AN ECONOMIC AND POLICY ASSESSMENT OF INDUSTRY FUNDED GEODUCK ENHANCEMENT IN BRITISH COLUMBIA

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ABSTRACT

The geoduck fishery in British Columbia has been managed by individual quotas since 1989. Individual quotas have fostered a co-operative management approach in the fishery, which is implemented through a non-profit society with membership made up of licence holders in the fishery. This non-profit society, the Underwater Harvesters Association (UHA), co-manages the fishery with the Department of Fisheries and Oceans and funds scientific research, surveys, monitoring, management, generic marketing and various other activities in support of the fishery and the industry. The UHA has also had a program of industry funded wild stock enhancement since 1995. Due to the very long life cycle of geoducks, no enhanced animals have been harvested to date. The UHA has also invested in geoduck aquaculture in recent years. This paper describes the UHA enhancement program and examines the various indicators of success of the program including estimates of the program's Net Present Value, ratio of cultured juveniles to estimated recruitment from the wild population, and estimated potential number of planted animals in the commercial catch. Enhancement of wild stocks has the potential to increase production in the wild fishery, however, to date there has been no commitment regarding allowing commercial licence holders to harvest stocks they have enhanced. Whether or not enhancement is economically viable depends critically on the institutional and policy frameworks to secure access to harvest. Otherwise, commercial harvesters may choose to collectively move more towards aquaculture with its strong property rights, rather than enhancement.

Keywords: geoduck, enhancement, aquaculture

INTRODUCTION

The Underwater Harvesters Association (UHA) is a non-profit society comprised of the geoduck (*Panopea abrupta*) and horse clam (*Tresus nuttallii* and *T. capax*) license holders in British Columbia and associate members representing crew and processors. In 1995 the UHA initiated a UHA funded geoduck enhancement program whereby geoduck seed is planted into the wild to augment the natural production of wild geoducks. This enhancement program was initiated in the absence of a crisis in wild stocks.

The B.C. geoduck fishery started in 1976 as an open access fishery without catch limits. In 1979, entry to the fishery was limited and total allowable catches (TACs) were introduced based on a fixed harvest rate of biomass estimates. Coast wide landings (pounds harvested) rose steadily until 1987, after which quotas and landing's declined due to improved knowledge of stock biomass. Quotas have stabilized in recent years. Recent descriptions of the fishery, research to date and geoduck biology can be found in Hand (2002), Hilborn et al. (2003), and Bureau et al. (2003). Information on the fishery is also available on the UHA web site at www.geoduck.org.

The primary objective of the enhancement program was initially to rehabilitate areas that were depleted as a result of over fishing in the early years of the fishery. Another objective was to mitigate for the loss of geoduck stocks due to alienation through activities such as marine pipelines and various marine tenures over existing geoduck beds. In addition, the UHA wanted to be involved at the leading edge of culture research and development for geoducks. At the end of the day, however, the real potential benefit of enhancement will be allowable catches that are higher than would have been the case without the enhancement program.

ENHANCEMENT PROGRAM DESCRIPTION

Geoduck enhancement involves brood stock collection; brood stock conditioning and spawning in a controlled hatchery environment; algae culture for the purpose of feeding brood stock, larvae and juveniles; and larvae rearing and metamorpahsis to juvenile stage. Once the juveniles are large enough to remove from the hatchery, they are either put into a nursery or pearl nets to grow larger for planting or planted directly into the wild. Early experiments in planting showed that predator exclusion netting is necessary for about 2 years to reduce mortalities. After 2 years the geoducks are deep enough that most predators will not target them. Exceptions are sea otters, sea stars (*Pisaster brevispinus)* and man.

The UHA has planted seed in 13 locations within the Strait of Georgia. Table 1 gives a history of planting to date and estimated survival rates. From 1994 to 2003, UHA divers planted 2.26 million seed. The estimated number surviving is 766,000 or a survival rate averaging 34%. In the early years of planting, survival rates were very poor. In the 11 years from 1995 to 2005, the UHA spent a total of just over $3.3 million CDN (current dollars) on its enhancement program. Due to hatchery failures in 2003 to 2005, no seed was planted in 2004 and 2005.

Table 1 – Enhancement Planting History

	Seed from Hatchery previous yr.	Seed Planted	% Survival	Est. # Surviving
1996	1,000,000	190,200	13%	24,774
1997	800,000	353,600	14%	47,802
1998	500,000	40,000	89%	35,510
1999	420,000	146,000	57%	83,700
2000	1,222,000	376,000	49%	182,700
2001	1,600,000	300,000	50%	150,000
2002	2,000,000	750,000	28%	209,000
2003		110,000	30%	33,000
Totals		2,265,800	34%	766,486

For 1996, 1997 and 1998 plantings, the number of surviving animals has recently been determined by UHA survey work with a independent third party observer. For the remaining years, numbers surviving animals are estimated based on sampling specific experimental plots where the exact number of geoducks planted is known. All animals can be taken from these small plots and measured for growth rates. By extrapolating experimental plot survival rates to the nearby planted geoducks, we can make fairly accurate estimates of the surviving planted geoducks.

To ensure brood stock is genetically representative of the population in the area to be seeded, the B.C. coast has been divided into five geographic zones. Juveniles can only be planted within a zone if the brood stock came from the same zone. The UHA has only carried out enhancement activities within the Strait of Georgia, which comprises one of these zones.

While there are no specific regulations governing the number of animals required for brood stock purposes, the UHA follows the recommendations of the Department of Fisheries and Oceans science staff for the collection of a minimum of 100 animals each year for spawning purposes. This recommended number of brood stock is for the purpose of maintaining genetic diversity in the geoduck population.

REGULATORY ENVIRONMENT

Federal Government Role

The wild geoduck fishery is co-managed by the Canadian Department of Fisheries and Oceans (DFO) and the UHA. It is regulated by the DFO under a limited entry individual quota management system. There are 55 licences and each licence has an equal share of the total allowable catch (TAC). The UHA collects fees from its members and uses the funds for a number of programs, including 100% independent port monitoring of landings; over 90% independent on grounds monitoring of fishing; over 90% independent monitoring of processing plant deliveries; research, science and management positions within the DFO; biomass surveys; water quality testing; bio-toxin testing; DFO enforcement and generic marketing. A significant portion of the membership fees also goes to operating a geoduck hatchery and planting geoduck to enhance wild geoduck stocks.

There is no specific policy supporting non-salmonid enhancement in British Columbia. None the less, UHA enhancement activities are authorized by both the Federal and Provincial governments through brood stock collection permits issued by the DFO and through transplant permits, authorized by a Federal/Provincial Transplant Committee. Transplant permits are issued by the DFO and are required when taking geoduck seed from the hatchery and planting them. The permit specifies the amounts expected to be planted and exact location of planting. As long as the transplant committee sees no technical (disease or genetics) problems or eco-system concerns (ie. enhancing a top predator like sea urchins), they will approve the activities required.

Provincial Government Role

The provincial government is the primary regulator of aquaculture in British Columbia and has the responsibility for land tenuring and aquaculture licensing. Land tenures (leases) for aquaculture purposes are established under the authority of the provincial *Land Act.* Aquaculture licences to operate on those tenures (leases) are issued under the provincial *Fisheries Act.* There is an annual lease fee for aquaculture tenures.

To bring enhancement activities under a further Provincial regulatory framework and to protect the enhanced areas from any conflicting Provincial designations/tenures, the Provincial government has recently required that geoduck enhancement be conducted on Provincial Map Reserves (MRs). These are tenure designations for specified experimental purposes, and are issued for a specified period of time. At the expiration of the MR designation, these areas would either be renewed as Map Reserves or be rolled back into the wild fishery with no guarantee that the area would not be alienated to another use. Because these MR designations are held by the Provincial government, they are not leases and there is no fee for their use.

Ownership

The primary difference between enhancement and aquaculture is who owns the cultured product and how the harvest of the cultured product is regulated, monitored and managed. On a tenure, the geoducks are owned by the aquaculturalist and can be harvested totally at their discretion. There are, however, harvest notification procedures and paper reporting requirements for geoduck harvest from aquaculture sites.

Enhanced geoduck stocks can only be managed as part of the DFO integrated management plan for the geoduck that combines wild and enhanced stocks. There are harvest notification procedures, on grounds monitoring requirements and 100% independent port monitoring of all landings required in the commercial geoduck fishery. Total allowable catches of combined wild and enhanced stocks are set by the DFO.

The other difference between enhancement and aquaculture is that aquaculturists intensively rotate planting and harvest over their tenure, attempting to harvest 100% of the geoducks in the rotation on their farm. The UHA enhancement program, however, hopes to leave a certain portion of the planted geoducks in place as spawning biomass and move on to new areas to plant – spreading the benefits of enhancement over a much larger area.

PROGRAM EVALUATION

There are essentially two areas of program evaluation being considered by the UHA. First is to look at some of the biological indicators of success. Second is to take the biological indicators of success and do an economic or cost benefit assessment of the program. Both of these are addressed in the following sections.

Biological Indicators of Success

Survival rates from seed to market size are the most important biological indicator. To date the survival of animals to marketable size appears to range from 13% to 89% with an average of 34%. The low survival rates from the first two years are indicative of a learning process with respect to predator protection. We learned the hard way that predator protection is required for about two years.

Another biological indicator is the ratio of cultured juveniles to the estimated recruitment from the wild population. Population modeling indicates that annual recruitment in B.C. may range on average from 1.76 to 9.9 million juveniles (Hand, pers. com.) depending on environmental conditions. Because of the long life span and assumed low reproductive rate for geoducks, the annual commercial harvest rate ranges between 1.2 and 1.8% of current biomass. The UHA is planning on planting between 600,000 and 1.7 million juveniles per year. This represents a significant contribution to the total wild recruitment.

Any biological assessment of enhancement needs to also ask the question whether the carrying capacity of the area has been exceeded. The areas where enhancement is taking place have, for the most part, had extensive commercial fisheries in the past. Both the UHA and the DFO assume there is significant carrying capacity in the enhancement areas and that production could be substantially higher than it is today. Growth rates in particular areas can be monitored over time to assess whether there is any impact on food supply from higher densities of geoducks.

The other biological concern is to make sure that gains in geoduck production are not made at the expense of other species or damage to wild stocks through reduced genetic diversity or introduction of diseases to wild populations. Geoduck feed low on the food chain and do not interact directly with other species. Genetic and disease concerns are dealt with at the hatchery level through brood stock collection protocols and transplant permits that restrict where planting can occur. There are currently no diseases of concern amongst geoduck in B.C.

The final indicator of success is the number and proportion of planted animals in the commercial catch. At present the commercial quota and catch of geoducks in B.C. is 3,437,500 pounds annually. Assuming an average weight of 2 pounds per geoduck, if 100% of the enhanced geoducks to date could be harvested, enhanced harvest would be between half of one percent and one percent of the total commercial catch.

Economic Assessment of Geoduck Enhancement to Date

Surviving planted geoducks provide two distinct benefits. The first is the value of the harvest of the planted geoducks – this is the direct benefit and fairly easy to measure. The second benefit is that planted geoducks will add to the spawning biomass and contribute to future recruitment.

Economic projections can be used to estimate the net present value (NPV) of the harvested portion of geoduck enhancement (Caddy and Defeo, 2003). An enhancement program will be economically efficient if it maximizes the NPV of the yield obtained, which can be estimated as:

$$NPV = \sum_{i=1}^{t} \frac{TR_t - TC_t}{(1+d)^t}$$

where *TC* is the total costs in time *t* for the enhancement project, *TR* is the total annual expected revenues from harvesting enhanced stocks. The discount rate *d* considers the past value of money expended and the future value of the benefits derived. A higher discount rate diminishes the value of any future yield.

Expected revenues are calculated assuming various percentages of all currently estimated surviving geoducks are harvested 10 years after they were planted and using various price scenarios. At 10 years of age, we assume the average weight of a geoduck is 2 lbs. We also assume that harvesting of each enhanced plot is all done in one year 10 years after planting rather than a bit at a time over a number of years. The reason for this is the efficiency of harvesting an entire area at once due to the density of the planted geoducks and the fact that the preferred market size is 2 lbs. In reality, however, the UHA will likely recommend that the differences between the numbers of geoduck surviving each year be smoothed out by spreading the available enhanced product harvest more equally between years – in particular delaying some of the harvest of geoducks planted in 2000 through 2002 to cover the years when few or no geoducks were planted (2003-2005).

The current ex-vessel price of geoducks is $9.50 per pound. This analysis also looks at a price of $8.00 per pound in order to be somewhat more conservative and to reflect the net value to the fishermen by subtracting the approximate incremental costs of fishing and management. When the SARs epidemic hit China in 2003, the ex-vessel price of geoduck dropped quickly by about 25% and has not yet fully recovered. With increased supplies from aquaculture and reliance on essentially one market (China), geoduck prices could easily decline.

Table 2 shows the NPV in 2006 of the geoduck enhancement program to date using actual costs to date and assumptions about benefits in the future. This analysis assumes no further investments in enhancement after 2005 and no benefits beyond the actual harvest of already planted geoducks. In fact, however, the enhancement program has carried on this year (with planting over 600,000 geoduck juveniles in 2006) and will carry on in the future.

Table 2
Net Present Value (2006) of Geoduck Enhancement to Date at Various Price, Harvest Rate and Discount Rate Assumptions

		Price assumption - $/lb.	
Discount Rate	Allowable harvest rate	$8.00	$9.50
2.50%	20%	($1,651,347)	($1,238,303)
	50%	$1,653,000	$2,685,609
	80%	$4,957,348	$6,609,521
5%	20%	($2,476,434)	($2,103,906)
	50%	$503,790	$1,435,110
	80%	$3,484,014	$4,974,126

If the management strategy is to apply the existing TAC calculations for wild stock and only allow access to the equivalent of 1.8% per year of planted geoducks we assume that this would be approximately equivalent to a one time harvest of 20% of surviving enhanced geoducks. At this harvest level, enhancement makes no financial sense leading to substantial negative Net Present Values at both price assumptions and both discount rates. However, this option provides the highest level of additional spawning biomass.

The highest assumed harvest rate in this analysis is 80% because experience has shown that, even with planted geoduck which are lined up nicely in rows, it is impossible to harvest them all without repeated harvest events. The remaining geoduck are available to add to spawning biomass.

This analysis shows that the NPV of enhancement, measured by the value of the harvest, is most sensitive to the allowed harvest rate. The break even harvest rate at a discount rate of 2.5% and a price of $8.00 per pound is about 35% and the break even point at a discount rate of 5% and a price of $8.00 per pound is a harvest rate of about 45%.

The second benefit of enhancement is additional spawning biomass. Geoduck are broadcast spawners and one of the benefits of enhancement is to increase the spawning stock of wild geoducks. The minimum density required for successful fertilization is unknown (Hand and Marcus, 2004). The age at 50% maturity from a geoduck sample collected from the Tofino area on the west coast of Vancouver Island was 2 years, compared to 3 years from a sample of slower growing geoducks collected in the Strait of Georgia (Campbell and Ming, 2003). Geoducks are fully mature by the age of 8 years. Experience from hatcheries in B.C. is that geoducks as young as 3 years are very successful spawners (Bruce Clapp, UHA, pers. com.). This means that planted geoducks likely have 7 years of spawning prior to harvest.

Wild spawning has a very low survival rate. The total biomass of commercially accessible geoducks in B.C. is estimated at 600 million pounds. Therefore, the total estimated biomass of enhanced surviving geoducks of about 1.5 million pounds is a tiny fraction of the wild spawning population and the impact of adding that few spawners will be undetectable. On a more localized scale, however, it may be possible to see larger numbers of wild recruits in the localized area of the enhancement planting, even though we might not be able to determine if they are the progeny of the enhanced stocks. There are no genetic markers developed for geoduck, and therefore no way of telling whether increases in local recruitment are due to planted geoducks or not.

Even at an 80% harvest rate, the densities of remaining geoducks left on the current enhanced sites will be equal or higher than the densities in surrounding geoduck beds. Densities at the surveyed areas planted in

1996, 1997 and 1998 range from 1.29 geoducks per square meter to 5.3 geoducks per square meter, with an average of 3 geoducks per square meter. At an 80% harvest rate the remaining densities will be .26 per square meter to 1.06 geoducks per square meter with an average of .6 per square meter. This is higher than the average survey density for wild geoducks in Georgia Strait of .45 per square meter.

MANAGEMENT OF ENHANCED STOCKS

At this point, there is no specific management framework for enhanced stocks and there has been no commercial harvest of enhanced geoduck. Because there is no policy supporting non-salmonid enhancement in British Columbia, the fishery managers have no direction for how to manage enhanced stocks.

One option is to apply the current management framework for wild stocks to enhanced stocks. The current management framework calls for an annual 1.2 to 1.8% harvest rate of current biomass with specific geoduck beds closed to harvest once a limit reference point of 50% of the original biomass has been harvested. Even if the planted geoducks add significantly to natural recruitment in the area, the slow pay back from harvest at this low harvest rate makes enhancement economically unsustainable.

An alternative to this management model would be to allow a higher harvest rate on enhanced stocks since their recruitment is outside of the biological model currently being used to determine TAC's. The UHA is recommending that TAC setting for the commercial fishery on enhanced stocks be based on 80% of surveyed enhanced geoduck plots at a minimum of 8 to 10 years after planting and that these TAC's be calculated separately and added to the overall commercial TAC. Enhanced geoducks would thus come under all the regulatory, cost recovery, and management requirements for the regular commercial fishery. Our goal is to start harvesting enhanced stocks as part of the overall commercial TAC in 2007.

CONCLUSIONS

In an FAO report on shellfish enhancement, the authors conclude that "Institutional changes are needed in support of enhancement schemes, based on an adequate legislation that must recognize the concept of ownership and adequate use rights to protect investments. This topic has been considered as a necessary condition for any enhancement programme to succeed" (Caddy and Defeo, 2003).

The real question to be asked is "does Government want to support and encourage industry funded enhancement with the objective of increasing production above and beyond what would have occurred without enhancement?"

It is clear that such support would have to take into account and minimize genetic, disease, and ecosystem impacts on wild stocks and environments from enhancement. These are the same concerns that would apply to government support for aquaculture and need to be part of the regulatory environment.

Assuming that the support for enhancement is tempered by the above factors, the next step is to put in place policies that provide adequate use rights to protect investments in enhancement. The geoduck fishery in B.C. generally has these adequate use rights in the form of limited entry Individual Transferable Quotas. For the moment, this has been sufficient for the fishermen to invest their own money in enhancement even without government encouragement or support. With some of the planted geoducks now growing to market size, the issue of whether and how they will actually get access to those planted stocks is coming to the fore.

Whether or not geoduck enhancement is economically viable for the UHA depends critically on the government's response to requests to harvest enhanced stocks. If the management framework was in place to allow for the decisions on harvest of enhanced stocks to be left to the UHA or if that access could be defined and assured, then the UHA could make it's own financial decisions on whether the program is economically viable or not.

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