishes, managers should first segregate native and non-native stocks, then designate each watershed or sub-watershed for the exclusive management of one stock or fishery type or the other. These authors also point out, however, that this strategy must consider the interconnections between drainage networks so that native fish are not isolated or prevented from exchanging genetic material with their conspecifics once barriers are constructed.

All five of the barrier projects I reviewed were effective at excluding non-native fish from areas with depressed native stocks. My reviews included various types of barriers including electrical fences, and some of the studies I examined noted that additional barrier types including nets, screens, rock-filled gabions and wooden cribs, and the creation of waterfalls had also been tried (Shepard, B. pers. com. 2007). As part of deciding on the specific type of barrier, managers must consider the natural conditions of the site and the abilities of the non-native species. For example, Thompson and Rahel (1998) found that brook trout were capable of getting past some rock gabions. As a result, the design and construction of effective barriers requires not only multidisciplinary expertise, but also ongoing monitoring to ensure that environmental conditions or barrier integrity and effectiveness do not change over time. In addition, the benefits of preventing re-invasion of non-native stock must exceed the risk of preventing native stock to move freely between spatially diverse habitats. The Montana Cooperative Fishery Research Unit maintains a comprehensive website of barriers and their uses at: http://wildfish.montana.edu/projects/.

Best Use: Barriers can be used to effectively exclude non-native stocks following their removal, however, these structures must take into account natural site conditions and the abilities of the non-native stock and must be monitored over time to ensure ongoing effectiveness. An interdisciplinary team is usually required to assist with barrier design and construction, and resources must be available for monitoring and maintenance. This method is most effective in the short-term to provide relief to resident (non-migratory) native stocks.

(i) Non-native-Free Zones

Once non-native fish are removed from an area, the habitat can be isolated then restored and managed for native stocks. In the Colorado River watershed, for example, the Bureau of Reclamation restored and developed historically common habitats such as oxbows favoured by native fish (Minckley et al. 2003). The Bureau considers these non-native free zones as temporary, with staff removing non-native fish and restocking with native fish on an ongoing basis. Given the monitoring and maintenance this strategy requires, the construction of non-native free zones may only be feasible in small areas, or where individual native stocks are isolated or in danger of extinction.

Best Use: This strategy involves removing non-native fish, restoring or improving the habitat for native stocks, then conducting long-term monitoring and maintenance to remove any re-invading non-native fish. Because of the ongoing monitoring, this approach is likely only feasible in small areas, or where there is a danger of extinction of the native stock.

(b) Habitat Alteration to Impact Non-native Stocks

(i) Drawdown

Drawdown can be used in artificial reservoirs where water level can be controlled, or in small ponds where water can be easily pumped out. In addition to being used as a sole method of impacting non-native stocks, drawdown is also sometimes used in combination with other methods, for example, to minimize surface area and volume prior to the application of piscicides, or to concentrate target species and thereby increase the efficiency of netting or electrofishing (Govindarajulu, 2006, Hill and Cichra, 2005). This method can also be used to expose redds of shoal-spawning species such as bass, and/or kill vegetation used by recently hatched walleye.

While drawdown has the advantage that native species and non-target organisms can be removed and returned when water levels are restored, this technique is not practical for large bodies of water where water levels or variable discharge regimes will affect recruitment of non target species, or where there are recreational facilities. And while in some situations this method may be low cost, easy to implement and publicly acceptable, it may not be entirely effective if there is water remaining in areas within the treatment site. Drawdown can also be detrimental to non-target species, there may be water rights considerations or limitations, and it is not practical for unregulated stream habitats.

<u>Best Use:</u> Drawdown projects are feasible in small or managed areas, for example, water bodies controlled for hydro purposes. This technique is best used to target specific life-history phases of non-native fish, for example, to expose redds of shoal-spawning species such as bass, and/or to kill vegetation used by the juveniles of species such as walleye. Drawdown can also be used to concentrate target species prior to implementing chemical treatments or electrofishing, however, fisheries managers must consider potential impacts to native species frequenting drawdown target areas.

(ii) Temperature Alteration

I reviewed one study that outlined investigations by the Oregon Department of Fish and Wildlife and the Army Corps of Engineers to reduce predation on native species by non-native pike minnow by releasing cool water from upstream reservoirs which researchers suggested would slow pike minnow metabolism and thereby reduce their activity. The effectiveness of this technique remains to be seen however, as investigations were in the initial stages. This strategy also has some inherent limitations in that it can only be implemented in managed watersheds, and the flush of cool water may impact native fish.

<u>Best Use</u>: The effectiveness of this technique is still unknown but it will likely be expensive and feasible only in small areas and where native fish will not be impacted by reduced temperatures.

(iii) Vegetation Removal

Given that the abundance of some non-native species including bass is related to the availability of vegetation (Durocher et al. 1984), controlling emergent macrophytes may be an effective technique for controlling these species. Unfortunately, 2 of the 3 (67%) jurisdictions I reviewed relied on the introduction of other non-native species such as grass carp to remove vegetation. Alternative methods such as herbicides and mechanical removal can also be used, however Daily et. al. (1999) point out that these methods may be limited, for example, in the amount of area they can affect. In addition, the effectiveness of mechanical removal may be reduced if it leaves behind plant fragments that can re-root. Nonetheless, given existing problems associated with eutrophication and exotic plant species in urbanizing areas, large-scale aquatic vegetation control programs are likely to increase in the future (Bettoli et al. 1993). In fact, an aquatic vegetation removal project was implemented at Elk/Beaver Lake by the local government several years ago (Reid, G. pers. com. 2007), consequently, this technique is already available in Region 1 (Vancouver Island).

Best Use: In small contained waters with limited shoal areas that can be treated with herbicides, or where mechanical removal is feasible. Ongoing monitoring is required to ensure that plant fragments left following mechanical removal do not re-root. This technique may already be available through parks or maintenance departments of local or municipal governments in urban centres of highly populated regions.

(c) Habitat Restoration to Increase Native Stocks

The literature on biological invasions tentatively suggests that invasion success is negatively correlated with the richness of the receiving fauna (Fridley et al., 2007, Diamond and Case, 1986), and while prior habitat degradation is not a necessary precursor to impacts from introduced species, habitat degradation or simplification can make a species and its supporting ecosystem more vulnerable to the effects of a non-native species (Lassuy, 1995). Unfortunately, this may tip the scales in favour of non-native species, particularly piscivorous fish, because species indigenous to depauparate faunas tend to have narrower tolerance ranges and, therefore are less competitive and more vulnerable to predation (Fuller and Drake, 1999). As a result, identifying and addressing habitat limitations to native species is an important first step in protecting against non-native invasion, and/or establishment.

(i) Barrier Removal

Since a common bottleneck contributing to the decline of native stocks is blocked and/or destroyed migration corridors, it follows that restoration of these areas can help strengthen native stocks and help minimize potential population level impacts from non-native fish. In Montana, fish passage barriers are removed to restore stream connectivity, promote genetic exchange between local populations, and facilitate recovery of migratory populations of native westslope cutthroat trout (O. clarki lewisi) (Knotek et al. undated). While this was the only study I found that noted barrier removal in the context of managing against non-native species, this strategy is an increasingly common approach in restoring native fish and their habitat in many jurisdictions including BC. Although engineering advice and equipment are often required to design and implement these projects, clients including stewardship groups and angling clubs can be engaged to help with project execution. Moreover, in BC, agencies including the ministries of Forests, and Transportation and Highways are becoming increasingly willing partners in habitat restoration, including barrier removal projects.

Best Use: Barrier removal projects can be implemented alone or as part of an overall watershed restoration program, and these types of endeavours may be particularly attractive options where other agencies have responsibility and/or interest in providing funding and/or participating in project implementation. This technique also allows fisheries managers to involve clients such as angling clubs and stewardship groups which provides an opportunity to educate about the vulnerability of native stocks and the impacts of non-native fish introduction.

(d) Effectiveness of Habitat Alteration Techniques

Nine of the 16 (56%) habitat alteration techniques I investigated were effective at achieving their objectives, most of which focused on providing short-term relief to native stocks (**Table 15**, **Appendix 8**). Each of the four barrier construction projects I reviewed were effective, however this technique requires ongoing monitoring and maintenance to ensure success. I also found that 50% of the drawdown projects I reviewed were effective at reducing the density of bluegill and bass stocks, however, Meronek et. al., (1996) found only a 25% success rate of these projects at reducing yellow perch and crappie.

Table 15. Summary of results of 16 habitat alteration studies and projects including total number and percent of projects defined as successful/effective.

Approach	Projects Reviewed	Number Successful/Effective	Percent Successful/ Effective
Habitat Alteration to Exclude Non-native Stocks			
Barrier Construction	4	4	100
Habitat Alteration to Impact Non-Native Stocks			
Drawdown	6	3	50
Temperature Alteration	1	0	0
Vegetation Removal	3	1	33
Habitat Restoration to Increase Native Stocks			
Barrier Removal	1	N/A	N/A
Habitat Restoration	1	1	100
Total	16	9	56

(i) Overall Effectiveness of Fish Management and Control Projects

I've summarized the results of the evaluations conducted by Meronek et al. (1996) and my own reviews regarding the success of fish control strategies in **Table 16**. Overall, only 39% of projects were successful or effective when both studies are considered. Habitat alteration projects were the most consistently effective, but the objectives of most of these projects were to control or exclude non-native species for a short time, not eradicate fish over the long term. Moreover, these projects, like all other management strategies including chemical removal, must be conducted over a several-year period. Consequently, not only does it appear there are no quick-fixes when a non-native species is introduced into a new habitat, but management efforts have <40% chance of success even when implemented over multiple years.

Table 16. Summary of results of 343 non-native fish management studies from literature searches and interviews including total number and percent of successful/effective projects.

Management Strategy	Literature searches conducted by Meronek et al. 1996*		Literature searches and interviews conducted by Michalski		Total Projects Reviewed	Total Successful/ Effective	Percent Successful/ Effective
	Projects Reviewed	Number Successful/ Effective	Projects Reviewed	Number Successful/ Effective			
Regulations	0	N/A	20	7	20	7	35
Chemical Removal	140	61	26	8	166	69	41
Mechanical Removal	68	29	34	12	102	41	40
Biocontrol	29	7	7	3	36	10	28
Habitat Alteration	0	N/A	16	9	16	9	56
Total	237	97	102	38	339	135	39

* The project occurred on water bodies ranging from 0.2 – 55, 752 ha and were located in 36 states and 3 countries. Fish control treatments were divided into four categories: chemical application (145); physical removal and reservoir draw-downs (70); stocking of fish (29); and any combination of chemical and physical methods, and success was judged by changes in standing stock, growth, proportional stock density, relative weight values, catch or harvest rates, and other benefits such as angler satisfaction. Success was judged as changes in target fish standing stock, growth, proportional stock density, relative weight values, catch or harvest rates and other benefits like angler satisfaction.

(ii) Reasons for Fish Management Project Failure

There are a number of reasons why non-native fish management projects may fail or become ineffective over time, including the fact that some fish communities have such complex interactions that the removal of one species has little effect on the remaining species, or the fact that non-native species may not respond to traditional approaches such as no-limit regulations. According to the literature I reviewed and the fisheries managers I spoke with, the effectiveness of fish control and management projects can be increased when fisheries managers:

1. Identify and address the specific problem affecting the native fish or fishery. Specifically, are native fish, the fisheries, or Red- or Blue-Listed species declining, or is native habitat being adversely affected because of the non-native species? While a non-native fish management or control project may succeed in removing a non-native stock in the short term, these projects will ultimately be ineffective, costly, and possibly controversial if native species or the fishery is not declining, or is declining for reasons other than the existence of the non-native species.

2. Understand the ecology and biology of the non-native species. In any given situation, the most successful plan is usually the one that expands, not limits, potential options and, in the case of non-native species management, the only way to determine the range of options is to understand the ecology of the new species. To ensure the greatest likelihood of success,

therefore, a detailed assessment of the new stock must be conducted before any decisions regarding general management or control strategies are made.

3. Identify the appropriate technique(s) required for the non-native species and/or life history phase. Clearly, one-size-fits- all management responses have a far less likelihood of success than several techniques tailored to each stage in the life history of the target species. Only after attributes including habitat use, movements and timing, and periods of highest vulnerability of the new species are determined can the most appropriate techniques be identified, and it is likely that several different techniques implemented throughout the life-history of the target species will be required if eradication is the objective.

4. Consider the technical requirements of the technique(s). Many fish control projects fail because of a lack of understanding of the technical problems inherent in the strategy including identifying the correct dosage of toxicants and/or neutralizers, the amount of sustained effort required for mechanical removal, and the most appropriate application techniques (Dawson, 2003) depending on the life history phase targeted. Consequently it is imperative that fisheries managers investigate not only strategies with the highest likelihood of success, but also the technical requirements and constraints of those strategies.

5. Implement projects and monitoring programs over multiple years. Most of the effective projects I reviewed accounted for the fact that management techniques must be repeated over a several-year period regardless of whether the objective was eradication or suppression of the target stock. In addition, even if the technique is not implemented each year, monitoring must continue to ensure there is no re-infestation. Multi-year implementation and monitoring require funds and staff and, and consequently, a commitment from the agency that non-native stock control or eradication, or protection of native stocks, is a priority. Ensuring institutional constraints, such as limited resources do not limit managers is central to the success of non-native species control and/or management.

6. Address the potential for illegal re-introductions. In some cases, re-expansion of a non-native stock following an eradication program may be the result of natural range extension from neighbouring waters, or compensatory responses of remaining individuals. As pointed out by some fisheries managers I spoke to, however, re-colonization following management actions often has more to do with a repeat of the illegal introduction that led to the introduction in the first place. This consideration underpins the fact that while fish control techniques may be the first step in non-native species control or management, the most important strategy a fisheries management agency can undertake to stem the spread of non-native species is enforcement, public education and the involvement of anglers and clients in the management of non-native species.

7.0 Preventing Non-native Fish Introductions

7.1 Legislation

(i) Federal Legislation

Numerous binding and non-binding instruments including codes of conduct and guidelines have been developed to address the issue of non-native species in North America over the past two decades (**Table 17, Appendix 9**). In Canada, invasive, alien species were identified as a priority in 2001, and there is now a national code regarding the development of consistent approaches to the conservation of aquatic ecosystems (Government of Canada, 2003). It is the *Fisheries Act,* however, that outlines federal legislation governing specific activities concerning fish and fisheries including fish transport and release of live fish. In the past, only section 33 of the *Fisheries Act* was concerned with the unlawful sale or possession of fish, however this section was not designed to deal with introduced species (Heusen, R. pers. com. 2007). A new *Fisheries Act* was recently tabled which includes section 69(1) prohibiting the export, import and transport of any member of a prescribed aquatic invasive species, and section 69(2) prohibiting the release of any member of a prescribed aquatic invasive species into waters frequented by fish. In both cases, these sections may be contravened when in possession of a licence allowing the release of live fish into fish habitat, or the transfer of live fish to a fish rearing facility.

Table 17. Summary of international, Canadian and BC provincial legislation, codes and policies regarding the transport and transplant of aquatic species.

Level	Legislation, Code, or Policy
International	United Nations Code of Conduct for the Import and Release of Exotic Biological Control Agents (1995). United Nations Convention on Biological Diversity Article 8 (Introduction of alien species). World Conservation Union (IUCN) Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species (2000). The Commission for Environmental Cooperation (CEC) Article 10 (Recommendations regarding alien species). Great Lakes Region Legislation, Regulation and Policy for the Prevention and Control of Non-indigenous Aquatic Nuisance Species Section 5 (Prohibited non-indigenous aquatic species); Section 8 (Designation of waters); Section 12 (Enforcement and penalties); Section 15 (Emergency action plan).
National	National Code on Introductions and Transfer of Aquatic Organisms (2003). *Fisheries Act* (1985) Section 33(Unlawful sale or possession of fish), No release of live fish (Fishery General Regulations). *Fisheries Act* (Proposed, 2007) Section 69 (Prohibition of export, import, transport and release of prescribed species). Wild Animal and Plant Protection and Regulation of International and Interprovincial *Trade Act* Section 3 (Interprovincial transport)
Provincial (BC)	*Wildlife Act* (1996) Section 37 (Transport of wildlife). *Fisheries Act* General Regulations Section 55 (Release of live fish). Pacific Fishery Regulations Section 5 (Import of Schedule VIII fish). *Fisheries Act* Fish Health Protection Regulations Section 3 (Import of fish or eggs). Federal Provincial Transplant Committee (Transplant Permit). Ministry of Environment Policy and Procedure 3-7-01.05 (Fish and aquatic invertebrate transplant and introduction).

(ii) Provincial Legislation

Each Canadian province has their own *Act* and regulations governing the possession and transport of non-native species (**Appendix 9**). In BC, section 37 of the *Wildlife Act* regulates the transport of wildlife including fish; section 55.1 of the BC Fishery General Regulations prohibits the release of live fish; and section 5 of the Pacific Fishery Regulations prohibits the import of fish including bass, blue gill sunfish, and pike (**Table 17**). Finally, section 3 of the Fish Health Protection Regulation prohibits the import of cultured fish or eggs of wild fish without an import permit.

Each province also has a federal-provincial Transplant Committee which includes representatives from the Fisheries and Oceans Canada, and in BC, the ministries of Environment, and Agriculture, Fisheries and Food. The primary role of this technical committee is not to address the illegal transport and introduction of non-native species, but to advise member agencies on legal fish introduction and transfer (Kieser, D. pers. com. 2007). Issues regarding illegal movement and introduction of aquatic species are left to the Fishery and Conservation Officer Services of the federal and provincial governments (Kieser, D. pers. com. 2007). On a related level, the BC Ministry of Environment has policy and procedures regarding applications to the Transplant Committee for the approval of legal transport and introduction of fish.

(iii) Penalties

In North America, penalties for the illegal transport and/or transplant of invasive or non-native species usually involve nominal fines although in some US jurisdictions, such as Montana and Oregon, persons convicted of these offences may also be charged for the costs associated with destroying the introduced fish and restoring the habitat (**Appendix 10**). In BC, penalties under provincial legislation include tickets, and under the proposed *Fisheries Act*, include fines up to $200,000 for a first offence and up to $200,000 and/or 6-months imprisonment for subsequent offences.

(iv) Enforcement

I interviewed fisheries managers and conservation officers from 12 jurisdictions, and only staff from Montana said their agency had an effective enforcement program related to illegal fish movement. In this state, the Montana Fish, Wildlife and Parks Agency Enforcement Officers regularly check boaters for transporting fish contrary to the regulations, charges are common, and there are severe penalties including the requirement that convicted persons be responsible for the cost of removing the introduced fish and restoring the habitat (Shepard, B. pers. com. 2006). Although it is still too early to judge its effectiveness, Washington State recently implemented a program where a Conservation Officer with specialized training works solely on issues related to illegal fish movements, including enforcing regulations and implementing public awareness and education initiatives (Meacham, P. pers. com. 2007) (**Table 18**).

Table 18. Summary of interviews with fisheries managers and conservation officers from Canadian and US jurisdictions regarding the level of enforcement and actions taken with respect to illegal fish movement and introduction.

Jurisdiction	Agency	Level of Enforcement*	Action*
Alberta	Alberta Fish and Wildlife	Occasional	One charge in recent times
British Columbia	Ministry of Environment	Occasional	Occasional tickets
California	California Department of Fish and Game	Occasional	Charges rare
Colorado	Colorado Division of Wildlife	Occasional	Charges rare
Idaho	Idaho Fish and Game	Occasional	Charges rare
Manitoba	Manitoba Conservation	Rare	No charges in recent times
Montana	Montana Fish Wildlife and Parks	Extensive	Charges and penalties common
Nova Scotia	Nova Scotia Agriculture, Fisheries and Aquaculture	Occasional	No charges in recent times
Ontario	Ontario Federation of Anglers and Hunters	Occasional	Charges rare
Oregon	Oregon Department of Fish and Wildlife	Occasional	No charges in recent times
Utah	Utah State; Division of Wildlife Resources	Occasional	Charges rare
Washington	Washington Department of Fish and Wildlife	Occasional	Charges rare**

* Note: responses to these questions are impressions or opinions of fisheries managers or Conservation Officers interviewed and do not represent quantitative data or information regarding this issue.

** New program with Conservation Officer dedicated solely to invasive species recently introduced – no data on success rate as yet.

While enforcement activities are now strong in Montana, this has not always been the case and, in the past, enforcement action in this state was similar to that still occurring in most other jurisdictions. In Manitoba, for example, it is agency biologists who are responsible for investigating illegal fish transplants (**Appendix 2**). In this jurisdiction, like many others, staff cannot remember the last time there were charges or convictions for the illegal introduction of fish. In BC, although conservation officers have laid charges, often as a result of incidental checks (Heusen, R. pers. com. 2007), approximately 1% of the warnings and tickets issued since 1985 have been for the illegal transport and/or introduction of fish (Truscott, J. pers. communication, 2007) (**Table 19**).

Table 19. Total number of tickets, penalties or sanctions issued under section 37 *Wildlife Act*, and section 55(1) BC Fishery General Regulations compared to total number of warnings and tickets issued 1995-2006 (Source: Truscott, John Corporate Services Division, Ministry of Environment).

Year	Number of Charges or Warnings under s37 *Wildlife Act* and s55(1) BC Fishery General Regulations	Total Number of Charges/ Warnings under *Wildlife Act* and BC General Fishery Regulations	Percent
1985-1989	99	12,888	0.8
1990-1999	296	32,119	0.9
2000-2006	166	17,324	1.0
Total	561	62,331	0.9

(a) Legislation and Penalty Review

When asked why they felt charges for illegal fish movement were so rare, fisheries managers and conservation officers cited a number of issues related to problems within their agencies, the difficulty apprehending those responsible for illegal fish movement, ineffective legislation, and inadequate penalties (**Table 20**). In particular, staff I spoke with from a number of areas including BC said the laws and penalties in their jurisdictions were outdated or inadequate with respect to non-native fish movement. As an example, current provincial legislation is reactive and perpetrators must be caught in the act which is difficult given the covert nature and geographic scope of the problem, and the common time delay between fish introduction and discovery. To remedy this in BC, Heusen (Heusen, R. pers. com. 2007) suggests a review of the provincial legislation and penalties to identify areas where the legal framework can be strengthened.

Table 20. Problems cited by fishery managers and conservation officers for the lack of enforcement action related to illegal transport and/or transplant of fish.

	General Problem		
	Legislation	**Systemic/Agency**	**Discovery and Response**
	• Dated -does not appropriately address the issue. • Legislation reactive and individual must be caught in the act. • Inadequate penalties.	• Lack of staff and resources. • Failure to identify issue as an agency priority and/or failure to communicate this to staff and the public. • Committees, policies and procedures deal only with legal transplant of fish.	• Discovery often by chance/difficult to anticipate next probable transplant site. • Time delay between when fish are introduced and discovered precludes apprehending/charging person(s) responsible. • No arrests even with client-assisted whistle-blower programs.
General Suggested Approach	Legislation/Penalty Review	Define Agency Priorities Internal Communication Programs Internal/Interagency Coordination	External Awareness/Education Programs Agency/Community Surveillance/Rapid Response Programs

Some fisheries managers I spoke with also felt that increasing penalties would address the problem of illegal fish movement (**Appendix 2**). However, as Daily et al. (1999) point out, legal constraints, including increased penalties, are effective only when the probability of being apprehended is high and, as many I spoke to noted, the difficulty catching those responsible is one of the reasons this issue is difficult to address. Some jurisdictions, including BC, have implemented whistle-blower programs to help increase the number of arrests for illegal fish introductions (Koopmans, 2005). However, here, as in most other areas, this initiative has not resulted in additional arrests or charges perhaps because, as Heusen (pers. com. 2007) points out, the fish and wildlife clubs helping implement these programs likely have members responsible for the illegal fish movements. It is unreasonable, therefore, to expect that club members will expose fellow members, especially if those responsible are seen as creating angling opportunities. Fisheries managers in Oregon suggested that increased media coverage following the discovery of illegally introduced fish, and the subsequent charge and conviction of those responsible would both deter others and encourage would-be whistle-blowers to come forward. Again, however, this requires that individuals be caught, charged and convicted, which has not been the norm. Consequently, while a review of penalties associated with legal infractions must be a part of the recommended legislative review, solutions addressing the difficulties apprehending individuals must also be developed.

(b) Defining and Communicating Agency Priorities

Fisheries biologists from Oregon noted a number of systemic problems contributing to the spread of non-native species including a lack of resources, the absence of a state-wide policy promoting a consistent management approach and, underpinning both of these issues, the inability of the agency to define non-native species as a priority, or to communicate that to staff (Schrader, T. pers. com. 2006).

Non-native species management is listed as a priority activity within the BC Fisheries Program Plan (Ministry of Environment, 2006). However, within this province, non-native fisheries species occur in <10% of provincial waters and in primarily four regions (**Table 3**), consequently this issue is a higher priority in some regions than in others. Nonetheless, staff I spoke to in a region with a high occurrence of non-native species did not know if this issue was a provincial, or even regional priority. Moreover, these individuals noted that while the implementation of field-level projects to address this problem were in fact possible, there had been no direction from management to initiate programs, and as a result, no coordination between staff to implement specific projects. Clearly the definition of non-native species management as an agency priority within over-arching documents is important and necessary, however it is of little benefit if this is not communicated to staff and resourced as such by management.

Suggested Approach: Define the provincial and regional level of priority related to non-native species introductions, and communicate this both to senior-level management and to staff during annual Ministry business planning meetings to ensure related projects can be articulated into regional yearly work-plans. In addition to supporting activities and projects related to non-native species management and control, the agency must provide adequate resources to implement specific programs identified by staff.

7.2 Internal Communication

Internal communication both between, and within management and staff levels is what Paul Shafland, Fish Eradication Biologist for the Florida Fish and Wildlife Commission, calls agency in-reach and, says Shafland, it is critical to the management and control of non-native and invasive species (Shafland, P. pers. com. 2007). In fact, Hickley and Chare (2004) note that one of the most important methods employed by the UK Environment Agency in the management of non-native species is the information provided by fisheries officers and staff to anglers and the general public. As these researchers also note, however, staff must be extremely well informed on the issue for this strategy to work.

The Washington Department of Fish and Wildlife offers a number of information programs for staff, managers and legislators, including:

- biennial, regional non-native species workshops for resource managers;
- biennial field days for legislators and staff to visit invaded sites; and,
- a Western-states conference on alien non-native species.

In addition to ensuring staff are well-versed on the subject, these programs allow discussion between and within staff and management levels, and bring the issue of non-native species introduction to the forefront of individuals making decisions affecting agency priorities and budgets (Meacham, P. pers. com. 2007). In addition to workshops and field trips, this agency also posts information, including species lists on agency websites so that staff can remain up-to-date on what is happening with respect to this issue in other areas of the state.

Suggested Approach: Implement regular (biennial) workshops which include general information for senior management and technical topics for field staff. In addition to workshops, implement regular (biennial) meetings between senior level managers and field staff to discuss agency priorities and field-level issues relating to non-native species introduction and spread.

(a) Internal Technical Working Groups

Information gaps regarding non-native species movement, and/or their response once within a system can seriously handicap efforts to respond to, and manage those species, therefore, in addition to providing mechanisms such as technical workshops where fisheries managers can receive information, it is also important there are established, ongoing links so staff can regularly exchange information between one another. In BC, some regions have more experience than others with this subject, consequently their knowledge is valuable to staff in regions where this issue is just emerging. Internal technical working groups are an ideal way to facilitate regular information exchange between field staff, and the existing provincial Small Lakes Committee is an appropriate body, either within which to address these issues directly, or from which can be developed a separate working group focused solely on the subject.

Suggested Approach: Expand the provincial Small Lakes Committee mandate to address issues related to the management, control, and prevention of illegal non-native species transplant, or establish an associated working group to address specific non-native species issues as they arise.

(b) Interagency Communication - The Federal-Provincial Transplant Committee

While within-agency communication is vital to ensuring consistent approaches between regions, fisheries managers in Washington State have found that cooperation between agencies is critical in preventing the spread and responding to new introductions of non-native species (Meacham, P. pers. com. 2007). The federal-provincial Transplant Committee is currently only responsible for legal introductions of aquatic species, however expanding the responsibility of this committee to include illegal introductions will facilitate information exchange between agencies, and increase the network of staff able to contribute to addressing this issue. This particular body can also help identify legal and regulatory mechanisms and options for dealing with non-native species movement and, as such, is an appropriate committee to oversee the recommended legislation and penalty review. Fisheries and Oceans Canada is currently reviewing the system of approving introductions of aquatic species (Kieser, D. pers. com. 2007), therefore, this is an opportunity to make adjustments in the mandate of the Transplant Committee.

Suggested Approach: Expand the mandate of the federal-provincial Transplant Committee to address legal and policy issues regarding the illegal transplants of non-native fish species, and charge this committee with overseeing the recommended review of provincial legislation and penalties related to illegal fish movement and transplants.

7.3 External Communication

External communication was seen by agency staff as the single most important single strategy in preventing the illegal introduction of non-native species in 50% of the jurisdictions I contacted (**Appendix 2**). To that end, agencies have implemented a variety of education and awareness programs including publishing brochures and pamphlets, providing displays at public events, and enlisting angler involvement in non-native species control and management (**Table 21**). In fact, involving anglers in both general and specific projects dealing with non-native species was the most commonly employed strategy, perhaps because as noted by fisheries managers in California, Florida, Montana and Nova Scotia, involving anglers not only provides an opportunity to educate clients, but also enables staff and clients to work toward common objectives which ultimately results in higher client acceptance and support of agency goals when it comes to the management, and even control of non-native species.

Table 21. Summary of public awareness and education programs regarding non-native species used by 14 North American Fish and Wildlife management agencies.

	Publications							Press		Angler Involvement Programs		School Programs
Jurisdiction	**Books**	**Brochures/ Pamphlets/ Newsletters**	**Databases/ Websites**	**Displays/ Talks/ Shows/**	**Regulations Inserts**	**Signs**	**Videos**	**Print Press Releases**	**TV/ Radio**	**General**	**Project Specific**	
Alberta	✓			✓						✓	✓	
California		✓		✓							✓	
Colorado			✓			✓						
Florida					✓			✓		✓	✓	
Idaho				✓	✓					✓		
Manitoba				✓						✓		✓
Minnesota	✓	✓					✓					
Montana								✓	✓	✓	✓	✓
Nevada		✓			✓			✓		✓	✓	
Nova Scotia		✓		✓					✓		✓	
Ontario										✓	✓	✓*
Oregon								✓	✓		✓	
Utah		✓	✓	✓		✓				✓	✓	
Washington	✓	✓								✓	✓	
Total	**3**	**6**	**2**	**6**	**3**	**2**	**1**	**4**	**3**	**9**	**10**	**3**
Percent of Total	**21**	**43**	**14**	**43**	**21**	**14**	**7**	**29**	**21**	**64**	**71**	**21**

* Program in development

(a) Angler Awareness Programs

(i) Angler Education and Project Involvement

Over 60% of angler-focused communication programs in jurisdictions I contacted were general in nature, e.g., speaking at fish and wildlife club meetings, while over 70% of programs involved anglers in specific projects focused on non-native species control and/or management (**Table 21**). Fisheries managers in Alberta work with Trout Unlimited Canada to implement client-focused education programs, while states including California, Montana and Oregon routinely involve anglers in projects removing native species before non-native fish eradication (**Appendix 2**). And, while fisheries managers in California recognize there is likely minimal benefit to fish or the project overall from these programs, they also contend that these programs get anglers involved, provide opportunities for specific education initiatives, and build partnerships so that clients argue for projects, or support the agency in future endeavours (Blume, R. pers. com. 2007).

Involving anglers in projects would be extremely useful in addressing some client backlash regarding non-native species management in BC. In an article published in Outdoor Canada, Shawn Smith, of the West Coast Bass Anglers Association, noted that BC Fisheries was not collecting the information required to make their claim that bass impact trout (Kylie, 2002). He further observed that there was a perception among some bass anglers that the agency was giving bass a bad name without really having any education on them, which was angering individuals to the extent that some were defying Fisheries and doing the wrong thing (Kylie, 2002). Involving these anglers in data-gathering projects would provide an opportunity to not only gather much-needed information on provincial bass stocks, but would also build a relationship with a growing client body and one possibly in contact with individuals responsible for illegal fish movements.

(ii) Angler Consultation and Agency-Angler Steering Committees

Consulting with anglers facilitates discussions between the agency and its clients, and many fisheries managers I spoke with maintained that this is key in preventing illegal movements of non-native species. For example, Shepherd (pers. com. 2007) noted that education and up-front communication with clients, including soliciting their input and opinions, has been central to managing non-native species in Montana, and he further pointed out that client and public support of agency projects and non-native species management increased considerably once the Montana Fish, Wildlife and Parks agency began intensive consultation with clients. In Florida, fisheries managers have a close working relationship with anglers and the press, and the agency uses both to promote non-native eradication or management programs, to solicit information on the potential value of a new non-native fishery, and to foster involvement in developing non-native fisheries (Shafland, P. pers. com. 2007).

Beyond general consultation, agency-angler working or steering committees foster shared decision making and allow participants to work together in managing non-native fisheries and stocks. Jurisdictions including California, Oregon, Washington State and Nova Scotia include angling organizations, particularly bass clubs, in decisions concerning bass management, and this has been extremely useful in controlling the spread and preventing new introductions of those species in some areas. Fisheries managers from both Washington State (Jackson, S. pers. com.) and Nova Scotia (LeBlanc, J. pers. com. 2007) noted that illegal movements of bass slowed or stopped when staff and anglers began working together to manage those fisheries.

(b) Public Awareness Programs

(i) General Programs

Since some of the spread of non-native species occurs through ignorance or the misguided actions of private citizens, education and awareness campaigns aimed at the general public are also extremely important in preventing non-native fish movement. Fisheries agencies have implemented a number of general public awareness programs, from public service announcements on radio and television to magazine publications and agency web sites, to civic speaking engagements (**Table 21**). States from Texas through North Dakota and into Canada have even cooperated to implement the 100th Meridian Proposal which provides information on preventing the distribution of exotic species to travelers through a series of billboards on seven major US highways (Warburton, 1998).

It is difficult, if not impossible to gage the effectiveness of general public awareness projects given that most agencies do not monitor changes in public attitudes before and after the implementation of an information project. This oversight can not only diminish the success of even the most well-intentioned education program, but may even cause it's undoing. Fisheries managers from 2 jurisdictions I surveyed maintained that by not providing enough information, or considering the understanding and beliefs of their target audience, public awareness programs in these regions may have provided the impetus for additional illegal transplants. Consequently, both managers noted that it is critical that an agency evaluate the audience and consider the message carefully before implementing a public awareness campaign. In addition to assessing the level of understanding of the audience, and tailoring the message specifically to that group, it is also important to measure the change in understanding or attitudes during and following project implementation so that future education projects can either address gaps in initial projects, and/or build on the previous programs to further advance the knowledge level of the target group.

(ii) Community Watch Programs

Public information initiatives are only one part of what must be a much larger program to foster a stewardship ethic aimed at protecting native species and habitats from non-native fish introduction and spread. Because of their closeness to nature, local citizens are more likely to be aware of species and habitats, and recognize the disappearance of formerly common plant or animal species and the arrival of a non-native species (IUCN, 2000). Community Watch programs involve private citizens in monitoring potential target habitats for illegal introduction, and, therefore, can address the need for improved surveillance required to increase the effectiveness of illegal fish movement legislation. Involving the general public, rather than angling clubs, also separates would-be whistle-blowers from those associated with individuals involved in illegal fish introductions. Finally, by providing ongoing monitoring, Community Watch programs can decrease the time between non-native species introduction or invasion, and the implementation of management and/or control measures by the agency.

(iii) Student Programs

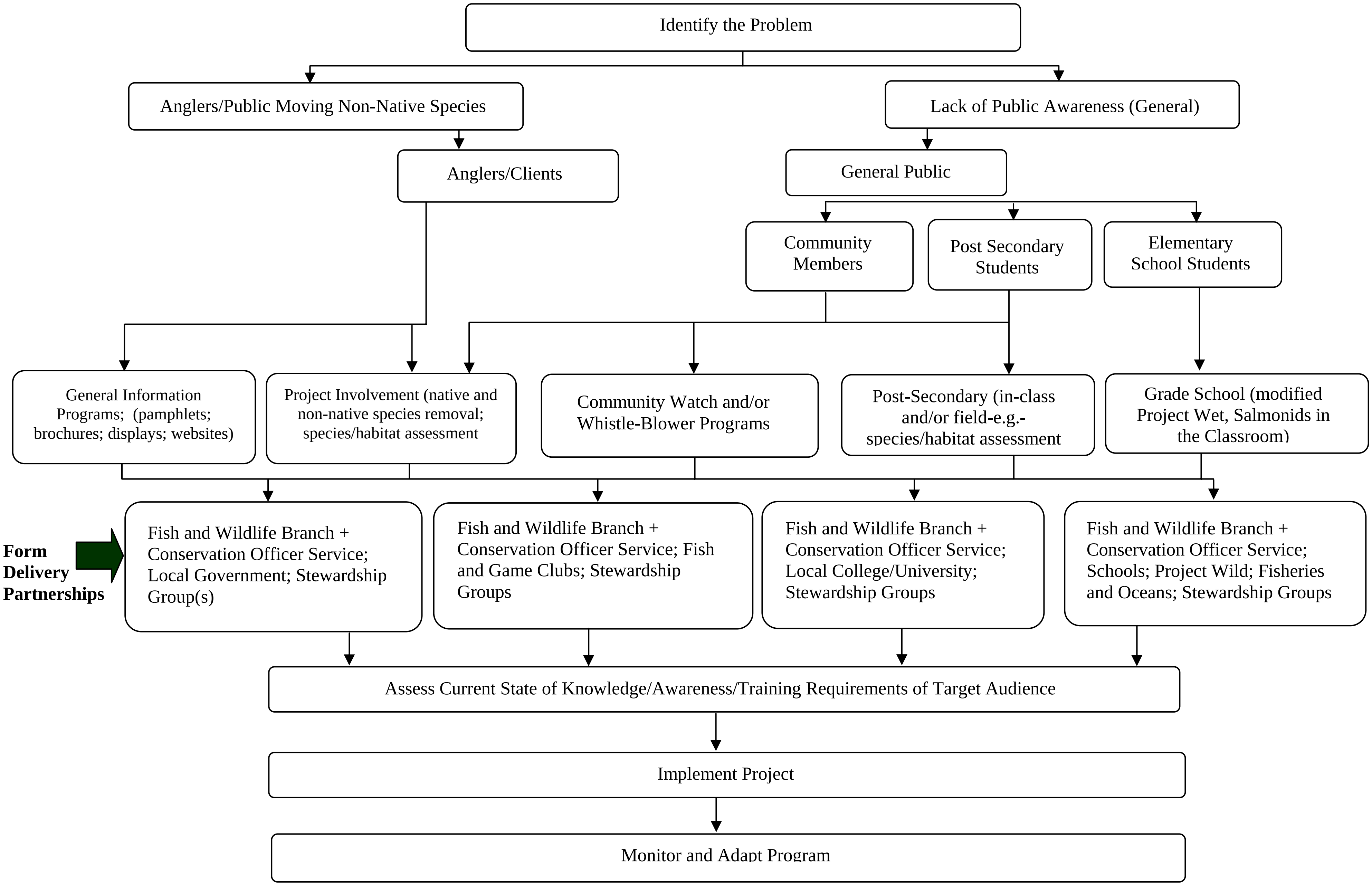
Of the 14 jurisdictions I found that have implemented public awareness and education initiatives, only Manitoba and Montana include post-secondary student involvement in their non-native species management programs, and only Ontario is developing a grade school student awareness program focused on the subject (**Table 21, Appendix 12**).

In BC, there are 2 existing education programs that can be used as vehicles to introduce issues related to non-native fish species to students. The Salmonids in the Classroom program offered to grade schools through Fisheries and Oceans Canada has several environment-focused modules which could be adapted to provide information regarding the consequences of introducing and moving non-native fish. In addition to this program, Wild BC, a provincial initiative that provides education, stewardship opportunities, workshops and resource materials to early childhood educators and teachers at post-secondary institutions, also has several water-focused modules which could be adapted to include information on non-native species. At the post-secondary level, some local colleges including Malaspina University College in Nanaimo are receptive to offering college-agency non-native species programs, or implementing joint field projects focused on this issue (Morgan, J. pers. com. 2007).

(c) Internal and External Communication Program Strategy

I've presented a flow chart outlining a recommended general communications strategy in **Figure 4**. The first step in this strategy is to determine the type and extent of the issue, then to identify the target audience and the most appropriate project(s). I recommend that, to help defray project costs and increase program acceptance, the agency develop delivery partnerships with fish and game clubs and stewardship groups, and the Conservation Officer Service. In BC, Fish and Wildlife staff has an opportunity each year to request the inclusion of creel surveys, water body and angler checks, and public information and education projects in regional Conservation Officer work plans. It is possible to focus this work on non-native fisheries species, however projects must be developed jointly by the Conservation Officer Service and the Fish and Wildlife Branch, and be identified early in the fiscal year (Heusen, R. pers. com. 2007).

Figure 4. External communications strategy aimed at preventing the introduction and spread of non-native fisheries species.



8.0 Rapid Response

8.1 Predicting Non-native Fish Movement

A study of smallmouth bass angling opportunities on Vancouver Island found that access to fishing locations and better launch sites encourage more angling (Roberge, 2005) while an investigation of species invasions in North American Shield lakes by Vander Zanden et al. (2003) found that road access, the presence of boat launches, and urban and residential development may be important in the invasion of non-native species.

Understanding the client base, for example, where the bulk of the anglers live, fish, and like to fish is important in predicting where non-native fisheries stocks could be moved to next. Moreover, since the fish used in illegal introductions often come from stocks of naturalized non-native species, it is also critical to develop a clear picture of the current distribution of non-native stocks within a region. This is especially important since the expansion of non-native species can also be the result of the unassisted movement of fish through connecting waterways.

GIS-linked databases highlighting affected areas and potential pathways have been extremely useful in tracking the invasion of non-native species in jurisdictions including Washington State (Cabreza, J. pers. com. 2006). GIS databases, or stand-alone maps, are also an ideal way of alerting agency staff, individuals involved in Community Watch programs, and the general public to the potential movements, either natural or human-assisted, of non-native species and, as such, are a key first step in the implementation of surveillance programs and the development rapid response plans.

<u>Suggested Approach:</u> Develop regional GIS-linked databases identifying current concentrations of non-native fisheries stocks, connecting pathways, road networks and popular angling locations prior to, or in concert with, agency surveillance and/or Community Watch programs and rapid response plans.

8.2 Rapid Response Plans

Effective risk management for non-native species includes identifying high risk pathways and developing a comprehensive rapid response strategy that includes clear accountabilities, monitoring and taxonomic expertise. While early detection is possible for some species, the lag time between introduction and species establishment is often measured in years or even decades, consequently, by the time a fisheries manager becomes aware of the presence of a new species, it has often become well-established in its new habitat (Li et al. 2000). Regardless of when a new species is discovered however, a rapid response plan must allow for quick implementation of all aspects of management including eradication. As a result, even though it is termed “rapid response,” this strategy may take months or even years to implement if permits, for example those required for chemical removal, and public consultation must be in place before a project is implemented. In the ensuing time however, management strategies including liberalized regulations and mechanical removal can be initiated (**Figure 5).**

Figure 5. Rapid Response Flow Chart. (Adapted from Washington Department of Fish and Wildlife, 2005, Kaeding et al. 1996, and Cordone and Frantz, 1966).

Potential pathways mapped; long-term agency surveillance/Community Watch Programs in place

Non native species reported

Confirm species (positively identify specimen, or conduct initial lake assessment)

Implement Education/Public Awareness and Fisheries (Angler) Management Strategies

1. Internal Awareness Program: Fisheries/CO staff
2. External Awareness Program: Anglers/community: public alert & reward program for additional information on sightings, additional/planned introductions)
3. Fisheries (Angler) Management Strategies: remove limits if any; implement derby where possible.

Predaceous species (yellow perch, black crappie walleye, Northern pike), and Single year class, and No Red/Blue-Listed species present

Non-predaceous species (bass), or multiple year classes of predaceous species, or Red/Blue-Listed species present

Implement Chemical Removal Planning Process (permits, plan/budget, and public consultation)

Conduct Detailed Assessments:
Biological (species life history characteristics; annual fish movements; identification of spawning sites) and Limnological (information for design of management strategies)

Chemical Removal (years 2-3)

Non Chemical Management Strategies (year 1 predacious species; years 1-3 other)

Monitoring and Enforcement Programs (Years 2+)

1. Biological (determine strategy effectiveness; adapt strategies)
2. Angler Creel Survey (monitor impacts to native and non native fisheries);
3. Enforcement (demonstrate agency diligence regarding illegal introductions; monitor for subsequent illegal introductions);
4. Community Watch Programs (information regarding new sightings; additional/planned illegal introductions).

Ongoing Awareness/Education Programs: Internal and External (to provide ongoing information regarding status)

9.0 Non-Native Fishery Species Management, Control and Introduction Prevention Summary

Once non-native fisheries species are discovered or established, all efforts should be made to assess, manage and, if possible, utilize them in a beneficial manner (Shafland, 1986). To that end, decisions regarding the selection of strategies to control and manage non-native fisheries species, and prevent their illegal re-introduction will be most effective when fisheries managers consider:

1. The specific problem affecting the native stock and/or fishery and whether it is as a result of the non-native species. Specifically, are native fish, the angler effort and catch, or Red- or Blue-Listed species declining, or is native habitat being adversely affected because of the presence of the non-native species? If so, then some action is warranted. If not, then management strategies to provide new opportunities based on the non-native species can be examined.

2. The ecology and biology of the target non-native stock. No importation is so urgent that it should not be subject to careful evaluation (Simberloff, 2003). Understanding the life-history and movements of non-native species is necessary to identify when target stocks are most vulnerable and accessible and, consequently, what management/control strategies are most appropriate and when these will be most effective.

3. The technical requirements of the management and/or control technique(s). Even seemingly foolproof strategies such as piscicides have limitations and it is critical that these be identified during the project planning phases. One of the most commonly overlooked considerations is that fish control and management strategies must be repeated over several years and the subsequent fish response monitored to address previously unidentified technical limitations or biological considerations such as compensatory responses.

4. The operational requirements of the project and whether the agency can support these over multiple years. The most effective non-native species control and management projects are implemented over multiple years, consequently, project funding must be available over a several year period. In addition, staff resources must be consistent and agency priorities must be identified and clearly communicated so that regional fisheries staff can plan, budget and implement non-native fisheries species management programs with the highest likelihood of success.

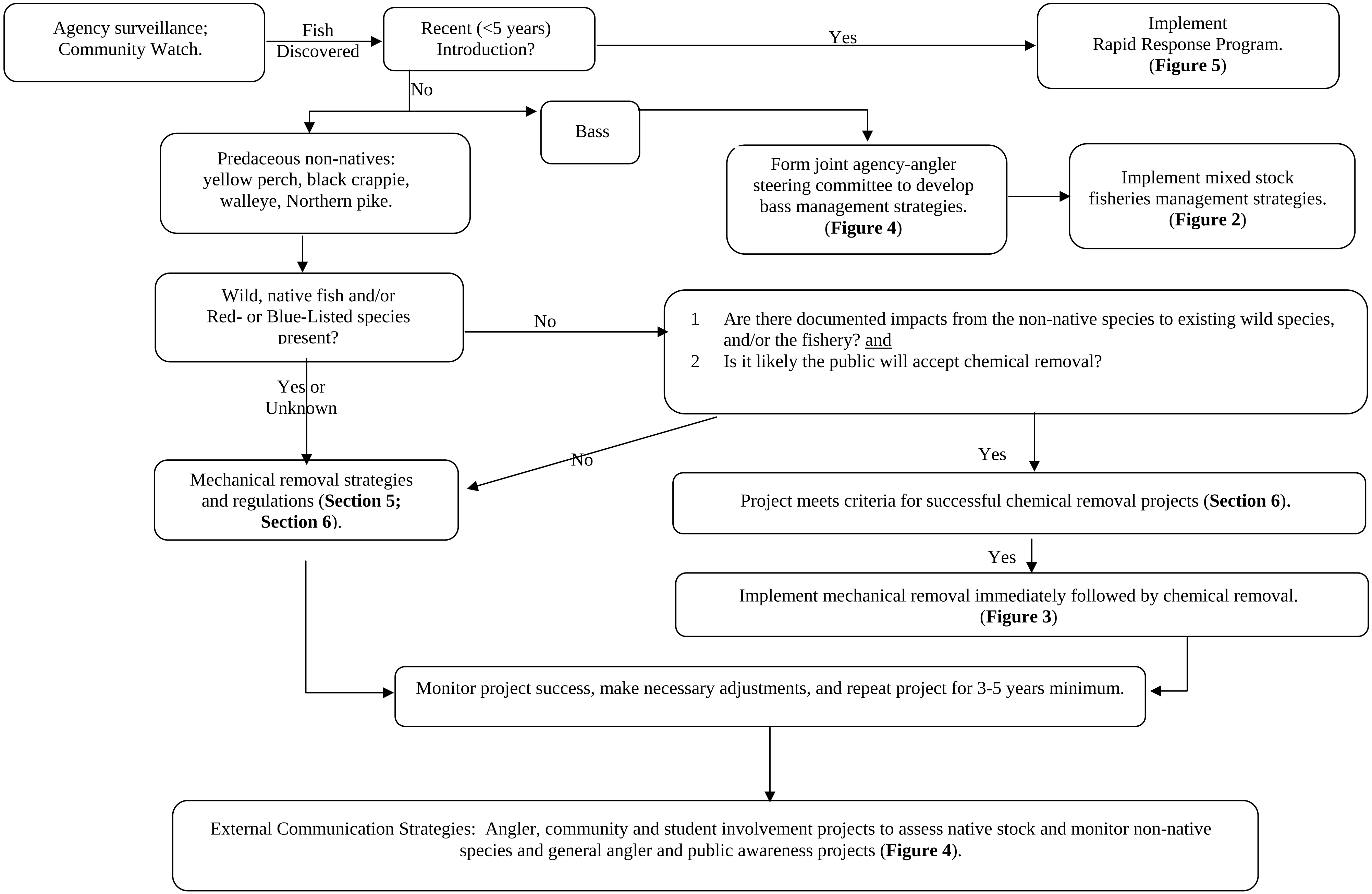
5. What the public and our clients will accept. Fisheries managers must consider whether a fish control or management program is socially, politically and/or legally acceptable (Beamesderfer, 2000). If clients and the general public do not accept proposed management actions then the result may be a backlash, not only regarding the immediate project, but on larger issues as well. Moreover, this backlash may result in increased efforts to re-introduce non-native species into the same, or even new systems.

6. The possibility of illegal re-introduction. Throughout history, humans have moved fish from one ecosystem to another to such an extent that today the dominant fishes in many lakes and

rivers in North America are now introduced (Li and Moyle, 1993, Moyle, 1986). Different anglers have different preferences and it is reasonable to expect that clients will move preferred species to favoured locations to increase opportunities. It is important, therefore, especially given legislative and enforcement limitations, that improved water-body surveillance and general public awareness programs be part of fish control and management programs. In addition, however, as noted by many fisheries managers I spoke to, illegal non-native species movement slows or stops when anglers are included in fish management decisions and as such, client consultation is key to controlling and managing non-native species, and preventing their illegal transplant.

In **Figure 6** I've outlined a flow chart that can be used to guide decisions regarding the selection of strategies to control and manage non-native fisheries species, and prevent their illegal introduction. I've based this chart on the preceding steps adapted from Beamesderfer (2000), and the concepts developed and presented in the separate sections throughout this report. As such, some of the individual strategies and methods noted in **Figure 6** relate to previously outlined flow charts or sections and I've highlighted these where applicable.

Figure 6. Flow chart to guide management, control and the prevention of non-native fisheries species introduction.



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Appendix 2 Interviews

Appendix 3 Literature

Appendix 4. Summary of types and effectiveness of various regulations implemented by North American jurisdictions.

Jurisdiction	Species	Regulation	Project Summary	Outcome	Source
Alberta	Hatchery trout	Harvest Limits – Catch and Release on natives; kill on hatchery	Native cutthroat and rainbow listed on COSEWIC so are Catch and Release while non-native cutthroat and rainbow are kill fisheries.	Undetermined - No information yet – Agency is concerned, however, that anglers will see stocking hatchery fish on protected rivers as positive since they will be able to keep those fish and so will continue to illegally stock fish in these areas.	Michael Sullivan, Alberta Fish and Wildlife
Delaware	largemouth bass	Length Limits - Slot Limits	Agency assessed the utility of two protected slot limits in restructuring populations of largemouth bass in ponds.	Ineffective - slot limits to manage largemouth bass stocks did not meet all objectives: in lake with low slot limit to produce moderate-density fishery, harvest had little impact on the population; in lake with high slot limit designed to produce trophy fishery, anglers did not remove enough surplus bass below the limit. Promoting angler cooperation key to improving success of this management tool.	Martin, C., 1995
Georgia	black crappie	Harvest Limits - Restrictive	Agency evaluated fishing pressure, harvest, and catch rates to determine if populations were providing acceptable fisheries.	Ineffective - crappies entered the fisheries at age-2-3 and numerically dominated total harvest; all populations characterized by low survival regardless of angler exploitation. Numerous small fish probably will not attract anglers making even liberal creel limits ineffective for control of these stocks.	Larson et al. 1991
Idaho	walleye	Harvest Limits - Liberal	No limits on walleye or northern pike in Lake Pend O'relle	Undetermined –system too large to poison or remove fish physically so agency just relies on no limits for walleye and northern pike.	Fred Partridge; Idaho Fish and Game
Idaho	yellow perch	Harvest Limits - Liberal	Agency tried using liberal regulations as well as other control methods.	Ineffective – Yellow perch became one of the largest fisheries despite liberal regulations and other methods to control stocks. When fish decreased because of changes to water quality, disease and competition from native northern pike minnow, agency started managing for perch and against native pike minnow. Note: liberal regs changes the population size structure which does not foster good, attractive fisheries.	Fred Partridge; Idaho Fish and Game
Iowa	largemouth bass	Length Limits – Minimum	Agency assessed catch rates and harvest results under a 14-in minimum length limit for largemouth bass.	Effective - minimum length limit prevented over harvest because catch and release equalled or exceeded population size each year but most critical problem with bass was poor year-class success which affected fishing quality and subsequent exploitation so agency reduced limit to 12-in to compensate for fishery declines. Study notes the importance of information program for Conservation Officers and anglers explaining regulation rationale to ensure compliance.	Paragamian, 1982
Kentucky	smallmouth bass	Length Limits - Slot Limits	Agency evaluated whether slot resulted in reduced densities of small, smallmouth bass and increased densities of larger smallmouth bass.	Ineffective - slot limit not effective in increasing growth rates of small fish likely because angler harvest not high enough to make reg. effective. Smallmouth bass recruitment patterns directly impacted densities of fish recruiting to the slot limit. Note: with slot limits, agency must consider variability of year-class strength and subsequent recruitment to the protective slot and harvest or potential harvest rates.	Buynak and Mitchell, 2002

Jurisdiction	Species	Regulation	Project Summary	Outcome	Source
Michigan	bluegill/walleye	Harvest Limits – Restrictive	Agency combined piscicide use with stocking and catch-and-release regulations on predator walleye to address stunting in bluegill stocks and, therefore, regulate stocks of that species. Agency studied antimycin-only lakes, walleye (predator) stocked-only lakes, antimycin and walleye-stocked lakes, antimycin and catch-and-release regulations.	Ineffective – antimycin and catch-and-release regulations resulted in a response and satisfactory compliance resulted in short-term gains. In general, however, agency found stunted bluegill populations and their communities tend to be stable and resist management efforts to effect permanent change, therefore, control through regulations may be unlikely for this and other panfish such as crappie.	Schneider and Lockwood, 2002
Minnesota	walleye	Length Limits - Minimum	Population and fishery responses to minimum length limits were compared with population trends in a reference lake.	Walleye frequently exhibit within-population variability in growth, mortality, and recruitment which must be accounted for when evaluating the outcome of any management strategy, therefore, long term monitoring is recommended for evaluation of any regulations. In this study, there was no direct evidence that walleye abundance, size structure or age structure was improved after implementation of length limits or that the regulations reduced annual variation in size structure. Observed improvements in fishery-related metrics such as size structure of harvested fish may reflect changes in angler behaviour rather than actual improvements in the population.	Isermann, D., 2007.
Missouri	white crappie	Harvest Limits – Restrictive	Agency used models and evaluated how different restrictive regulations affect crappie populations in 5 reservoirs.	Undetermined - models indicated regulations that reduce harvest of age-1 and 2 fish would result in fewer fish harvested but increased yield to the fishery. When restrictive regulations imposed, greater proportion of harvest shifted to age-3 and older fish. Age-1-2 crappies could not be sampled effectively enough to determine changes in survival, so direct assessment of reg effects could not be made. Note: in addition to compliance, growth rates influence the apparent effectiveness of restrictive regulations and declines in growth rate can decrease size of crappies available to anglers even when restrictive regulations are in place – managers must monitor to determine effects of regs and growth rates.	Colvin, M., 1991
Missouri	largemouth bass/bluegill	Length Limits - Slot Limits	Agency objective was to improve growth, size distribution and harvest of largemouth bass while maintaining a satisfactory bluegill population.	Effective - slot limit reduced catch and increased mean lengths, gradual but dramatic shift in length distribution, gradual downward shift in size distribution of bluegill, increase in relative abundance of young bluegill . Estimated 30% non-compliance by anglers – authors note anglers play the key role in effectiveness of slot length limits for largemouth bass because fishing pressure and harvest is necessary to produce the desired response.	Eder, 1984
Oklahoma	largemouth bass	Harvest Limits – Restrictive; Length Limits – Minimum	Study evaluated a method of analyzing the need for length limits for bass populations.	Not Applicable - models can be used for objective first assessment to determine limits at individual lakes. Note: regulations only effective if anglers comply and compliance enhanced if understand and support intended effect on fishery. Catch-and-release fisheries are increasing with bass anglers which is important if agency is imposing liberal bag limits as a control measure.	Dean and Wright, 1992

Jurisdiction	Species	Regulation	Project Summary	Outcome	Source
Ontario	largemouth bass; smallmouth bass	Harvest Limits - Liberal	Study quantified vulnerability to angling by nesting male largemouth and smallmouth bass.	Effective - largemouth and smallmouth bass unable to differentiate between potential predators and angled lures - both attacked aggressively and males that showed aggressive behaviour toward predator more likely to respond to angling; 2. Angling during closed times reduces individual and population-level reproductive success which may reduce annual recruitment. Negative population-level changes can occur as a result of the harvest of the largest spawning individuals from a population - largest, most aggressive males with largest broods will be captured preferentially Note: likely problems selling this to anglers in areas with established bass fisheries.	Suski and Philipp, 2004
Oregon	bass	Harvest Limits - Liberal	Various areas through state.	Ineffective – agency notes that liberal regulations for bass does not make a difference – you cannot get rid of them this was and since big bass are predaceous liberal limits will only decrease their size which decreases the predation that keeps their own numbers in check so this approach will backfire.	Terry Schrader; Rhine Messmer; Oregon Department of Fish and Wildlife
South Dakota	walleye	Harvest Limits – Restrictive; Length Limits – Minimum	Study evaluated the effects of various regulations on walleye in the Missouri River basin.	Undetermined - during first 2 years following reg implementation walleye abundance and proportional stock density increased significantly and angler use declined. By the third year, angler use and harvest increased to pre-regulation levels. Length limit increased abundance of fish>356 mm and reduced mortality of year 2-3 fish with no detectable changes in recruitment. Decreased bag limit had uncertain effect on changes in walleye abundance and size structure. Evaluation confounded by changes in environment.	Stone and Lott, 2002.
Texas	largemouth bass	Length Limits – Minimum; Length Limits - Slot Limits	Study evaluated largemouth bass fishery responses to minimum-length and slot-length limits.	Ineffective - minimum-length limits generally failed to achieve the goals stated for their use Effective - Slot-length limits resulted in an increase in relative abundance of quality and prefer-ed size largemouth bass and in largemouth bass population size. Study notes that slot limits offer a means for manipulating prey fish by protecting largemouth bass or other predatory fish until they are large enough to become effective predators. Also, importance of angler behaviour in effectiveness of slot length limits and number of years required by largemouth bass fishery to fully respond to a length limit is unknown but may occur within 2 years. Fishery must be monitored to determine effectiveness.	Wilde, 1997
Utah	smallmouth bass	Harvest Limits - Liberal	Agency implemented catch-and-kill regulation for smallmouth bass at Grantsville reservoir	Ineffective – regulation not biologically effective but may have sent message to anglers that if they introduce non-native species, they will be managed as invasive: i.e. with no regulations and agency will introduce eradication programs. Agency may also consider designating some species as aquatic nuisance so they can be managed as such.	Roger Wilson Utah Division of Wildlife Resources

Jurisdiction	Species	Regulation	Project Summary	Outcome	Source
Wisconsin	rainbow smelt/walleye	Harvest Limits – Restrictive	Study objective was to determine changes in non-native populations that occurred concomitantly with increased native predator abundance in lakes where fishing regulations changed.	Effective - in lakes where predator stocking and predator harvest regulations facilitated increases in the native predator, food web returned to one dominated by native species. Predation by walleye reduced non-native stock size and population density. Fishery regulations to restore walleye to high densities in lakes invaded by rainbow smelt may restore native planktivores that have co-evolved traits. Authors note that fishery managers need to identify food web configuration and predator consumption regime that suits their objectives and ecology of the target species.	Krueger and Hrabik, 2005
Wisconsin	bluegill	Harvest Limits – Restrictive	Study used population modelling to simulate restrictions on harvest of male bluegills under various conditions of vulnerability to angling.	Ineffective - regulations and male vulnerability to angling had little effect on size structure. Effective - Spawning season closure produced modest increase in mean length. Vulnerability of bluegill and other pan fish during spawning season may provide some rationale for increasing harvest during spawning to control stocks – modelling should be employed to determine if approach would accomplish management objectives.	Beard Jr. et al. 1997
Wisconsin	smallmouth bass	Length Limit – Minimum	Study compared mean population statistics and fishery parameters under minimum-length limit regulations for bass.	Effective - reduced exploitation rate resulted in higher survival rate for age-3 fish during the 10-in limit period than during the no-limit and 8-in limit periods. Increased age-3 survival rate during the 10-in limit resulted in higher age-4 fish and biomass sizes than during periods with less restrictive regulations. Study notes that bass first year recruitment at study site dependent on shoreline habitat quality/availability.	Hoff, M, 1995

Appendix 5. Summary of North American piscicide projects including non-native species targeted, project summary, and outcome and information source.

Jurisdiction	Species	Project Summary	Outcome	Source
Alaska	yellow perch	Yellow perch found in one lake on Kenai Peninsula and eradicated using rotenone.	Effective	Fay, V., 2002
Alberta – Parks Canada	brook trout	Agency considering use in remote lakes in 2008	Not Applicable - Parks Canada will implement depending on results of Parks Canada – Quebec's success with public acceptance for their proposed rotenone project	Charley Pacus; Parks Canada; Banff National Park
British Columbia Region 3 - Corbett Lake	redside shiners	Treated in 1974 and restocked with rainbow trout from wild stocks of Pennask Lake	Unknown- fish kill observed until following day, however, no follow-up assessment found	Larkin and Cartwright, 1977
British Columbia Region 3 – Forest Lake	non-salmonid species	Treated in 1972 and restocked annually with rainbow trout fry.	Ineffective - northern pike minnow, largescale suckers, and reside shiners re-populated the lake; largescale sucker population very healthy in 2001.	Ministry of Environment, 2001
British Columbia Region 3 – Hatheume Lake	prickly sculpins	Treated in 1980; and stocked yearly since 1982; lake managed as a quality fishery with quota, timing and gear restrictions.	Effective - no sculpins found in 2000 assessment.	Ministry of Environment, 2000
British Columbia Region 3 - Jimmy Lake	lake chub	Treated in 1982, restocked with rainbow trout fry 1 in 1983 and regulate to 1 fish/day with minimum size limit of 50 cm.	Ineffective - no chub found in 2001 assessment, however, lake chub again captured in 2004.	Ministry of Environment, 2001; Ministry of Environment, 2004
British Columbia Region 4 - Cherry Lake	redside shiners, longnose sucker	No project report found; reference to Cherry Lake rehabilitation found in a memo attached to the Davis, Boss and Tahla Lakes report; lake survey reports found in ecocat	Ineffective - redside shiner and longnose suckers caught in 1982 fish assessment. Suspect problem was effectively treating weeded shorelines and dense beds of submergent vegetation.	Fisheries Improvement Unit, 1984;
British Columbia Region 7 - Chubb Lake	cyprinids including longnose suckers, redside shiners, northern pike minnow	Treated in 1972 Pennask and possibly Blackwater rainbow trout stocked and reproductive Eastern brook trout stocked until 1989	Ineffective – incomplete kill - 2004 catch contained a large number (>100) northern pike minnow which was the first record of this species since the lake was treated.	Ministry of Environment, 2004
British Columbia Region 7 - Eena Lake	burbot , finescale suckers, coarse scale suckers, peamouth chub, redside shiners, northern pike minnow	Treated in fall 1990 with powdered rotenone applied to lake surface by gravity feed and pump/spray from boats. Lake destratified using portable diesel air compressors before treatment to disperse chemical through lake waters and circulate lake after treatment.	Unknown - FISS database notes hatchery produced brook trout and rainbow trout only but no sampling dates. Relatively low risk of failure as little vegetated littoral areas to provide refuge during treatment and no inlet or outlet streams.	Ableson, D., 1988
British Columbia Region 8 - Bolduc Lake	Pumpkinseed	Treated in late 1990's restocked following spring and reopened 3 years later. Rotenone dispersed into marsh and creek from portable backpack sprayers and drip stations; in lake by boat using drums and gravity feed hoses.	Unknown - no data in FISS and no monitoring data found in reference report	Fisheries Improvement Unit, 1984
British Columbia Region 8 – Chain,	finescale suckers, peamouth chub	Treated in 1971 with rotenone emulsified in diesel oil dispensed from drums carried on pontoon barges;	Ineffective - efficacy of 1971 treatment questionable because of staff and time constrains; fish barrier bypassed by	Bull, 1982

Jurisdiction	Species	Project Summary	Outcome	Source
Link, Osprey Lakes		coarse fish barrier constructed on Upper Hayes Creek between Link and Chain Lakes, chemical drip stations set up along Hayes creek prior to treatment; swamp cleared, drained and treated by backpack sprayer. Chain Lake treated again in 1981.	flood waters; suckers and trout poisoned, suckers reported in Chain Lake in 1977 and prevalent by 1978. Thereafter, catch success and fish growth deteriorated.	
British Columbia Region 8 - Courtney Lake	redside shiners	Treated in 1973 using boats equipped with barrels fitted with taps and plastic hoses, shoal/swamp areas treated by hand spray using back-packs. Lake stocked spring 1974 wild Pennask stock, reopened 1974.	Unknown - fish kill observed within 1 hour of application, persisted for several hours and appeared nearly complete by non the day following treatment but no follow-up monitoring data found.	Larkin and Cartwright, 1976
British Columbia Region 8 – Davis, Boss, Tahla Lakes	redside shiners	Treated lakes and streams in 1985, treatment included main lake surfaces; associated marsh; small lake/pond and up to 8.5 ha of tributary streams.	Ineffective - Redside shiner noted in FISS database in 1995 for Davis and Boss Lakes	Fisheries Improvement Unit, 1984; Fisheries Improvement Unit, 1985; Fisheries Improvement Unit, 1986
California	northern pike, white bass, brook trout, smallmouth bass, brown bullhead, catfish	Agency uses rotenone only on species considered harmful like white bass and northern pike; smallmouth bass, brown bullhead, catfish are too widely distributed.	Effective under following criteria: stocks are new; project objective is to bring back native species; it is a harmful aquatic species (e.g.. white bass, northern pike) and the system is isolated	Brian Finlayson; California Department of Fish and Game
Florida	largemouth bass; blue tilapia; Oscars, cyclids, butterfly peacock (agency biocontrol)	Agency rarely uses rotenone now – the non-native has to be very destructive economically. Agency has killed 12-13 species in Florida using rotenone but cost and isolation criteria must guarantee project success before they consider implementing this option.	Effective under following criteria: projects with high potential for success are implemented. Project must meet following criteria: small isolated ponds, <10 days effort and <$5,000 (approx 3-4 gallons of rotenone). In large areas e.g.. lakes <5m deep and <30 acres it will cost approx. $100K to treat. Eradication projects are species specific e.g. would poison if piranha found as it would affect tourist industry. Agency knows what to do in each situation because they monitor the species extensively once it is found. If a species can't be eradicated then the agency next moves to: assessment then management with rules/regulations/enforcement.	Paul Shafland; Florida Fish and Wildlife Conservation Commission
Idaho	walleye	Agency uses rotenone in small and isolated projects and recently used rotenone and electrofishing to remove walleye from Bear River.	Effective under following criteria: new populations of species identified, water is isolated areas and removal is fiscally practical. State currently has 3 approved walleye removal projects and is working with Wyoming to help with similar case in bordering waters.	Fred Partridge; Idaho Fish and Game
Idaho	yellow perch	Agency implements single treatment projects where area is small, where rainbow stocked so no problem if all fish killed, and where public and anglers support approach. Agency then restocks and opens the fishery the next year.	Ineffective – there was a decrease in yellow perch at one treated reservoir but might have been because of increased non-point source pollution and nematode. In this case, agency reversed its management because yellow perch became such an important fishery. When perch was depressed because of all factors, native northern pike minnow started out completing perch so agency trapped pike minnow out and moved >80,000 perch into area.	Fred Partridge; Idaho Fish and Game

Jurisdiction	Species	Project Summary	Outcome	Source
Michigan	bluegill/walleye	Agency conducted study to evaluate impacts of using antimycin, coupled with walleye stocking and catch-and-release regulations for walleye to increase predation on bluegill to address stunting.	Ineffective - antimycin-only lakes showed modest bluegill responses to antimycin treatment; walleye-stocked-only lakes showed no noticeable reduction in bluegills; antimycin and walleye-stocked lakes showed relatively few bluegills eliminated by antimycin and low survival of walleye and decreased stunting; antimycin +catch-and-release resulted in enough bluegills removed by antimycin to illicit positive change in bluegill population.	Schneider and Lockwood, 2002
Michigan	Yellow perch, bass	Derris root applied to warm surface waters of two trout lakes in Ann Arbor Michigan	The author notes that the compound did not penetrate to the colder, deeper water so that apparently, the perch, rock bass and largemouth black bass were destroyed, with very slight damage to the trout population. No long term monitoring conducted	Greenbank, 1941
Montana	lake trout, brook trout, brown trout; bass in one area of Lower Clark River	Used on 60 mile length of creek treated at 10-15 miles/year and minimum of 2 years treatment/section with option to treat in 3rd year. Project to remove rainbow, brook trout and brown trout so cutthroat and grayling can be restored/stocked	Effective under following criteria: projects must be considered as long term with several treatments to ensure success. This agency only uses rotenone in streams <10cfs and in areas with no beaver dams or heavy vegetation as fish can escape. Agency wants to get away from rotenone because of environmental concerns, had switched to antimycin but problems because only limited supply and now ineffective batches that can't be traced.	Brad Shepard; Montana Fish Wildlife and Parks and Montana Cooperative Fisheries Unit
Nevada	northern pike	Agency used rotenone on Comins and Basset Lakes in the 1980s to remove northern pike.	Ineffective – agency believes project was successful but northern pike now again large components of fish community in these lakes and impacting trophy trout and bass fisheries; agency suspects reintroduction by anglers.	Doug Neilson, Nevada Department of Wildlife
New Brunswick	chain pickerel	Rotenone used in area with chain pickerel.	Ineffective – chain pickerel were eradicated initially but then re-introduced. Now agency does not use rotenone or any poison to eradicate non-native stocks.	Jason LeBlanc; Nova Scotia Agriculture, Fisheries and Aquaculture
Ontario	smallmouth bass; black crappie; bluegill	General use throughout the province but use was stopped because of environmental concerns and requirements.	Ineffective - agency did not re-register rotenone because of Environmental Assessment requirement – may register in the future for use on species such as round goby.	Francine MacDonald; Ontario Federation of Anglers and Hunters
Oregon	Tui chub	Diamond Lake in the Umpqua River basin supported a premier recreational trout fishery but rainbow trout deteriorated due to competition from non-natives. Lake treated with rotenone in 1954 and trout fishery responded for about 40 years thereafter.	Ineffective - Due to economic importance of fishery, a management plan for control of tui chub was drafted in 2004. Plan includes all types of management action from education to eradication using rotenone. Currently several societies are opposing the plan due to the proposed use of rotenone	Shapiro and Associates, 1999

Jurisdiction	Species	Project Summary	Outcome	Source
Utah	Variety including smallmouth bass and Utah chub	Strawberry Lake and 55 miles of streams treated with approximately 4,000 gallons of liquid and 60,000 lbs of powdered rotenone in 1961. Treatment repeated to parts of the system in 1973 and almost 7,000 lbs of explosives with approximately 40 miles of detonation cord used to treat springs. Treated again in 1980s with approximately 875,000llbs of powdered and 4,000 gallons of liquid rotenone, over 6,000 workdays using 260 personnel and US$3.8 million were required.	Ineffective - initially treatment eliminated Utah chub, Utah sucker, common carp, and yellow perch. Chub and sucker increased and by late 1980s agency re-treated the area. Trout fishery improved following 1980's treatment but both Utah chub and Utah sucker have reappeared. At US$3.5 million, this was the largest rotenone project in the United States. Now in general, agency moving away from rotenone because of lack of success, and lengthy planning and regulatory process.	Roger Wilson Utah Division of Wildlife Resources, Govindarajulu 2006, Lentsch et al.. 2001, Cailteux et al.. 2001
Washington	yellow perch, black crappie, pumpkinseed sunfish, bass, walleye, tiger muskie	Poisoned several lakes several times	Ineffective - agency has never had long-term success with this method.	Steve Jackson; Washington Department of Fish and Wildlife
Washington	northern pike	Rotenone used only lakes designated as hatchery. Also recently used when northern pike introduced into coho/trout reservoir; reservoir then closed to all fishing indefinitely; agency uses reservoir now for coho production only.	Effective under following criteria: projects are long term and ongoing - Agency rehabilitates hatchery lakes repeatedly over 5- 7 year cycle (treated in the spring, stock with catchables in fall and fingerlings thereafter). Agency doesn't rotenone lakes where there is a valuable rainbow stock.	Steve Jackson; Washington Department of Fish and Wildlife

Appendix 6. Summary of various mechanical removal projects implemented in other jurisdictions including information regarding project summary and effectiveness.

Technique	Jurisdiction	Species	Project Summary	Outcome	Source
Angling	Alberta	brook trout	In 1998, Quirk Creek became the subject of a suppression project which used volunteer anglers to harvest all brook trout caught by angling during the June-October fishing season. In the 3 years of the study, anglers expended an average of 525 angler-hours per year and harvested over 3,600 brook trout from 380 meters of stream.	Ineffective - anglers did not measurably impact the brook trout population despite harvesting 77-138% of the standing crop of large (>150mm) brook trout. 52% of anglers failed on first try of a required fish identification course and 23% failed on their second attempt. Fish identification course to volunteer anglers is necessary for these projects. Also, incidental (hooking) mortality of native vs. target stock must be considered as authors believe intensive angling may have impacted native stock.	Stelfox, et al. undated
Bounties	Idaho	rainbow trout, lake trout	Idaho Fish and Game implemented the Lake Pend O'reille Angler Incentive Program which provides US$10 for every rainbow trout or lake trout >12inches	Ineffective - managers believe they need to cut the rainbow trout and lake trout population in half to make significant improvements in kokanee survival.	Idaho Fish and Game Department, 2006 http://fishandgame.idaho.gov/
Bounties	Oregon	northern pikeminnow	Anglers paid up to US$6/fish depending on how many fish returned.	Ineffective – program has succeeded in catching >240,000 fish in approximately 10 years and was implemented in addition to gillnetting project by Department of Fish and Wildlife.	Takata and Ward, 2002
Bounties	Washington	pike minnow	$2 bounty offered on each pike minnow	Ineffective – project did thin out the stocks but when species became more popular as game fish started to be transplanted into other areas	Steve Jackson; Washington Department of Fish and Wildlife
Commercial Fishing	Alberta	lake trout	Commercial fishing using gillnets in Lesser Slave Lake and Touchwood lakes in early 20th century.	Effective – target species removed, however, massive fishing effort had to be applied over a period of decades	Parker et al. 2001
Electrofishing – Boat	New York	smallmouth bass	Boat electrofishing was used to attempt removal of smallmouth from Little Mouse Lake (271 ha; 44 m. maximum depth) in the Adirondack mountains	Ineffective – however, researchers noted native fish abundance increased after first year and 90% reduction (almost 29,000) of bass after 3 years intensive effort.	Govindarajulu, 2006; Weidel et al., 2002
Electrofishing – Boat	Wisconsin	Smallmouth bass	Operators remove approximately 48,000 smallmouth bass from Little Moose Lake by boat electrofishing (99.5% of removals), gillnetting and angling. Electrofishing was the most efficient method with catch averaging approximately 275 fish/trip compared to 9 fish/trip for gillnetting and 12 fish/trip for angling.	Project removed enough smallmouth bass to increase native fish abundances, but further experimentation needed to determine the removal effort required to maintain increases in native fish abundance. Authors note that while their results showed that smallmouth bass removal can increase native fish abundances, they do not advocate smallmouth bass removal from all waters where they have been introduced because of the popularity of bass fishing which has created a clientele for this species.	Weidel et al, 2007

Technique	Jurisdiction	Species	Project Summary	Outcome	Source
Electrofishing - Stream	Alberta	brook trout	Agency conducted repeated electrofishing removals of brook trout after volunteer angler program failed on Quirk Creek.	Effective – but agency notes this strategy must be implemented over long-term.	Michael Sullivan, Alberta Fish and Wildlife
Electrofishing - Stream	Idaho	brook trout	Study examined whether 3 years of electrofishing removals could eliminate or suppress brook trout and increase abundance of native salmonids including redband trout.	Ineffective - no long-term effects on the abundance of brook trout and no increase in native redband trout abundance. No control stream, therefore, cannot be certain that environmental conditions did not confound the results, also possible that brook trout ascended a barrier constructed after project implemented. Project may have had more success if effort was spread over the year, there had been a higher frequency of effort within the years, and if the project had extended over more years.	Meyer et al. 2006
Electrofishing - Stream	Montana	lake trout, rook trout, brown trout	Electrofishing used to remove brook and brown trout from streams.	Effective – project extended over 3 year period	Brad Shepard; Montana Fish Wildlife and Parks and Montana Cooperative Fisheries Unit
Electrofishing - Stream	Montana	brook trout	Electrofishing to remove and relocate brook trout to enhance native westslope cutthroat stocks.	Ineffective - relocation of brook trout using electrofishing was not sufficient to eliminate the population but appeared to provide short-term benefits to the westslope cutthroat. Relatively poor electrofishing capture efficiencies for small brook trout may be responsible for not reducing brook trout population to where they can be eliminated	Shepard, B., undated
Electrofishing - Stream	Montana	brook trout	Study objective was to document efforts to remove and relocate brook trout..	Variable – project effective and brook trout believed eradicated from 2 of 6 streams but unsuccessful in streams with dense riparian; woody debris and beaver dams. In some cases re-invasion over man-made barriers occurred following the project; complex channels with riparian vegetation created difficulties and limited success and beaver ponds provided refuge even after draining. Researchers note total removal requires 6-10 multiple-pass efforts and it is more effective to conduct repeated removals over 3 years and 1 removal/year for 5 years. Also removals best before spawning and when fish aggregated in pools over wintering and vulnerable to capture. Trampling redds may result in increased reductions.	Shepard and Nelson, 2004
Electrofishing - Stream	North Carolina/ Tennessee	non-native rainbow trout	Study objective to remove or reduce non-native rainbow trout in water bodies in Great Smokey Mountains National Park	Effective with repeated, intensive electrofishing removals conducted over time	Moore et al. 1983, Moore et al. 1986, and Larson et al., 1986

Technique	Jurisdiction	Species	Project Summary	Outcome	Source
Electrofishing - Stream	Wyoming	brook trout	Evaluate depletion electrofishing for removal of brook trout in 3 Wyoming streams to conserve Colorado River cutthroat trout	Ineffective – densities of brook trout could not be eradicated but could be dramatically reduced by three-pass depletion electrofishing	Thompson and Rahel (1996)
Electrofishing - Stream		rainbow trout		Ineffective – at studied rate of removal but authors found that condensing removal efforts over a 1-2 year period was most effective at reducing densities.	Kulp and Moore (2000)
Electrofishing - Stream	Oklahoma	Smallmouth bass	Project objective was to determine how biological sampling, and stream habitat variables affect the capture probability of smallmouth bass during electrofishing in streams.	Not applicable – however, study does illustrate that smallmouth bass can be captured in streams using this methods and that depth has a high effect on capture probability. As with trout, large individuals are more easily captured with this method.	Dauwalter and Fisher, 2007
Explosives	Alberta	Lake trout	Study objective was to compare mortality of lake trout eggs exposed to explosive blasts and assess whether egg mortality occurred as a result of limited exposure during early development or repeated exposure through incubation period.	Ineffective – at the blasting levels tested no measurable effects of blasting during early-exposure period when eggs were most vulnerable to physical shock. Higher blasting levels than reported in this study may be effective in increasing egg mortality.	Faulkner et al, 2006
Explosives	California	northern pike, white bass, brook trout, smallmouth bass, brown bullhead, catfish	Explosives are being investigated more - this is just in its infancy; being investigated at Humboldt State University.	Unknown – California looking into using this technique as fewer environmental concerns than with chemicals but use depends on whether water body is on private/public property. Also need a certified blaster which may be difficult to find and a drawback is that managers don't know what the kill is because of ruptured swim bladders, fish don't all come to the surface after blasting.	Roger Blume; California Department of Fish and Game
Explosives	Idaho	Columbia pike minnow	Managers used explosives in combination with gillnetting over a 6-year period in an almost 4,000 acres lake.	Ineffective – project reduced levels to approximately 10% of original levels but did not eliminate the stock. See more details under Gillnetting section below.	Jeppson and Platts, 1959
Explosives	California	northern pikeminnow	Detonation cords used in the Eel River in California to control northern pikeminnow	Ineffective – at eradication but quote notes that this method has been used for control – not removal – of target species.	Govindarajulu, 2006
Gillnetting	Alberta	brook trout, non-native cutthroat trout	Agency gillnetting brook trout from 1 of 2 alpine lakes in Banff National Park. Lakes were fishless before Parks stocking. Lake too deep (>30m), poor temp and too much glacial till for rotenone. Netted lake is 20 ha and agency has used 40 nets fishing from ice-off until ice returns for 4 years.	Effective - agency has reduced brook from 1000s to 100s to 6 fish in both lakes last year. Also have been electrofishing stream and found no young-of-the-year last year. Project is expensive - cost to fly in is $5,000 for return flight/session and project must be done 4-5X/year requiring 9 days of each staff time each time out.	Charley Pacus; Parks Canada; Banff National Parks

Technique	Jurisdiction	Species	Project Summary	Outcome	Source
Gillnetting	California	northern pike, white bass, brook trout, smallmouth bass, brown bullhead, catfish	Agency have been using gillnetting to restore native species such as Golden Trout. Special nets are ordered and nets are left fishing for the entire winter.	Effective - especially in trout restoration projects. Strategy has fewer environmental restrictions and requires fewer permits and is faster than chemicals-e.g. 1 yr of netting vs. several years of chemical treatment depending on conditions.	Roger Blume; California Department of Fish and Game
Gillnetting	Idaho	Columbia pike minnow	Study objective was to document the ecology and control of pike minnow. Control methods included gillnetting, dynamiting of spawning schools; spot treatment with rotenone also done but not evaluated.	Ineffective – study found: 24,000 pounds of pike minnow killed and catch indices declined by 90% over the study but target fish not eliminated totally. Frequent tending of gillnets had demonstrated effect of increasing catches especially when levels of fish abundance is high. Selectivity of the gear-i.e. the mesh sizes are important as is the net material which affects catch efficiency. In following years managers controlled species using more explosives and partial spot treatment with rotenone.	Jeppson and Platts, 1959
Gillnetting	Montana	lake trout, rook trout, brown trout, walleye	Agency gillnetting for brook/brown trout from streams and walleye from lakes	Effective - gillnetting successful for brook/brown trout from streams with at least 3 pass removal at 3 times per section. Project took 7 years and was expensive. Gillnetting for walleye not effective in one case because agency started to net record-size fish and walleye anglers had project stopped.	Brad Shepard; Montana Fish Wildlife and Parks and Montana Cooperative Fisheries Unit
Gillnetting	New Zealand	perch	Project objective was to determine if perch could be eradicated from wetland ponds using netting and trapping and to determine if number of adult perch in remaining populations would decline over time.	Effective in small lentic habitats using gill and fyke netting. Type of net critical - fyke nets catch smaller fish; large perch (>300mm) captured when gill and fyke nets used in combination. Because of cannibalism, timing is critical – young-of-the-year perch survival low where adult perch present so remove in fall when predation has reduced juveniles to low levels. Also, as pond/lake size increases, increased habitat heterogeneity and increased difficulty netting. Community responses may take several years. Authors suggest sterile large perch could be introduced to control young then removed when the absence of juveniles suggests fertile perch eliminated. Knowledge of ecology of perch within habitat improves nets and traps placement which increases the efficiency of removal.	Ludgate and Closs, 2003
Gillnetting	Nova Scotia	goldfish	Gillnetting used in small, contained ponds in urban areas around Halifax.	Ineffective at total removal but does keep populations at low levels. Agency considering other methods including biocontrol then netting out introduced predators after goldfish removed.	Jason LeBlanc; Nova Scotia Agriculture, Fisheries and Aquaculture
Gillnetting	Washington	yellow perch		Ineffective - agency could knock back the stock in bays or shorelines at spawning time but were ineffective at totally eradicating stocks. Agency found they would kill half the stock but perch would come back and would have gained in size.	Steve Jackson; Washington Department of Fish and Wildlife
Gillnetting	California	non-native brook trout and rainbow trout	Gillnetting used in small, high elevation lakes	Effective - authors note the removal of non-native brook trout and rainbow trout	Knapp and Matthews, 1998, Vredenburg, 2004

Technique	Jurisdiction	Species	Project Summary	Outcome	Source
Netting	Idaho	crappie	Nets used to try and control crappie in lakes in Idaho	Ineffective - crappie are probably the most difficult warm water species for the Department to manage successfully and their populations fluctuate year-to-year regardless of regulations. Crappie are usually most vulnerable when concentrated near shoreline during spring spawning season therefore, an opportune time to capture and control using nets but at other times of the year, they suspend off the bottom in pelagic waters making them more difficult to catch	Idaho Department of Fish and Game, 2007
Gillnetting	Finland	coarse fish	Used under ice to remove fish.	Effective – reference notes that large populations of coarse fish have been removed using this method	Turunen et al. 1997 *In:* Govindarajulu, 2006
Nets and Seines	Oregon			Variable – netting worked to capture perch because they school but did not work on bass because this species doesn't school. The effect of capturing yellow perch rather than bass was a surprise because managers suspected bass were at much higher population levels than perch.	Terry Schrader; Rhine Messmer; Oregon Department of Fish and Wildlife
Nets and Seines	Utah	perch		Ineffective - netting perch was tried but found to be expensive because they are difficult to remove from nets.	Roger Wilson Utah Division of Wildlife Resources
Nets	New York	yellow perch	Researchers used fyke nets to capture adults and manipulated water levels to destroy eggs at water bodies in the Adirondack mountains	Ineffective – at controlling yellow perch	Flick and Webster, 1992 *In:* Govindarajulu, 2006
Traps	Minnesota	northern pike	Study objectives included testing the effectiveness of light traps in the capture of northern pike juveniles from raceways and managed wetlands.	Effective - in hatchery raceways light traps an efficient method for collecting larval northern pike and effectively caught all sizes of fish ranging from active larvae until juveniles too large to fit through trap entrance. Large differences in light-trap catch rates among wetlands indicated post-stocking mortality differences and difficult to determine the trap effectiveness in this case. Factors affecting the efficiency of light traps in natural environments include ambient light, water clarity, and vegetation density. Not known if fish larger than 66 mm. remain positively phototropic and researchers speculate trapping efficiency may be reduced with increasing fish density.	Pierce et al. 2006
Traps	New Zealand	carp	During a routine trapping exercise, researchers noted that trapped carp displayed pronounced escape behaviour of jumping out of the water. Because the behaviour was not exhibited by native fishes, researchers were able to design the Williams Trap – a trap specially	Effective - the Williams cage has proven to be a relatively inexpensive but extremely useful tool in carp management in this jurisdiction. It is also becoming an increasingly wide-spread solution for removing fluvial carp and more cages are being designed and integrated into fishways to provide automated carp removal	Stuart et al., 2006

Technique	Jurisdiction	Species	Project Summary	Outcome	Source
			designed to segregate native fish and allow them to pass while capture carp as they jumped		
Traps	Wyoming	brook trout	Study objective to test whether pheromones can be used to attract brook trout so they can be trapped and removed from streams.	Unknown – technique in its infancy - tests appear to confirm that brook trout use pheromonal communication and that selectively trapping large numbers of adults is feasible. Researcher speculates that technique may not eliminate large populations of brook trout but could suppress recruitment or eliminate early stages of an invasion. Still to be determined is identity of the behaviourally effective pheromone in most salmonid species and different patterns of attraction between salmon/trout and char.	Young, M., undated

Appendix 7. Summary of some examples of biocontrol (the introduction of predaceous fishes) used to control non-native species in North American jurisdictions.

Jurisdiction	Non-native Prey Species	Predator Species	Project Summary	Outcome	Source
Florida	mixed non-native species	Butterfly peacock (Cichla ocellaris)	The agency did considerable research prior to introducing this species into the urban canals in metropolitan Miami-Fort Lauderdale. Agency objective was both to control exotic species and create urban fisheries. Agency has studied the effects of this fish on target prey species and on other warm water fishery species such as largemouth bass for 10 years.	Effective - no substantial deleterious effects on native fishes; have consumed large numbers of exotic fishes; and have generated considerable socioeconomic benefits. Results of agency studies also show no effect on other game species such as bass, and are staying in the same locations where they were introduced because of their temperature tolerances.	Shafland, P. 1999a; Shafland, P. 1999b; Shafland, P. 1999c
Idaho	northern pike, brook trout	Tiger muskellunge (muskellunge×northern pike; sterile)	Tiger muskellunge introduced in 5 north Idaho lakes with balanced warm water fish communities and stocked put-and-take rainbow trout fisheries to provide safe alternative to provide a trophy fishery as a safe alternative to northern pike and brook trout and to create fishery. Tiger muskellunge also used on limited basis for experimental control of brook trout in alpine lakes and to control stunted fish populations. Advantage is no reproduction but has had to depend on egg imports from the Great Lakes.	Effective – at controlling and reducing northern pike and brook trout and have created a substantial fishery. The drawback now is recent discovery of disease and related moratorium on eggs. Idaho and other western jurisdictions are looking into local production.	Fred Partridge; Idaho Fish and Game ; Idaho Department of Fish and Game, 2007
New Zealand	yellow perch	yellow perch (sterile adults)	Large perch are piscivorous and cannibalistic, consequently, have a potential role in structuring perch populations and reducing intra-specific competition amongst juvenile perch. In the northern Hemisphere, cannibalism has been noted to maintain low abundance and stabilize the structure of perch populations and cannibalism regulates the population of perch which may facilitate their successful removal in small lentic habitats.	Unknown - Researchers suggest a possible strategy for controlling perch populations is introduction of sterile large perch into habitats from which fertile large perch have been removed by netting or other means. Sterile fish will not contribute offspring to existing fish populations, but through cannibalism will serve to limit subsequent young-of-the-year survival should successful spawning occur between remaining adult non-sterile fish. Sterile fish could subsequently be removed when the absence of juvenile perch suggests that fertile perch have been eliminated.	Ludgate and Closs, 2003; Treasurer, 1993; Persson, 1988

Jurisdiction	Non-native Prey Species	Predator Species	Project Summary	Outcome	Source
Nova Scotia	goldfish	bass	Agency has also tried draining contained, urban ponds in Halifax where goldfish creating water quality problems. Draining not effective so agency will try putting bass into ponds to prey on goldfish and will remove bass once goldfish gone or under control.	Unknown – proposed for 2007	Jason LeBlanc; Nova Scotia Agriculture, Fisheries and Aquaculture
Oregon	tui chub	William River rainbow trout	Agency stocked predaceous William river rainbow trout in sufficient numbers and sufficient size/age classes as predators and create a fishery at Diamond Lake	Ineffective - no significant improvement in the trout fishery was observed possibly because of the negative competitive effect of tui chub on trout fingerlings.	Lightcap, 2004; Shapiro and Associates, 1999
Utah	chub	Tiger trout (brook trout×brown trout); Bear Lake/Bonneville cutthroat	Agency uses tiger trout (sterile) and Bear Lake/Bonneville cutthroat which is a native, lacusterine species that is highly predaceous. Agency has also used tiger muskellunge but not any longer because of the moratorium.	Effective at controlling non-native and popular with anglers. Tiger muskellunge have been the largest sport fish in Utah. Agency investigating, with other states local culture of tiger muskellunge.	Roger Wilson Utah Division of Wildlife Resources; Donaldson, 2007
Washington	walleye/perch; bass/sunfish combinations	Tiger muskellunge	Agency has used tiger muskellunge when available and in the future might try. This type of an approach might just work to keep the rough population in check.	Variable – effective when tiger muskellunge were used but no longer available. Agency may try pike minnow or suckers to control perch. Probably can't stock the control species in the numbers where they'd be effective to eradicate the prey and at those levels predator would turn for trout. Agency believes this may be enough to keep the rough population in check.	Steve Jackson; Washington Department of Fish and Wildlife

Appendix 8. Summary of habitat alteration techniques used to exclude or impact non-native fish or promote recovery of native stocks used in a variety of North American jurisdictions.

Jurisdiction	Native or Non-native Species	Technique	Project Summary	Outcome	Source
Habitat Alteration to Exclude Non-native Stocks					
Arizona	native: trout and non-natives: various	Barrier Construction	Managers use barriers to segregate native and non-native fish then implement separate management strategies in South Western high elevation, cold water streams. Managers identify native trout recovery reaches, erect physical barriers to prevent contamination by non-natives, chemically or otherwise remove non-natives above the barriers, and reintroduce native trout.	Effective - for recovery of native trout while maintaining sport fish fishing opportunities for non-native trout. Managers note, however, that of connectedness is critical to long-term conservation of native fishes and that the geographic scope of strategy needs to include interconnected drainage networks so populations can exchange genetic material.	Clarkson et al.2005; Finlayson et al. 2005; Rinne and Janisch 1995
Minnesota	non-native: common carp; bigmouth buffalo	Barrier Construction	Study objective was to determine the effectiveness of electrical barriers in limiting movement of common carp and bigmouth buffalo.	Effective - no evidence that fish moved through the electric barrier. Water depth changed over the barrier at one point in the study, however, manufacturer fitted the barrier edges with extensions that protruded into the water column and forced fish into the current. He also altered the pulse interval to increase the current time and both modifications stopped carp movement.	Verrill and Berry, 1995
Montana	non-native: rainbow trout, brook trout, brown trout	Barrier Construction	Barriers used where non-native populations are fairly isolated, resident (not moving far) and threatening subspecies of cutthroat. Also used for short term suppression projects – for example used to block rainbow, brook and brown trout at lower reach then removed.	Effective – in short term and used only when a more permanent solution is planned and primarily for protecting 2 subspecies of west slope cutthroat.	Brad Shepard; Montana Fish Wildlife and Parks/Montana Cooperative Fisheries Unit
Montana	non-native: brook trout	Barrier Construction	Bureau of Land Management, Montana Fish, Wildlife and Parks and Forest Service collaborate to construct a wood/rock crib barrier on a tributary to the Boulder River. Agencies then annually electrofish and relocate non-native brook trout to below the barrier, and westslope cutthroat trout to a previously fishless reach above a natural waterfall.	Effective – over short term. Almost 2,000 brook trout moved over a 3-year period. Objective not to eliminate brook trout but provide short-term benefits to native trout population. Native stock increased over 4 years (each year of study, and 1 year of monitoring).	Shepard and Spoon, undated
Various	native: gizzard shad and alewife	Barrier Construction	Electric fences and fields used to repel fishes.	Effective – study notes that electricity and electrical fields has been used to control or guide fishes away from water intakes of hydroelectric plants but does not provide details.	Wydoski and Wiley, 1999
Habitat Alteration to Impact Non-native Stocks					

Jurisdiction	Native or Non-native Species	Technique	Project Summary	Outcome	Source
California	non-native: northern pike, white bass, brook trout, smallmouth bass, brown bullhead, catfish	Drawdown	Agency has used this technique in streams.	Undetermined	Roger Blume; California Department of Fish and Game
Illinois	native: bluegill	Drawdown	Study objective was to reduce the density of bluegill stocks. Drawdown decreased the lake surface area by 35%.	Effective – study reduced the bluegill population by 60% through drawdown. The density of fry and intermediate-size bluegills was reduced by the process of forcing fish out of the shelter of littoral vegetation and in stranding fish in vegetation which increased predation of small fish by largemouth bass. Density of both fry and intermediate-size bluegills reduced.	Summerfelt 1999; Bennett et al. 1962
Minnesota	non-native: carp	Drawdown	Managers used partial lake drawdown to facilitate winterkill of common carp in the Heron Lake system in south western Minnesota. Managers also used electrical barriers to prevent fish migration	Effective - in assisting in winterkill of carp. Note results for effectiveness of electrical barrier in this table.	Verrill and Berry (1995)
Missouri	native: bass and bluegill	Drawdown	Researchers noted that drawdown increased the vulnerability of prey to predation and that largemouth bass predation on small bluegills was enhanced by lowering water levels to force the bluegills out of the shelter of littoral vegetation. A summer drawdown that reduced lake surface area by 42% and volume by 58% reduced the percentage of largemouth bass and accelerated their growth at a Missouri lake.	Effective - summer drawdown reduced lake surface area by 42% and volume by 58% and reduced the percentage of largemouth bass while accelerating their growth.	Summerfelt, 1999; Heman et al. 1969
Various	walleye	Drawdown	In lakes, walleye generally spawn at depths of 0.3-3.0 m on gravel and rubble shoals and in reservoirs, walleye generally spawn in water <1.5m deep over gravel and rubble substrate and on the rock riprap of dam fences.	Undetermined - drawdown to expose redds may help to control walleye stocks by decreasing year-class strength.	Newberg, 1975
Various	bass	Drawdown	There is a high correlation between the amount and duration of flooded terrestrial vegetation and abundance of young-of-the-year largemouth bass and survival of bass eggs is enhanced by the presence of macrophytes or flooded terrestrial vegetation.	Undetermined - researchers recommend that fisheries management effort be directed to produce a high water level through most of a growing season every 3-4 years to flood terrestrial vegetation and produce strong year classes of bass. It may follow that drawing down water levels during spawning/nesting may have the opposite effect.	Shirley and Andrews, 1977; Aggus and Elliott, 1975
Oregon	non-native: Umpqua pike minnows	Temperature Alteration	The Department of Fish and Wildlife have been working with the Corps of Engineers to reduce predation by pike minnows in the Rogue River by releasing cool water from upstream reservoirs to slow pike minnow metabolism.	Undetermined – researchers note this strategy may have potential for streams where stored water can be used to reduce temperatures when introduced fish are actively feeding on a species of concern. Managers also note that this action will also have to be balanced against	Daily et al. 1999

Jurisdiction	Native or Non-native Species	Technique	Project Summary	Outcome	Source
				corresponding temperature effects on native species.	
Oregon	non-native: grass carp; native: coho	Vegetation Removal	Researchers found the reduction of submergent aquatic vegetation in Devils Lake resulted in a decrease in the warm water fish population and preliminary evidence suggested an increase in coho smolt production. This jurisdiction introduced triploid grass carp to remove macrophytic plants which researchers believe destabilizes the warm water fish community and increases the likely predation by fish eating birds.	Effective – reduction in some warm water species. Other methods for removing aquatic vegetation from lakes include herbicides and harvesting machines. Herbicides can provide effective short-term control but the amount required to reach an effective level in a large lake may be costly and environmentally unacceptable. Implementation of these methods must be monitored to ensure enough vegetation removed to affect the target species.	Daily et al. 1999
Texas	non-native: grass carp	Vegetation Removal	Study objective was to changes in abundance of fish species in Lake Conroe following vegetation removal/control by introduced grass carp.	Variable - prey: predator ratios remained similar for large (>250mm) predators but increased for small predators; there was a substantial increase in numbers of percids, shad, catfish and general decline in adult recruitment by white crappie; decline in largemouth bass density; decline of crappie but not attributed completely to vegetation removal.	Bettoli et al. 1993
Various	non-native: bass	Vegetation Removal	Researchers have found that largemouth bass density declines after macrophyte removal. This agrees with some model predictions that the abundance of bass is directly related to vegetation abundance.	Undetermined – but authors suggest that large-scale aquatic vegetation control programs could be of benefit in reducing bass stocks.	Bettoli et al. 1993; Durocher et al. 1984
Habitat Restoration to Increase Native Stocks					
Montana	native: Westslope cutthroat trout and other salmonids	Barrier Removal	Study objective was to survey road crossings to identify and characterize upstream native salmonid passage barriers then restore native fish migration corridors and stream connectivity to promote genetic exchange between local native stocks.	Undetermined –study found 52 road crossings on one creek and tributaries and numerous culverts the most common problem and accounted for almost 75% of fish passage problems. Authors believe addressing these will assist with recovery of native stocks.	Knotek et al. undated
Colorado	native: bonytail; razorback sucker	Habitat Restoration	Managers developed a conservation plan that included the creation of predator-free habitats where native fish could sustain populations that resembled isolated oxbow communities that were historically common.	Effective - over the short-term. These communities are considered temporary and when compromised by predators managers salvage native fish, remove the non-natives then restock with natives.	Minckley et al. 2003

Appendix 9. Summary of international and national legislation, codes and policies governing the import/export, possession, handling and transfer of invasive and non native species.

Jurisdiction, Legislation/Code/Policy	Section	Details
International		
United Nations Food and Agriculture Association (1995)	Code of Conduct for the Import and Release of Exotic Biological Control Agents	Code objective is to facilitate safe import, export and release of biological control agents by introducing internationally acceptable procedures for all public and private entities particularly where national legislation does not exist or is inadequate. The Code also outlines specific responsibilities for authorities of exporting and importing country regarding transfer of biological control agents.
United Nations Convention on Biological Diversity	Article 8(h)	Parties to prevent the introduction of, and control, or eradicate those alien species which threaten ecosystems, habitats or species.
World Conservation Union (IUCN) (2000)	Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species	The goal of these guidelines is to prevent further losses of biological diversity due to the deleterious effects of alien invasive species and to give effect to Article 8 (h) of the Convention on Biological Diversity. Guidelines are designed to increase awareness and understanding of the effect of alien species and provide guidance for the prevention, re-introduction, and control and eradication of alien invasive species by: improving understanding and awareness; strengthening management response; providing appropriate legal and institutional mechanisms; enhancing knowledge and research efforts.
The Commission for Environmental Cooperation (CEC)	Article 10(2)(h)	The Commission for Environmental Cooperation (CEC) is an international organization created by Canada, Mexico and the United States to address regional environmental concerns, prevent environmental conflicts, and promote the effective enforcement of environmental law. Article 10(2)(h) states that the Council may develop recommendations regarding exotic species which may be harmful.
American Fisheries Society (AFS)	AFS Policy Statement #15 - Introductions of Aquatic Species	Policy deals with intentional introductions and states that all species considered for release be prohibited and considered undesirable for any purposes of introduction unless that species has been evaluated. Also urges that there be international harmonization of guidelines, protocols, codes as they apply to introduction of aquatic species, and urges fisheries professionals to become aware of issues relating to introduced species.
Great Lakes Region Legislation, Regulation and Policy for the Prevention and Control of Non-indigenous Aquatic Nuisance Species	Section 5 - Prohibited Non-indigenous Aquatic Species	It is illegal to import, transport, purchase, possess, propagate, sell in the state/province or introduce/release into waters of the state/province any species that is not on the regulated/unregulated species list as defined in this legislation. Prohibited species shall not be imported/transported/possessed in the state/province or introduced/released into waters of the state/province except under a permit. The Director is authorized to seize or dispose of all prohibited species unlawfully possessed in the state/province or introduced/released into waters of the state/province.
	Section 8 – Designation of Waters	The Director shall designate waters of the state/province as infested by selected aquatic nuisance species that are a proven nuisance. There will be public notification of those waters. The Department shall enforce the provisions of those waters including: prohibiting water taken from infested waters. A person shall not transport fish, plants and other living organisms in water taken from infested waters; water access and related recreational and commercial activities including angling, in infested waters is subject to closure by the Director for a period of time needed to adequately apply control treatments.
	Section 12 – Enforcement and Penalties	A person shall be issued a warning or assessed a civil penalty if engaging in conduct that violates legislation; suggested fine is \$50-\$1000; watercraft/vehicle licence suspension or permit revocation and forfeiture of equipment/vehicles.

Jurisdiction, Legislation/Code/Policy	Section	Details
	Section 15 – Emergency Action Plan	The Director shall develop an emergency action/response plan and implement plan upon sighting/emergence of new non-indigenous aquatic nuisance species or the impact of an existing species necessitates such action. A person who allows or causes the introduction/release of a non-indgenous aquatic species shall notify the Director or other appropriate management authority within 48 hours after learning of the escape. The person shall make every reasonable attempt to recapture or destroy the introduced species. A person who does not comply with this section is subject to penalties.
<u>United States</u>		
California		State-wide regulations prohibit the movement of live fish. The regulation is aimed primarily at the spread of fish by bait transfers.
Colorado		In certain areas of the state it is illegal to stock yellow perch; this regulation is seldom enforced.
Florida		State-wide regulations prohibit the release of non-native fish.
Idaho		State-wide regulation prohibits the movement of live fish. If a person is caught moving fish, they can be liable for all the costs to remove the planted fish, and restore the system. In addition, there is also a state-wide regulation prohibiting live wells and prohibiting people from leaving a water body with life fish.
Montana	87-5-705. Regulation of exotic wildlife 87-5-715. Extermination of transplanted wildlife 87-5-721 Penalties	A person may not import into the state, possess, or sell any exotic wildlife without authorization from the Department of Livestock Any wildlife or feral species transplanted or introduced in the state may be exterminated or controlled by the Department if the species poses harm to native wildlife or plants or to agricultural production. The Department will revoke any licence/permit and deny application for licence/permit for a period not to exceed 2 years from conviction. A person who intentionally imports/introduces/transplants fish (a) is guilty of an offence punishable by a fine of not less than $500 or more than $5,000 and imprisonment for up to 1 year; (b) is civilly liable for the amount necessary to eliminate/mitigate the effects of the violation; (c) shall forfeit current hunting, fishing, or trapping licence for not less than 24 months. Any wildlife held in violation must be shipped out of state, returned to point of origin, or destroyed within 6 months of conviction. The Department may charge any person convicted for the costs associated with handling/housing/transporting/destroying the exotic wildlife.
Nevada		It is prohibited in Nevada to transport live fish and there is a Prohibited Species List governing transport of fish in-and out-of the state.
Oregon	Transplant Permits	The Oregon Department of Fish and Wildlife has sole management authority over introduced fish species. The Department regulates the introduction, transport, and stocking of fishes through its administrative rule authority and enabling statues. Transplant permits are required to transport, hold, or release live fish. By rule, illegally introduced fishes have no standing in the Department's fish management unless they are included in the objectives of fish management plans adopted by the Department.
	635-007-0615 Penalties	Fish imported or released in violation of rules/laws of the state are subject to seizure or destruction by the Department at the expense of the person who imported or released those fish. 2. The Department may prescribe alternative methods in lieu of destruction to control illegally imported fish. 3. The Department is not liable for the cost of destroying fish or for the cost of

Jurisdiction, Legislation/Code/Policy	Section	Details
		the fish destroyed. 4. The person who imported fish illegally shall be held liable for incidental kill of any other species due to or during destruction of illegally imported fish.
Utah		State-wide regulation – Class B Offence – it is prohibited to move live fish.
Washington	WAC 323-12-271	No person other than the director of Fish and Wildlife may authorize planting aquatic plants or release of any species or sub-species of animal that does not already exist in the state.
	RCW 77.32.010	The director of the Washington Department of Fish and Wildlife may issue a permit for the propagation, possession, importation, purchase or transport of a non-native species for the purposes of disposal, control, research or education
	RCW 77.44.04.	Transplantation and introduction of non-native warm water fish are reviewed and managed by the warm water fish program.
<u>Canada</u>		
National Code on Introductions and Transfer of Aquatic Organisms (2003)	Intentional Introductions and Transfers of Aquatic Organisms	Code stresses the need for a consistent, complementary approach among the federal and provincial/territorial jurisdictions of Canada for the conservation of aquatic ecosystems. The Code does not deal with accidental introductions or cover federal and provincial *Acts*, regulations and policies relating to aquarium fish, bait fish and live fish for the food market, although it may be applied to the introduction and transfer of aquatic organisms through the aquaculture industry.
Fisheries Act (RS 1985, cF-14)	Section 33	Unlawful sale or possession of fish
Fisheries Act (Proposed) (2007)	Section 69(1) Prohibition export, import, transport	No person shall export, import or transport any member of a prescribed aquatic invasive species.
	Section 69(2) Prohibition of release	No person shall release into waters frequented by fish or permit to be released into waters frequented by fish any member of a prescribed aquatic invasive species.
	Section 69(3) Exceptions	No person contravenes subsection (1) or (2) if the action in question is done in conformity with the regulations.
	Section 70 Destruction of members of aquatic invasive species	The Minister may, subject to the regulations, destroy or authorize any person to destroy, in accordance with any conditions imposed by the Minister, any member of (a) a prescribed aquatic invasive species; or (b) any other species that the Minister considers to be an aquatic invasive species as defined in the regulations.
	Section 71Regulations	The Governor in Council may make regulations for the conservation or protection of fish or fish habitat, including (a) regulations defining "aquatic invasive species" for the purposes of this Act; (b) regulations prescribing aquatic invasive species for the purposes of section 69 and paragraph 70(a); and (c) regulations for controlling aquatic invasive species, which in turn include regulations (i) preventing the spread of such species, (ii) respecting the export of members of such species, their import and their transport, (iii) respecting the release into waters frequented by fish of members of such species, (iv) respecting the destruction of members of such species under Section 70, (v) respecting the handling of members of such species, or (vi) respecting any conditions that the Minister may impose on a person authorized to destroy a member of such a species under Section 70.
	Section 72 Offences and punishment	Every person who contravenes any provision of this Part or of the regulations made under this Part, or fails to comply with a condition imposed on them by the Minister under section 70, is guilty of an offence punishable on summary conviction and

Jurisdiction, Legislation/Code/Policy	Section	Details
		liable, for a first offence, to a fine not exceeding $200,000, and, for any subsequent offence, to a fine not exceeding $200,000 or to imprisonment for a term not exceeding six months, or to both.
Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act	Section 3 – Interprovincial Transport	No person shall, except under and in accordance with a permit issued pursuant to subsection 10(1), transport from one province to another province any animal or plant, or any part or derivative of an animal or plant. Every person who contravenes a provision of this Act or the regulations is guilty of an offence and is liable (i), to a fine not exceeding $25,000 or to imprisonment for a term not exceeding six months, or to both; or (b) is guilty of an indictable offence and is liable to a fine not exceeding $150,000 or to imprisonment for a term not exceeding five years, or to both.
Alberta, Alberta Fisheries Act		Illegal to transport live fish; the penalty is a fine.
<u>British Columbia</u>		
Wildlife Act, RSBC 1996, c-488 Fisheries Act – Fisheries (General) Regulations SOR/93-53 Pacific Fishery Regulations Fisheries Act - Fish Health Protection Regulations Federal Provincial Transplant Committee	Section 37 Transportation of Wildlife Section 55 Release of live fish Section 5 Section 3 Prohibition Transplant Permit	A person who ships or transports in British Columbia, or engages another person to ship or transport in British Columbia, wildlife or fish or parts of them, except as provided by regulation, commits an offence. No penalties noted. No person shall, unless authorized to do so under a licence, (a) release live fish into any fish habitat; or (b) transfer live fish to any fish rearing facility. Licence means a licence to release live fish into fish habitat or to transfer live fish. Schedule VIII - Tickets may be issued for failure to produce a licence and for failure to return fish to water No person shall bring into the province any live fish of a species set out in Schedule VIII. Schedule VIII includes bass, blue gill sunfish; and pike. No person shall import cultured fish or eggs of wild fish without an import permit Transplant permit required for all transport of aquatic fish and invertebrates. Permits reviewed by a federal/provincial board.
Ministry of Environment	3-7-01.05 Fish and aquatic invertebrate transplant and introduction - Policy 3-7-01.05 Fish and aquatic invertebrate transplant and introduction - Procedure	It is the policy of the Ministry that approval of the Federal/Provincial Transplant Committee must be obtained before any transplant or introduction of fish or aquatic invertebrates is undertaken by Ministry staff. Fisheries Officers and many employees of the Department of Fisheries and Oceans and Ministry of Environment are exempt from prohibitions regarding transplants and introductions outlined in the Fisheries Act, however, not from this policy. Purpose is to establish steps to be followed when applying for approval to transplant or introduce fish or aquatic invertebrates including: submitting the application to the Committee chairman at least 6 months prior to date of transfer or release; provide the information required on the application. Considerations on the Possible Spread of Contagious Disease criteria: transfer fish/eggs only within tributary or adjacent tributaries; transfer surface-disinfected eggs; if no eggs, use stock from population sampled according to Manual of Compliance to Fish Heath Protection Regulations (1977); younger fish; fish cultured in ground water; prevent coincident introduction of undesirable plants/animals.
Ontario, Fisheries Act General Regulations		It is prohibited to move live fish. People must have a stocking licence for public waters, but not for private waters.
Nova Scotia, Provincial Fish Act SNS 2006		Only minnow species allowed for bait.

Appendix 10. Summary of field-level enforcement activities regarding the transport and introduction of non native species in a number of North American jurisdictions.

Jurisdiction	Agency	Details/Additional Information
Alberta	Alberta Fish and Wildlife	It is illegal to transport live fish and there is a fine but no one has been caught and with only one exception, no charges have been laid.
British Columbia	Ministry of Environment	Until recently, this has not been identified as a major issue. Conservation Officers (CO) have ticketed people transporting live fish but this has occurred as a result of random checks. The CO Service does have an Undercover Section which would be available for investigating non native fish transport/introduction. There needs to be a much closer working relationship between the CO Service and the Fisheries Section, however. Fisheries staff must identify specifics of what they want the CO's to work on including the areas and times when illegal introductions might be a problem. CO's are available to implement all types of projects including public education, however, these projects must be clearly identified and defined between agencies then outlined in CO annual work plans. Also suggest a review of the provincial regulations to ensure non native species issues are adequately covered.
California	California Department of Fish and Game	State has a don't move finfish regulation which is set up to limit spread by bait transfers. The agency says the regulation has been somewhat effective depending on the ethics of the person involved in the transfer, i.e., in some cases, the person has been ignorant of the regulation but wants to do the right thing so they stop moving fish when they are caught, in other cases, the person does not care about the implications of their actions and continues to move fish even after being caught.
Colorado	Colorado Division of Wildlife	In certain areas of the state it is illegal to stock yellow perch but this regulation is not enforced regularly.
Idaho	Idaho Fish and Game	Occasional tickets issued but agency might get more aggressive on this issue because of the increase in aquatic nuisance species. Agency recognizes it is too hard to catch people in the act of transporting/introducing. Not enough Enforcement staff and little enforcement agency involvement; no charges laid to date and the agency relies on the angling community to police this issue because there are not enough Enforcement staff to dedicate to this issue.
Manitoba	Manitoba Conservation	No Enforcement staff involved in this issue. The illegal introduction program is run by Department Biologists who conduct some summer inspection programs using students at popular boat launch sites. Student examine boats and provide information on invasive species and provide public information on harmful effects of non-native species introductions.

Jurisdiction	Agency	Details/Additional Information
Montana	Montana Fish Wildlife and Parks	Enforcement Officers are aggressive in non-native species introduction/movement and officers have consistent, dedicated time to activities such as checking boaters; in the past officers issued only courtesy citations but charges are now routine. In one case, a person was caught stocking yellow perch into a lake with a valuable kokanee fishery - the conviction was on the basis of eyewitness testimony by a member of the public and the person responsible was made to pay the costs of removing the perch and restoring the lake.
Nova Scotia	Nova Scotia Agriculture, Fisheries and Aquaculture	In Nova Scotia it is not illegal to possess live fish although the agency working with DFO to change that. Because of the current regulation enforcement is difficult - ie a person could have live fish up to their daily bag limit in their possession in a live well and no charge could be laid even if officer believes the intention is to introduce fish to start a fishery.
Ontario	Ontario Federation of Anglers and Hunters	Enforcement/Conservation Service is not focused on this issue but are implementing some education regarding "don't dump bait buckets."
Oregon	Oregon Department of Fish and Wildlife	It is illegal to possess, transport or release fish; the agency attempted to increase fines for offences but was unsuccessful - no political will. There are also not enough Conservation Officers available and no charges have been laid for illegal transport/introduction.
Utah	Utah State; Division of Wildlife Resources	Officers have caught people moving fish on the highway but penalties are not stiff because fish movement is only a Class B offence. The agencies have proposed working on a covert multi-pronged enforcement project with increased fines and rewards for people who turn in offenders. This approach has worked for this agency in big game poaching.
Washington	Washington Department of Fish and Wildlife	Moving, transporting and introducing fish is illegal, however, these regulations are not enforced well enough and ticketing is slow. In the past, the agency has had two court cases but defence won. Agency believes enforcement is weak because it is difficult to catch offenders.

Appendix 11. Public education and awareness initiatives and angler involvement programs focused on providing information on the effects of non native and exotic species movements and introductions implemented in a variety of North American jurisdictions.

Jurisdiction	Organization	Public Education Programs	Angler Involvement Programs
Alberta	Alberta Fish and Wildlife	Agency biologist published a book - Fish of Alberta (Joynt and Sulivan) which included book tour, weekly CBC programs regarding native fish information and where the public can go to view these species. Agency believes the program was successful because people could relate to the antidotes of information regarding the fish and would know where fish existed.	Agency works with Trout Unlimited and implements programs to change attitudes of anglers to appreciating fish in general and native species in particular regardless of whether they are good fishery species (e.g. small headwater species)
Alberta	Parks Canada; Banff National Parks	Agency implements specific public education projects in association with planned and ongoing management/removal projects.	N/A
California	California Department of Fish and Game	General Programs - brochures, angler shows and hand-outs at the agency with the focus on teaching the value of native species and how exotics or non-natives and illegal movements threaten native fish. Rotenone Projects are always accompanied by public education and outreach programs concentrated on the problems with illegal introductions especially the ecological and financial cost of moving fish. Agency notes the success of the eradication programs over the long term increases depending on the success of the public education project.	Anglers commonly involved in removing desirable species before treatment for non-natives/invasive species. Agency feels there are likely only minimal benefits to the fish or the overall project but approach is important because it gets anglers involved, allows for education, and builds partnerships so these anglers argue for agency projects or support the department in other endeavours.
Colorado	Colorado Division of Wildlife	Agency only recently started implementing education programs including signs. Priority is to create overall state plan with an education component before more small projects are implemented. Agency will also plan to implement school programs to assist with prevention and will work with the US Fish and Wildlife Service to develop a publicly accessible database regarding invasive species.	N/A
Florida	Florida Fish and Wildlife Conservation Commission	Agency uses the press to publicize new and harmful introductions and for promoting fisheries for new exotics/non natives.	Agency works closely with anglers especially in determining the value of a new fishery on an introduced species including the regulations. Agency also includes angling clubs in fish/habitat assessments and research projects implemented on new exotics/non natives and ongoing studies regarding established exotics/non natives.
Idaho	Idaho Fish and Game	Agency is in the process of developing state-wide educational plan and materials regarding impacts of aquatic nuisance species - no specifics as yet. Until now, regional projects have been designed and implemented by regional biologists when a new species/stock discovered. Those limited projects have focused on the individual event and the ecological and financial costs of moving and introducing new species.	Information to anglers is provided in the fishing regulations.
Manitoba	Manitoba Conservation	Agency is in the process of developing education materials under the guidance of an overall Aquatic Invasive Task Force. The existing materials include only displays regarding zebra mussels and rusty crayfish.	Agency will involve/target anglers when educational materials have been developed: specifically - by going through trade shows, talks at club meetings, and by involving anglers in numerous province-wide watershed planning processes.

Jurisdiction	Organization	Public Education Programs	Angler Involvement Programs
Minnesota	Sea Grant Program	Educational materials have been developed for a variety of species aquatic nuisance species. Materials include: books, brochures, videos, pamphlets, and plasticized wallet-cards.	N/A
Montana	Montana Fish Wildlife and Parks and Montana Cooperative Fisheries Unit	This agency has extensive public education programs coordinated through a special department and education coordinators. Educational material is distributed regularly and this group also produces 30sec-1min TV spots aired regularly on local news programs particularly before and during eradication projects.	Anglers and local conservation districts are included in eradication and management projects and the agency has a strong partnership with Trout Unlimited which funds some of the education projects. Agency also involves the Montana Youth Conservation Corp in summer projects to help with eradication projects - the department pays half of the costs for this student-program.
Nevada	Nevada Department of Wildlife	Agency currently inserts information brochures into the regulations and has press releases. Agency biologist has suggested future focus of education programs should be on the licence-buying adults (to help combat falling licence sales) and should concentrate on the wide-range of outdoor activities to build appreciation for all native fish - not just fisheries species.	Agency has a number of programs where they involve angling clubs - especially bass clubs. These projects are not formal but evolve and are implemented as required.
Nova Scotia	Nova Scotia Agriculture, Fisheries and Aquaculture	Education and public awareness has been the agency focus to deal with illegal fish movements since the 1980s. Programs have included radio shows, TV news interviews, Public Service Announcements, brochures and presentations at clubs and sports shows. Agency feels these numerous and long-term programs have contributed to the decline/levelling of illegal fish movements.	Agency does not have organized/formal programs involving anglers but does solicit angler/client involvement on projects - especially smallmouth bass projects including research projects. Agency also uses bass anglers as volunteers on some projects. Agency feels that because of working these working partnerships, the bass organizations feel they have a hand in management, have stopped moving stocks and agree there are enough bass fisheries available in the province.
Ontario	Ontario Federation of Anglers and Hunters	This agency is working on a general Grade 9 fish curriculum and may include information on invasive species in that program.	Agency is proposing some education programs with angling groups, and at private and public hatcheries.
Oregon	Oregon Department of Fish and Wildlife	This agency has implemented small education programs including "Don't Move Live Fish" and the "Diamond Lake Treatment Program" These programs have also been profiled in the news papers and in various articles since the early 1990's. Agency biologists have suggested that a good approach would be to profile one entire situation - from introduction to eradication - and profile it so the public see/understands the whole picture. Agency also suggests ensuring other agencies know their audience and target the message to that audience to ensure effectiveness.	Agency uses anglers and volunteers to move bass and crappie as part of other management efforts. Also, agency and local bass anglers have implemented reward programs for information regarding illegal introductions.
Utah	Utah State; Division of Wildlife Resources	Agency has implemented signage and web information programs, brochures, public presentations. The focus of these programs is on how non-native species will interfere with sport fishing activities. No programs in schools yet.	Have a community watch/monitoring program and intense education program for anglers and especially aquaculture industry about the impacts of whirling disease; working with anglers - an angler coalition especially bass anglers who take the information to their groups and educate others
Washington	Environmental Protection Agency	EPA in Washington has a quarterly newsletter distributed to the Pacific Northwest states regarding aquatic nuisance species. They also endorse a book published by the University of Washington entitled: Invasive Species in the Pacific Northwest	N/A
Washington	Washington Department of Fish and Wildlife	Agency implements public awareness programs to accompany lake rehabilitation programs.	If the species is regulated - for e.g. bass - then the agency promotes the fishery to anglers to help keep stocks in-check where exploitation rate is sufficient ($\geq$ 25%).

Appendix 12. Student involvement or education programs implemented in three North American jurisdictions.

Jurisdiction	Organization	Student Involvement or Education Program
Manitoba	Manitoba Conservation	Department biologists implement summer inspection programs at boat launch sites using students; students examine boats and provide information on invasive species. The Department is also involved in developing new education materials under the guidance of the Aquatic Invasives Task Force.
Montana	Montana Fish Wildlife and Parks and Montana Cooperative Fisheries Unit	Agency involves the Montana Youth Conservation Corp in projects; the Department pays half the wages of these summer students who then help with non-native species eradication projects.
Ontario	Ontario Federation of Anglers and Hunters	Developing a general Grade 9 curriculum which may include information on invasive/non-native species.