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A Review of the Biology and Fisheries of Horse Clams (*Tresus capax* and *Tresus nuttallii*)

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Abstract

A review of the biology and distribution of horse clams (*Tresus capax* and *Tresus nuttallii*)and a review of the fisheries of horse clams from British Columbia, Washington and Oregon is presented, based on previous surveys, scientific literature, and technical reports. Stock assessment strategies and management strategies are presented. Recommendations for additional information requirements for stock assessments and management plans are given.

Résumé

Un examen de la biologie et de la distribution de la fausse-mactre (*Tresus capax* et *Tresus nuttalli*) et un examen de la pêche de la fausse-mactre en Colombie-Britannique, à Washington et en Orégon, fondés sur des relevés antérieurs, des publications scientifiques et des rapports techniques, sont présentés. On y traite aussi des stratégies d'évaluation et de gestion. Des recommandations sont formulées relativement à l'obtention de renseignements supplémentaires pour les plans d'évaluation et de gestion des stocks.

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1. Introduction

Two species of horse clams (*Tresus nuttallii* and *T. capax)* have been harvested incidentally in the geoduck (*Panopea abrupta*) fishery since 1979. Harvest is restricted to G licence holders and to subtidal areas deeper than 10 feet below chart datum. There has never been an assessment of horse clam stocks in British Columbia, or a specific recommended or allocated quota. Current management includes time/area openings co-incident with the geoduck fishery and, in recent years, arbitrary catch caps. There is a building desire on the part of G licence holders to develop the markets for this potentially high value product and to expand the fishery from an incidental one to a targetted or directed fishery.

Fisheries and Oceans Canada (DFO) placed a moratorium on new invertebrate fisheries in the Pacific Region in 1992, as the department lacked the resources to collect and analyze the biological information necessary to develop a sound management strategy. Since then, DFO and the Ministry of Agriculture, Fisheries and Food (MAFF) proposed several new invertebrate stocks for potential exploitation, including the neon flying squid (*Ommastrephes bartrami*), Pacific milky venus clam (*Compsomyax subdiaphana*), and the deepwater or grooved Tanner crab (*Chionoecetes tanneri*). In addition, octopus (*Octopus dofleini*) and horse clams (*Tresus capax* and *Tresus nuttallii*) were identified as high priorities for expansion from incidental fisheries to targetted fisheries.

There are ongoing discussions between DFO and MAFF to develop policy and guidelines for the development of new fisheries, with a phased precautionary approach, to ensure an orderly development of a sustainable, viable fishery.

1.1. Plan for the Development of a Directed Fishery on Horse Clams

Within the Stock Assessment Division of DFO, a framework was developed for the provision of scientific advice for the management of new and developing invertebrate fisheries, including established fisheries whose expansion is limited due to a lack of information of the species distribution or abundance (Perry *et.al.* in prep). This framework included three phases for the precautionary development of a fishery:

> <u>Phase 0:</u> Collection of all available information on the target species, and from similar species elsewhere, to provide a baseline with which to advise on the alternative management options and to identify areas where information is lacking;
> <u>Phase 1:</u> Involves surveys and experimental fishing where the objective is the collection of data required to fill in the information gaps identified in the first phase and to explore the fishery potential.
> <u>Phase 2:</u> Fishing for Commerce. A fishery is developed at the commercial level, while stocks are monitored and management strategies are evaluated.

This paper presents the Phase 0 review of known and derived information on the two species of horse clams found in British Columbia, *Tresus capax* and *T. nuttalii.* It includes a review of horse clam distribution, life history and biology, population dynamics, abundance and a summary of horse clam fisheries in B.C and elsewhere.

1.2. Biological Objectives

The biological objective for a fishery on horse clams is to maintain a viable, healthy, and productive stock throughout their natural range in British Columbia. Three basic biological objectives were provided for the management of Pacific Region fish and invertebrate stocks by Rice *et.al.* (1995). These provided the framework for the specific biological objectives for horse clams:

(1) Ensure the population and subpopulations of horse clams along the B.C. coast do not become biologically threatened, as defined by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), throughout their ecological range.
(2) Ensure sufficient production and survival of progeny, after accounting for all sources of mortality (including all fisheries and natural mortality), to ensure sustainable reproduction throughout its ecological range.
(3) Ensure that a fishery for horse clams does not violate the two previous objectives for other ecologically related species.

There is an underlying requirement to collect sufficient biological data in order to determine a safe (in terms of risk averse) level of harvest, as well as to be able detect changes in stock dynamics (from any cause) in time to prevent long-term decline or collapse of the stock due to over-exploitation.

2. Review of Current Information on *Tresus capax* and *Tresus nuttallii*

2.1. Description

There are two species of horse clams in British Columbia waters: *Tresus capax* (Gould 1850) and *Tresus nuttallii* (Conrad 1837). There are of the Class Bivalvia, Order Veneroida, Superfamily Mactroidea, Family Mactridae, and subfamily Lutaniinae. *T. capax* is also known as the gaper clam, fat gaper clam, gaper, Alaskan gaper, blue clam, empire clam, greyneck clam, and the horseneck clam. *T. nuttallii* is also known as the gaper clam, Pacific gaper clam, blue clam, empire clam, big-neck clam, great Washington clam, horseneck clam, otter-shell clam, rubberneck clam, and the summer clam (Wolotira *et.al.* 1989).

The maximum adult shell length of both species is 200 mm, it varys from thin and brittle to thick and heavy, with a broad siphonal gape at the posterior end. The *T.capax* shell varies from white to yellow, with a dark brown to black periostracum. The *T. nuttallii* shell is yellowish, with a brown periostracum, which flakes easily (Haderlie and Abbott 1980).

The distinctive anatomical differences between the two species include the shape of the shells, siphonal plates, and internal anatomical features. The posterior region of *T. nuttallii* valves is extended and upswept, while the *T.capax* valves are slightly extended, resulting in a more oval appearance in *T.capax* (Bourne and Smith 1972b). There are also significant differences in the height-length and postumbone-preumbone ratios between the two species (Quayle 1960; Quayle, unpublished manuscript report *cited* in Bourne and Smith 1972b). *T. nuttallii* has thick siphonal plates with a hard surface which support epizootic growth (Swan and Finucane 1952, Stout 1970). *T.capax* has a visceral skirt not found in *T. nuttallii.* This is a prolongation of the inner palp lamellae which forms a curtain-like structure which hangs from the dorsal extremities of the visceral mass (Pearce 1965).

2.2. Geographic Distribution

The two horse clam species have overlapping ranges. *T. capax* are found in the eastern Pacific from Kodiak Island and the mouth of Prince William Sound in Alaska (60°N), to Monterey, California (37°N) (Bernard 1983). *T. nuttallii* is found in the northeast and northwest Pacific (Bernard 1983). In the northeast Pacific, *T. nuttallii* ranges from southeast Alaska (58°N) to Baja California (28°N). *T. nuttallii* is most common along the northern and central California coast (Kozloff 1983, Bernard 1983).

2.3. Habitat, Ecological Relationships, Co-occuring Species

Throughout their geographic range, *T. capax* is found from the mid- and low-intertidal (Haderlie and Abbott 1980) to subtidal depths of 30 m (Bernard 1983), buried to depths up to 1 m, but usually 25-50 cm. They are found in a range of substrates varying composition from mud-shell-gravel (Bourne and Smith 1972b) and pea gravel, gavel and shell (Goodwin and Shaul 1978) to sand, silty sand (Stout 1967), and fine sandy mud substrates (Haderlie and Abbott 1980). In Humboldt Bay, California, young recruits and adults rarely occurred in muddy substrates, indicating that recruits may select sandy substrates for settlement (Wendell *et.al.*1976). In British Columbia waters, *T. capax* is most abundant on beaches with a higher gravel than sand content (Bourne and Smith 1972b). *T. capax* occurs in salinity ranging from 27-33 ppt (Machell and Martini 1971, Bourne and Smith 1972a). Juvenile and adults survive in temperatures ranging from 2-20°C (Bernard 1983), but larvae survive at 5-18°C, and die at 20°C. (Bourne and Smith 1972a).

T. nuttallii is found from the low intertidal (Haderlie and Abbott 1980) to subtidal depths of 50 m (Bernard 1983), buried to depths of at least 1 m. They are most commonly found in fine sand or firm sandy mud substrates, but is also found in stiff clay and mud with gravel (Quayle and Bourne 1972). *T. nuttallii* appears to have minimum salinity requirements of 27 ppt. (Marriage 1958).

T. capax commonly occurs with littleneck clams (*Prothaca staminae*) and butter clams (*Saxidomus giganteus*) (Bourne and Smith 1972a, Schink *et.al.* 1983). *T. capax* is host to two species of commensal pinnotherid crabs, *Pinnixa faba* and *P. littoralis* in it's mantle cavity. These small crabs are sheltered by the visceral skirt, and scrape a share of plankton entrapped in mucus (Haderlie and Abbott 1980). *T. nuttallii* occurs with littleneck clams, butter clams, and *T.*

capax in the intertidal and shallow subtidal. At greater depths, it ocurrs in the some of the same areas as geoducks (*Panopea abrupta*) (Goodwin and Pease 1987). As previously mentioned in the introduction, *T. nuttallii* is distinguished from *T. capax* by it's siphonal plates which provide a hard substrate for epizootic growth, often in an environment (mud flats) where a hard substrate is rare. As a result, up to 50 species of animals, and several different plant groups have been found growing on the siphonal plates (Stout 1967).

T. capax occurs with, and may compete with *T. nuttallii*, where there ranges overlap, from southern B.C. to northern California (Wolotira *et.al.* 1989). However, *T. capax* does not burrow quite as deeply as *T. nuttallii* (Swan and Finucane 1952, Stout 1967, Quayle and Bourne 1972), is usually found in a more gravelly/shell substrate in B.C. in comparison to *T. nuttallii* (Quayle and Bourne 1972b), and is found higher in the intertidal and not as deep in the subtidal in comparison to *T. nuttallii* (Bernard 1983). Campbell and Bourne (in prep) found the highest densities of *T. capax* at the low intertidal and less than 1 m depth at Seal Islets, in comparison to the highest densities of *T. nuttallii* occurring at 3-6 m depths in Ritchie Bay.

In British Columbia waters, only *T. capax* has been found intertidal surveys (Bourne and Cawdell 1992, Bourne *et.al.*1994). However, there is anecdotal information on intertidal *T. nuttallii* populations (N. Bourne, pers. comm.). Subtidally, the species composition varies widely from > 99 % *T. nuttallii* in Ritchie Bay and Klaskino Inlet, in comparison to > 99 % *T. capax* at Sandy Islets, or a species mix observed from Lemmens Inlet (Campbell and Bourne in prep).

In Humbolt Bay, California, the distribution of *T. capax,* along with *T. nuttallii,* closely follows the eelgrass (*Zoostera marina*) distribution (Stout 1967). On the East and West coast of Vancouver Island, highly productive horse clams beds are closely associated with extensive sea grass beds and other submerged vegetation used by spawning herring (Haegle and Hamey 1979a,b; Haegle and Hamey 1981). Wendell *et.al.* (1976) found that *T. capax* recruitment occurred primarily where there was a unifom cover of eelgrass.

2.4. Predators, Parasites and Disease

Known adult horse clam predators include invertebrates, such the moon snail, *Euspira lewisii*; Dungeness crab, *Cancer magister*; sea star, *Pisaster brevispinus* (Wendell *et.al.*1976, Van Veldhuizen and Phillips 1978); fish, such as the bat ray, *Myliobatis californicus* (Wendell *et.al.*1976); and marine mammals such as the sea otter, *Enhydra lutris* (Kvitek *et.al.*1988, Kvitek and Oliver 1992; Watson and Smith 1994). The siphon tips of *T. nuttallii* are eaten by rays and flatfish (Bonnot 1940). Copper rockfish have been shown to prey on juvenile *T. capax* (Prince and Gotshall 1976), and juvenile *T. nuttallii* are prey for starry flounders (Haderlie and Abbott 1980).

Parasites found in *T. capax* from Yaquinna Bay include infection by haplosporidians (Armstrong and Armstrong 1974), and parasitic cyclopoid copepods on the gills (Smith and Carlton 1975). Haplosporidian infections have not been reported in Canada. (Bower 1996). In Elkhorn Slough, *T. nuttallii* is often heavily infected with larval tapeworms (*Echeneibothrium* sp), which is harmless to humans (Haderlie and Abbott 1980). The host of the adult tapeworms is the bat ray, *Myliobatis californicus*, which is not found in B.C. waters.

2.5. Physiology, Food and Feeding

Both species of horse clams are filter feeders, feeding on suspended diatoms, flagellates, dinoflagellates and fine detritus (Reid 1969, Haderlie and Abbott 1980). Separate inhalant and exhalant tubes in the long siphon provide and continuous flow of seawater with oxygen and food items. Food particles are filtered from the water by the gills, and sorted by the palps (Haderlie and Abbott 1980). The upper limits of acceptable particle size is 150 μ (Reid 1969). Reid (1969) studied an intertidal population of *T. capax* in Esquimalt Lagoon and found a seasonal variation in diet. Mainly diatoms, flagellates and dinoflagellates were consumed in the spring, summer, and fall, followed by mainly detritus, combined with a few diatoms and flagellates in the winter (mid-December to late February). In this study, Reid (1969) also found seasonal variability in digestive diverticula lipid, gonadal lipid and gonadal glycogen. Digestive diverticula lipid varied from a summer level of 13% dry weight to a winter low of 8 %. This lipid is regarded as an energy store which is used only after several months of food scarcity, during which time the gonadal glycogen is being rapidly depleted. Gonadal lipid varied from a mid-December peak of approximately 20% dry weight to a March low approaching 8%. This lipid is regarded as an energy store which is used only after several months of food scarcity, during which time the gonadal glycogen is being rapidly depleted. Gonadal glycogen peaks in mid-July at over 80% dry weight, gradually decreasing to the 50% range in late November, and plumetting to less than 10% in late December. The sudden decrease in glycogen levels in November is due to the scarcity of food, as well as the increased metabolic cost of gamete production. Increases in glycogen levels lags about one month behind increasing phytoplankton availability, and steadily increases between April and July, when food availabilty exceeds energy requirements, and there is rapid storage (Reid 1969).

In *T. nuttallii*, the proportion of the detrital and algal components are not known (Frey 1971, Wolotira *et.al.* 1989).

The digestive system of *Tresus* is typical of Lamelibranchs. Suitable size particles are ingested, and rejected material is rejected as pseudo-faeces, through the siphon, where periodic valve closure force water out. Following ingestion, food particles pass through a short esophagus to the stomach. Cilia further sort particles in the stomach, and some of the larger, coarser particles are voided directly through the intestines without any further digestive activity. Other particles are processed by the crystalline style, a mass of gelatinous material, which secretes digestive enzymes, and is rotated by ciliary action in the stomach and grinds particles against a gastric shield. The rotating action also pulls in food-laden mucous strands from the esophagus into the stomach. Finer particles are directed into the digestive glands for absorbtion and digestion, and wastes are voided to the intestines for excretion. (Schink *et.al.*1983).

2.6. Reproduction

Sexual maturity for horse clams is dependent on size rather than age and is attained at shell length of 70 mm for both species (Bourne and Smith 1972b, Clark *et.al.* 1975). The age at maturity is 3 to 4 years for *T. capax* (Bourne and Smith 1972b) and 3 years for *T. nuttallii* (Campbell *et.al.* 1990).

T. capax and *T. nuttallii* are dioecious (separate sexes) and fertilization is external (Bourne and Smith 1972a, Machell and Martini 1971). *T. capax* typically spawns at seasonal low temperatures (Bourne and Smith 1972b) and salinity (Machell and DeMartini 1971) and the process begins at progressively later dates as one moves from south to north. In Humboldt Bay, California, spawning occurs from January through March (Machell and DeMartini 1971). In Yaquina Bay, Oregon, *T. capax* spawning occurs from early February to late April (Robinson and Breese 1982, Breed-Willeke and Hancock 1980) and was found to be synchronous in intertidal and substidal populations (Breed-Willeke and Hancock 1980). In British Columbia waters, *T. capax* spawns starts in late February or early March, and spawning of a population extends over a period of 6 - 8 weeks until early May and individuals may spawn repeatedly during the spawning season (Bourne and Smith 1972a,b).

T. nuttallii is a summer spawner throughout most of its range (Goodwin 1971, Quayle and Bourne 1972). In British Columbia waters, *T. nuttallii* spawning probably occurs from April to August (Campbell *et.al.*1990). In Elkhorn Slough, California, the primary spawning period is from February to April (Clark 1973, Clark *et.al.*1975), and there is evidence of limited year-round spawning (Clark *et.al.*1975), or bimodal spawning, with peak spawning activity from April to June and from November to February (Laurent 1971). Elkhorn Slough had wide variations in daily water temperatures (Clark 1973), which may explain the year-round spawning observed in Elkhorn Slough as well as the differences in peak spawning activity observed by Laurent (1971) and Clark (1973), as sampling was in different years. *T. nuttallii* individuals may spawn more than once in a spawning season in some areas, but this is doubtful in British Columbia waters (Wolotira *et.al.*1989).

Five distinctive stages of gonadal development in *T. capax* have been identified and well documented (Machell and DeMartini 1971, Bourne and Smith 1972b): Stage I-inactive; Stage II-active; Stage III-ripe; Stage IV-partially spent; and Stage V-spent. At Seal Island, Bourne and Smith (1972b) found the inactive phase ussually ocurred from May to August, but has been seen as early as mid-April, and as late as late October. The active phase was most frequently seen from the end of September to early January. The ripe phase was most frequently seen from January to early April, but from as early as late November to as late as mid-May. The partially spent phase was seen most frequently from early February to mid-March, and the spent stage was most frequently seen in March. During this study, there was considerable variablity in timing, which may have been due to record cold temperatures encountered one winter.(DFO 1997). The decreasing levels of gonadal lipid from a mid-December peak to March lows is attributed to the ripening of gonadal tissue and subsequent release of the gametes (Reid 1969).

T. capax eggs are 60-70 μ in diameter (Bourne and Smith 1972a). Laboratory observations by Bourne and Smith (1972a) showed polar bodies developed 40 minutes after fertilization, and the first cleavage was 50 minutes later. Trochophore larvae were observed 24 hours after fertilization. Larval development showed straight-hinge in larvae 48 hours later at a size of 80 by 65 μ (length by height); umbones present in larvae at 140-150 μ length; and a prominent foot in larvae at 210-220 μ length. Larvae started to show signs of pre-settlement behaviour, short periods of swimming, with longer periods of crawling on the foot at 230-250 μ length, and metamorphosis occurred at 260-280 μ length.

Larval development of *T. capax* was found to be similar to other mactrid clams and dependent on temperature (Bourne and Smith 1972a). A mean shell length of 260 μ was attained in 24 days at 15°C, in 26 days at 10°C and in 34 days at 5°C. With mean monthly water temperatures in the Strait of Georgia in February to April varying between 7.0 and 9°C (DFO 1997), it is expected that *T. capax* larvae would settle approximately 30 days after fertilization in those waters.

The larval development of *T. nuttallii* has not been described as with *T. capax*, however, like *T. capax*, the larval development and growth rate of *T. nuttallii* is probably similar to that of other mactrid clams. Clark (1973) estimates a veliger larval stage of 21 to 30 days for *T. nuttallii* in Elkhorn Slough.

The critical phase in determining the chances of successful bivalve recruitment has been found to be in the newly settled larvae (Wendell *et.al.* 1976, Feller *et.al.* 1992).

2.7. Growth and Age

Growth of juvenile horse clams after settlement is rapid; up to 12 mm in a few months and 25 mm by the end of the first year (Quayle and Bourne 1972). Initial growth rates in *T. capax* are 22-25 mm/yr in the first 3 years (Bourne and Smith 1972b, Breed-Willeke and Hancock 1980), and then gradually decreases with age. Growth occurs primarily in the late spring and summer and virtually ceases by October, which forms a distinct annulus (Bourne and Smith 1972b, Wendell *et.al.* 1976).

As new *T. capax* recruits grow, they are found increasingly deeper in the substrate (Wendell *et.al.* 1976). As they increase in size, they are less able to burrow, and by the time they are 75 mm long, they have lost the ability. A similar decrease in burrowing ability with increasing size was seen with *T. nuttallii*, which loses the ability to burrow at 60 mm length (Pohlo 1964). There was also a gradual change in the shape of *T. nuttallii* shell with age. Young clams had a pointed elongated end, and appeared to be relatively streamlined, an advantage when burrowing. However, as the clams grew and inhabited increasingly deeper burrows, the shape of the shell changed, as well as the angle of the siphon relative to the shell. The angle of the larger animals in deeper burrows changed so that it was no longer perpendicular to the water-substrate interface, nor was it parallel to the long axis of the siphon. This angle gave the clam a greater resistance to being pulled upward as the siphon is retracted (Pohlo 1964)

Growth rates in *Tresus* have been shown to be highly variable. In Humboldt Bay, Wendell *et.al.*(1976) found significant differences in growth rates between beds (Table 1) and between year classes within a bed. Littoral height has an effect on growth. In Table 1, a comparison of von Bertanlanffy growth parameters for *T. capax*, shows a higher growth rate in subtidal and lower intertidal in comparison to the intertidal and high intertidal. In Yaquinna Bay, Breed-Willeke and Hancock (1980) showed that subtidal clams grew more rapidly than intertidal clams. The substrate in the intertidal area was mainly mud and silty sand, in comparison to the sand and sand-shell substrate of the subtidal areas sampled. However, Pearce (1965) compared intertidal populations and found that *T. capax* from an silty mud overlying hardpan clay grew 40 mm larger than *T. capax* from an area with fine sand overlying broken shell and organic debris.

The growth rates for subtidal *T. capax* in Yaquinna Bay reported by Breed-Willeke and Hancock (1980) were lower than those reported earlier by Marriage (1954) for an intertidal population in the same area, but similar to growth rates of intertidal populations at Seal Island (Bourne and Smith 1972b). Differences in *T. capax* growth rates between Doyle Island in Queen Charlotte Strait and Seal Island in the Strait of Georgia seen by Bourne and Smith (1972b) (Table 1) were attributed to differences in temperature and food abundance. The mean monthly temperature at in the vicinity of Seal Island is 3-7 °C higher than the monthly mean temperature in the vicinity of Doyle Island during the summer growth period (DFO 1997).

Campbell and Bourne (in prep) show considerable variation in growth between populations of *T. nuttallii* as well as differences in growth rates between *T. nuttallii* and *T. capax* (Table 1). They also found that with increasing size, shells became heavier than the soft body parts for *T. nuttallii* but not for *T. capax*.

The length-weight relationship of intertidal *Tresus* spp. dug from Seal Island in 1995, is shown in Figure 1, with the derived allometric equation for the total wet weight and length relationship.

The maximum age of *T. capax* seen in British Columbia waters is 18 years, at a shell length of approximately 180 mm, and the maximum age of *T. nuttallii* seen in British Columbia waters is 22 years, at a shell length of approximately 220 mm (Campbell and Bourne in prep).

2.8. Recruitment and Mortality

In Humboldt Bay, Wendell *et.al.* (1976) found that recruitment varied spatially and temporally between clam beds. The spatial distribution of new recruits was usually random at low densities (< 3 clams/0.5m^2) and aggregated at higher densities with a negative binomial distribution. Recruits did not appear to settle annually on all beds, or if they did, mortality was so high that it resulted in either very poor or unsuccessful recruitment for most years (Wendell *et.al.* 1976). In addition to the suspected high mortality of new recruits, a large scale mortality of adult clams, from undetermined causes, was observed during this study.

Estimates of instantaneous natural mortality (M) (with 95% confidence limits) by Campbell and Bourne (in prep) for *T. nuttallii* greater than 10 years, range between 0.44 (0.26 to 0.63) in Ritchie Bay, and 0.20 (0.06 to 0.33) in Kalskino Inlet. At Seal Islets intertidal *T. capax* greater than 10 years, the instantaneous natural mortality (with 95% confidence limits) was estimated to be 0.20 (0.04 to 0.35). For *T. capax* greater than 3 years at Seal Islets, the instantaneous natural mortality estimated to be 0.16 (0.05 to 0.26) for the subtidal zone, and 0.15 (0.09 to 0.21) for the intertidal zone (Campbell and Bourne in prep).

Natural mortality estimates can also be made with Hoenig's (1983) generalized mortality model, using the predictive equation:

$$\ln(z) = a + b \ln(t_{max}) \qquad \text{where for molluscs: } a = 1.23;\ b = -0.832$$

At a maximum age of 15, the estimated mortality rate is 0.36; at maximum age 18, the estimated mortality rate is 0.31; and at maximum age of 22, the estimated mortality rate is 0.26.

The instantaneous natural mortality estimated for *T. capax* and *T. nuttallii* greater than 10 years by Campbell and Bourne (in prep) are similar to the predicted rates from Hoenig's (1983) model, but instantaneous natural mortality estimated for *T. capax* greater than 3 years appear to be significantly lower in the intertidal zone at Seal Islets, than is predicted by Hoenig's (1983) model.

2.9. Density and Biomass

Density estimates for subtidal horse clams, which were derived from geoduck surveys, resulted in very low densities in the surveyed areas over most of the B.C. coast, with the highest density estimates occurring at Yellow Bank on the west coast of Vancouver Island (Table 2). However, show factors for horse clams during these surveys were not assessed. Density estimates derived from geoduck transect surveys in the Yellow Bank/ Elbow Bank area conducted in 1995, show the highest density and variability at Elbow Bank, in comparison to the other areas sampled (Table 3) (Hand unpubl. data). Density estimates derived from horse clam study plots, sampled from 1 m intertidal to 10 m subtidal by Campbell and Bourne (in prep), showed overall mean densities ranging from 0.32 clams/m^2 (Ritchie Bay), to 4.54 clams/m^2 (Seal Islets). In Ritchie Bay, most of the horse clams (99.22%) were *T. nuttallii*, with the highest densities (0.5-0.6 clams/m^2) occurring at 3-6 m depths, which is within the range of the fishery. At Seal Islets, most of the horse clams (100% in intertidal to < 2 m depths, 99.5% in > 2 m depths) were *T. capax*, and the highest densities (6.4-9.8 clams/m^2) were either intertidal or in depths less than 1 m.

Subtidal horse clam densities as high as 108 to 135 clams/m^2 in 2.5 to 3 m depths at Dungeness Spit in Washington were documented by Goodwin and Shaul (1978). Their density estimates were highly variable, due to the apparent sparse distribution of horse clams in Washington state waters, and their biomass estimates generally had very wide 95% confidence intervals.

Historical census data for intertidal *T. capax* at Seal Island were provided by Kingzett and Bourne (1995) from data collected for butter clam surveys. They show widely fluctuating densities and biomass estimates, with densities ranging from a high of 14.80 clams/m^2 in 1964, to a low of 1.33 clams/m^2 in 1980 and biomass estimates ranging from 85 tonnes in 1967 to 22 tonnes in 1979 and 1980 (Table 4). Coincidentally, following the decline of the intertidal biomass at Seal Island, there was a large increase in landings of subtidal horse clams in adjoining beds (Figure 2).

3. Fisheries

3.1. Review of Tresus *Fisheries in British Columbia*

First Nations people have historically used horse clams throughout the west coast where they were dug at low tides (Suttles and Sturtevant 1990). The Nootka dug horse clams, which were usually steamed. and the shell was used as a ladle and as a cup for fish broth (Arima 1983). The Skidegate dug horse clams during extreme low tides at Legace Island. They were cooked in one of three ways, or were dried skewered on waxberry stems (Ellis and Wilson 1981). The Kelsomat and Clayoquot people usually steamed horse clams, and other West Coast First Nations were also known to smoke-dry them. The shell was used as a ladle, especially for "fish juice" for the elders (Ellis and Swan 1981). There is archaeological evidence that Nanaimo Coast Salish people used horse clams shells as cups (Burley 1989).

The present-day commercial horse clam fishery has been limited to vessels licenced to fish geoducks by dive (G Licence) since 1981, and presently restricted to 55 licences. Typically, less than half the fleet participate in this fishery (Harbo and Hobbs 1997). There is presently no fishery for intertidal horse clams, although they are probably taken incidentally to the butter clam fishery and reported as such (Randy Webb, pers. comm.). The fishery is subtidal and restricted to depths greater than 10 feet below chart datum. There was a directed fishery from 1986 to 1991. The fishery is presently restricted to an incidental catch from the geoduck fishery. While horse clams occur in some of the same areas as geoducks, the fishery has usually taken place in adjoining or different grounds (Ken Ridgeway, pers. comm.). A history of management actions is shown in Table 5.

Landings have been reported since 1979 and have fluctuated widely, as have the number of vessels participating, and the value of the product (Tables 6 & 7, Figure 2). Reported landings peaked in 1987 at 355 tonnes, valued at $360,000, and have steadily declined to only 24 lbs in 1996. The majority of landings have been reported from Area 24 (32.2%), Area 14 (31.8%), Area 17 (17.9%) and Area 15 (8.1%).

There was a directed fishery in Statistical Area 24 between 1988 and 1991, with total landings shown in Table 7. Statistical Area 24 was first subdivided into separate horse clam harvest areas in 1988, and in 1991, this was modified into three areas for a rotational harvest with a an annual precautionary limit of 90.7 tonnes (Harbo and Hobbs 1997). The three rotational harvest areas were: Lemmens Inlet; Morfee-Dunlap Islands; and Epper Pass-Yellow Bank. Landings from the rotational harvest area are shown in Table 8. Within Area 24, the Yellow Bank area has been the most productive area, with 18% of the total coast-wide production to date. Vessels in Area 24 reported 25 to 40 cages (50 lbs/cage) per day (R. Harbo, pers. comm.).

There was also a brief directed fishery in the late 1980's in Statistical Areas 14 and 17. Within Area 14, Comox Bar was the heaviest producing area, with 16 % of total coast-wide production to date, followed by the area west of Seal Islets, with 9.1 % of total coast-wide production to date. The reported landings are shown in Figure 3. Fishing success for horse clams in the directed fisheries, as determined by CPUE (kg/diver hour) is comparable to the geoduck fishery (Table 9).

Although area catch ceilings and rotational fishing in some areas has been recently implemented, harvests were unrestricted previous to 1981. Landings of horse clams peaked briefly in 1982, which was attributed to more extreme intolerance to dark geoducks than usual by the Japanese market (K. Ridgeway, pers. comm). The increase in landings starting in 1986 was due to market development efforts, which required sufficient amounts of product for shipping to overseas markets. These markets require full container loads, which consist of 4000 cages, at 50 lb/cage, and an average 15% marketable meat recovery (R. Harbo pers. comm.). The incidental nature of the fishery was reinforced by 1992 when fishers were reminded that no targetting on horse clams shall occurr and any evidence of such would result in the closure of the area for the harvest of both geoducks and horse clams. In 1992, catch ceilings of one tonne were imposed for Statistical Areas 12,13,17, 23 and 27, 2 tonnes for Area 14 and 5 tonnes for area 24, based on historical fishing effort and landings. The reduced landings after 1987 was due to these restrictions, and to the prohibition of harvest on the very productive Elbow and Yellow Banks in 1989 to protect the extensive eelgrass beds. Vessels did not follow a compliance limit of harvest greater than 20 feet below chart datum in this area (R. Harbo, pers. comm.). Because of the minimal market development, product value has remained low and this led to instances of dumping. Conditions of licence were modified in 1997 to specifically state that all product removed from the substrate must be brought to the surface and recorded as catch.

Processors prefer *T. capax* to *T. nuttallii*, as *T. capax* does not have the hard siphonal plates found on *T. nuttallii*. The hard siphonal plates, with often with epizootic growth, are more difficult and costly to process (K. Ridgeway, pers comm.). Processors at one time (1987) paid more for larger sizes: $0.40/ lb for large; and $0.30-0.35/lb for small clams.

Current management measures include area catch ceilings, area closures, licences limited to geoduck licences (G Licences), and fishing is limited to incidental fishing at times and in areas of geoduck fishing. There is currently no directed fishery for horse clams until more biological data about horse clam stocks is available and analyzed. Since 1989, when rotational fishing was implemented, fishing is permitted in Statistical Areas only once every 3 years, with the exception of Statistical Area 24, where it is permitted annually under it's own rotational harvesting plan. Gear is restricted to a hand-held manually operated water nozzles guided and controlled from underwater by a diver, and each nozzle is limited to an inside diameter of 5/8 inch. All harvesting of horse clams must be conducted from depths greater than 10 feet below chart datum, and no harvesting is permitted within eelgrass beds. All catch must be logged in an approved logbook, and since 1995, all catch must be validated at landing.

3.2. *Review of Tresus Fisheries in Washington and Oregon*

In Washington, there is presently no commercial fishery for horse clams; it is illegal to land horse clams from the geoduck dive fishery (A. Bradbury, WDFW, pers. comm.). There was a commercial fishery, using hydraulic clam harvesters, from the mid-1960's to the mid-1980's, when the fishery was stopped due to the adverse public reaction to the harvest method. The annual landings averaged 108,000 lbs. There is now an interest in developing a horse clam fishery from the tribes for crab bait. The current limit for recreational harvest of horse clams is seven per day.

In Oregon, horse clams are landed intertidally in a recreational fishery, and *T. capax* accounts for 18.8 % of the recreational harvest. There is a very limited commercial fishery, where *T. capax* is harvested by hand subtidally with divers. The commercial fishery is limited to 10 licences, with a TAC of 2500 pounds. In 1997, commercial landings were 1,000 lbs (Jean McCrae, ODFW, pers comm). There was a directed fishery for horse clams using mechanical suction dredges subtidally from the mid 1970's to the mid 1980's. Due to poor recruitment of *Tresus* in subtidal areas and the efficiency of harvest, mechanical harvest methods have not been permitted since 1983 (Jean McCrae, ODFW, pers comm).

4. Discussion

The horse clam fishery has been limited to an incidental fishery to the geoduck fishery, and since 1992, development has been restricted until analyses can be conducted for stock assessment and productivity. This is not a new fishery, as horse clams have been landed (and managed) with geoducks for almost 20 years. However, horse clams have considerably different biological characteristics in comparison to geoducks, including: maximum age; growth rates; recruitment; natural mortality rates; vertical distribution in the sediments; and tide height/depth distribution. Potential yields have not yet been calculated for horse clams in British Columbia, however input parameters are well estimated and yield modeling could be conducted for horse clams. The applicability and appropriateness of yield models still needs to be assessed. Horse clam yields were modeled using an age-structured equilibrium yield model in Washington State, using published parameter estimates from B.C., and the most conservative estimate of annual exploitation rate was calculated to be 0.135 (Bradbury, unpublished manuscript).

There are no clear trends in fishery statistics in British Columbia; landings are complicated by market-driven factors and arbitrary closures, and horse clam and geoduck fishing events are so closely linked that any trends in CPUE in a non-directed fishery would be meaningless. There are conflicting results from horse clam fisheries elsewhere. In Washington State, the 20-year fishery using hydraulic clam harvesters was closed, not because of any biological concerns but due to adverse public reaction. However, the 10-year mechanical dredge fishery in Oregon was closed due to poor recruitment.

Since harvest by diving is currently restricted to depths greater than 10 feet and not at all in eelgrass beds (and there is no reason to change this in a directed fishery), it seems likely that the fishery would be harvesting the fringes of the population and that the majority of recruitment would come from shallower waters and/or eelgrass beds, thus there would be a form of protection from recruitment overfishing. However, there is conflicting evidence as to the location and depths of the high density areas, as the highest density of horse clams in Ritchie Bay were found at 3-6 m depths, well within the range of the fishery. Yet, at Seal Islets the highest densities were found in the lower intertidal or depths < 1 m. However, the highest horse clam production appears to be in, or in close proximity to eelgrass beds.

It is extremely difficult for divers to differentiate between the two species of horse clam, as well as assess individual size, until they are extracted from the substrate. Thus any fishery should be considered a mixed species/stock/age fishery. In addition, show factors for horse clam siphons have not been adequately assessed, and this needs to be addressed before directed horse clam surveys proceed.

4.1. Biological Considerations

Given the uncertainty of stock recruitment relationships in bivalves (Bourne 1995), the highly variable recruitment patterns generally seen in bivalves (Bourne 1987, Feller *et.al.* 1992), and the very high mortality of young *T. capax* recruits in particular (Wendell *et.al.* 1976), one must assume that there are many complex relationships (stock/recruitment and environmental factors) affecting bivalve recruitment. The critical and particularly sensitive stage of newly settled larvae should be considered in planning the type, timing and duration of harvest activities. In light of this, a rotational fishery would likely be less detrimental than an annual one.

From a community standpoint, the effects of harvesting activities on co-occurring species should be evaluated. The eelgrass community in particular has been shown to be productive habitat for horse clams, as well as for other species, and has been identified as a community requiring a high degree of protection. While harvesting of horse clams is not permitted in eelgrass beds, the close proximity of concentrated harvesting and related activities, such as anchoring, or dragging anchor chains, lines and stinger hoses across particularly sensitive habitat may have an unpredictable and devastating effect on this community. Habitat assessments of proposed fishing areas should address habitat sensitivity issues, and whether or not harvesting activity should be permitted in a proposed area. This is particularly important, as the most productive horse clam beds appear to be in, or in close proximity to, highly sensitive eelgrass habitat.

There have been incidents of unexplained high adult mortalities, over a very short period of time (Wendell *et.al.*1976), as well as anecdotal information on winter mortalities due to freezing. Horse clams appear to have a narrow salinity tolerance range, with a minimum salinity of 27 ppt. Intertidal or high subtidal horse clam populations at the head of coastal inlets may be particularly vulnerable to salinity fluctuations due high rainfall events. An incident of high natural mortality, coupled with high fishing pressure in an area may have devastating effects on the local stocks.

Many species of bivalves can reburrow if disturbed by harvesting activities, however horse clams lose the ability to reburrow at 60-75 mm length. Any individuals which are approximately this size or greater, which are disturbed or exposed, but not harvested, should be considered mortalities.

4.2. Stock Assessment Considerations

To date, the majority of the horse clam density estimates are based on geoduck surveys, with inherent shortfalls. For example, very few directed horse clams surveys have been conducted, and the coincidence of horse clam distribution with geoduck distribution is not well known. There also has not been an assessment of show factors for horse clams in geoduck surveys. Therefore, the true extent of horse clam biomass in B.C. is not known. Directed horse clam surveys and an assessment of show factors are required to determine horse clam distribution and density estimates.

Data has been collected on growth and natural mortality. However, the estimates of instantaneous natural mortality resulted in relatively wide 95% confidence limits, and this may be addressed by collecting additional age-frequency data to reduce the variability. Since mortality estimates are a critical parameter in yield modeling and setting the harvest rates, it is important to have an accurate and realistic estimate of natural mortality. The instantaneous natural mortality estimates in this report were derived from a catch curve regression of age-frequency data. Natural mortality estimates could be also be determined from marked experimental plots.

There is very little information on recruitment, in particular, on the stock-recruit relationship, variability in recruitment, and the effect of fishing on recruitment. Repeated surveys of experimental plots, where there is no fishing, and fishing at various eploitation rates could be used to assess recruitment. In addition, the role of critical threshold levels should be investigated.

Yield modelling work can proceed with the available data to produce a range of yield options, and this can be further refined as additional data in collected and analyzed. However, an estimate of biomass is required.

The questions raised with this Phase 0 review are:

1. Is yield modelling completed and reviewed by PSARC before proceeding with Phase 1 ?
2. Is an assessment/adaptaive management plan developed and reviewed by PSARC before proceeding with Phase 1 ?; or
3. Can precautionary exploitation rates be developed based on estimates of M published in this report, and proceed with Phase 1?

4.3. Management Strategies

The current management strategies of the horse clam fishery, including: limited access: catch ceilings; protective measures for the environment; and a data collection system, parallel the guidelines for the development of new fisheries developed by FAO (1995). These management strategies have kept the fishery in a "holding pattern", until appropriate stock assessment plans have been developed and implemented, appropriate yield models were developed and evaluated, and harvest strategies were recommended. Presently, the lack of sufficient quantities of product is impeding market development.

Interim management strategies appropriate for horse clams should include, a continued limited entry, a limited expansion of exploratory fishing areas, area catch ceilings, time and area closures, continued rotational harvesting, and permanently closed areas in order to monitor regime shifts, protect broodstock and protect particularly environmentally sensitive areas. A limited expansion of exploratory fishing areas could focus on confirming anecdotal information on pockets of subtidal *T. capax* populations and assess the viability of commercial harvest in these areas. Rotational harvesting as well as time and areas closures should be retained due to protect the critical stages of juvenile recruitment.

Long-term management would likely take the form of quotas, calculated in a similar way to geoducks. That is, estimating biomass from area, density and mean weight, and applying an estimate of yield.

5. Conclusions

The information gaps identified through this review include horse clam recruitment mechanisms, the distribution of horse clam stocks and estimates of biomass. The horse clam fishery has concentrated in only 12% of the geoduck beds in southern B.C. However, these beds are also the ones closest to port, and therefore most convenient to fish. They are also the beds that were first fished in the geoduck fishery. The degree of coincidence of horse clam beds with geoduck beds is not known, as very few directed horse clam surveys have been conducted. The true extent of horse clam biomass in B.C. is not known.

The next steps in the development of a horseclam fishery would be to:

- produce yield estimates for horse clams based on what is known about natural mortality, longevity, growth and assumptions of recruitment;
- investigate the appropriateness of critical threshold levels;
- conduct surveys of horse clam populations to determine distribution, density and show factors;
- design exploratory fisheries, in consultation with stakeholders, to determine the distribution and extent of populations relative to geoducks, and to collect detailed catch information from these fisheries;
- collect biological samples from key index sites (both fished and unfished) to monitor the effects on the population structure of fishing and to develop an understanding of recruitment;
- conduct habitat assessments in proposed fishing areas to ensure sensitive habitats are protected from harvesting and related activities.

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Table 1. Von Bertalanffy growth parameters for *T. capax* and *T. nuttallii* from British Columbia and California. Values in brackets are approximate 95 % confidence intervals. (Adapted from Campbell and Bourne, in press)

Species and Area	Year	L_∞	k	t_0	Source
T. capax (intertidal)					
Humboldt Bay, Cal (PSA)	1973	171(± 5)	0.131(±0.010)	-0.450(±0.154)	Wendell *et.al.* 1976
Humboldt Bay, Cal (Clam I)	1973	170(± 3)	0.142(±0.005)	-0.625(±0.055)	Wendell *et.al.* 1976
T. capax (low intertidal)					
Seal Islets	1993	196(±13)	0.139(±0.027)	-0.26(±0.41)	Campbell and Bourne in press
T. capax (high intertidal)					
Kitkatla Inlet	1990	149(±15)	0.180(±0.043)	0.17(±0.29)	Bourne and Cawdell (1992)
Seal Island	1969	155(± 5)	0.189(±0.021)	-0.11(±0.23)	Bourne and Smith (1972)
Doyle Island	1971	169(± 4)	0.132(±0.008)	-0.10(±0.13)	Bourne and Smith (1972)
T. capax (subtidal)					
Seal Islands	1993	192(± 5)	0.148(±0.013)	-0.13(±0.22)	Campbell and Bourne in press
Lemmens Inlet	1989	195(± 7)	0.154(±0.016)	-0.01(±0.18)	Campbell and Bourne in press
T. nuttallii (subtidal)					
Ritchie Bay	1993	200(±13)	0.139(±0.024)	-0.15(±0.33)	Campbell and Bourne in press
Klaskino Inlet	1993	231(± 6)	0.116(±0.010)	-0.15(±0.23)	Campbell and Bourne in press
Newcastle Island	1989	183(± 5)	0.168(±0.012)	0.51(±0.10)	Campbell *et.al.* 1990
Lemmens Inlet	1989	202(± 3)	0.167(±0.006)	0.50(±0.05)	Campbell *et.al.* 1990

Table 2. Density estimates of horse clams, *Tresus* sp. derived from geoduck (*Panopea abrupta*) dive surveys. Data from Hand (unpubl data)

Region and Area Sampled	Number of *Tresus* sp. sampled	Density of *Tresus* sp.
North Coast		
Principe Channel, N/E Bank	4	
Weetean Bay, S. Aristazabal Is.	0	
Otter Pass, S. Bank Is.	0	
Kettle Inlet, W. Aristazabal Is.	248	0.021/m^2
Griffith Harbour, N/W Banks Is.	2	
Bardswell Group	37	0.002/m^2
Anderson Island, N/W Aristazabal Is.	109	0.01/m^2
Queen Charlotte Islands		
Hotsprings Is.	1278	0.12/m^2
Cumshawa Inlet	970	0.08/m^2
Houston Stewart	149	0.01/m^2
Inside Waters		
Oyster River	141	0.015/m^2
Duncan Island	480	0.02/m^2
West Coast Vancouver Island		
Yellow Bank	4648	0.55/m^2
Ahousat	514	0.07/m^2
Winter Harbour	144	0.01/m^2

Table 3. Mean density of horse clams (*Tresus* sp.) derived from transect surveys conducted in the Yellow Bank/Elbow Bank area of the west coast of Vancouver Island, Sept.-Oct. 1995 (from Hand, unpubl. data)

	Density per transect (No/m^2)	**STD**
Elbow Bank		
Minimum	0.00	0.00
Maximum	2.48	2.81
Mean	0.58	0.92
Yellow Bank		
Minimum	0.16	0.24
Maximum	0.88	0.81
Mean	0.46	0.60
Epper Pass		
Minimum	0.04	0.05
Maximum	0.43	0.29
Mean	0.29	0.36
Morfee/Dunlap		
Minimum	0.68	0.37
Maximum	1.50	0.73
Mean	0.81	0.83
All Areas	0.55	0.75

Table 4. Results of census data for horse clams (*T. capax*) at Seal Island from surveys performed 1952-1992. Data from Kingzett and Bourne (1995)

Survey year	1952	1955	1961	1964	1967	1970	1973	1976	1979	1980	1981	1992
# of plots (m^2)s	121	119	126	119	140	112	119	140	112	28	28	20
# clams/plot (m^2)	2.93	3.29	5.45	14.80	5.37	4.12	1.66	3.79	1.48	1.33	1.89	6.20
STD	4.26	5.19	9.08	16.00	7.54	5.19	2.67	5.37	2.28	2.67	3.12	4.79
95%CL	0.77	0.93	1.59	2.88	1.25	0.91	0.48	0.89	0.39	0.76	1.16	2.10
Mean Wt/ plot (m^2)gm	1024.53	1352.05	--	--	1405.96	--	--	884.18	359.61	370.92	456.58	947.48
STD	1505.72	2235.62	--	--	2187.24	--	--	1252.09	572.93	807.97	792.11	991.39
95%CL	271.68	401.68	--	--	362.32	--	--	207.41	99.25	228.58	293.40	434.50
Mean Shell Ln (mm)	--	--	--	--	--	--	--	94.85	105.15	112.67	108.33	87.60
STD	--	--	--	--	--	--	--	45.69	31.57	28.69	30.51	28.70
95%CL	--	--	--	--	--	--	--	4.34	4.50	7.03	11.30	6.05
Ttl Biomass (kg) in 6.069 ha	62183	82061	--	--	85333	--	--	53664	21826	22513	27711	57506
STD	91388	135688	--	--	132751	--	--	75994	34773	49039	48076	60171
95%CL	16489	24379	--	--	21990	--	--	12588	6024	13873	17808	26371
Number of clams Obs'd	--	--	--	--	--	--	165	443	190	64	53	124

Table 5. History of management actions for the horse clam fishery in Pacific Region

	Management Actions
Prior to 1980's	Horse clams were dug intertidally with butter clams. Reported in "mixed clam" category
Late 1970's to early 1980's	Horse clams were landed by divers using geoduck "stingers". Horse clam species codes were assigned
1981	Licence limitation under G licence
1982	Attempts at market development due to grading and low prices for geoducks
1986-1991	Renewed market development efforts and directed fisheries
1988	Rotational fishery implemented on a 3 year rotation between areas Area 24 divided into 3 areas for rotational fishery
1990	Area 24 rotational areas modified; annual precautionary harvest limit of 90.7 tonnes
1992	Restricted fishery to incidental landings while fishing for geoducks, with targetting of horse clams prohibitted; catch ceilings of 1 tonne for Areas 12,13,117,23 & 27, 2 tonnes for Area 14, and 5 tonnes for Area 24; Area 14 divided into geoduck & horseclam harvest areas,
1995	Validation of horse clams required

Table 6. Summary of horse clam landings (tonnes) by management area from South Coast and North Coast areas, 1979 to 1996, as reported on sales slips or harvest logs.

	HORSE CLAM LANDINGS BY MANAGEMENT AREA (TONNES)																								
	North Coast							Inside Waters										West Coast V.I.							Total Coast-wide
Year	2E	4	5	6	7	8	Total N.C.	12	13	14	15	16	17	18	19	29	Total Inside	20	23	24	25	26	27	Total W.C.	Landings
1979									*	27	0.3	6.5	0.2				34.0				4.3			4.3	38.30
1980								0.1	0.5	22	46	50	9		*		127.6		0.4		*	*		0.4	128.00
1981								5.2	*	7.3	1.4	1.7	4.2		2.3		22.1		1.2	27.1	0.7			29.0	51.10
1982								3.1	0.3	163	0.3	2.6	14.8				184.1		2.3	123.6	3.4	6.6		135.9	320.00
1983										0.2		*					0.2		0.2	4.5	*	16		20.4	20.60
1984									3.9	2.3							6.2							0.0	6.20
1985										6		*	0.1				6.1					*		0.0	6.10
1986									23	67	0.9	0.2	2	3			96.1		*	0.2	0.2			0.4	96.50
1987	0.2						0.20	24	0.5	132	42	5.9	146	0.3	*	3.4	354.1	0.1	0.1	1.1				1.3	355.60
1988	0.7		0.1				0.80		14.4	57.7	0.3	9.2	77.1	4.9	1.5	5.3	170.4		7.3	140.7	0.9	4.2	1.2	154.3	325.50
1989					0.1		0.10	22.5	1.6	0.2		0.2	7.9		0.1		32.5		4.8	78.1			0.1	83.0	115.60
1990										29		6		*			35.0			90				90.0	125.00
1991		1					1.00				6.0		22.0				28.0			78.0	2.0			80.0	109.00
1992					1	1	2.00	0.2									0.2							0.0	2.20
1993										6.65		1.59					8.2			14.1			0.9	15.0	23.20
1994'	4.2						4.20				57.5		1.9				59.4				0.1			0.1	63.70
1995'				*	*	*	0.11			2.5							2.5			0.20				0.2	2.78
1996'				*			*																		0.00
Area Totals	5.1	1.0	0.1	*	1.1	1.0	8.4	55.1	44.2	522.8	154.7	83.9	285.2	8.2	3.9	8.7	1166.7	0.1	16.3	557.6	11.6	26.5	2.2	614.3	1789.4

Data for 1979 to 1993 obtained from DFO records.

* landings less than 100 t.

' landings reported from harvest logs, other years landings are from sales slips.

Table 7. Horse clam landings (tonnes) and effort for British Columbia, 1979 to 1996, as reported on sales slips and harvest logs.

Year	Type and Number of Licences Issued	Number of Vessels with Landings	Fishing Days	Landings (t)	Landed Value ($·10³)	Whole Landed Value ($/t)	X CPUE[1] (t/vessel day)	X CPUE[2] (kg/diver hr)	X CPUE[2] (kg/diver day)
1979	G 101	N/A	N/A	37	N/A		N/A	N/A	N/A
1980	G 95	28	N/A	128	79	617	0.6	65	232
1981	G 52	12	N/A	51	38	745	1	ND	ND
1982	G 52	40	N/A	321	235	732	0.5	87	225
1983	G 54	8	N/A	21	12	571	0.7	ND	ND
1984	G 54	5	N/A	6.7	5.5	821	0.2	N/A	N/A
1985	G 55	7	N/A	6.3	5.9	937	0.1	N/A	N/A
1986	G 55	15	193	96	63	656	0.5	170	630
1987	G 55	27	471	355	359	1011	0.8	152	621
1988	G 55	33	405	325	300	923	0.8	119	588
1989	G 55	16	118	116	144	1241	1	220	559
1991	G 55	17	183	110	119	1082	0.6	128	479
1992	G 55	2	8	2	2	1088	0.2	N/A	N/A
1993	G 55	17	118	23	49	2121	0.2	N/A	N/A
1994[2]	G 55	11	168	64	111	1734	0.4	N/A	N/A
1995[2]	G 55	8	15	3	3	1000	0.2	N/A	N/A
1996[2]	G 55	1	1	0.01	ND	ND	0.01	N/A	N/A
1997[2,3]	G 55	12	114	7.44					

N/A - data not available

ND - no data

[1] from sales slip data

[2] data from harvest logs

[3] preliminary data for 1997

Table 8. Horse clam landings (kg) from Area 24 rotational harvest areas, from harvest log reports, 1988 to 1994 (Harbo and Hobbs 1997).

Year	Yellow Bank	Morfee/Dunlap	Lemmens Inlet	Total
1988	15,870	97,310	5,957	119,137
1989	37,936	5,364	15,659	58,959
1990	41,670			41,670
1991		54,706		54,706
1992			0	0
1993	14,065			14,065
1994		0		0
Total	109,541	157,379	21,616	274,471

Table 9. Catch per unit effort (CPUE kg/diver hr) for horse clam directed fisheries and geoduck fisheries.

	Statistical Area 14			Statistical Area 17		Statistical Area 24			
Year	1986	1987	1988	1987	1988	1988	1989	1990	1991
Horse clams	172	211	92	92	114	121	171	151	147
Geoducks	114	131	114	130	114	153	194	143	141

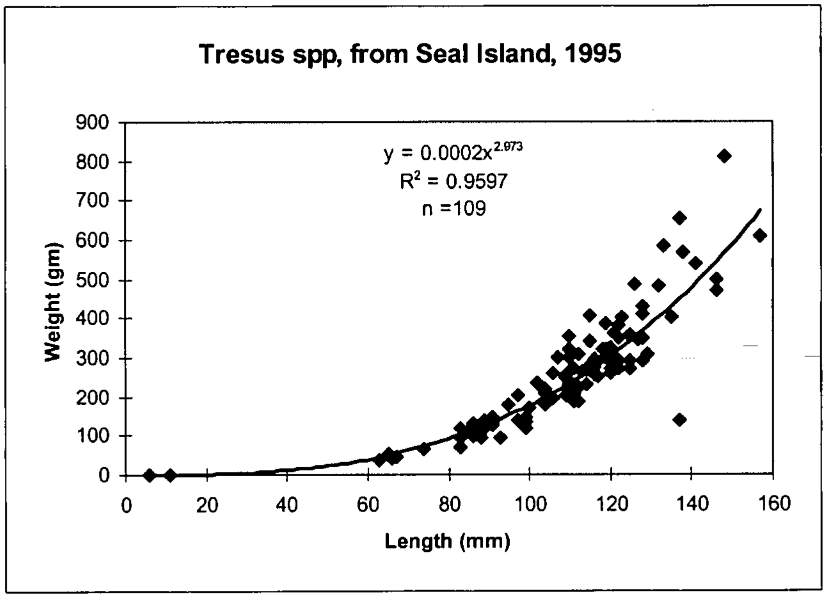

Figure 1. Wet weight-length relationship for *Tresus* spp. dug intertidally from Seal Island in 1995.

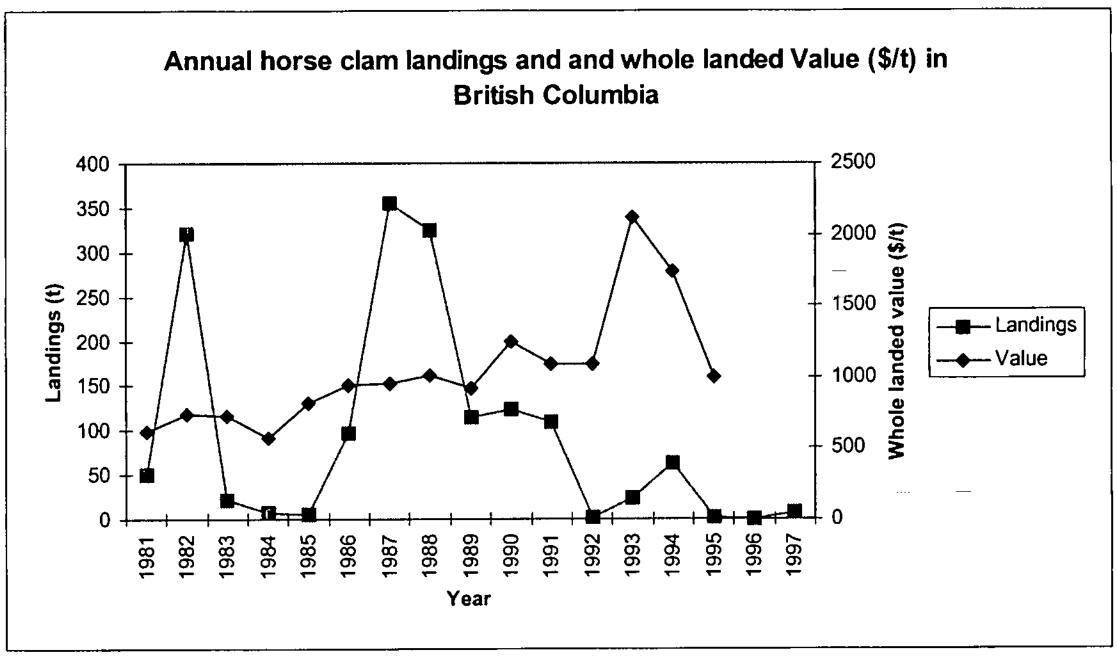

Figure 2. Annual horse clam landings (all *Tresus* spp.) and whole landed value ($/t) in British Columbia.

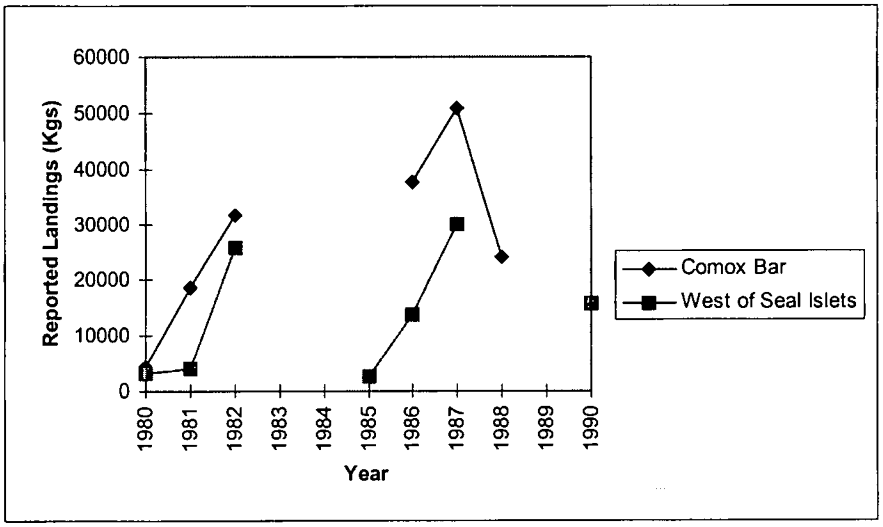

Figure 3. Total annual reported landings (all *Tresus* spp.) from major producing beds in Statistical Area 14.