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Potential Impacts of Subtital Geoduck Aquaculture on the Conservation of Wild Geoduck Populations and the Harvestable TAC in British Columbia

Impacts potentiels de l'aquaculture infralittorale de la panope sur la conservation des populations sauvages de panope et le TAC en Columbie-Britannique

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Geoduck aquaculture is viewed by many as a viable and promising new industry, and there is increasing interest by the shellfish industry to culture and enhance geoduck stocks. Federal and Provincial governments have committed to implement a phased approach to geoduck aquaculture expansion in 2005. This paper was written in response to the need to evaluate the conservation issues for wild geoduck populations and to assess the impact on the commercial fishery that may result from aquaculture activities. The objectives of this paper are to identify the factors that may compromise conservation, evaluate the potential risks and make recommendations for consideration in future decision-making. A summary of current approaches to assess and manage wild geoduck stocks and the underlying conservation strategy for the commercial fishery is provided, along with relevant available information on the genetics of geoducks, and known bio-physical requirements for recruitment and growth. A framework for phased development of aquaculture is outlined, in which site selection criteria are defined which allow a ranking of the level of impact on wild stocks and the existing commercial fishery.

To ensure that conservation objectives for natural geoduck populations are met, impacts of aquaculture need to be incorporated into assessment and management frameworks. It is further recommended that geoduck aquaculture expansion follow a phased-approach that will allow the collection of information on genetic impacts and disease issues as they relate to transfer and transplant of these animals, leading to the development of sound procedures.

RESUME

Nombreux sont ceux qui considèrent l'aquaculture de la panope comme une nouvelle industrie viable et prometteuse. L'industrie de la conchyliculture montre un intérêt croissant envers la culture et la mise en valeur des stocks de panope. Les gouvernements fédéral et provincial se sont engagés à mettre en oeuvre une stratégie progressive d'expansion de l'aquaculture de ce mollusque en 2005. Le présent document vise à combler le besoin d'évaluer les enjeux relatifs à la conservation des populations sauvages de panope et l'impact des activités d'aquaculture de cette espèce sur la pêche commerciale. Le but de ce document est d'identifier les facteurs qui peuvent compromettre la conservation, évaluer les risques potentiels et formuler des recommandations à considérer lors de prises de décision futures. Ce document inclut un résumé des approches prises à l'heure actuelle pour évaluer et gérer les stocks sauvages de panopes, la stratégie de conservation sous-jacente visant à assurer la durabilité de la pêche commerciale, ainsi que les renseignements disponibles sur la génétique de la panope et les exigences biophysiques sous-tendant le recrutement et la croissance. Un cadre pour l'expansion graduelle de cette activité aquacole est établi et des critères pour le choix des sites sont définis, ce qui permet de classer hiérarchiquement le niveau d'impact sur les stocks sauvages et la pêche commerciale existante.

Afin d'assurer que les objectifs de conservation pour les populations naturelles de panope soient atteints, les impacts de l'aquaculture doivent être incorporés dans les cadres d'évaluation et de gestion. Il est recommandé en outre que l'expansion de l'aquaculture de la panope se fasse graduellement de telle sorte que des données sur les impacts génétiques et les problèmes de maladie imputables au transfert et à la transplantation de panopes puissent être recueillies, ce qui permettra d'élaborer des procédures judicieuses.

INTRODUCTION

Geoduck (*Panopea abrupta*) clams are one of the most valuable commercial shellfish species harvested in British Columbia (BC), with a landed value of 32 million dollars in 2003. There is increasing interest by the shellfish industry to culture and enhance geoduck stocks in order to increase yields in this lucrative fishery. This interest has resulted in a federal/provincial commitment to implement a phased approach to geoduck aquaculture expansion for 2005. The objectives of this paper are to examine the conservation issues for wild subtidal stocks and the potential impacts on the wildstock fishery that may result from subtidal geoduck aquaculture activities.

The paper provides a brief summary of federal/provincial authority and aquaculture policy development as it pertains to geoduck culture. A summary of the current approaches to assess and manage wild geoduck stocks and the underlying conservation strategy is provided, along with relevant available information on genetics of geoducks, and known bio-physical requirements for recruitment and growth. A phased approach to expanding geoduck aquaculture is outlined. Information gaps that prevent a better understanding of aquaculture impacts in BC are identified and recommendations made for consideration in decisions regarding aquaculture development.

Aquaculture Policy in Canada

In 2002, Fisheries and Oceans Canada (DFO) adopted the Aquaculture Policy Framework (APF), which states that DFO's vision of sustainable aquaculture development is "to benefit Canadians, now and in the future, through the culture of aquatic organisms, while upholding the ecological and socio-economic values associated with Canada's oceans and inland waters." The APF acknowledges aquaculture as a significant opportunity for Canadians that may include the specific benefit of reducing pressure on wild fish stocks, thereby helping to sustain and enhance wild fisheries. The APF confirms DFO as a regulator and enabler of aquaculture which encourages, rather than restrains, responsible aquaculture development.

In 2004, DFO released the national policy, "Access to Wild Aquatic Resources as it Applies to Aquaculture" in recognition of the needs of the aquaculture industry to access wild fish for a variety of purposes. These purposes include access to seed stock and spat, brood stock collection, access for relay and "on-growing", predator management of non-mammalian species, and the harvest of existing natural sets of wild stock "by-catch" of the lease species on the aquaculture tenure. An important aspect of the national policy is that wild stock of the licensed aquaculture species on tenures becomes the property of the aquaculturist. In cases where a valuable commercial species (e.g. geoduck) is resident on a potential lease site, DFO and the Province may allow a limited opportunity for commercial fishers to harvest the lease area prior to granting of the lease. This harvest is intended to allow a significant portion of the economic value of the wild species to be accrued to the public fishery, and to prepare the site for intensive planting of juvenile geoduck. Even after this pre-seeding harvest (or "purge fishery") has occurred, amounts

of wild geoduck of significant value can remain on the site to accrue to the aquaculture operation. As well, the lease-holder owns all future natural recruits.
The National Code on Introductions and Transfers of Aquatic Organisms, released in 2003, sets in place a mechanism (Introductions and Transfers Committees) and a process (Risk Assessment procedures) for assessing proposals to move fish from one body of water to another. The Introductions and Transfers Committee in BC is engaged in drafting operational guidelines for shellfish based on the National Code to address such concerns as the disease and genetic risks of hatchery production, and origin of brood stock relative to outplanting destination.

Shellfish Aquaculture in British Columbia

In British Columbia, the Ministry of Agriculture, Food and Fisheries is the lead agency for aquaculture development. In response to requests from coastal communities to help diversify local economies, the Provincial Shellfish Development Initiative was introduced in November 1998. One goal of the initiative is to double the amount of Crown land available for growing of shellfish culture species (largely clams, oysters and mussels, and some scallop and geoduck) to 4,230 hectares within 10 years. Shellfish farming is considered by the provincial government to be an environmentally friendly activity with the potential to create significant economic opportunities for all British Columbia's coastal and First Nations communities. The total land under tenure in 2004 is estimated to be 2962 hectares, which is still far short of the goal.

Regulatory Authority for Aquaculture in BC

Provincial authorities have the legislative responsibility for land and aquaculture licensing in BC. Land tenures for aquaculture purposes are established under the authority of the *Land Act* by Land and Water BC. Aquaculture licenses are issued under the provincial *Fisheries Act* by the Ministry of Agriculture, Food and Fisheries. The Aquaculture Regulation made pursuant to this *Act* establishes further requirements for conducting the business of aquaculture.

At the federal level, applications for new or expanded aquaculture tenures are reviewed under three statutes– the *Fisheries Act* (FA), the *Navigable Waters Protection Act* (NWPA) and the *Canadian Environmental Assessment Act* (CEAA). Sections 34 to 36 of the *Fisheries Act* concern impacts to fish habitat. Generally, where there are no structures proposed, as is normally the case with a subtidal geoduck farm, an exemption is issued under Section 5.2 of the *Navigable Waters Protection Act* (NWPA) and a review under the *Canadian Environmental Assessment Act* (CEAA) is not triggered. The Minister of Fisheries and Oceans has the right to advise the Province of BC on applications regarding fishery management considerations for new aquaculture sites, however has no decision-making authority other than that described above.

The federal Minister of Fisheries and Oceans has the authority under Sections 54, 55, and 56 of the federal Fishery (General) Regulations to licence the release of fish into fish bearing waters or to a fish-rearing facility. The federal-provincial Introductions and Transfers Committee reviews such proposals, issues licences and recommends where risk assessments are appropriate based on the National Code of Introductions and Transfers and the draft regional guidelines.

History of Geoduck Aquaculture in the Pacific Northwest

In the early 1990's, a hatchery in Washington State began experimenting with geoduck brood stock to develop hatchery and seed grow-out technology. Geoduck aquaculture has since developed on private intertidal lands, and cultured geoducks have been harvested since 2001. Washington State Department of Natural Resources (DNR) is currently reviewing the feasibility of subtidal culture and assessing potential impacts on habitat and the existing wild fishery.

In 1996, a Canada-BC Experimental Geoduck Culture Letter of Understanding (LOU) established a strategy for a pilot commercial subtidal geoduck aquaculture project. Five test areas were agreed upon as pilot sites to determine the feasibility of geoduck culture in British Columbia. Under the terms of the LOU, DFO established a separate Collaboration Agreement with the existing commercial geoduck fishery association, the Underwater Harvesters Association (UHA) and the aquaculture proponent, Fan Seafoods Ltd. The intent of the Collaboration Agreement was to mutually establish conditions for site marking, access to, pre-seeding harvest ('purging') and disposition of wild geoduck on the test sites. The duration of the pilot culture project was set at five years from the agreement date in February 1996.

There was soon significant interest and pressure to expand aquaculture to include additional sites and participants. Several intertidal geoduck culture sites were approved, before a moratorium on new culture sites was established in 1998, pending the assessment of the Fan Seafoods experimental pilot project. At that time, governments were concerned about: a) the existing geoduck on a tenured site and implications for the existing commercial fishery, b) the potential for windfall profits from the wild stocks to accrue to the individual obtaining an aquaculture tenure, c) the implications of 'purge fishing' (removing as much wild stock from a site as possible prior to seeding) on the conservation of geoduck stocks and the calculation of the commercial Total Allowable Catch (TAC) and, d) the lack of a traceability process for cultured geoduck and concerns of illegally harvested wild geoduck to enter the marketplace.

At the end of the five-year project in 2001, it was not possible to assess the success of the Fan Seafoods pilot project or the economic feasibility of geoduck aquaculture. Grow-out to harvestable size had taken longer than anticipated and the first harvest of cultured geoduck did not occur until 2002. The development of both an aquaculture policy and of management tools for purge fishing, traceability processes, and site assessments are still in process, and the moratorium on new geoduck culture sites has continued to date. However, geoduck culture is viewed by many as a viable and promising new industry. DFO and the province of BC, in consultation with industry stakeholders, have adopted a proactive approach to expansion planning.

WILD GEODUCK POPULATIONS AND THE COMMERCIAL FISHERY

This section contains a description of pertinent aspects of geoduck biology, an overview of stock assessment and management methods, and the conservation strategy in place for geoduck populations.

Overview of Geoduck Biology

Geoducks are long-lived animals, with a maximum recorded age of 168 years (Bureau et al. 2002). Every year, they broadcast millions of gametes in synchronized spawning events. Fertilization occurs in the water column and the developing larvae are planktonic for up to 6 weeks, therefore having high dispersal capabilities (Goodwin 1976, Goodwin et al. 1979). Larvae settle to the bottom and have limited mobility for a few more weeks until the development of siphon feeding apparatus and foot, when it begins to dig. Until recently it was suspected that the presence of adult geoducks was critical for larval settlement, however results of recent research have shown that experimental plots depleted by heavy harvest experienced similar levels of recruitment as unharvested plots (Campbell 2004). The minimum density required for successful fertilization is unknown. Sexual maturity has been found to be more related to size than age. The age at 50% maturity from a geoduck sample collected from the Tofino area on the west coast of Vancouver Island (WCVI Management Region) was 2 years, compared to 3 years from a sample of slower growing geoducks collected in the Strait of Georgia (Inside Waters Management Region) (Campbell and Ming 2003). Geoducks are fully mature by the age of 8 years.

Geoduck stocks are structured as metapopulations that are connected with each other by means of the dispersal of larvae. The availability of recruits in any segment of the metapopulation depends on the density of spawning animals, environmental conditions, tidal current patterns and survival of larvae. Results of recent genetic research in BC found a correlation between genetic divergence in geoduck and distance among sample sites, which supports a model of genetic structure referred to as the 'isolation by distance' model (Kristina M. Miller, DFO, pers. comm.). The study concludes that geoduck populations exhibit gene mixing at small spatial scales of 50-300 km, where gene flow is restricted to immediately adjacent populations, and stepping-stone gene flow at intermediate scales of 500-1000 km. Cluster analysis identified regions that should be considered as separate populations and managed accordingly. In particular, the sites in the Queen Charlotte Islands were distinctive from more southerly sites. Sites in Washington State exhibited the second most distinctive genetic patterns and were significantly different from most of the sites in the Strait of Georgia. It was recommended that Washington be designated as a separate population and that broodstock from there should not be used to produce juveniles for outplanting within BC.

A limited amount of published material is available on the factors that affect geoduck recruitment. Experimental plots initiated in the early 1980's in Washington State by Lynn Goodwin (Washington Department of Fish and Wildlife), described in Orensanz et al. (2004), showed evidence of highly variable recovery rate after harvest, which prompted the question of whether there is some identifiable environmental correlate. It was observed (Goodwin 1990, p.29) that “in general, recruitment is higher in tracts where water currents are of medium velocity”. Beds with good recruitment are likely those that lie along a steady tidal current path which can contain the larvae from a number of spawning events.

Factors that are important to post-larval and juvenile survival have been investigated, stemming from interest in aquaculture. Significantly better growth in early post-larvae was found when food was available on the substrate surface rather than just in the water column (Cole et al. 1991). The burrowing rate of juvenile geoducks was highest at salinities of 30 to 32 ppt and was greatly reduced at salinities less than 26 ppt (Davis et al. 1999). Experiments on geoduck embryos revealed they have narrow temperature and salinity limits. For 70% or more of the embryos to develop into normal strait-hinge larvae, the salinities had to remain between 27.5 and 32.5 ppt and the temperatures between 6 and 16 °C (Goodwin 1973). It is speculated that older life stages of geoduck clams can tolerate a wider range of salinity and temperature (Goodwin and Pease 1989).

Fishermen have reported the existence of sandy substrate on the Sunshine Coast in the Strait of Georgia that, for unknown reasons, has not been recruited by geoducks. This area was the target of an experiment in 1995 to plant geoduck seed in ‘exclusion cages’ in order to monitor survival and growth (Alan Campbell, DFO, pers. comm.). These cages are actually large bottomless garbage cans that were sunk into the substrate to a depth of approximately 1 m, leaving the upper edge to extend approximately 20cm above the seabed. A total of 200 geoduck seed were planted in 10 cages in 1995, and 62 geoducks were retrieved in 2002. Ages ranged from 6 to 16 years, which suggests that at least a few naturally-recruited geoducks were present in the area prior to the experiment. Survival of the seeded animals ranged from 5% to 40% per cage and preliminary analysis indicated that growth appeared normal.

Both growth rate and maximum size vary considerably between locations, often within spatial scales of a few kilometers (Bureau et al. 2002, 2003, Hoffman et al. 2000). The highest growth rates in all BC samples collected to date have been associated with moderate to strong tidal currents (Bureau et al. 2002) and Hoffmann et al. (2000) found growth to be greatest in sites that were subject to intermediate tidal flow.

To date, no infectious diseases or pathogenic organisms have been found in cultured geoducks in BC (Bower and Blackbourn 2003). It remains to be shown, however, that juveniles from one Region are not carriers of disease for clams in other Regions, nor whether disease issues might arise in the higher densities likely to be found in geoduck farms. Although wild geoducks do suffer from lesions and warts, none of these conditions were found to be contagious to other geoduck clams in a laboratory situation.

Stock Assessment

Geoducks are found in almost all sedimentary substrates, but are generally only harvestable in soft sand, mud and small aggregate sediments. Commercially harvested beds range in size from large banks of hundreds of hectares to small pockets among rock or boulder outcrops of less than one hectare. Beds are assigned unique identification codes for stock assessment purposes; often several smaller beds are grouped together under the same code. There is currently an inventory of over 2000 unique bed codes for the coast of BC, approximately half of which are comprised of assemblages of two or more smaller beds. The area of all beds totals 24,500 hectares coastwide: 6500 ha (27%) in the North Coast, 5900 ha (24%) on the west coast of Vancouver Island (WCVI), 788 ha (3%) in northern Inside Waters (east coast Vancouver Island, north of Campbell River) and 9696 ha (46%) in the southern Inside Waters (Strait of Georgia).

Stock assessment methodology is described in Hand 2002. For each bed listed in the DFO inventory of commercial beds, virgin biomass is calculated as the product of bed area, virgin geoduck density and mean geoduck weight.

Bed Area

Bed area has been identified as the factor that is estimated with the least accuracy, particularly in the South Coast (Hand 2002). Areas are estimated by digitizing polygons, drawn on nautical charts, which represent the geographic area of harvest activities. Polygons are constrained to lie within the 3m to 20m depth contours as the depth zone most available to harvest with the dive fishery gear. Until the mid 1990's, mandatory harvest log charts provided by fishermen formed the basis of these chart polygons. Combinations of variable reporting accuracy and chart accuracy, and evolving interpretations and conventions by DFO staff over the years resulted in many inaccuracies in bed area estimates. Efforts have been focused to improve these bed area estimates through substrate surveys using acoustical back-scatter analysis (Murfitt and Hand 2004) and through the use of more accurate geo-referencing of fishing events available in recent years from on-grounds monitor reports and increased use of Global Positioning Systems (GPS) by fishermen. More recently still, the institution of bed by bed management in 2004/2005 has revealed, via feedback from fishermen, that many listed beds were visited but briefly, and found to be lacking in qualities (e.g. suitable substrate, adequate bed size) required to sustain an on-going fishery. Bed areas are continually being evaluated and re-estimated. Most bed reviews have led to a decrease in bed area.

The distribution of bed sizes varies between management Regions. In the southern Inside Waters, a few large beds contribute to most of the area, compared to the North Coast where much of the total bed area is made up of smaller to mid-size beds (Fig. 1). In every Region, a high proportion of beds have been fished in only one year (Fig. 2). The larger the bed, the more number of years they are fished (Fig. 3). For instance, in southern Inside Waters, about 55% of small beds (less than 5 ha) have been fished in only one year since 1976, whereas about 90% of large beds (50 to 100 ha) have been fished in more than six years (Fig. 3). There is a decreasing trend in harvest intensity (kg/hectare) with increasing bed size, i.e., the smaller beds, even if fished only in one year, have received more harvest pressure than the larger ones (Fig. 4). This could be due to real density differences or to the over-estimation of bed size, but it suggests that small beds are potentially vulnerable to depletion.

Geoduck Density
Density of geoducks is calculated from transect survey data. To 2003, approximately 46% of the estimated bed area from the North Coast Region, 27% from WCVI and 25% from the southern and northern Inside Waters has been surveyed. For unsurveyed beds, density estimates are extrapolated from nearby surveyed beds or assigned the average density from surveys conducted within the Region (Hand 2002). Virgin density is calculated by adding the density of geoducks removed by the fishery (number of animals per square metre harvested over the area of fishing) to the estimated survey density. Sources of uncertainty in density estimates include inappropriate extrapolation, pitfalls associated with back-calculation of biomass to virgin states after over 25 years of fishing, wide confidence bounds that result from patchy distribution, and the variable number of geoducks showing their necks above the substrate surface (the show factor) at the time of the survey. The approach of extrapolation by proximity is recognized as being faulty, and work is being conducted to classify geoduck beds by indices of density and productivity to enable a more appropriate extrapolation. The use of virgin density and biomass estimates for quota calculation is under review.

Geoduck Weight
Mean individual geoduck weight, the most accurately estimated parameter (Hand 2002), is based on harvest log piece-count data, where the number of geoducks landed are counted and weighed during the catch validation process. These estimates may be biased if size selectivity is occurring in the fishery. Even though geoduck size reaches an asymptote at around the age of 10 to15 years (Bureau et al. 2002, 2003) and fishers cannot determine the size of clam before extracting it, selectivity may still occur if fishermen avoid areas of small clams. An examination of market sample data (harvested clams weighted at the dock) and biological sample data (clams sampled during surveys and weighed at the processing plant) does suggest that harvested geoducks are heavier, on average, than sampled geoducks from the same area, and that only some of the difference is due to water loss (Hand 2002). A conversion factor to correct for this bias has been incorporated into biomass calculation procedures.

Total coastwide virgin biomass is estimated to be approximately 300,000 t: 144,000 t in the North Coast, 94,000 t on WCVI, 9700 t in northern Inside Waters and 57,778 t in the southern Inside Waters. These estimates are known to be flawed for the reasons described above. It is anticipated that substantial improvements to biomass estimates will be possible over the next three years as all geoduck beds currently listed are verified during the bed by bed fishery. Geoducks are known to occur deeper than fishable depths and shallower than fishing regulations allow, although estimates of inaccessible biomass have not been attempted in BC. An estimated 76% of total geoduck biomass in Washington State is deeper or shallower than the harvestable biomass (Bradbury et al. 2000). The growth rate and reproductive potential for deepwater stocks is unknown.

Commercial Fishery Management

The BC geoduck fishery is managed through a combination of limited entry licensing and individual licence quotas (Heizer 2000). Quota options are calculated for each geoduck bed listed in the DFO inventory of commercial beds, using a harvest rate of 1% of estimated virgin biomass. Beds are grouped into and managed by Geoduck Management Area (GMA – subsets within management Regions) with quotas based on the sum of individual bed quotas therein. Approximately one third of the GMA's within each Region are fished each year to maintain a three-year rotation of harvest areas and to limit the number of authorized landing ports for logistical reasons.

Until 2004, fishermen were permitted free access to any bed within the GMA, and often vessels would continue to fish a few favourite beds rather that spreading effort evenly over all beds in the GMA. A pilot bed-by-bed management regime began in the North Coast Region in 2004, with expansion to the West Coast of Vancouver Island planned for 2005. The objective of the new regime is to spread out fishing effort and to gather information from each bed on inventory in order to improve stock assessment.

The harvest rate of 1%, applied to virgin biomass estimates, is the proportion of the biomass that is expected to provide a sustainable fishery over the long term, based on analyses and modelling of early estimates of growth, mortality and recruitment (Breen 1982). More recent age-structured models have suggested, in one case, that a 1% harvest rate on virgin biomass is conservative (Breen 1992) and, in another case, that a more appropriate harvest rate would be 0.5% where recruitment was low and 2% where recruitment was high (Campbell and Dorociez 1992). No change in harvest rate was implemented at that time, as the rate of 1% was considered to be conservative. Yield modelling is currently underway which utilizes new estimates of natural mortality, growth and recruitment rates from an extensive biological and survey database. Preliminary results of these investigations have suggested sustainable harvest rates ranging in the neighbourhood of 0.9% to 3.0% of current biomass.

Conservation Objective

The conservation objective in the commercial geoduck fishery is to maintain a minimum of 50% of the original (unfished) biomass in each known geoduck bed. This limit reference point of $0.5B_0$ is somewhat arbitrary, but based loosely on results of early yield modelling that suggested that populations harvested at 1% of B_0 would stabilize at 50% of virgin levels (Breen 1982). Commercial harvests are planned for a 50-year time horizon and annual bed quotas are adjusted down to evenly spread the remainder of $0.5B_0$ to the end of the 50-yr period.

Feedback from commercial fishermen suggests that some geoduck beds are inappropriately penalized or closed, and that the high removals experienced by these productive beds are sustainable. Protocols are being developed to collect information from closed beds to evaluate their status. Specific beds are surveyed to estimate the current biomass (B_c), annual quota is set at 1% of mean estimated B_c for a proposed 5-year period, after which the beds are re-surveyed.

Sea otters, reintroduced to coastal BC, pose a significant threat to geoduck populations. Their range now extends over much of the west coast of Vancouver Island Region from Clayoquot Sound to Quatsino, as well as Goose Island and the McMullen group in the Central Coast Region. Anecdotal reports from geoduck harvesters, along with video footage, show sea otters are effective geoduck predators. In recent years, adjustments to the quotas and the fishery have occurred in a number of areas where it has not been possible to meet the TAC due to suspected high levels of otter predation.

IMPACTS OF GEODUCK AQUACULTURE DEVELOPMENT

Conservation of Wild Populations and the Commercial Fishery

Geoduck aquaculture has a direct impact on the commercial fishery through the alienation of subtidal ground. Commercial quota options are reduced in proportion to the estimated biomass of wild geoducks in the tenured area. A total of 87 ha has been alienated from the fishery to accommodate the FAN Seafoods experimental aquaculture sites.

"Purge fishing", described earlier, is the practice of intense fishing to remove existing wild geoduck stock from a site destined to be tenured for aquaculture. Purge fishing was initially undertaken at the FAN Seafoods experimental sites with three objectives: 1) to remove as much of the wild stock as practical to prevent windfall profits accruing to the aquaculturist, 2) as some measure of compensation to the displaced wild harvesters at productive fishery sites, and 3) to prepare the subtidal ground for planting. The "Access to Wild Aquatic Resources as it Applies to Aquaculture" policy supports purge fishing where a valuable commercial species is present on a potential lease area.

Purge fishing is an additional source of fishing mortality which contributes to the reduction in standing stock of wild geoduck populations, along with commercial fishing. In the commercial fishery, biomass estimates, harvest amounts and the application of the limit reference point of $0.5B_0$ are tracked and implemented on a bed by bed basis; i.e. beds are closed when cumulative landings reach 50% of estimated virgin biomass. In purge fisheries, the objective is to harvest a significant portion of the resident population prior to tenure for aquaculture, and the $0.5B_0$ threshold will, by definition, be exceeded. A larger-scale view of geoduck populations must therefore be adopted in fishery management efforts to continue the implementation of the conservation strategy and maintain minimum populations of wild geoducks. The size of the area to which the limit reference point should apply (i.e., 50% of what population?) would depend on the amount of information available to genetically define geoduck populations. Regardless of scale, if 50% of the estimated virgin biomass in a defined area were to be removed to allow aquaculture, it follows that the commercial fishery would be closed.

Loss of biomass through purging may be mitigated by the likelihood that cultured geoducks will spawn before being harvested and the high probability of successful fertilization given the concentration of spawners in a farm situation. Additional gametes or larvae may be produced from residual wild geoducks that were missed during the purge fishing. Further investigations are required as the aquaculture industry develops to determine the potential risks and benefits of recruitment resulting from hatchery-reared populations; this is discussed in greater depth below.

In 1994, the UHA initiated and funded an experimental geoduck enhancement program, the objective of which was to rehabilitate depleted areas and increase production in the wild fishery. Since that time, approximately 2 million geoduck seed have been planted and monitored at 14 small sites in the Strait of Georgia. Additional research projects funded by the UHA, in association with the enhancement project, include work on diseases and genetics, geoduck hatchery development, rearing, planting and grow-out experiments. Large-scale enhancement projects, supported by appropriate government policy, may help to offset aquaculture impacts on wildstock conservation and the commercial fishery.

Geoduck Genetics and Disease

The projected first-harvest of farmed geoducks is approximately 8 years. Given that geoducks mature as early as two to three years of age, it is highly likely that hatchery-reared and outplanted geoducks in will spawn at least once before being harvested. The higher density of farm geoducks would increase fertilization success and the amount of viable larvae which, if they survive and settle, could have a large impact on the genetic makeup of surrounding populations and future generations. The genetic make-up of the second and succeeding generations would depend on many things, including the origin and number of parents used in the hatchery spawning, the number of spawners that actually contributed to the pool of surviving larvae, the number of spawning events with different broodstock, etc. The possibility of loss of genetic fitness of wild stocks through interactions with hatchery-produced animals is of considerable concern, and highlights the importance of sound genetic protocols for broodstock collection and the management of the lineage of outplanted geoduck. Studies to investigate the range of larval drift and therefore the range of potential genetic impacts should be a high priority.

Genetic impacts can be minimized, at the very least, by limiting broodstock collection and outplanting to genetically defined areas, for example the Strait of Georgia. Impacts may also be minimized by restricting the gene flow through geographic isolation, by making use of oceanographic or physical features. Experimental work to monitor the extent of larval drift should be carried out by establishing a series of larval collectors around aquaculture sites, testing settled juveniles of future generations for genetic signature and comparing to genetic signatures of the founder population. The lower the effective parent population, the greater the loss of diversity and the more inbreeding will occur, with the ultimate result of gametes becoming less viable with time.

Geoduck hatchery techniques have not been perfected in BC to date, despite efforts over recent years of several hatcheries. Consequently, there is pressure from industry to allow the importation of seed from hatcheries in Washington State. Since Washington geoduck populations are genetically distinct, they may have evolved different mechanisms for dealing with local environmental conditions and/or parasites and disease. Therefore, there are genetic and disease risks from importing seed from outside areas such as Washington State entering BC waters. Seed imports from Washington are not currently permitted. There has been interest expressed by industry in sending BC brood stock to Washington hatcheries and returning the resultant seed for out-planting. The National Code on Introductions and Transfers of Aquatic Organisms was released in 2003 to provide a mechanism for assessing these and other activities. The policies and procedures available through the local Introductions and Transfers Committee give guidance to acceptable quarantine and isolation processes, and to health and genetic testing requirements for broodstock transfers and seed imports.

Change to Species Composition

An increase in abundance and concentration of geoducks as a prey species in early life stages could enhance the abundance of predators in an area. Predator exclusion netting has been shown to be effective in reducing predation on seeded geoducks as well as reducing the increase in predators in areas following initial planting (B. Clapp, UHA, pers. comm.). The impact on surrounding native adult populations, which do not enjoy such protection, is thought to be low because most predators, other than the sea otter, do not target adult geoducks. The sea star *Pisaster brevispinus* also prey on adult geoduck but it has been observed that wild geoducks seem to have a faster response to *P. brevispinus* than cultured geoducks. If predator abundance increases after the seeding of an aquaculture tenure, there could be significant impacts on naturally recruited juveniles in the vicinity.

There are reports from fishermen of depleted geoduck beds where populations of horseclams or sea pens now dominate. In the event that a site is purged but the geoduck farm does not proceed, there may be a risk, therefore, of purged beds being re-populated by a different species. This could delay or prevent the recovery of geoduck populations by impairing the settlement and survival of geoduck larvae.

Sediment Structure and Meiofaunal Community Structure

Intensive geoduck harvest has been shown to have limited impact on substrate composition in small-scale subtidal studies (Breen and Shields 1983), and harvested sediments in larger studies returned to near normal conditions within weeks of disturbance (Goodwin 1979). Turbidity plumes associated with geoduck fishing have been shown to be small, short-lived and the amount of material that settles out of suspension from these plumes has no significant impact (Short and Walton 1992). Nonetheless, downstream impacts from intensive subtidal harvesting of farm operations may be a concern and should be monitored. Impacts to meiofaunal organisms by geoduck harvesting were investigated in one location on the west coast of Vancouver

Island. The study found no significant effect on the numbers of animals from harvesting activity, and the species diversity appeared to actually increase with the disturbance of harvesting activity (Breen and Shields 1983).

Indirect Impacts to Stock Conservation and the Existing Commercial Fishery

Concerns have been expressed that the harvest of cultured geoduck may not be subject to the same level of monitoring and controls as the wild commercial fishery. User-pay monitoring, such as third-party landing validation, may not be acceptable in farming operations with higher overhead investment in site development, tenure fees, crop seeding and infrastructure. Both governments and industry acknowledge, however, that effective traceability programs are required. An enforceable traceability ("chain of custody") program for cultured geoduck entering the market is required as a means to curtail illegally harvested wild geoduck from entering the market place. The incentive for poaching is high, given the high value of geoduck, and the lack of effective means to discourage poachers may ultimately threaten conservation and the wild fishery. Traceability is also important in order to ensure that bivalves entering the market have been harvested from approved growing waters and are not contaminated. Federal and provincial governments, along with shellfish growers and commercial harvesters, are actively engaged in discussions of options for acceptable traceability processes.

FRAMEWORK FOR THE DEVELOPMENT OF GEODUCK AQUACULTURE

The viability of subtidal geoduck aquaculture has not yet been demonstrated, albeit progress may have been impeded by the moratorium on subtidal aquaculture and the restriction of operations to FAN Seafoods. Nonetheless, the estimated grow-out time at the FAN Seafoods experimental sites was found to be greater than the original estimate of five years, and the eight to nine-year old clams are still not at optimum market condition. Eight years after the project initiation, FAN Seafoods has not yet planted all of their 87 ha with geoduck seed, due mainly to the inconsistent and limited availability of hatchery seed in BC to date.

National policies under the Aquaculture Policy Framework support Food and Agriculture Organization of the United Nations principles that aquaculture production augment or enhance but not replace wild fisheries. The impacts of tenuring the most productive wild geoduck beds and to purge fish a high percentage of existing wild stock, replacing it with hatchery stock, may be unacceptable. As a result, a means to facilitate the development of sub-tidal geoduck aquaculture in BC that minimizes impacts on the conservation of the wild population and the existing wildstock fishery is the most desirable from federal government's perspective.

A Phased Approach

Working with both the aquaculture and wild fishery industries, Federal and Provincial governments have agreed to a phased approach for geoduck aquaculture expansion in

2005. The lowest impact to wildstock conservation may be achieved by encouraging aquaculture development in beds where purge fishing may not be necessary because of earlier depletion by the fishery and/or beds where natural recruitment is irregular or rare. From a commercial fishery standpoint, the lowest impact may be achieved by targeting beds that do not form an important basis of the current fishery. The status of stocks in any given bed varies widely as a result of its individual inherent productivity and harvest history. In relation to commercial potential, beds can be grouped and ranked into the following categories:

1 – No or low natural geoduck populations, but bed may have the biophysical characteristics required for geoduck growth;
2 – Depleted beds and recovering slowly or not recovering;
3 – Beds that support geoduck populations and are open to the fishery, but not popular due to logistical or access challenges;
4 – Depleted beds and recovering quickly;
5 – Beds currently being harvested in the fishery.

Of these categories, the first three would have the least impact on both the commercial fishery and on stock conservation. Beds in Categories 1 and 2 would require no or little purging, therefore there would be minimal net loss to standing stock biomass. These beds currently do not contribute to the TAC. Category 3 beds may have quota available to the fishery, but are not regularly fished due to inconvenient access or other logistical constraints (e.g. distance from validation port). Beds that fall into Category 4 are either closed for recovery, or have a reduced quota, but are recovering from depleted states through natural recruitment; loss of these to the wild fishery would have future impacts to the fishery. Some of the most productive beds are currently closed for conservation and should not be viewed as candidates for aquaculture just because they are closed. Purging may be required in Category 3 and 4 beds. Category 5 includes beds that are productive and currently support the fishery. Purging would likely be required should Category 5 beds be allocated for aquaculture. Loss of these to the wild fishery would have immediate impacts to the fishery.

The classification of all commercial beds, using fishery and research data that considers recruitment and growth rates, carrying capacity and remaining density, harvest history and recovery rates, is underway in Stock Assessment programs. Along with the information that will begin to be collected in 2005 from bed by bed management, significant advances towards bed classification are expected.

In order to facilitate pro-active aquaculture expansion planning, the Underwater Harvesters Association (UHA) was invited to provide advice on initial categorization and identify potential sites in the Strait of Georgia for new sub-tidal aquaculture. Geographically, the Strait of Georgia is the logical place to begin this process because of the convenience of roads for access to farmers, markets, services and regulators; the north coast is largely remote, as is the west coast of Vancouver Island which, in addition, has growing populations of sea otters. Consultations among experienced Strait of Georgia fishermen took place, where harvesters were asked to use their collective experience and local knowledge to suggest locations with suitable substrate, low current densities of geoducks and a history of good quality geoduck harvest. Twenty-three geoduck beds or potential areas, with a total area of 550 ha, were proposed as candidates (Table 1, Figure 5) and are here used as examples to analyze the potential impacts of aquaculture expansion on the geoduck fishery.

Attributes of Example Beds

Only two of the candidate beds presented in the Table 1 have been surveyed for density or biological data, and hence estimates of area and biomass are largely based on harvest log data and extrapolations from surveys conducted at Marina Island and Comox Bar in the Strait of Georgia (Campbell et al. 1996a, 1996b). Estimates of bed area and virgin biomass are likely overestimated for many of the beds, as discussed earlier in the paper, and hence none of the suggested beds have been closed for conservation. However, advice from fishermen has resulted in the majority of beds not being allocated quota in the fishery in recent years.

Most of the beds can be classified into Categories 2, 3 or 4, as described above, according to input from fishermen and the knowledge of fishery management and stock assessment personnel. Beds in Statistical Areas 13 and 15 are the most heavily harvested and are considered to be depleted. The biological samples collected from the two surveyed beds (portions of Savary and Hernando Islands) were almost exclusively young juveniles, indicating that the beds are recovering from harvest. It is not unlikely that the other beds in these Statistical Areas would recover in time. The beds in Area 16 have not been allocated quota in the commercial fishery since 1999; they are logistically difficult to harvest in the commercial fishery because of the distance from designated landing ports to the fishing ground. The two commercial beds and some additional unharvested area in Statistical Area 29 were suggested because they are distant (therefore logistically difficult to harvest in the commercial fishery), and have either low densities or are entirely devoid of geoducks, even though the substrate is apparently suitable.

Portions of three beds front Indian Reserves, where appropriate consultations with the Sechelt and Klahoose First Nations would be required prior to consideration for tenuring for aquaculture. Three beds are seaward of intertidal sanitary closures, although the subtidal waters are not closed. One bed is within a sanitary closure, where all shellfish harvest is prohibited. A depuration process has not yet been proven for geoduck, nor a decontamination plan accepted under the Canadian Shellfish Sanitation Program at this time. The allocation of a geoduck aquaculture site in a closed contaminated area is not recommended until such time as there is an approved depuration process.

Three beds (five polygons) are located in the Baynes Sound Conditional Management Plan (CMP) area of west Baynes Sound and Deep Bay (portions of Subareas 14-8, 14-11, and 14-15) along the Vancouver Island shore. These have been closed to the commercial fishery because of inshore contamination concerns resulting from land drainage after high amounts of rainfall, and because of management challenges associated with fishery timing. They may be suitable for aquaculture, however, because farm operations are better suited to sampling regimes and managing harvests around rainfall closures. Two beds (four polygons) are in the subtidal area adjacent to the Baynes Sound CMP closures, and are closed to the fishery. Further investigation is required to determine if these bed closures are a result of risk management, a lack of water classification or product sampling for contamination, or for other reasons.

Impacts of Example Beds on Current Assessment and Management Framework

In summary, these sites are presented as examples and would require further verification and examination by potential aquaculture applicants. Alienation of any of the suggested geoduck beds from the commercial fishery through re-allocation to the aquaculture industry would be reflected in adjusted quota options simply by the removal of the beds from the inventory used to estimate the biomass available for harvest. The limit reference point of 50% virgin biomass would not be approached in the southern Inside Waters Region through alienation of the subtidal land described in the 23 example beds and, in essence, the commercial fishery would be minimally affected by the selection of any of these.

DISCUSSION

Geoduck aquaculture has the potential to become a viable new industry that can provide new employment opportunities in BC. Additionally, aquaculture may provide some benefit to the wild fishery by enhancing recruitment and yields, and farmed geoducks may help the marketing of wild geoducks by maintaining a consistent supply of product to world markets. However, there are several ways in which geoduck aquaculture could negatively impact natural stocks and the commercial fishery, although none have been directly assessed. Potential impacts include reduced genetic fitness, transmission of disease, increased numbers of predators, competition for food, and habitat impacts. Because of these unknowns, and to accommodate the risk and uncertainty related to the stock status of natural geoduck populations, aquaculture development should be controlled and fully integrated in the geoduck stock assessment and management frameworks. Geoducks are long-lived animals and negative impacts on populations may be slow to detect.

Site-selection criteria, established through a system of commercial bed categorization, could be used to minimize impacts on wild populations and the existing geoduck fishery by choosing from among Categories 1 to 4; beds with low biomass that do not currently support commercial harvest. Selection from the list of beds and areas suggested by the UHA, and presented as example sites for early development, could provide a low-impact head-start to aquaculture planning. In particular, there may be potential for successful aquaculture in areas where natural juvenile settlement and survival is poor, possibly due to periodic low salinity conditions to which larvae and early juvenile stages are sensitive.

In order to promote integrated and sustainable geoduck aquaculture and commercial fishery industries in BC, an adaptive management approach should be adopted where aquaculture expansion opportunities are used to facilitate the development of sound procedures and the collection of information. One of the largest areas of concern and uncertainty is the genetic implications of geoduck aquaculture. The introduction of dense beds of cultured geoducks, which may be reproductive for several years before being harvested, will almost certainly lead to increased juvenile settlement in nearby beds or possibly over larger expanses. The magnitude of the risks of genetic pollution and loss of genetic fitness would, in part, be influenced by broodstock collection and hatchery practices. Research to understand the implications of loss of genetic fitness resulting from successful reproduction of farm animals and interbreeding of seeded geoduck and wild populations should be a priority.

Questions remain about how large tenures should or need to be, or how many sites are required for optimum industry development. Decisions on the spatial distribution of aquaculture tenures would require a better understanding of geoduck recruitment dynamics. For instance, knowing whether it is better to concentrate aquaculture operations in one or a few areas in order to restrict the extent of genetic impacts, or to have farms distributed evenly within a Region in order to dilute the potential effects would depend on an understanding of the environmental conditions that affect spawning, advection and survival of larvae and larval dispersal patterns. In particular, work towards identifying source populations, those characterized by age-structures with good representation of different age classes and hence frequent successful recruitments, would greatly help in recommendations for future siting of aquaculture or enhancement activities. Non-source populations (sinks) can be harvested or alienated with fewer repercussions on the metapopulations. As more survey and biosampling data are collected, these source beds can be identified. A network of larval collectors set up in different habitat conditions would provide information on the distribution and frequency of larval settlement.

Besides ongoing work to improve the estimates of geoduck biomass and distribution, the geoduck stock assessment program is currently working towards clustering and classifying the commercial beds according to stock status and productivity. Project results will provide information on existing geoduck beds that will aid in the selection of future aquaculture sitings, specifically by assigning beds to one of the five categories of stock status described earlier.

Research is required on the benthic impacts of both subtidal and intertidal geoduck culture. Standards need to be set for monitoring habitat impacts and conducting habitat assessments which should consider harvest and culture techniques. Data submission standards are also required, and a data repository established for future assessments.

RECOMMENDATIONS

1. **Incorporate impacts of aquaculture into the assessment and management frameworks for management of wild stocks of geoducks.**
   - Additional mortality as a result of purge fishing needs to be considered in the application of the 50%B_0 limit reference point.
   - There are implications to consider of the potential contributions to biomass that a spawning population of cultured geoduck may make in the future.

2. **Develop a phased approach to geoduck aquaculture expansion that will allow the collection of information on genetic impacts of cultured stock on wild populations and disease issues as they relate to transfer and transplant of these animals.**
   - Genetic protocols, monitoring systems and policies for the management of the lineage and out-planting of offspring from cultured geoduck need to be developed.
   - Collaborative work with the aquaculture industry, the UHA and the Provincial government is needed in order to develop monitoring systems, collect data, evaluate habitat and ecosystem impacts, set policy and standards and implement control systems.

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Table 1. Commercial geoduck beds recommended by the UHA for aquaculture development, with comments and categories added.

Site #	Stat Area	Sub Area	Bed Code	Description	Area (ha)[1]	Portion of Bed Area	Estimated Biomass (lb)[2]	Historical Landings (lb)[3]	# Yrs Fished	Last Fished	# vessels	Annual Quota (lb)	Cat.[4]	Comments
1	13	13	3	Open Bay, Quadra	16.05	1.00	277,664	43,859	6	2003	6	2,777	2/4	
2	13	14	1	S of Rebecca Spit	54.54	0.78	875,714	48,984	7	2003	10	8,757	2/4	
3	13	16	2	Cortes Is – Plunger Pass	4.49	0.39	72,411	16,088	8	2003	8	724	2/4	
4	14			W Baynes and Deep Bay (2 beds)	26.9	1.00		46,832	9	2003	12	n/a	-	Beds no longer in fishery due to sanitary closure concerns
5	15	2	4/2	Manson Pass./ptn. Savary Is.	89.11	1.0/0.07	1,333,743	56,475	15	2003	21	13,337	2/4	All of one bed and portion of another. Surveyed 2004; results not yet available. Some recruitment
6	15	2	2	Savary Is, S coast	71.04	0.19	772,402	99,704	15	2003	21	7,724	2/4	Seaward of existing FAN site
7	15	3	6	Hernando Is, S coast	65.47	0.67	1,787,899	98,059	10	2003	13	17,879	2/4	Surveyed 2004; results not yet available. Some recruitment
8	15	5	1	Cortes Is, Squirrel Cove	34.79	1.00	544,006	155,660	8	2003	18	5,440	2/4	Northern third of bed fronts IR
9	16	5	1	Poropoise Bay, head	37.20	1.00	468,045	118,262	4	1999	10	4,680	3	Intertidal sanitary closure; subtidal ok, Small portion on west side fronts a small IR
10	16	5	2	Sechelt Inlet	7.80	1.00	98,189	4,609	3	1999	3	982	3	Intertidal sanitary closure; subtidal ok
11	16	5	3	Angus Creek	11.03	1.00	138,740	9,576	2	1999	3	1,387	3	Intertidal sanitary closure; subtidal may be OK A portion of the bed fronts IR
12	16	11	1	btwn Saltery & Thunder Bay	13.59	1.00	211,897	3,189	2	1999	3	2,119	3	
13	16	11	2	Saltery Bay	11.48	1.00	179,125	16,363	3	1999	4	1,791	3	Small portion of bed in the sanitary closure
14	16	11	3	Copper Island	2.57	1.00	40,071	2,752	1	1979	1	401	3	Assessment - reason for low use [5]
15	16	11	4	Scotch Fir to Thunder Pt	9.95	1.00	155,136	6,636	2	1999	4	1,551	3	
16	16	11	5	Thunder Bay	10.95	1.00	170,781	7,572	2	1999	2	1,708	3	Most of bed in the sanitary shellfish closure[6]
17	16	11	6	btwn Ball Pt & Alexandra Pt	3.81	1.00	59,350	212	1	1999	1	593	3	Reason for low use needs assessment [5]
18	16	16	1	Telescope Passage	6.28	1.00	97,908	19,965	1	1980	1	979	3	Reason for low use needs assessment [5]
19	16	16	2	SW corner of Hardy Is	2.63	1.00	41,022	106	1	1999	1	410	3	Reason for low use needs assessment [5]
20	16	17	2	S Nelson Is	19.80	0.85	320,038	7,335	2	1999	3	3,200	3	
21	29	1	2	Trail Islands	23.38	1.00	318,803	16,483	3	1988	4	3,188	1/3	Reason for low use needs assessment [5]
22	29	1	3	Wilson Creek	27.33	1.00	372,575	6,324	2	1988	4	3,726	1/3	Reason for low use needs assessment [5]
23	29	1		south & east of Trail Island beds	Not a commercial bed							n/a	1	No commercial history, but good substrate.
	Total				550.19		8,335,519	785,045				83,355		

[1] May be only a portion of the bed

[2] Product of density, area and average geoduck weight.

[3] Where only a portion of a bed is proposed, the recorded landings are proportionally reduced; assumes equal distribution of harvest over whole bed

[4] Category 1 – no or very low natural geoduck populations but may have required biophysical characteristics for growth.
Category 2 – depleted beds and not recovering
Category 3 – open beds in the fishery but not regularly fished due to access or other logistical challenges.
Category 4 – depleted beds but recovering
Category 5 – beds currently being harvested in the fishery.

[5] Bed area or landings may be inaccurate, density low, quality poor, etc.

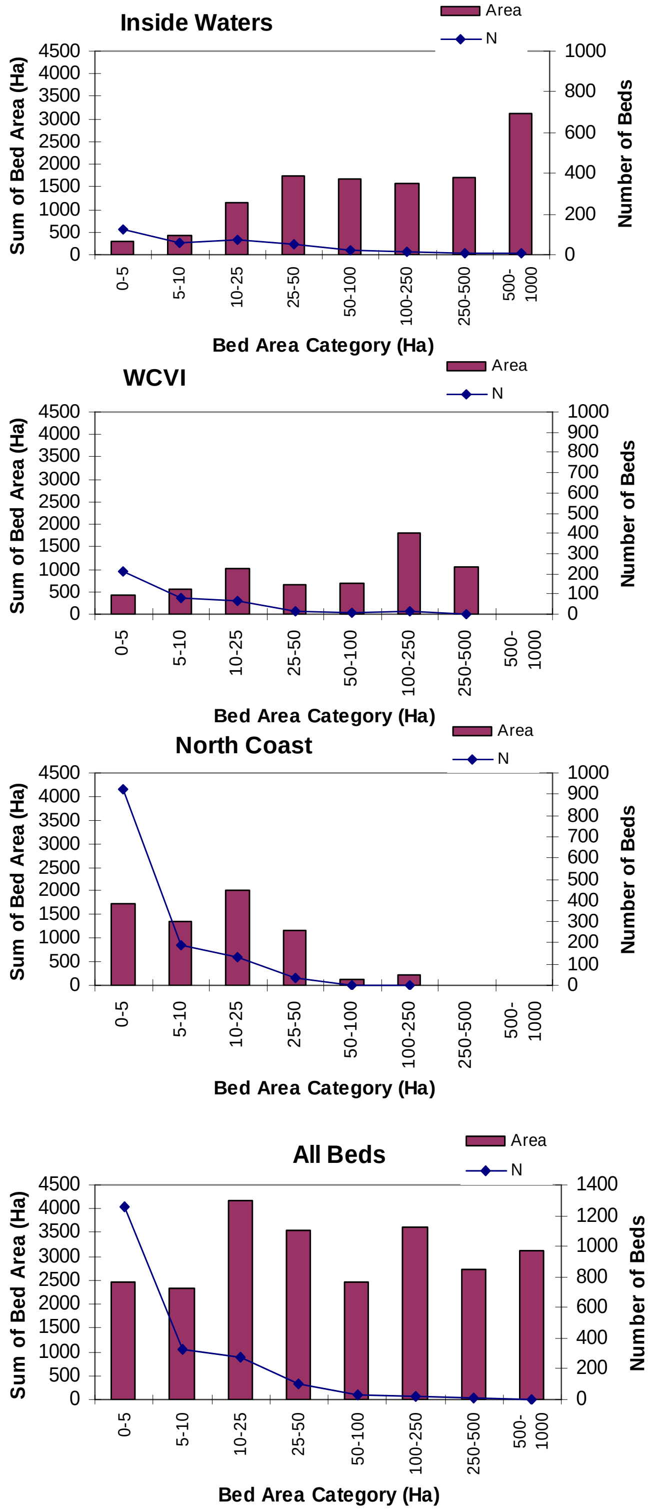

Figure 1. Frequency distribution of number and size of geoduck beds by bed-size category and Region.

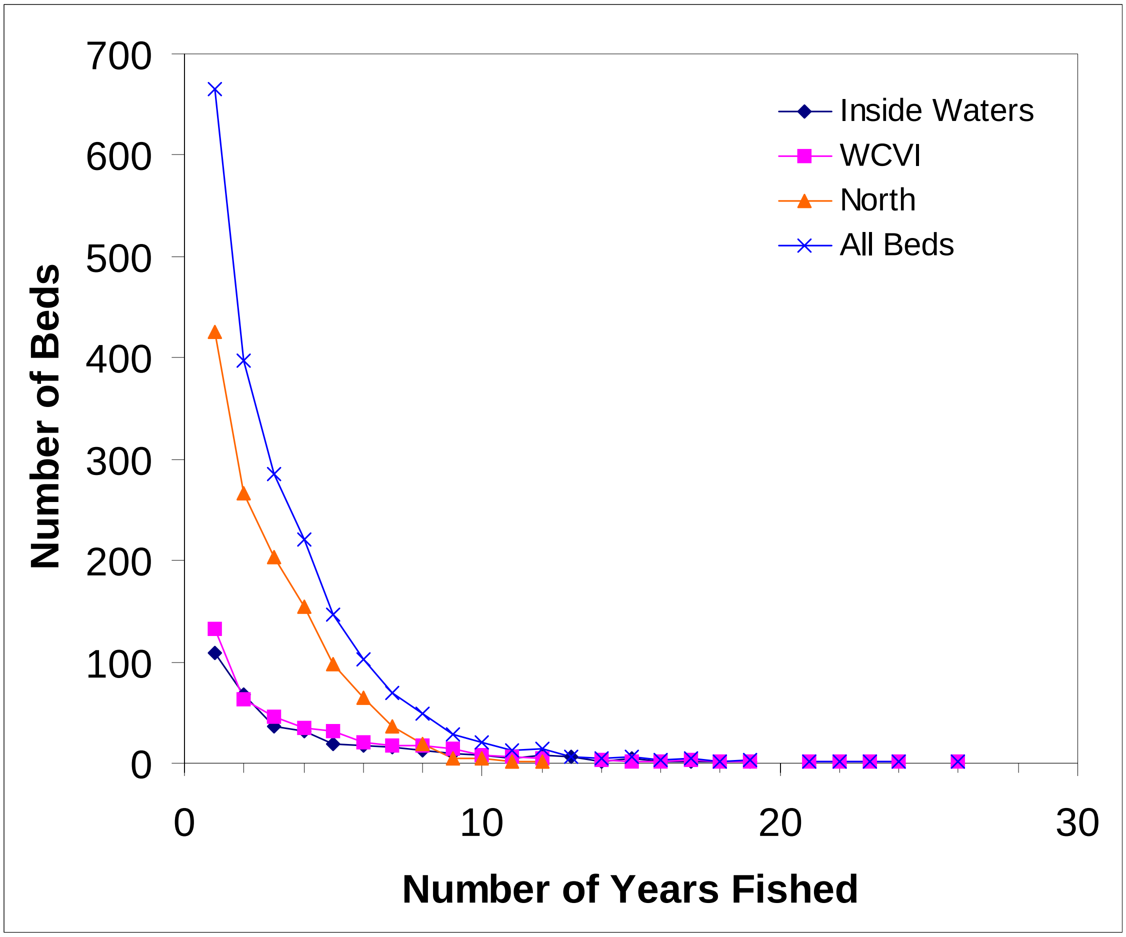

Figure 2. Frequency of number of years that commercial geoduck beds have been fished, by Region.

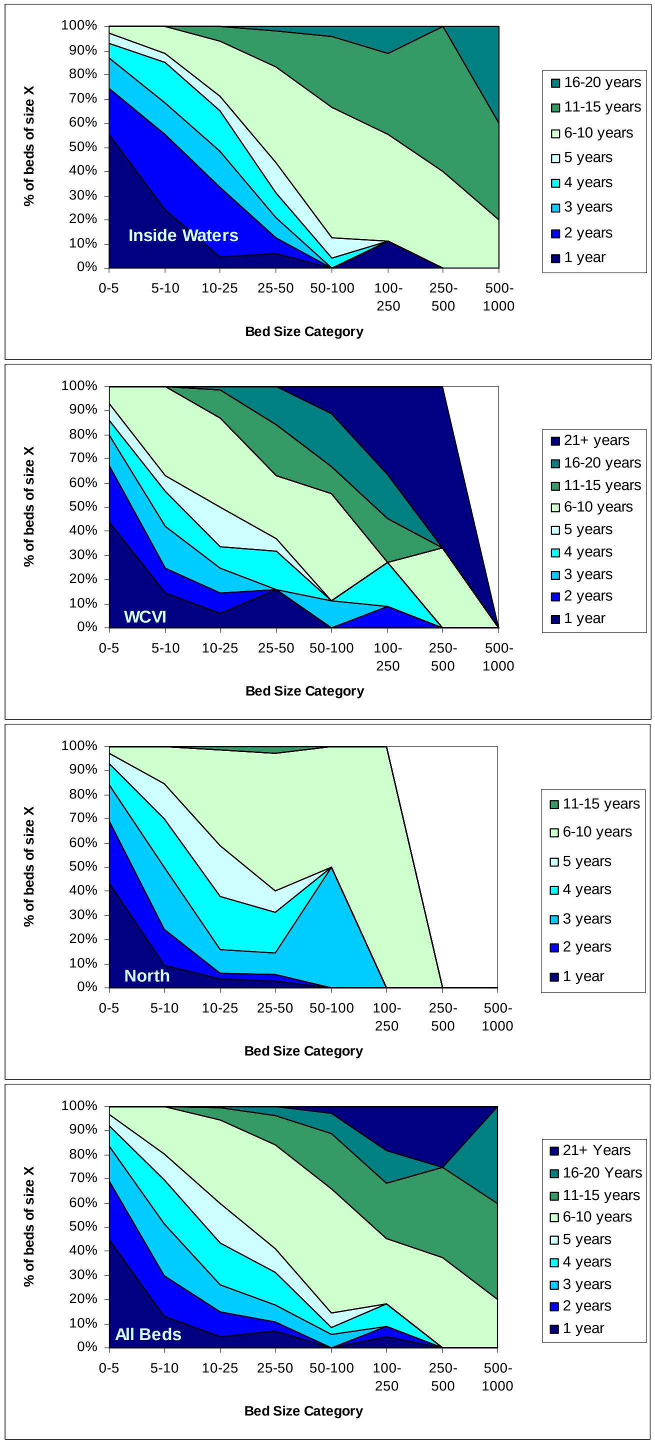

Figure 3. Proportion of beds of different size categories that have been fished for different number of years, by Region.

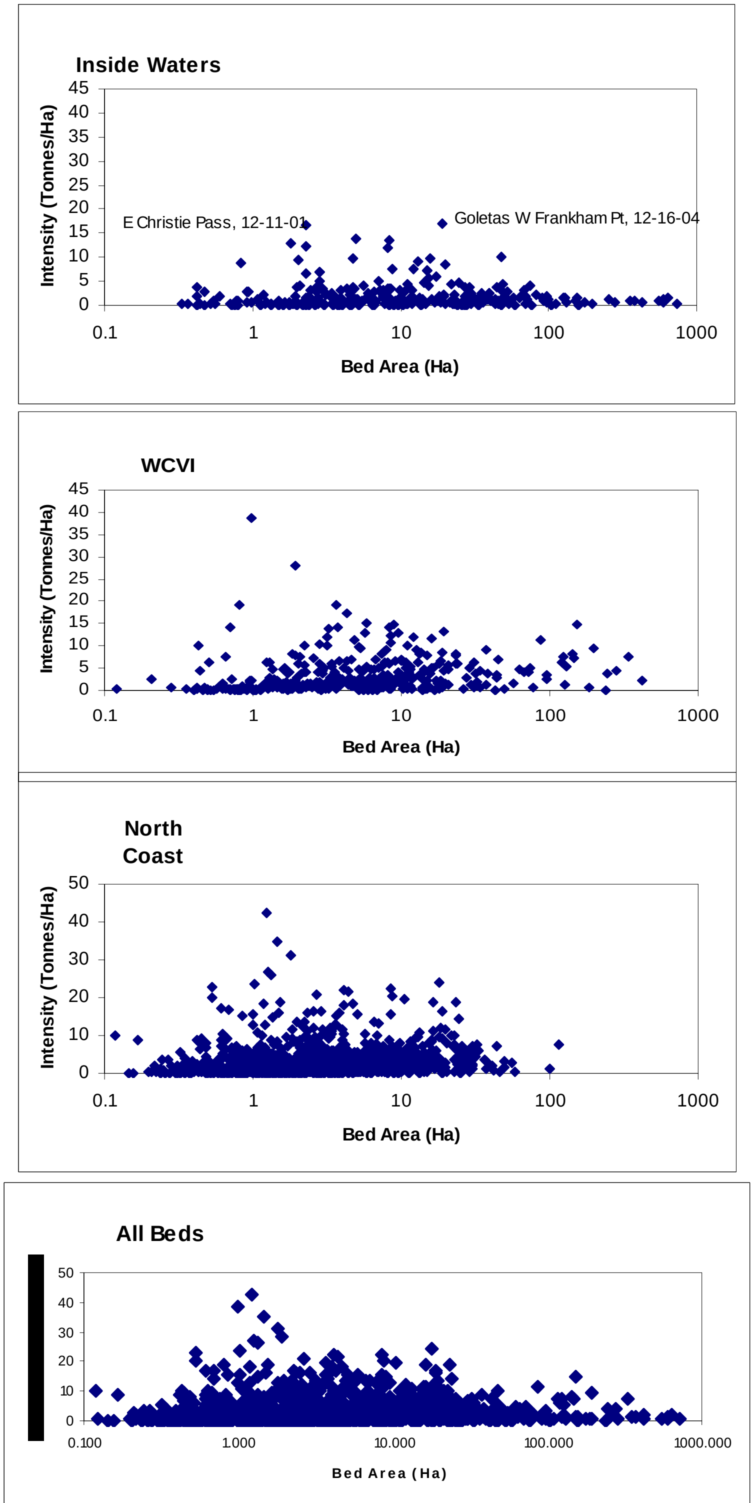

Figure 4. Geoduck harvest intensity in tonnes fished per hectare, by bed area and Region.

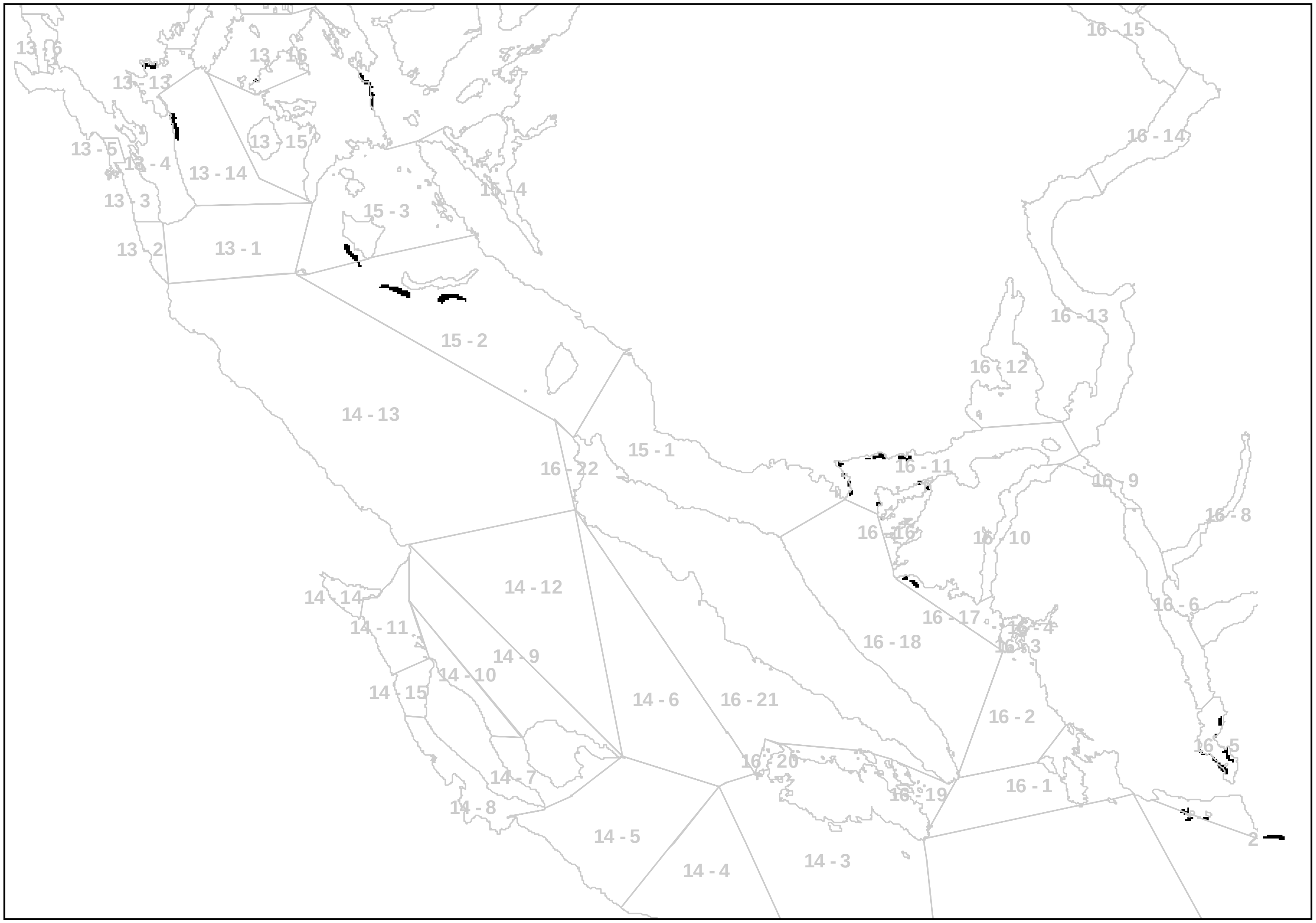

Figure 5. Areas recommended for aquaculture development by the Underwater Harvesters Association.

Appendix 1. Request for Working Paper.

PSARC INVERTEBRATE SUBCOMMITTEE

Request for Working Paper

Date Submitted: **August, 2004**

Individual or group requesting advice:

- Harpreet Gill- Aquaculture Division, K. Marcus, R.Harbo, S. Heizer, J. Rogers- Resource Management; in support of requests from the province of B.C., the Underwater Harvester's Association and companies/individuals interested in the development of subtidal and intertidal geoduck aquaculture

Proposed PSARC Presentation Date: November 2004

Subject of Paper (title if developed): Implications of geoduck aquaculture on the conservation of wild geoduck populations and the harvestable TAC in British Columbia.

Science Lead Author: Claudia Hand

Resource Management Lead Author: Kerry Marcus

Rationale for request:

- There is considerable interest from the province of BC and the aquaculture industry to expand geoduck culture beyond the existing few experimental sites. The department and the province have committed to developing policy for expansion of geoduck culture by early 2005.
- The conservation of wild stocks must be considered in the development of geoduck aquaculture.
- A proactive approach to planning for geoduck aquaculture has been adopted, with DFO (in consultation with wild harvesters, the province of B.C. and prospective aquaculturists) recommending new areas (sub-tidal and inter-tidal) for culture that will minimize conservation risks and industry conflicts.
- Ideally, DFO wishes to categorize all beds according to the best information available. This coastwide work will not be completed in time for the first phase of expansion, and industry advice will be sought to identify some potential sites. The categories suggested are as follows: :
    a. Category 1 – no natural geoduck populations but may have required biophysical characteristics for growth.
    b. Category 2 – depleted beds and not recovering
    c. Category 3 – depleted beds but recovering
    d. Category 4 – open beds in the fishery but not regularly fished due to access challenges
    e. Category 5 – beds currently being harvested in the fishery.
- Given the interest of existing shellfish farmers in species diversification through the addition of geoduck to existing operations, a scientific assessment of this

activity on wild geoduck populations is required.
- A proactive approach will support the orderly development of a geoduck aquaculture industry.

Objectives of Working Paper:

- Examine the conservation issues for wild stocks as a result of the alienation of geoduck habitat and the intensive removal of wild geoducks prior to seeding on tenures.
- Identify information gaps and recommend a framework for collection to assist with developing (a) precautionary guidelines and biological reference points to maintain sustainable geoduck stocks and (b) assess the impact of intertidal and subtidal geoduck culture activities on the ecology and species complex in an area.
- To document known biophysical requirements for geoduck culture , known genetic/biodiversity concerns and potential mitigation measures in the initial phase of geoduck aquaculture development
- To assess the proposed approach of categorising beds, impact on geoduck conservation, and calculation of the harvestable TAC by undertaking culture activities ;
- To provide advice on specific areas for new subtidal geoduck aquaculture opportunities on impacts to geoduck conservation, and calculation of the harvestable TAC;
- Update the geoduck stock assessment framework to account for geoduck aquaculture areas in calculating the harvestable TAC.

Question(s) to be addressed in the Working Paper:

GEODUCK BIOLOGY

- What are the biophysical requirements for geoduck recruitment success and growth/productivity (literature review in BC and WA; unpublished DFO data)?
- What is known about the recruitment patterns and growth characteristics of individual beds in different areas of coastal BC, from published/unpublished survey and biosample data and as reported by harvesters and on-grounds monitors?
- What is known about the size and age of reproduction for wild geoducks and cultured geoducks? What is the likelihood that seeded geoducks and/or remnant wild geoducks can successfully spawn before they are farm-harvested?
- Identify what is currently known about the genetics of geoducks? Initial results of studies have suggested that geoducks showed more genetic differentiation than other invertebrates (abalone, red sea urchins).
- Are there areas that do not currently have wild geoduck populations, but could support seeded stocks? What studies have been undertaken by DFO and the UHA in areas that do not support geoducks?

WILD GEODUCK POPULATIONS

- What is the estimated population size and total bed area in BC, by region (north coast, northern and southern inside waters, west coast of Vancouver Island)?
- What is the long-term effect of geoduck removal, by both the wild fishery and aquaculture industry (through purging) on the abundance of geoduck stock of

optimal reproductive ages through-out BC and within discrete areas?
- What is known of the deep stocks and whether these populations contribute to recruitment?
- What is the scale of area that we are concerned about for recruitment that may be impacted by loss of habitat to aquaculture?

IMPACTS OF AQUACULTURE ON WILD GEODUCK CONSERVATION
- Describe stock assessment framework currently applied to the wild fishery for sustainable management
- What are the conservation issues surrounding the loss of productive (active) or documented fishing area and the loss of the wild populations through pre-seeding harvest (purging)? How will the loss impact the current stock assessment framework and estimates of biomass for each “category” of geoduck bed?

PHASED GEODUCK AQUACULTURE DEVELOPMENT THROUGH SITE SELECTION
- What advice on bed categories and a phased approach can be made for aquaculture in new areas (sub-tidal and inter-tidal) that will minimize conservation risks and potential industry conflicts?

Stakeholders Affected:
- Geoduck fishers, particularly commercial fishers, due to alienation of harvestable geoduck beds as they are converted to aquaculture.
- BC Shellfish Growers Association, First Nations groups and other interested parties are anxious to obtain tenures to culture geoduck.

How Advice May Impact the Development of a Fishing Plan:
- Where tenures overlap existing fishery areas, the tenured areas will be removed from the fishing plan and the harvestable TAC adjusted.

Timing issues related to when Advice is necessary:
- Commercial aquaculturists and the Province of BC are extremely anxious to develop and expand a competitive geoduck culture industry, fearing that Washington State and Alaska may out-compete the development of a BC industry.
- There is considerable risk that further delays by the Department to address geoduck culture issues will result in the province tenuring geoduck culture areas without the department’s input.
- The Department and provincial authorities have committed to providing opportunity for geoduck culture expansion by early 2005. A draft strategy for the first phase of development is required by Dec 2004.