

WebPanel 1. Costs

Below, we attempt to make estimates of the costs involved in our eradication strategy. We have separated the costs by type of structure. The numbers presented are based on our own estimates and those made by academics and government scientists in Prince Edward Island (PEI). All monetary figures are given in Canadian dollars (CDN\$1.00 = ~ US\$0.998 at time of writing).

Docks

For estimates, we took every dock to have three supporting poles, 35 cm in diameter, located every 3 m (J Morrissey pers comm). Another, solid form of dock, commonly called a Berlin Wall dock, would have a surface area comparable to the pole-supported dock. The largest of the docks, located in Montague, with an estimated 150 poles (G Arsenault pers comm), was taken as the upper boundary for size of main docks; using this as an analog for each bay's main dock is an overestimate. Each bay has only a few smaller docks, each taken to be 30 m in length. Again taking the Montague River as the model, each bay has 10 small, personal structures, 10 m in length. This gives a total area on the order of 3000 m² per bay. For five infested bays, the total is 15 000 m². The clearance rate was estimated at 4 m² hr⁻¹. This yields 750 hours per bay. At 4 hours per diver-shift, this would be 187 diver-shifts per bay to clear all public and private docks. A team of 10 divers could therefore clear all docks and wharfs in a bay in the 20-day time window. At an estimated \$600 per diver-shift, the total cost for all five infested bays would be \$561 000 per pass.

A voluntary removal order for all temporary structures, such as mooring buoys, floating wharfs, and swimming docks, would both decrease the cost and increase the effectiveness of the effort. Most of the smaller docks could be removed from the water with the cooperation of owners.

Lines and socks

Based on information from mussel harvesting operators, the costs of boat fuel and labor per longline were estimated to be \$100 and \$150, respectively (J Davidson pers comm). Based on 200 socks per line (J Davidson pers comm), \$0.40 per liter of vinegar, and 1 liter per sock sprayed, each line would require approximately \$80 worth of vinegar. This brings the total for spraying to \$330 per longline. We estimated this to be much less expensive than dipping and equally effective (Carver *et al.* 2003). There are a total of 11 110 mussel lines, as estimated from the DFO economic analysis. Thirty-one percent of these lines are in infested areas (DFO 2006), so the total cost of treating all infested lines would be \$1.1 million each for the two passes required. The supporting lines and buoys themselves could be treated in concert with the socks, since they too must be lifted with the socks. This would be expected to add little to the cost or time required.

Natural structures

From GIS data, the total area of the infested bays (minus the newly infested Murray Harbour) is 67 km² (Cambell 1973; MacWilliams and Judson 1973; Murchison 1973). The described area contains several different substrata. *Ciona* may settle on rocky substrata (2.53 km²), but are probably sparse to absent in PEI (Locke *et al.* 2006). Given this sparseness, scouring would be limited mainly by swim and search speed, because *Ciona* would require little handling time to clear. We estimated diver swim speeds of 0.125 km hr⁻¹ to search every centimeter of the rocky substrate. Based on a 1-m swath of viewing, we estimated 5060 diver-shifts, for a total of \$3 million per pass. This effort would need to be conducted within the same time window as other structures, and would require as many passes as a dock. Based on these numbers, a team of 126 divers could achieve this in a 20-day time window. Given the ranges of this estimate, search rate should be validated before an eradication effort is started. While this would undoubtedly be a major effort, it is not unreasonable, given the potential gains.

We estimate the complete eradication to cost \$4.4 million; if natural substrates are infested, this could increase to \$16.4 million.

Cost-benefit calculations

By conducting a cost-benefit comparison, we can estimate the potential gains of an eradication effort or estimate the required probability of success for eradication. Alternatively, we can calculate how long the invaders must be kept away for the management to remain financially reasonable. A case study that incorporates additional fuel, disposal, labor, and processing fees to eradicate tunicates estimates a current \$0.242 additional cost per kilogram of mussels (McDonald 2003). Based on production weight in the infested bays of 5575 metric tons, annual spending to control *Ciona* in the infested bays totals approximately \$1.4 million. Therefore, the estimated cost of continued treatment is:

$$c = \sum_{i=0}^{\infty} \frac{\$1\,400\,000}{(1 + 0.05)^i} \approx \$28\,000\,000$$

where *i* is the number of years the treatment is applied, and *c* is the total cost, using a 5% discount rate, as is typically done in economic analyses. Discounting can be applied to estimate present-day value of future money. Thus, the benefit-to-cost ratio is \$28 000 000 to \$4 400 000, or a 6.3:1 ratio. According to our estimate, the eradication effort will cost \$4.4 million. Put another way, eradication would also be optimal if there were a ≥ 16% chance of eradication or if it could keep *Ciona* at a level at which they had no impact on industry for 4 years.

$$c_4 = \sum_{i=0}^{i=4} \frac{\$1\,400\,000}{(1 + 0.05)^i} > \$4\,400\,000$$

WebPanel 1. Costs – continued**■ References**

- Cambell KM. 1973. Estuarine resource inventory Cardigan River, Prince Edward Island. Charlottetown, Canada: Prince Edward Island Department of Fisheries. Technical report #106.
- Carver CE, Chisholm A, and Mallet AL. 2003. Strategies to mitigate the impact of *Ciona intestinalis* biofouling on shellfish production. *J Shellfish Res* **22**: 621–31.
- DFO (Department of Fisheries and Oceans, Canada). 2006. An economic analysis of the mussel industry in Prince Edward Island–Gulf region. Moncton, Canada: DFO Policy and Economics Branch, Gulf Region.
- Locke A, Hanson JM, Ellis CM, *et al.* 2006. Invasion of the southern Gulf of St Lawrence by the clubbed tunicate (*Styela clava* Herdman): potential mechanisms for invasions of Prince Edward Island estuaries. *J Exp Mar Biol Ecol* **342**: 69–77.
- MacWilliams K and Judson IW. 1973. Estuarine resource inventory, Brudenell River and Cardigan River, Prince Edward Island. Charlottetown, Canada: Prince Edward Island Department of Fisheries. Technical report #105.
- McDonald C. 2003. What is the tunicate situation in Atlantic Canada? Proceedings of the Atlantic Canadian Tunicate Workshop; 2003 Mar; Charlottetown, PEI. Ottawa, Canada: DFO. Aquaculture Collaborative Research and Development Program report MG-02-11-003.
- Murchison J. 1973. Estuarine resource inventory, St Mary's Bay, Prince Edward Island. Charlottetown, Canada: Prince Edward Island Department of Fisheries. Technical report #104.