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From cannery to culinary luxury: The evolution of the global geoduck market

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ABSTRACT

The global geoduck market evolved substantially over the past four decades. This paper identifies the key transitional periods and discusses the catalysts that contributed to the evolution of the global geoduck market since its commercial inception during the 1970s. Specifically, this paper focuses on how the transition to rights-based fisheries management in Canada's wild geoduck fishery fostered changes in product form and ex-vessel prices that impacted the entire wild geoduck industry. This evolution in turn facilitated the emergence of intertidal and subtidal geoduck aquaculture, which led to further changes in the global geoduck industry including changes in: sources of supply, volume of production, trade patterns, primary markets, preference for product attributes, and fishery value. The global geoduck industry is still evolving, and this paper identifies and discusses the key drivers and constraints facing the market as it moves forward.

1. Introduction

The geoduck's ascent to a globally-traded luxury commodity is an interesting tale of evolution and expansion in an industry that didn't commercially exist prior to 1970.[1] This paper chronicles the development of global geoduck industry and identifies the key catalysts that influenced the progression of the industry. In many ways, the evolution of the global geoduck industry follows a path that has been predicted by theory and observed in practice in other open access and regulated open access fisheries that have transitioned to rights-based management systems [2–11]. The shift from regulated open access to rights-based management in the Canadian wild geoduck fishery alleviated many of the economic and biological inefficiencies that previously prevailed. However, this shift in fisheries management did more than just improve the economic and biological performance of the Canadian wild geoduck fishery. Rather, it also had the added effect of fundamentally and permanently altering the global geoduck industry, ushering in major changes in product form and ex-vessel prices that affected the entire global geoduck industry. This evolution in turn served as a catalyst for another major transition in the global geoduck industry—the emergence of intertidal and subtidal geoduck production. This new source of production itself fostered additional changes in the global geoduck industry. Market interactions emerged between wild and cultured geoduck, altering key aspects of the global market, including: sources of supply, volume of production, trade patterns, primary markets, preference for product attributes, and fishery value. In general, the degree of market interaction between wild and farmed species can vary depending on a variety of factors including the market size and structure, the availability of substitute species, biological and/or regulatory constraints on the supply of the wild species, biological and/or regulatory constraints on the supply of the farmed species and the actual or perceived differences in product attributes [12,13]. However, unlike the predictions of Anderson (1985) and Asche et al. (2001), the emergence of farmed geoduck production has not led to a decrease in price, despite a continued increase in the global supply of geoduck (Fig. 1). Rather, to date, the global market has absorbed this expansion in supply and prices have steadily risen. Looking forward, this paper identifies and discusses the key drivers and constraints facing the global geoduck market.

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[1] It is worth noting that the U.S. Pacific Northwest Tribes harvested geoducks for centuries prior to the establishment of commercial geoduck fisheries during the 1970s. Geoducks and other shellfish were commonly harvested for subsistence and/or ceremonial purposes [1].

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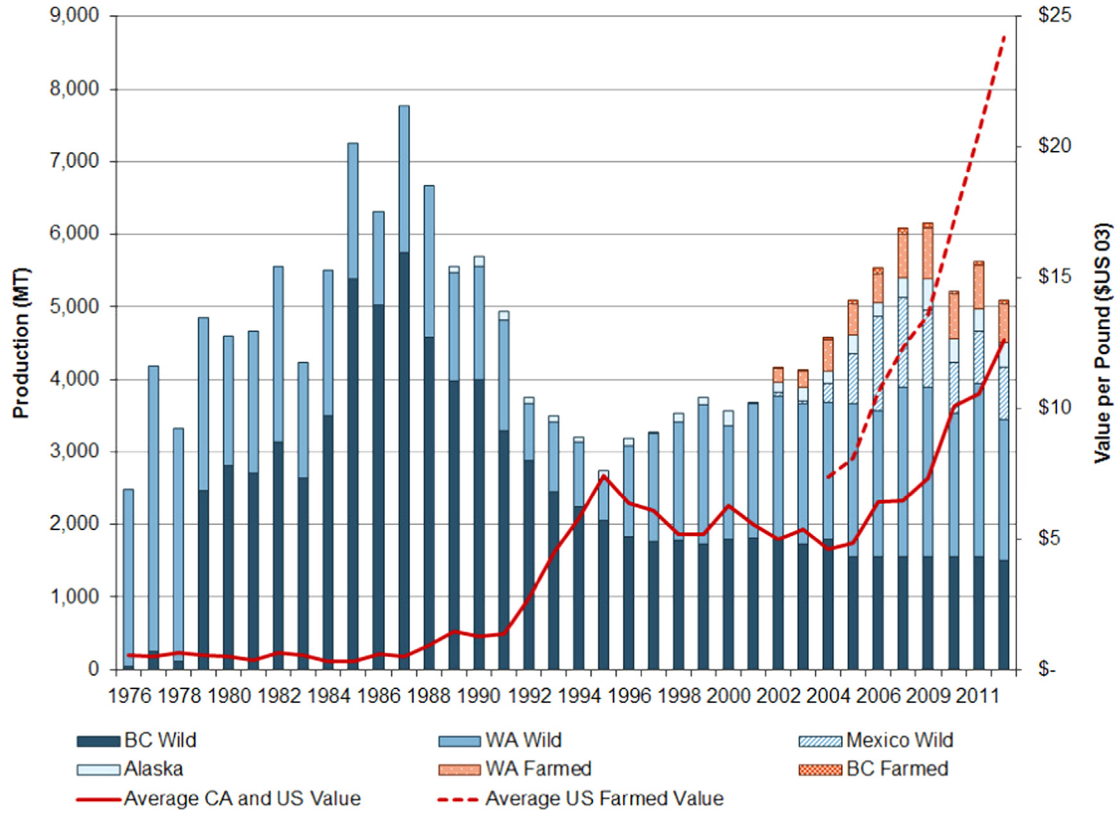

Fig. 1. World Production and Value of Geoduck by Country, 1976–2012.
Source: Washington Department of Natural Resources, NEI Calculations based on Aggregate WDFW Quarterly Farm Reports and Fish Ticket Data, Statistics Canada, Alaska Department of Fish and Game.

2. Background

The Pacific geoduck (*Panopea generosa,* Gould, 1850) inhabits both intertidal and subtidal substrates along the Northeast Pacific coast from Alaska to Baja California [14,15]. The name of this invertebrate, pronounced "gooey-duck", is derived from the Nisqually Indian word *gweduc,* which means "dig deep", a fitting name for the world's largest burrowing clam [16]. Since geoducks burrow extensively, they develop elongated siphons that can grow up to 1 m in length [17]. Their siphons are a culinary luxury in markets including China, Japan and Korea [18]. The meat is consumed either raw or cooked, depending on the country. In sushi restaurants, geoduck may appear on the menu as "*mirugai*", "giant clam", "long necked clam", "jumbo clam" or "horseneck clam" [15]. In China, geoduck is a central ingredient in the traditional and communal dish of hot pot, which is similar to fondue [18]. A single, live, top-grade geoduck can be sold for upwards of $100–$150 USD/lb in Asian retail markets [19,20].

3. Origin and evolution of the global geoduck market

The commercial harvest of geoduck was nonexistent prior to the 1970s. In 1967, a Navy diver discovered subtidal geoduck colonies near Puget Sound while searching for lost torpedoes [16,20,21]. Prior to this discovery, Washington State limited geoduck exploitation to recreational harvest on intertidal land due to overfishing concerns [21]. Following the discovery of substantial subtidal geoduck populations in Puget Sound, the Washington Legislature established a commercial wild geoduck fishery in 1970. In 1976, a commercial wild geoduck fishery was established in British Columbia, and in 1983, a commercial wild geoduck fishery was established in Alaska.

3.1. Phase one: the boom (1976–1988)

After the establishment of commercial wild capture geoduck fisheries in Washington, Canada and Alaska, global geoduck landings expanded rapidly, reaching a peak in 1988 (Fig. 1). Washington and British Columbia dominated global geoduck production during this phase. Starting in 1976, Canada's Department of Fisheries and Oceans (DFO) issued seven permits which allowed the holder the right to harvest geoduck from specific areas in the Strait of Georgia [22,23]. Aside from the restrictions on the depth of harvest, area of harvest and type of stinger,[2] there were no restrictions on the amount of geoduck landed per permit [22]. In 1977, DFO began issuing licenses to those interested in participating in the geoduck fishery. Between 1977 and 1979, the number of licenses issued increased from 30 to 101; however, the fishery continued to operate without any limits on landings [23]. As would be expected, landings increased rapidly during this phase of the fishery. Concerned about the rapid increase in effort and landings in the fishery, DFO placed a moratorium on new licenses in 1979 [22,23]. At the same time, the fishery transitioned to a limited-entry fishery with total allowable catch (TAC) restrictions to limit overfishing [22,23]. This type of fishery is sometimes referred to as a shotgun or derby-style fishery [2,22,24]. When

[2] The commercial harvest of geoducks, either subtidally or intertidally, typically involves the use of a stinger or high pressured water jet. Both wild and cultured geoducks are harvested using this method. The stinger liquefies the substrate surrounding the geoduck, allowing the harvester to extract the entire animal intact.

operating in a derby-style fishery, participants have the economic incentive to harvest large quantities of geoduck in a relatively short period of time before the TAC is reached and the fishery is closed.[3] Individually, each participant is attempting to maximize the number of fish caught; however, this behavior is neither economically nor biologically optimal for the fishery. While this change in fisheries management attempted to address biological concerns, it exacerbated economic inefficiencies including overcapitalization and excessive effort [22]. Furthermore, the quantity of geoduck landed, coupled with the dominant product form supplied to the market (canned or frozen) during this phase of the industry, served to depress ex-vessel prices (Fig. 1). During the early years of the fishery, geoducks were primarily consumed locally for meager prices. Sold for five to ten cents per pound, local chowder canneries purchased geoducks and the meat was used in the clam chowder served on Seattle ferries [25,26]. A partnership with a Japanese–American during the 1970s helped establish the steady export of geoduck into Asian markets, including Japan and China [16]. By the 1980s, there was a steady demand for geoduck in China, while demand in Japan waned as its economy faltered [25]. Despite the changes in the management of the fishery during early 1980s, the biological sustainability of the fishery was in question. Demand for the product was strong and the 'race to fish' still pervaded the fishery. Geoduck landings in Canada exceeded the TAC for the five year period 1984–1988. The sum of landings over this period exceeded the sum of the TAC by 34% [22]. In one year, harvests exceeded the TAC by 80% [27]. Thus, the change in fisheries management, from open-access to limited-entry with a TAC did little to change the underlying economic incentives facing fishermen. As such, geoduck landings were high and ex-vessel prices were low during this phase of the industry (Fig. 1).

In contrast to the rapid expansion of the Canadian geoduck fishery, wild harvests in Washington have been more stable since the inception of the industry due to the manner in which that fishery is managed. The Washington fishery is managed under a rights-based fisheries management regime where a TAC is established and then subdivided in the fishery via an auction process, creating a right to fish a certain quantity of geoduck in the fishery. The fishery is managed jointly by the Washington Department of Natural Resources (WDNR), Washington Department of Fish and Wildlife (WDFW), and the fifteen Native American tribes of the Puget Sound Treaty (Tribes), who have the right to 50% of the harvestable surplus of geoducks from the state. Together, these entities assess the biological health of geoducks and establish a TAC for the fishing season. Since 1997, Washington has managed the fishery through a deterministic age-structured equilibrium yield model. Based on this modeling framework and the extensive sampling of discrete geoduck 'tracts', the annual TAC is set to be 2.7% of the commercially available geoduck biomass [28]. Half of the TAC is allocated to the Tribes, while the other half is auctioned off to non-tribal entities. WDNR manages the public auction of commercial geoduck Harvest Agreements, which grant the holder the right to remove a designated number of pounds of geoducks from a specific area up to the stated Harvest Ceiling limit. WDNR "reserves the right to increase or decrease the Harvest Ceiling at any time during the Harvest Agreement to ensure that total pounds harvested from state-owned aquatic lands for the year meet the state's target sustained yield, and to ensure that the geoduck industry has an opportunity to harvest the state's share of the resource"[29]. The Harvest Agreement specifies a harvest period that is roughly three months long. Approximately four times a year current members of the geoduck industry and prospective bidders are invited to submit sealed bids for each quota available at the public auction. Accompanying the sealed bids must be a bid deposit in the form of a money order, certified check, or cashier's check equal to $100,000 for each of the quotas [29].

The money from the auctions supports programs run by WDNR and WDFW. Half of the proceeds goes into the Aquatic Lands Enhancement Account (ALEA) which fosters public access to state-owned aquatic lands and restores native aquatic habitat while the other half supports the management and protection of these lands [30]. WDFW estimates that the state generates $22 million USD annually auctioning these fishing rights [28]. WDNR budget data indicates that geoduck auctions provided nearly 9.8 percent of all WDNR revenues in FY 2014 [31].

3.2. Phase two: management-driven market evolution (1989–early 1990s)

In an effort to address the undesirable biological and economic inefficiencies associated with its derby-style fishery, the Canadian geoduck industry transitioned to a rights-based system at the behest of the industry in 1989. This transition is a notable development worth emphasizing since the impetus for this change came from the fishing industry itself. Often there is resistance to rights-based fisheries management regimes from the fishing industry, despite the demonstrated improvement in the biological and economic performance of the fishery [3,6,32–36]. Since 1989, the Underwater Harvesters Association (UHA) and Canada's Department of Fisheries and Oceans (DFO) have co-managed the fishery. At that time, individual vessel quotas (IVQ) were implemented, dividing the designated TAC equally among IVQ holders [22,37]. The 55 holders have an equal share of the TAC set by DFO and UHA, which is calculated as 1% of estimated biomass [38]. Those possessing an IVQ have the right to harvest a set portion of the Canadian quota at any time during the harvest season.

Following the shift to IVQs in the Canadian geoduck fishery, economic performance in the fishery improved; however, improvements in the performance of this fishery had spillover effects that impacted the entire global geoduck industry [22,23]. The reasons for the improvements are varied and interrelated. The shift to IVQs led to a number of changes on the supply-side of the market. Since 1989, the TAC in Canada has contracted 61% (Fig. 1). This reduction in supply led to upward pressure on ex-vessel prices. As predicted by economic theory and as demonstrated in practice, the transition to rights-based management systems alleviates the 'race to fish' and leads to longer season lengths and harvests that are spread throughout the year [4,5,10,35,39,40]. Under the IVQ system, Canadian divers now had the economic incentive to slow the speed at which they harvested geoducks in an effort to improve the quality and value of their landings [22]. Following the introduction of IVQs, a major shift in exported product form occurred. In 1989, 26% of Canadian geoducks were classified as processed fresh or live and by 2006, live geoducks represented 99% of Canadian landings [41]. This shift in product form was not exclusive to Canada's wild geoduck fishery. Detailed export data for the US were not available prior to 2000; however, data for 2000 show that live exports represented less than 1% of US total exports of geoduck. Two years later, live exports represented 76% of total exports, and by 2009, live exports represented 99% of total exports [42]. This shift in product form, coupled with a decline in global geoduck landings over the period 1989–1994 helped increase the average ex-vessel price received (Fig. 1).

In 1994, there was another change in the global geoduck market. It was during this year that the Rafeedie decision "affirmed and quantified the Puget Sound Treaty Tribes' right to 50 percent of the harvestable surplus of geoducks within their usual and accustomed grounds and stations" in Washington State

[3] Within the Washington State fishery, tribal groups occasionally hold shotgun fisheries to support tribal functions.

(United States v. Washington, 873 F. Supp. 1422 W.D. Wa 1994 and United States v. Washington, 898 F. Supp. 1453 W.D. Wash. 1995). Following the adoption of the Rafeedie decision, landings in Washington increased steadily. Since 2001, geoduck production in Washington has exceeded geoduck production in Canada (Fig. 1).

Up to this point, the geoduck narrative has focused on production primarily in Washington and Canada. The reason for this is that as a share of the geoduck market, Alaska accounts for approximately 5% of global annual production (Fig. 1). Historically, the Alaskan fishery has been handicapped by its relative remoteness and the lack of sufficient infrastructure to reliably transport a live product to market. As such, the industry often exported prepared siphon meat, a product that receives a lower price per pound relative to an exported live product. Additionally, the fishery had long-term issues with paralytic shellfish poisoning (PSP), a naturally occurring biotoxin that is not destroyed by cooking or freezing [43]. However, Alaskan harvest values have increased over the past 5 years following the introduction of a PSP testing program [44,45]. This program allows divers to pre-sample a plot for PSP. If the plot comes back below the threshold, divers have a 72-h window to harvest in that area [44]. While this program has reduced the amount of geoduck rejected for live export due to PSP infection, Alaskan producers still tend to receive a lower ex-vessel price per pound relative to Washington or British Columbia. However, this discount has diminished in recent years as the market has tightened and live geoduck has become more valuable. In terms of fisheries management, Alaska's geoduck fishery is a limited-entry, derby-style fishery managed by the Alaska Department of Fish and Game (ADF&G). The fishery typically operates from October to March or April, unlike the Canadian and Washington fisheries, which can supply geoduck throughout the year.

3.3. Phase three: steady increases in ex-vessel prices (1990s–early 2000)

In addition to the supply-side changes in the global geoduck market, demand-side factors also served to increase the value of the global market. Economic development and the globalization of trade improved the transportation of a live geoduck to Asia, opening up new markets and improving distribution channels. Furthermore, the improved economic conditions in China fostered an increase in demand for this luxury item and this trend is expected to continue as per capita incomes rise. In general, per capita fish consumption is significantly correlated with average per capita national income [46]. Conspicuous consumption, especially among the nouveau riche in China, is expected to fuel an increase in demand for many luxury products, including geoduck [47]. Additionally, the per capita consumption of seafood in China is forecast to increase to 35.9 kg per capita by 2020 [46]. The dual expansion of China's population and economy is projected to fuel this increase in seafood consumption.

3.4. Phase four: new sources of supply (2002–present)

Following a decade of steadily increasing ex-vessel prices coupled with fisheries regulations that limited the supply of wild geoduck, it is no surprise that in 2002 new sources of supply emerged to seek out a share of the lucrative global geoduck market. The first two new sources of supply came from the emergence of intertidal geoduck culture in Washington State and British Columbia. The third source of supply was the emergence of Mexico's wild geoduck industry. Mexican production rose rapidly from 49 MT in 2002 to 2225 MT by 2011, an increase of 4440% in less than a decade [48]. It is worth noting here that the Mexican production is based on the harvest of two different species of geoduck, *Panopea generosa* and *Panopea globasa*, while production from Washington, Canada, and Alaska is exclusively *Panopea generosa.* A cultured geoduck industry emerged in Mexico in 2008; however, cultured production has been hindered by mortality issues to date [49].

4. Global production of cultured geoducks

Currently, cultured geoduck production (652 MT) represents 10% of global geoduck production (6480 MT) (Fig. 1). The majority of cultured production occurs on intertidal land, although some subtidal production does occur. Washington accounts for approximately 90% of the global production of cultured geoducks (Fig. 1). Within the state, two main growers (Taylor Shellfish of Shelton and Seattle Shellfish of Olympia) account for 75% of farmed production [41]. At present, intertidal culture occurs exclusively on private rather than state-owned intertidal land. Washington has investigated leasing state intertidal land for geoduck culture; however, there are potential economic and ecological ramifications associated with such a decision [14,18]. In Canada, Fan Seafood Ltd. is the primary producer of subtidally cultured geoducks [41].

4.1. Production methods and product attributes

The emergence of cultured production affected the global geoduck market in a number of ways including fostering changes in ex-vessel prices for both wild and cultured geoduck, trade patterns, market power and market penetration. Each of the aforementioned shifts will be discussed in turn; however, in order to understand the economic impact of cultured geoduck production on the global geoduck industry, one must first understand the production of, and market preferences for, cultured geoducks.

Intertidal geoduck culture commonly involves the planting of seed within 10–12 in. sections of polyvinyl chloride (PVC) or rigid polypropylene mesh ("Vexar") tubes placed in intertidal zones along the coast [50]. Within the tubes, 2–3 geoduck seeds, ranging from 5–10 mm in shell length, are placed in the intertidal substrate by hand [51]. Typically, the tubes remain in place for 1–2 years of the grow-out cycle, which can range from 5–7 years [52]. Some producers affix netting to the tops of the pipes in order to protect the geoduck seed, dampen the impact of wave action in the intertidal zone and reduce the visual prominence of the farm [50]. With this external protection in place, the juvenile geoduck can focus its energy on developing an elongated siphon rather than focusing on developing its shell for protection. As such, cultured geoducks often develop more meat relative to their wild counterparts and possess thinner shells [18,41]. The product recovery rate (PRR) measures the percentage of an animal's round (whole) weight that can be used as product. The average PRR for wild geoducks is 33%, while cultured geoducks can achieve a PRR of 50–70% [18]. However, there is a tradeoff associated with this increase in edible meat. Since cultured geoducks have thinner shells, they are more prone to breakage relative to wild geoducks [18]. This in part explains why wild geoducks are perceived to travel better and are hardier than cultured geoducks. The added protection from the PVC tubes also impacts the color of the siphon, resulting in a whiter or lighter siphon. The market prefers a white or lighter colored siphon and cultured geoducks often receive higher grades for this attribute relative to wild geoducks [22,53]. In general, the color of a geoduck's siphon is affected by the intertidal substrate (muddy vs. sandy bottom), depth of the geoduck, and age of the geoduck [54].

4.2. Evolution of market preferences

Processors individually grade each geoduck based on key attributes that influence the overall price per live animal. Key attributes include the length and color of the siphon, the thickness/thinness of the shell (which relates to the PRR of the animal), and a measure of the freshness and vigor of the animal (to approximate shelf life and durability in travel) [41]. Table 1 presents a breakdown of the grade mix by product type (wild versus cultured). A grade of 1 corresponds to the highest quality category. On average, cultured geoducks receive a price premium relative to wild geoducks due to the fact that a larger share of cultured geoducks receive the highest grade ranking (Table 1 and Fig. 2). Additionally, cultured geoducks tend to have a more consistent size, which is an important attribute for buyers, particularly in the sushi market [41]

5. Emergence of wild Mexican production

In 2002, Mexico emerged as a new source of wild geoduck to supplying two distinct species to the global market, *Panopea generosa* and *Panopea globosa*. *Panopea generosa* is harvested along the Pacific Coast of the Baja peninsula, while *Panopea globosa* is harvested in the Gulf of California and in Bahia Magdalena [48]. Approximately 80% of Mexican wild geoduck landings are *Panopea globosa* [48,49]. Production increased rapidly from 49 MT in 2002 to 2225 MT in 2011 (Table 2).

The Mexican geoduck fishery is managed by SAGARPA-CONAPESCA and there is a fisheries management plan in place as required by Mexican Law [55]. The fishery is a limited-entry fishery, where fishermen are issued concessions granting the right to harvest on a particular tract of seabed. The concessions were issued on a first come-first served basis (no auctioning). The fishery is managed under a TAC that is set at 1% of the total virgin biomass [48]. Concessions to harvest require that an area be harvested in a rotational manner, in an effort to ensure the sustainability of the resource; however, this requirement is very difficult to enforce in practice. Concessions have been allocated for nearly every available inch of coastline. An implication of this institutional structure is that some leased areas do not have sizable quantities of geoduck located within their boundaries [49]. In contrast, the State of Washington conducts biological surveys of the harvestable areas prior to auctioning off the tracts, thereby ensuring that the areas will have harvestable geoduck. The fact that Mexican fishermen hold a concession to harvest a

Table 1
Breakdown of grade by method of production.
Source: GS Gislason & Associates Ltd [41].

Grade	Typical grade mix	
	Wild Canadian geoduck (%)	Cultured geoduck (%)
1	30	80
2	35	10
3	30	5
4	5	5

Table 2
Mexican geoduck production, by state and sea.
Source: Aragon-Noriega et al [48].

Year	Gulf of California		Pacific Ocean		Total
	Sonora	Baja California	BCS[a]	Mexico	
2002	13		36		49
2003	35		3		38
2004	255		10		264
2005	695		1		696
2006	961		332		1293
2007	909		275		1185
2008	905		340		1245
2009	931	59	225	37	1282
2010	1072	361	211	415	2058
2011	1050	434	275	450	2225

[a] BSC = Baja California Sur.

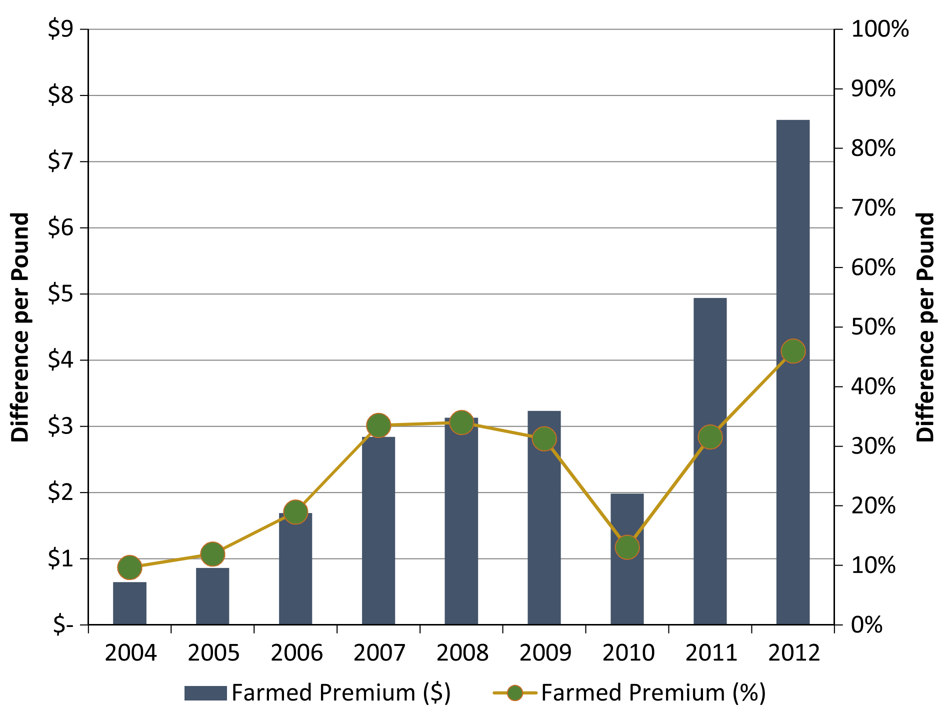

Fig. 2. Price Premium for Cultured Geoduck, Dollar Value Difference and Percentage Difference Per Pound, 2004–2012.
Source: NEI Calculations based on Aggregate WDFW Quarterly Farm Reports and Fish Ticket Data.

particular area, rather than the right to harvest a particular quantity of geoduck in an area, provides fishermen a perverse incentive to poach geoducks from another fisherman's concession. It is impossible to determine when and where a particular wild geoduck was harvested; therefore, it is difficult to determine whether or not a geoduck was taken from the designated concession or illegally from someone else's concession. While fishermen are required to harvest their concessions in a rotational manner, many fear that any geoducks left behind might be illegally harvested by another fisherman [49]. Poaching is also a concern in the Washington geoduck fishery, where poachers have illegally harvested geoduck in the past, and now more recently as the price of geoduck has risen [20,25,56]. Of the approximately 120 legal fishermen in the Mexican fishery, many have called for more enforcement and surveillance by regulators. Overfishing and eventually declines in geoduck abundance (and landings) in Mexico could occur in the foreseeable future if the incentives to overharvest and/or illegally harvest the resource persist.

The market preference for *Panopea globosa* is lower than for *Panopea generosa. Panopea globosa* is sometimes referred to as the 'water geoduck' due to the fact that the animal expels a significant quantity of its harvest body weight in water during transport, which results in a dehydrated and flaccid product when the animal reaches the market [57]. The meat of the *Panopea globosa* is also darker than *Panopea generosa*, which also serves to lower the market price received. *Panopea globosa* requires warmer water for transport, and it cannot tolerate waters colder than 45 °F, unlike *Panopea generosa* [18]. Due to the higher water temperatures required for transport, Canadian and United States regulations only allow live *Panopea globosa* into their borders for immediate re-export and not for entry into the domestic market [41]. One advantage of *Panopea globosa* is that it can survive in a holding tank for up to a month, double the typical holding time of *Panopea generosa* [41].

The processing and export of Mexican geoducks is dominated by two main processors in Ensenada [48]. The processors have monopsony power regarding the prices paid for geoduck within Mexico. Geoducks landed across all locations in Mexico are transshipped to Ensenada where they are packed and processed for exportation through Los Angeles International Airport [49]. In the Gulf of California, fishermen receive $2–$4 USD/kg, while on the Pacific Coast, ex-vessel prices can range from $8–$12 USD/kg [48]. This price differential is due in large part to the species landed in each location. The majority of landings in the Gulf of California are the lower valued *Panopea globosa*. At present, geoduck is not consumed domestically, although there are efforts to introduce geoduck into Guaymas and Ensenada [48].

In 2008 and 2010, the culture of geoduck began in the Gulf of California and on the Pacific Coast, respectively. To date, supply via this form of production is low due to a survival rate of approximately 5% [49]. In contrast, the survivability of cultured geoducks in Washington is 60% from the hatchery to planting and it is 40–50% from planting to harvest [58,59]. Until there are technological advancements in the culture of geoducks, the dominant source of geoducks from Mexico will continue to be from the wild fishery.

6. Evolution in global trade patterns

The introduction of new sources of supply stimulated a number of changes in the global geoduck market. In particular, the introduction of cultured geoduck into the market has altered historic export channels and has also affected trends in export value and volume. Historically, Vancouver, BC was a key distribution point for both Canadian and Washington geoducks. While the majority (90% or more) of US geoducks used to pass through Vancouver, BC prior to exportation to Asia, this share has fallen steadily since 2005 as more US product is directly shipped to China or Hong Kong (Fig. 3).

In contrast to Mainland China, Hong Kong does not require licenses for importers and exporters, nor does it impose import taxes, duties or quotas [60]. As a result, over half of the geoducks imported into Hong Kong are transshipped to mainland China [41].

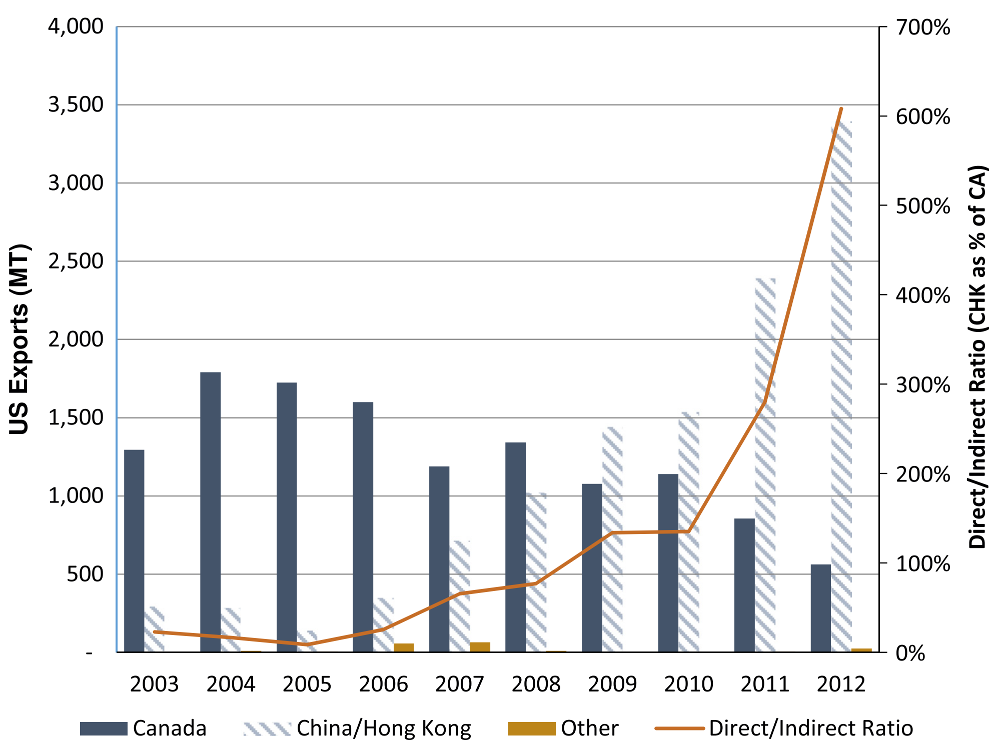

Fig. 3. United States Exports of Geoduck by Destination, 2003–2012.
Source: Statistics Canada, National Marine Fisheries Service, Gislason [41].

This trend in transshipment to mainland China through Hong Kong is prevalent for other high valued seafood species as well, for example, shark fins [47]. Currently, the geoduck market is concentrated in the major cities of Hong Kong, Guangzhou, Shanghai, Beijing, and Shenzhen [18]. The composition of US exports to China/Hong Kong includes both wild and farmed geoduck production. While US cultured production has increased steadily, it only represents approximately 18% of US production. Historically, darker (and less valuable) geoducks used to stay in the US domestic market; however, given the high demand for geoduck in Asian markets, those geoducks are now exported [53]. There is an additional sub-story driving the increase in the quantity of US geoducks exported directly to Asia. Importers and exporters that have close, and sometimes familial, connections to Asian markets have traditionally dominated US exports via import and re-export through Canada [18]. Furthermore, there has been a close relationship between Canadian IVQ holders and Canadian geoduck exporters. This relationship has benefitted both the exporters and the harvesters. Aside from seasonal restrictions on harvesting during herring season, Canadian geoduck harvesters are free to harvest wild geoduck when it is most convenient and economical to do so [41]. This flexibility in determining when and how much to harvest allowed Canadian producers and exporters to control the global geoduck market by influencing supply and thus prices. Furthermore, Canadian interests used to purchase US wild geoduck quota at auction in Washington [53]. This involvement by the Canadians in the US wild geoduck fishery further facilitated their ability to control the global geoduck market. The emergence of cultured geoduck production has eroded the ability of Canada to control the global geoduck market. Given the strong demand for geoducks, Chinese interests are putting up money in the US wild geoduck fishery to secure a direct share of the harvest, thereby cutting out the historical Canadian connection [53]. Both of these factors explain the increasing quantity of US geoduck going directly into Asian markets, rather than going indirectly to Asia via Canada. As a result, total US geoduck exports were fast approaching total Canadian geoduck exports (including US re-exports) and may have since exceeded Canadian export totals based on the data in Fig. 3. In addition to the changes in the quantity of exports flowing to Asia versus Canada, the value of US direct exports has changed substantially over a 10 year period. In 2003, US exports to Canada represented 83% of the total value of US geoduck exports (Fig. 4). However, starting in 2006 the market began to swing in the other direction, and by 2012 US exports directly to Asia accounted for 88% of the total value of US geoduck exports. Fig. 4 also captures a shift in the exported value (price per pound) for each trade channel. US direct exports to Asia are worth more per pound than the value of indirect US exports of geoduck through Canada via the traditional trade network.

6.1. *Creation of secondary markets*

The emergence of supply from Mexico has also stimulated changes in the global geoduck market. Historically, the major markets for geoduck were located in Hong Kong, Guangzhou, Shanghai, Beijing, and Shenzhen [18]. However, the newer sources of supply have extended into secondary markets. Since the majority of the geoduck coming from Mexico is the lower valued *Panopea globosa*, this increase in supply has served to expand the market both outward and downward, beyond the traditional metropolitan sources. The development of alternative distribution systems targeting regions and markets that have so far been ignored by the traditional distribution systems could further increase the demand for geoduck in Asian markets.

7. Forecasting the future of the global geoduck market: key drivers and constraints

The future demand for geoduck in Asia is expected to remain strong. China is the largest market for geoduck and is considered one of the fastest growing market economies in the world.

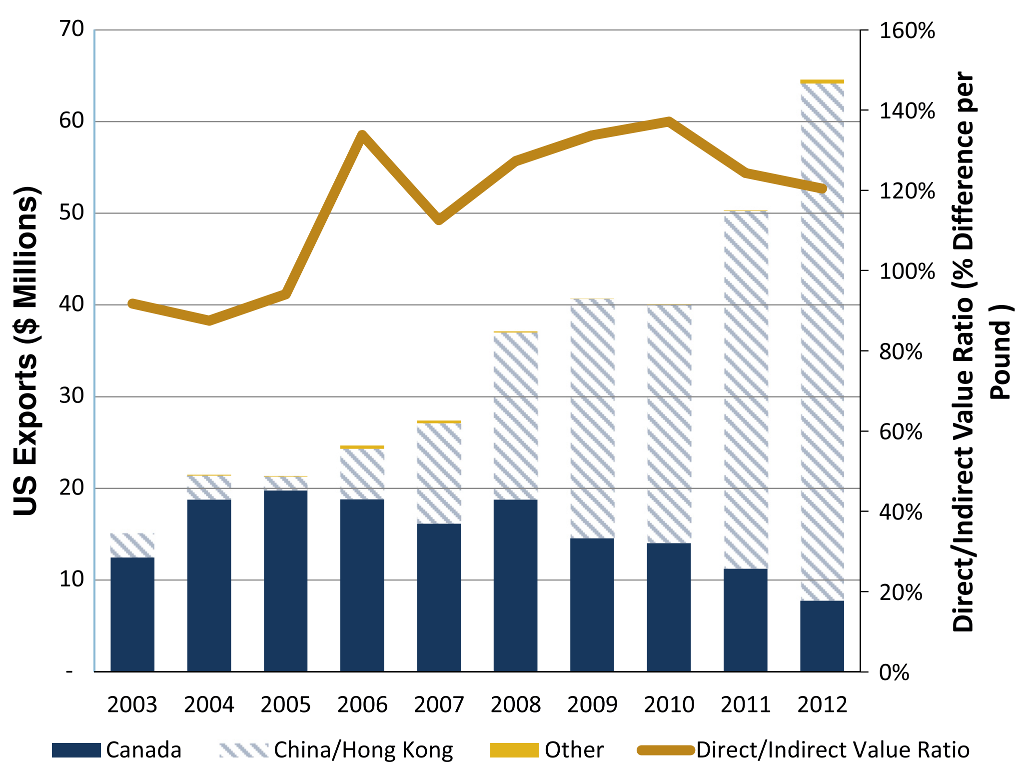

Fig. 4. Value of United States Geoduck Exports by Destination, 2003–2012.
Source: Statistics Canada, National Marine Fisheries Service, Gislason [41] .

Furthermore, China's middle class is forecast to expand, fuelling the demand for high valued and high quality protein products [61].

Moving forward, any real growth in the global geoduck market will most likely come from the supply side. In terms of wild geoduck production in the Pacific Northwest, harvests are essentially capped at MSY under the existing fisheries management plans. The management of the wild geoduck fisheries in Canada and Washington is deemed to be "highly effective" and both fisheries receive an overall recommendation of "Best Choice" by the Monterey Bay Aquarium's Seafood Watch Seafood Reporting program [15]. Therefore, it is unlikely that there will be any increases in landings from either of these wild fisheries. Wild production in Mexico could decline over time if illegal poaching or overfishing concerns are not adequately addressed. This concern is not restricted to the Mexican fishery. Given the high economic value of geoduck, the economic incentive to poach geoduck is strong. In Washington, approximately 800,000 pounds of geoduck were estimated to be missing from the fishery, an amount that is nearly one third of the annual allowable harvest in Puget Sound [20,56]. In response, the State Legislature appropriated $552,000 in the 2011–13 supplemental budget to hire two Fish and Wildlife officers and one detective to improve enforcement and monitoring in the fishery [56].

In terms of cultured production in Washington State, growth is not expected to increase rapidly in the near future for a few reasons. To date approximately 200 acres of private tidelands are cultivated throughout Puget Sound. One current impediment to the expansion of intertidal and subtidal geoduck culture is the availability of suitable substrate. Geoducks grow best in sandy or gravel-like substrates. At present, most of the intertidal land in culture occurs on the highest quality private acres. Bringing more marginal quality lands into production might not result in high quality and thus, highly graded geoduck. The state investigated the potential economic and ecological ramifications of leasing of state-owned intertidal land for geoduck culture [14,18,51,52]. The plan was met with resistance due to concerns about ecological impacts as well as economic impacts on both wild and cultured producers [62,63]. Depending on the market's ability to absorb an increase in supply, such a development could have a negative impact on ex-vessel prices. Additionally, a decline in ex-vessel prices could negatively affect the revenue generated by the State of Washington's geoduck harvest leasing program. Another major issue hindering the expansion of cultured production in Washington and Canada is access to hatcheries that can provide reliable seed to farmers. Therefore, in the near term, cultured growth in the Pacific Northwest is stymied. Until cultured producers in Mexico improve survivability, production there is not expected to increase substantially either.

The one wild card remaining is whether or not another country is able to find a source of supply that is reasonably unconstrained relative to current world supply. The only real threat in that category is an increase in supply from a new source of cultured production. Given the strong demand for geoduck in China, China could develop a cultured geoduck industry. This would not be new territory for China, as it successfully developed cultured industries for the yesso scallop (*Patinopecten yessoensis*) and for channel catfish (*Ictalurus punctatus*). The emergence of the Chilean farmed salmon industry further corroborates this lesson: a species does not have to be native to a country or region in order for it to become a major player in the global market for that species.

8. Conclusions

In summary, the evolution of the global geoduck market over the past 40 years is an interesting story of how a change in fisheries management can have a cascading effect on the growth and development of an industry. The shift to rights-based management was responsible for creating a fundamental transformation in the global geoduck industry. The transition away from the 'race to fish' and towards value creation led to changes in product form and ex-vessel prices that ultimately stimulated the emergence of cultured geoduck production. Market interactions between the cultured and wild product led to further changes in the global trade, value and supply of geoduck relative to historic trends. Looking forward, breakthroughs in the production of geoduck via cultured techniques could have a significant impact on the global geoduck market. Given the present constraints on cultured production in North America, it remains to be seen if another country, in particular China, emerges as a new source of cultured geoducks. The demand for geoducks is expected to remain strong as the Asian economy expands, both economically and demographically. For the foreseeable future, the geoduck should maintain its status as a lucrative seafood product with a luxury status among consumers.

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References

[1] Northwest Fisheries Science Center and Washington Sea Grant. Red tides: West Coast newsletter on marine biotoxins and harmful algal blooms. In: Harmful algal blooms and their impacts on west coast tribes; 2002.
[2] Casey K, et al. The effects of individual vessel quotas in the british columbia halibut fishery. Mar Res Econ 1995;10(3):211–30.
[3] Grafton RQ, et al. Incentive-based approaches to sustainable fisheries. Can J Fish Aquat Sci 2006;63(3):699–710.
[4] Sigler MF, et al. Alaska sablefish assessment for 2004. NPFMC Gulf of Alaska SAFE; 2003. p. 243–312.
[5] Griffith DR. The ecological implications of individual fishing quotas and harvest cooperatives. Front Ecol Environ 2008;6(4):191–8.
[6] Costello C, Gaines S, Lynham J. Can catch shares prevent fisheries collapse? Science 2008;321:1678–81.
[7] Leal DR, De Alessi M, Baker P. The ecological role of IFQs in US fisheries. Political Economy Research Center; 2005.
[8] Gutierrez NL, Hilborn R, Defeo O. Leadership, social capital and incentives promote successful fisheries. Nature 2011;470(7334):386–9.
[9] Clark IN, et al. The development and implementation of New Zealand's ITQ management system. Rights based fishing. Netherlands: Springer; 1989. p. 117–151.
[10] Gordon HS. The economic theory of a common property resource: the fishery. J Polit Econ 1954;62:124–42.
[11] Homans FR, Wilen JE. A model of regulated open access resource use. J Environ Econ Manag 1997;32(1):1–21.
[12] Asche F, Bjorndal T, Young JA. Market interactions for aquaculture products. Aquacult Econ Manag 2001;5(5–6):303–18.
[13] Anderson JL. Market interactions between aquaculture and the common-property commercial fishery. Mar Res Econ 1985;2(1):1–24.
[14] Straus K, Crosson L, Vadopalas B. Effects of geoduck aquaculture on the environment: a synthesis of current knowledge. In: Washington sea grant techincal report WSG-TR-08-01; 2009. p. 64.
[15] Trenor C, Danner S. Mirugai Pacific geoduck (*Panopea abrupta*), in Seafood watch seafood report; 2008, Monterey bay aquarium. p. 38.
[16] Welch, C. Geoducks: happy as clams. Smithsonian.com; 2009. Retrieved from: 〈http://www.smithsonianmag.com/science-nature/Happy-As-Clams.html〉 [11.03.12].
[17] Essington T, et al. Chapter 2A: biophysical condition of puget sound. Puget sound science update, 2011 version. Tacoma, Washington: Puget Sound Partnership; 2011.
[18] Northern Economics Inc. The world geoduck market and the potential for geoduck aquaculture on washington state lands. Anchorage, AK: Prepared for the Washington Department of Natural Resources; 2004. p. 84.
[19] Vedder T. Chinese mafia rakes in millions from 'Puget Sound gold'. KOMO 4 News: Online Article; 2011. Retrieved from: 〈http://www.komonews.com/news/local/117024808.html〉 [29.01.12].
[20] Welch C. China's demand for geoducks send prices, profits soaring. The Bellingham Herald online; 2012. Retrieved from: 〈http://www.bellinghamherald.com/2012/05/10/2514519/chinas-demand-for-geoducks-sends.htmlstorylink=cpy〉 [15.05.12].
[21] Geoduck.com. Geoduck commercial fishing; 2010. Retrieved from: 〈http://www.geoduck.com/commercial-fishing〉 [11.03.12].
[22] Muse B. Management of the British Columbia geoduck fishery: CFEC 98-3N. Juneau, Alaska: Alaska Commerical Fisheries Entry Commission; 1998. p. 23.

[23] James M. Co-operative management of the geoduck and horse-clam fishery in British Columbia. In: Case studies in fisheries self-governance. FAO Fisheries technical paper 504; 2008. p. 397–406.
[24] Heizer S. The commercial geoduck (*Panopea abrupta*) fishery in British Columbia, Canada-an operational perspective of a limited entry fishery with individual quotas. (Freemantle). Proceedings of the FishRights99 Conference on use of property rights in fisheries management. Australia: FAO Fish Tech Paper; 2000.
[25] Nobel J. The dark side of geoducks. Web exclusive; 2011. Retrieved from: 〈http://archive.audubonmagazine.org/incite/incite0811-webExclusives.html〉 [23.03.12].
[26] Howard M. Geoducks: monster bivalves worth big bucks; 2011. Retrieved from: 〈http://www.msnbc.msn.com/id/43687780/ns/business-us_business/t/geoducks-monster-bivalves-worth-big-bucks/.TyXyB4GwXw8〉 [29.01.12].
[27] Jones L. Changing fisheries management for the better. Fraser Forum 2003;1:25–7.
[28] Washington department of fish and wildlife. Wild stock commercial geoduck clam fishery; 2012. Retrieved from: 〈http://wdfw.wa.gov/fishing/commercial/geoduck/〉 [11.06.12].
[29] Washington State department of natural resources. February 24, 2015 invitation-to-bid. 2014 January 16, 2015. Retrieved from: 〈http://www.dnr.wa.gov/BusinessPermits/Topics/ShellfishAquaticLeasing/Pages/aqr_wildstock_geoduck_fishery.aspx〉 [23.01.15].
[30] Washington state department of natural resources. Commercial geoduck harvest opens in South Puget Sound October 21. Ear to the Ground; 2013. Retrieved from: 〈https://washingtondnr.wordpress.com/2013/10/18/commercial-geoduck-harvest-opens-in-south-puget-sound-october-21/〉 [23.01.15].
[31] Larson K, Chertudi D. Economic and revenue forecast: fiscal year 2015 – second quarter. (Editor). DNR office of budget and economics. Washington State Department of Natural Resources; 2014.
[32] Beddington JR, Agnew DJ, Clark CW. Current problems in the management of marine fisheries. Science 2007;316(5832):1713–6.
[33] Hilborn R, Orensanz JM, Parma AM. Institutions, incentives and the future of fisheries. Philos Trans R Soc B: Biol Sci 2005;360(1453):47–57.
[34] Worm B, et al. Rebuilding global fisheries. Science 2009;325(5940):578–85.
[35] Asche F, et al. Fisher's behaviour with individual vessel quotas-over-capacity and potential rent: five case studies. Mar Pol 2008;32(6):920–7.
[36] Campbell D, Brown D, Battaglene T. Individual transferable catch quotas: Australian experience in the southern bluefin tuna fishery. Mar Pol 2000;24:109–17.
[37] Lynham J. How have catch shares been allocated? Mar Pol 2014;44(0):42–8.
[38] Khan A. Sustainability challenges in the geoduck clam fishery of British Columbia: policy perspectives, in fisheries centre: The University of British Columbia Working Paper Series. Working Paper 2006-19: Vancouver; 2006. p. 21.
[39] Valderrama D, Anderson JL. Improving the economic management of the Bristol Bay (Alaska) sockeye salmon fishery in the age of aquaculture. Can J Agric Econ 2013;61(2):145–70.
[40] Dupont DP. Rights-based management in Canada: lessons from two coasts and a centre. Mar Pol 2014;44(0):60–4.
[41] GS Gislason & Associates Ltd. The market for geoduck. Prepared for Canada Fisheries & Oceans: Vancouver, CA; 2012. p. 48.
[42] National Marine Fisheries Service. US foreign trade online database; 2012. Retrieved from: 〈http://www.st.nmfs.noaa.gov/st1/trade/〉 [21.07.12].
[43] Washington State Department of Health. Paralytic shellfish poision (PSP) fact sheet. Washington State Department of Health. Division of Environmental Health. Office of Shellfish and Water Protection; 2011.
[44] Doherty P. Personal communication. Anchorage, AK: J. King; 2012.
[45] Alaska Department of Environmental Conservation. Geoduck Psp Sampling Protocol: 2011–2012 Season; 2011. Retrieved from: 〈http://www.dec.alaska.gov/eh/fss/seafood/Docs/Geoduck_Protocol_11-12_Updated_9-16-11-Current.pdf〉 [22.05.12].
[46] Delgado C, et al. Fish to 2020: supply and demand in changing global markets. Washington, DC: International Food Policy Research Institute; 2003.
[47] Godfrey M. Is China's taste for luxury a threat to sustainability? Seafood-Source.com: Seafood News Foodservice & Retail; 2012. Retrieved from: 〈http://www.seafoodsource.com/newsarticledetail.aspx?id=16941〉 [16.07.12].
[48] Aragon-Noriega EA, et al. Status of geoduck clam fisheries in Mexico. J Shellfish Res 2012;31(3):733–8.
[49] Calderon-Aguilera LE. Personal Communication. G. Shamshak; 2012.
[50] Washington State Department of Natural Resources. DNR and geoduck aquaculture; 2012. Retrieved from: 〈http://www.dnr.wa.gov/BusinessPermits/Topics/ShellfishAquaticLeasing/Pages/aqr_aqua_geoduck_aquaculture.aspx〉 [22.07.12].
[51] Davis J. Geoduck culture on intertidal beaches: procedures, expenses, and anticipated income for an intermediate-sized farm. Bainbridge Island, Washington: Baywater, Inc.; 2004. p. 11.
[52] Pacific Shellfish Institute. Geoduck culture in puget sound: environmental interactions. Olympia, Washington: Pacific Shellfish Institute; 2006. p. 7.
[53] Pearson J. Personal communication. Baltimore, Maryland: G. Shamshak; 2012.
[54] Goodwin CL, et al. Observations on rearing, seeding, and ecology of juvenile geoducks (*Panope abrupta*). In: National Shellfisheries Association (Pacific Coast Section) and Pacific Coast Oyster Growers Association-Abstracts. Portland, Oregon; 1985.
[55] SAGARPA. Plan de manejo para la pesqueria de almeja generosa (Panopea spp.) en las costas de Baja California. Mazatlan, Sinaloa: CONAPESCA; 2012. p. 57.
[56] The Olympian. Rampant poaching puts region's geoduck populations at risk; 2012. Retrieved from: 〈http://www.theolympian.com/2012/05/01/2088167/rampant-pouching-puts-regions.htmlstorylink=cpy〉 [18.01.13].
[57] Lentz J. Personal communication. Northern Economics Inc.; 2004.
[58] Gibbons J. Personal communication. Northern Economics Inc.; 2010.
[59] Lentz J. Personal communication. Northern Economics Inc.; 2010.
[60] Hong Kong Circle. Hong Kong emerges as transshipment hub. Hong Kong economic and trade office in Washington, DC Newletter; 2012. Retrieved from: 〈http://www.hketowashington.gov.hk/dc/circle/Jan08/Articles/article07.htm〉 [22.07.12].
[61] Burkitt L, Davis B. Chasing China's shoppers wall street journal; 2012. Retrieved from: 〈http://online.wsj.com/article/SB10001424052702303444204577460693377819420.html〉 [13.01.13].
[62] Williams T. Muddy waters. Audubon Magazine; 2011. Retrieved from: 〈http://archive.audubonmagazine.org/incite/incite0811.html〉 [18.01.13].
[63] Gordon DG. Geoduck studies: Washington sea grant coordinates effort to understand what's at stake. Sea Star: Summer; 2007. Retrieved from: 〈http://wsg.washington.edu/communications/seastar/archives/summer07.pdf〉 [18.01.13].