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Preliminary Review of Experimental Harvest Rates in the Depuration Fishery for Intertidal Clams

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Abstract

This paper reviews eight beaches managed experimentally in the depuration fishery for intertidal clams in British Columbia. The beaches were surveyed annually between 1997 and 1999, and total allowable catches calculated by applying harvest rates of 0.50, 0.25 or 0 to the estimated legal biomass of Manila clams.

Three of four beaches managed using a 0.50 harvest rate exhibited drastic declines, and were removed from the fishery. The fourth beach maintained stock levels at actual harvest rates of approximately 0.40. One of two beaches assigned a 0.25 harvest rate declined and was removed from the fishery. The second maintained stock levels for at least one year of harvest at an actual rate of 0.23. Three control beaches exhibited different stock trends: one showed increased legal densities, one remained relatively unchanged at low stock levels, and one declined throughout the three-year program. From these preliminary results, it was apparent that the harvest rates used were too high, and that there is no single harvest rate that ensures sustainability for all beaches.

Because recruitment is sporadic in clam populations, little information regarding recruitment patterns was gathered in the first three years of the program. The three beaches that exhibited significant recruitment were in a similar geographic area, perhaps indicating that recruitment fails or succeeds over larger areas, as opposed to on a beach-by-beach basis. However, these beaches all had relatively large stocks of legal clams, perhaps indicating that a large proportion of the larvae produced from a beach remain in the vicinity and settle on the same beach where they were spawned. The two hypotheses are not exclusive; conditions required for good recruitment may occur over a larger area, with the magnitude of recruitment on individual beaches in that area related to spawning stock size.

The paper proposes a management framework using biologically-based reference points. The limit reference point is a density of 30 legal clams/m^2, at which time the beach is closed for recovery. Harvest rates increase gradually with increasing legal density, from 0.10 at densities between 30 and 70 legal clams/m^2 to 0.20 at densities between 70 and 130 legal clams/m^2, and finally to 0.40 at densities greater than 130 legal clams/m^2. Beaches closed can be re-opened at densities above 70 legal clams/m^2. This framework allows moderation of harvest rates in response to stock characteristics, benefiting the stock when densities are declining, and allowing increased production when densities are increasing.

The paper recommends that the harvest rates used in the current framework be reduced, that alternatives to constant harvest rate management be considered, that protocols for estimating total landed weight and species composition be established, and that beaches managed using constant total allowable catches from a single baseline survey be re-assessed and this management framework be re-evaluated.

Résumé

On passe en revue les données sur huit plages faisant l'objet d'une gestion expérimentale de la pêche de coquillages intertidaux en Colombie-Britannique en vue de leur dépuration. Les plages ont été échantillonnées chaque année entre 1997 et 1999 et un total autorisé des captures a été calculé d'après des taux d'exploitation de 0,50, 0,25 ou 0 appliqués à la biomasse estimée de palourdes japonaises de taille légale.

Trois des quatre plages en question gérées à un taux d'exploitation de 0,50 ont affiché de fortes chutes et ont été fermées à la pêche, tandis que le niveau du stock de la quatrième plage exploité à un taux réel d'environ 0,40 est resté le même. Le niveau du stock de l'une des deux plages exploitées à un taux de 0,25 a baissé et la plage a été fermée à la pêche, tandis que l'autre a vu son niveau du stock se maintenir pendant au moins un an d'exploitation à un taux réel d'environ 0,23. Trois plages témoins ont affiché des tendances du stock différentes : la première a affiché des densités accrues des palourdes de taille légale, la deuxième est demeurée relativement inchangée du fait que le niveau du stock est resté bas et la troisième a affiché un déclin tout au long du programme de trois ans. D'après ces résultats préliminaires, il est évident que les taux d'exploitation étaient trop élevés et qu'il n'existe pas un taux unique qui assure la durabilité de toutes les plages.

Étant donné que le recrutement chez les populations de coquillages est sporadique, peu de renseignements sur les régimes de recrutement ont été recueillis au cours des trois premières années du programme. Les trois plages qui ont affiché un recrutement important étaient situées dans des secteurs géographiques semblables, ce qui indique peut-être qu'il réussit ou qu'il faillit sur de plus grandes étendues plutôt que d'une plage à l'autre. Toutes les plages en question abritaient toutefois des stocks relativement abondants de palourdes de taille légale, ce qui indique peut-être qu'une grande partie des larves issues d'une plage restent dans les environs et peuplent leur plage d'origine. Les deux hypothèses ne sont pas exclusives; les conditions sous-tendant un bon recrutement peuvent se manifester sur une grande superficie et l'ampleur du recrutement sur une plage de la région en question peut être liée à la taille du stock reproducteur.

On propose un cadre de gestion faisant appel à des points de référence d'origine biologique. Une densité de 30 palourdes de taille légale/m^2 est le point de référence limite; lorsque cette densité est atteinte, la plage est fermée à la récolte pour qu'elle puisse se repeupler. Les taux d'exploitation augmentent graduellement en fonction de l'accroissement de la densité de palourdes de taille légale, passant de 0,10 à des densités se situant entre 30 et 70 palourdes de taille légale/m^2 à 0,20 à des densités se situant entre 70 et 130 palourdes légales/m^2, puis à 0,40 à des densités supérieures à 130 palourdes de taille légale/m^2. Les plages fermées peuvent être rouvertes à la pêche lorsque la densité est supérieure à 70 palourdes de taille légale/m^2. Ce cadre permet de modérer les taux de récolte en réponse aux caractéristiques du stock, ce qui avantage le stock lorsque les densités sont à la baisse et résulte en une production accrue lorsque les densités sont à la hausse.

On recommande que les taux d'exploitation utilisés dans le cadre actuel soient réduits, que des mesures de gestion autres que le taux d'exploitation constant soient considérées, que des protocoles pour estimer le poids total des débarquements et la composition taxinomique soient élaborés, que les plages gérées en fonction d'un total autorisé des captures constant établi d'après un relevé de base unique soient réévaluées et que le cadre de gestion soit réexaminé.

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Introduction

Background

Intertidal clams have a long history of use by First Nations and early settlers to the British Columbia (B.C.) coast (Quayle and Bourne 1972; Bourne 1986). Commercial fisheries for clams have been carried out for over 100 years. However, the clam industry in B.C. has undergone a shift in focus in the last 20 years. Prior to 1980, the industry was based primarily on butter clams, *Saxidomus gigantea*, and to a lesser extent on littleneck, *Protothaca staminea*, Manila, *Venerupis philippinarum*, and razor clams, *Siliqua patula*. There were occasional landings of horse clams, *Tresus capax* and *T. nuttallii*, cockles, *Clinocardium nutallii*, and eastern softshell clams, *Mya arenaria*. Industry has recently landed primarily Manila and littleneck clams rather than butter clams, primarily due to processing costs and changes in market demand rather than fluctuations in abundance (Bourne 1986). The fishery for steamer clams expanded greatly between 1980 and 1988, with Manila clams being the dominant species taken (Table 1).

Sewage pollution closures of many oyster leases and clam beds in the 1960s precluded the use of what had been productive and accessible molluscan resources. In an attempt to access these resources, the process of depuration was explored. Depuration is the removal, in a controlled environment, of micro-organisms of public health significance from live molluscs (Quayle 1988). In 1971, a pilot project jointly funded by the federal and provincial governments and the B.C. oyster industry explored the feasibility of depurating oysters at a plant built at Ladysmith Harbour (Devlin 1973). In 1973 and 1974, the plant carried out purification experiments on butter, littleneck and Manila clams. These experiments demonstrated that it was possible to depurate commercial quantities of these species to acceptable bacteria levels within 48 hours and that all species exhibited similar depuration rates (Neufeld and Jackson 1975). However, commercial depuration for market was not economically viable and the plant closed.

Wild clam stocks were heavily exploited in the 1980s, resulting in fishery restrictions (*e.g.*, time and area closures) to address conservation concerns. The closure of numerous beaches due to contamination also hampered production from the fishery. Reduced harvests could not meet market demand and the product value increased. At this point, depuration became economically viable and processors began turning to depuration to access contaminated resources and provide a steady market supply.

There are presently five depuration facilities licenced for operation in B.C. Annual landings increased from approximately 100 t in 1990, when only a single plant was in operation, to 405.7 t in 1998 followed by a slight decrease to 380.2 t in 1999 (Table 2).

Fishery Management

Under current depuration fishery policy, specific groups can be allocated beaches for harvest. Licenced depuration facilities have been allocated marginally contaminated beaches not accessible through the wild clam fishery (Gillespie *et al*. 1998a). First Nations have been allocated access to marginally contaminated beaches that front reserve lands (Gillespie and Bond 1997). Processors or harvester groups (First Nations, Clam Management Boards) seeking depuration permits are required to submit proposed harvest plans to Fisheries and Oceans Canada (DFO). Proposed harvest areas must first receive Environment Canada approval after growing water quality assessments. Following this approval, Canadian Food Inspection Agency (CFIA) criteria must be satisfied for Harvest of Contaminated Shellfish Licences to be issued. DFO Fish Management Branch requires that a pre-harvest survey be carried out on any new beaches proposed for harvest, to establish harvest quotas. Survey designs are developed jointly by the processor or harvester group and DFO Stock Assessment Branch, surveys are carried out by processors, harvest groups or contractors and the results submitted to DFO Stock Assessment Branch for verification.

Commercial fisheries for Manila and littleneck clams in B.C. are managed under a minimum size limit of 38 mm total length. Manila clams can reach legal size in approximately 3-3.5 years under optimal growing conditions, littlenecks require approximately 3.5-4 years under optimal conditions. Growing conditions change with tidal elevation on a beach, thus the average time to recruit to legal size over the whole population is usually longer (Gillespie *et al*. 1998b; Gillespie and Kronlund 1999).

Certain depuration beaches are included in an experimental harvest program, and were fished at constant harvest rates of 0.25 or 0.50 of stock estimates from annual surveys (Table 3; Figure 1). Because DFO and industry funds are finite and annual surveys on all beaches were not feasible, other depuration beaches were assigned long-term total allowable catches (TACs) derived from baseline stock assessment surveys. TACs were set at 25 or 50% of the baseline stock size, depending on the harvest history of the stock. Those beaches that had been recently harvested before removal from the wild fishery (usually an extended period of harvest that was either continuous with commencement of the depuration fishery, or had not lain unfished for more than two years), *i.e.*, were already fished down, were assumed to be supported by annual recruitment. Annual recruitment was assumed to be relatively large when compared to the fishery-depleted standing stock, since recruitment was assumed to come from elsewhere. TACs for these beaches were set at 50% of initial legal sized stock, under the rationale that regular recruitment would replace the relatively small removals (based on relatively low legal biomass levels). Beaches that had not been fished for at least two years and had accumulated legal-sized stock were assumed to be unable to sustain the 50% TAC as they were fished down. TACs for these beaches were set at 25% of initial stock size. In either case, these harvest rates were considered to be conservative relative to the 0.60 harvest rates believed to occur in conventional commercial fisheries managed with size limits and fishery-based closure criteria (Gillespie and Bond 1997).

In 1996, quotas were allocated for a clam season beginning November 1 and ending October 31 of the following year. The rationale was to allow summer daylight tides for survey work, a period to allow processors to complete analysis and reporting of the surveys, and a reasonable period for quality assurance and verification of survey results by DFO Stock Assessment Division before DFO Fish Management finalized quotas.

Objectives

This paper provides a preliminary review of results of the experimental harvest program in the depuration fishery for intertidal clams in B.C. Its objectives include:

1. To review survey results from eight beaches in the program, which began in 1996, through the surveys completed in the summer of 1999. This review includes discussion of quality of data from industry-conducted surveys.
2. To propose a management framework based on biologically-based reference points, with the objective of rebuilding stock size on over-harvested beaches, and providing threshold reference points for reduction in harvest rate as stock size decreases. This includes discussion of the quality of industry-estimated landings and the importance of recruitment to sustainable harvests.
3. To outline the implications of this review for depuration beaches harvested under a constant TAC management framework.

Methods

Surveys

Survey design varied with the beach and the confidence of the surveyors. Survey designs were either stratified random or stratified two-stage designs (Kronlund *et al*. 1998; Gillespie and Kronlund 1999). Strata were established to cover the full extent of the beach that supported clam beds, using industry knowledge or information from previous assessment work. Sampling intensity was 30 quadrats/ha, with a minimum of 10 quadrats/stratum, except in the case of large beaches using stratified two-stage designs, where a target of at least 200 quadrats/survey, or approximately 18 quadrats/ha, was used. Once established, survey designs remained constant (Table 4).

Both Manila and littleneck clams were harvested in some cases, and the relative abundance of the two species can provide inference about beach characteristics, so littleneck survey estimates are presented in this report.

Beaches were harvested at rates of either 0.25 (Goldstream, Craig Bay) or 0.50 (Booth Bay, Parksville, Mud Bay) or were unharvested controls (Mill Bay, Royston and Wall Beach). The unharvested controls were surveyed to track changes in stock size and characteristics that might be the result of environmental conditions rather than harvest.

Selection of beaches for the program was constrained by issues of stewardship and the decision rules for assigning harvest rates. In the first case, an attempt was made to distribute costs of the program equitably to all industry participants. Each participant was assigned a beach to be harvested at 0.50, 0.25 and an unharvested control. This was complicated somewhat by a shared stewardship arrangement at Parksville and Craig Bay, where two processors were involved. Consideration was also given to the size of the beach included in the experimental harvest program. Beaches selected were large enough to be considered significant contributors to harvests, and in some cases (Goldstream, Mud Bay and Royston) where previous assessment information was available. Final selection of beaches for the program occurred after all of these considerations, not as random assignment of treatments. The lack of random selection of program beaches and assignment of harvest rates limits the ability to draw inferences regarding other beaches in British Columbia.

Landings

Landings were reported by depuration facilities following harvests. In most cases, landed weights were measured at the beach at time of harvest or upon delivery to a processing plant. In some cases, landed weights were measured after a period of wet storage which resulted in some mortality (termed "shrinkage"). In some cases, where mixed clam products were sold, landed weights for individual species were only roughly estimated, while in others, the species were sorted and weighed separately. Inconsistencies in species identification apparent in historic landings (see sections detailing individual beaches, below) were presumed to have been corrected before harvests in 1996/97 began.

Simple Production Modeling

Simple models relating production (change in density of legal size clams) to the post-harvest density of legal size clams and density of sublegal size clams from the previous year. Post–harvest legal density, $D_{i'}$, was calculated as:

$$D_{i'} = D_i * \left(1 - HR_i\right) \qquad (1)$$

where D_i is the estimated legal density in year i and HR_i is the actual harvest rate achieved in year i. Change in legal density, ΔD, was calculated as:

$$\Delta D = D_{i+1} - D_{i'} \,. \qquad (2)$$

Sublegal densities were simply those estimated from surveys. The production relationship was modeled using simple linear regressions.

Results

Booth Bay

The Booth Bay harvest area (48º52'N, 123º34'W) is primarily within Booth Inlet, on the west side of Saltspring Island (Figure 1). Booth Bay has been harvested for depuration since 1991. Landings totaling approximately 300 t, all reported as littleneck clams, were reported from Booth Bay between 1991 and the survey in July 1996. The 1996 survey indicated that the stock in the harvest area was primarily Manila clams, so these reports are assumed to be misidentified.

Surveys conducted under the experimental harvest program have been of stratified random design, consisting of 16 strata totaling 3.13 ha (Table 4). The first survey was undertaken in July 1996 to establish quota for the 1996/97 season (Table 5). Harvests did not take the entire quota, and the final harvest rate was 0.42. The August 1997 survey indicated that legal Manila biomass has increased 6% while sublegal Manila biomass also increased 26%. Harvests in the 1997/98 season also fell short of the quota, with a final harvest rate of 0.41. The August 1998 survey indicated that legal Manila biomass had decreased 25% and the sublegal Manila biomass decreased 27%. 1998/99 harvests did not achieve quota and the final harvest rate was 0.39. The August 1999 survey showed that legal Manila biomass had increased 16% while the sublegal biomass likewise increased 13%.

During the experimental harvest program, biomass levels at Booth Bay have remained remarkably consistent, ranging between 90 and 120 t of legal Manilas and 6 and 9 t of sublegal Manilas (Figure 2). The beach supports remarkable densities of both legal and sublegal Manilas, ranging between approximately 150-200 legal Manilas/m^2 and approximately 200-280 sublegals/m^2.

Craig Bay

Craig Bay (49º19'N, 124º15'W) is located just south of Parksville, between Madrona nad Brant Points (Figure 1). Craig Bay was fished in the regular commercial fishery until it was closed for contamination in November 1995. It was a major contributor to clam production in the area, along with Parksville and Lasqueti Island. There was no harvest in 1996.

In the spring of 1996, a significant clam mortality was reported in Craig Bay. Samples of live and moribund clams collected in April 1996 showed characteristic ctenidial damage consistent with a winter kill (Bower *et al*. 1986; Bower 1992). Winter kills are the result of low temperatures in winter coinciding with night-time low tides, usually with a prevailing wind over the exposed beach. The clams' gills are damaged in mid-winter, but mortality is not expressed until the spring, when rising water temperatures increase metabolism in the clams, causing them to succumb to ctenidial damage. Large quantities of moribund and dead clams are found on the surface of the beach after a winter kill, and considerable quantities of dead shell remain for one to two years after.

Under the experimental harvest program, stratified two-stage surveys were conducted each year. The survey area consisted of 20 strata totaling 16.50 ha (Table 4). The first survey was undertaken in May 1997 to establish a quota for the 1996/97 season (Table 6). The survey incorporated an unbalanced design which included two strata that were sampled with only a single first stage unit. The initial analysis by the processors' staff was incorrect, and the survey was re-analyzed using a mixed model in which 18 strata were analyzed as a stratified two-stage survey, the remaining two strata analyzed as a stratified random survey, and the resulting biomass estimates and their associated variances added to yield a total estimate for the beach. Review of the survey material for this paper revealed an error in the calculation of stratum areas, which resulted in a higher biomass estimate. Thus, although the quota allocated in 1997 was taken, the actual harvest rate was 0.19. Craig Bay was harvested co-operatively by two depuration processors, with the allocated quota divided equally between them.

Craig Bay was surveyed again in August 1997 to establish a quota for the 1997/98 season. Legal Manila biomass had decreased by approximately 7%, while sublegal biomass had decreased by approximately 54%. This was interpreted as a large portion of the sublegal stock growing above legal size to nearly replace the legal stock that had been removed by harvests or lost to natural mortality. The 1997/98 harvests achieved their assigned quota, with a final harvest rate of 0.25.

The August 1998 survey indicated that legal Manila biomass had decreased by 62%, from 105 t to 40 t. There was no accumulation of dead shell on the beach, which is indicative of winter kill or other unusually high mortality. The greater-than-expected decrease in legal biomass remains unexplained. Sublegal Manila biomass remained virtually unchanged. The 1998/99 quota was taken, with a final harvest rate of 0.24.

The August 1999 survey showed both legal and sublegal Manila biomass to have decreased by 12% each. After discussions between DFO and industry regarding the steadily decreasing biomass estimates and the projected size of the 1999/2000 quota (8,920 kg split between two processors) the beach was removed from the depuration fishery.

During the experimental harvest program, Craig Bay exhibited a steady decreasing trend in biomass, from 114 t to 36 t of legal Manilas and from 83 t to 34 t of sublegal Manilas (Figure 3). The greatest decrease in sublegal stock occurred between May and August of 1997, as clams near the legal size limit grew into legal size over the summer growing period, coincident with the smallest decrease in legal biomass. Legal biomass decreased most profoundly between August 1997 and August 1998, a loss too great to be accounted for by the reported harvests, without any evidence of increased natural mortality. There is no previous survey data to determine whether these stock levels are high or low relative to levels before the program.

Goldstream

Goldstream (48º29'N, 123º33'W) is at the southern end of Finlayson Arm, Saanich Inlet (Figure 1). The harvest area is a large, gently sloping estuary crossed by several active stream channels. the substrate is a thick layer of silt, except in and near the stream channels, where it is primarily gravel and sand. The harvest permit extends from the overhead power lines adjacent to the mouth of Arbutus Creek to the southern tip of Sawluctus Island.

The Goldstream site was first harvested in 1990, and has been continuously harvested since. Landings in 1990 were reported as Manila clams only, and landings in 1991-1993 were reported as littleneck clams only. In total, landings of approximately 40 t of Manilas and 130 t of littlenecks were reported from Goldstream between 1990 and the survey in August 1997. As with Booth Bay, these landings were assumed to be misidentified, and that landings for each year likely represented a mixture of the two species.

Surveys were undertaken at Goldstream in 1994 (Gillespie *et al*. 1998a) and 1996 (Gillespie and Kronlund 1999). The 1994 survey differed drastically in layout from later surveys, and encompassed only 3.84 ha. The 1996 survey had four of the five strata that made up later surveys, and encompassed 4.54 ha. Surveys from 1997 through 1999 had five strata totaling 5.34 ha (Table 4). Because of differences in the areas surveyed in 1994 and 1996, these surveys are not directly comparable to those undertaken in 1997-1999.

The first survey under the experimental program was undertaken in August 1997 (Table 7). Limited harvesting, primarily because Booth Bay remained free of PSP closure, did not allow the entire quota to be taken, and final harvest rates were 0.04 for Manilas and 0.11 for littlenecks. Landings for the area were reported as an even split of Manilas and littlenecks (*i.e.*, the species composition of the landings was estimated, not measured).

The August 1998 survey showed an increase in legal Manila biomass of 61% and a decrease in sublegal Manila biomass of 17%. Legal Manila abundance increased 60% and sublegal Manila abundance decreased 34%. In the 1998/99 season, the total quota for both species combined was not entirely achieved, but an estimated species composition of 60% Manilas and 40% littlenecks resulted in final estimated harvest rates of 0.18 for Manilas and 0.37 for littlenecks. If the species composition were determined in proportion to the legal biomass of the two species from the 1998 survey, then harvest rates would have been 0.23 for Manilas and 0.22 for littlenecks. The August 1999 survey indicated a decrease in legal Manila biomass of 3% while sublegal Manila biomass decreased 36%.

During the experimental harvest program, Manila biomass at Goldstream was relatively stable, with legal biomass ranging from 63 to 101 t, and sublegal biomass ranging from 14 to 26 t (Figure 4).

Surveys completed in 1994 and 1996, although not directly comparable to the 1997-99 surveys, indicate that biomass levels have been realtively consistent. Manila biomass in 1994 was 2.54 kg/m^2 for legals and 0.16 kg/m^2 for sublegals (Gillespie *et al*. 1998a). Manila biomass in 1996 was 1.11 kg/m^2 for legals and 0.47 kg/m^2 for sublegals. Manila biomass in 1997 was 2.13 kg/m^2 for legals and 1.56 kg/m^2 for sublegals.

Mill Bay

Mill Bay (48º39’N, 123º33’W) is on the west side of Saanich Inlet, north of Goldstream (Figure 1). The survey area is relatively small, and consists of two strata on the north side of the bay, west of Whiskey Point, and two strata on the south side of the bay near the mouth of the creek. The intervening area had a soft mud substrate which did not support large populations of Manila or littleneck clams. The area was harvested for depuration in 1994 and 1995, with a total of approximately 5 t of littlenecks reported. 1996 survey results would indicate that historic landings are likely misidentifications, and probably represent a mixture of Manila and littleneck clams.

Mill Bay was first surveyed in August 1997 (Table 8). The survey was a stratified random design consisting of four strata totaling 0.56 ha (Table 4). The August 1998 survey indicated that legal Manila biomass had increased by approximately 76%, while sublegal biomass increased by approximately 54%. The August 1999 survey indicated that legal Manila biomass had increased approximately 5% while sublegal biomass had decreased approximately 19%.

Legal biomass increased consistently over the three years of the experimental harvest program, from approximately 4.3 t to 7.8 t (Figure 5). Over the same period sublegal biomass increased from approximately 1.8 t to 2.8 t, with a decrease in the final year to 2.3 t. There is no previous survey information available to judge whether these levels are comparable to historic stock levels.

Mud Bay

Mud Bay (49º28'N, 124º44'W) is a large, gently sloped gravel/sand beach west of Ship Point in Baynes Sound (Figure 1). The area has been harvested for depuration since 1993, with landings totaling 100 t of Manilas reported between 1993 and the August 1997 survey. The area was surveyed in 1995 using different methodology and a different survey area, and as such, the results of this survey are not directly comparable to later surveys.

The harvest area is interspersed in areas above a number of aquaculture tenures, and is naturally divided into two halves with relatively poor clam ground in between. Following consultation with industry in 1998, these two areas were separated and termed Mud Bay East and Mud Bay West. The western portion was to have its harvests complete and be surveyed in the late summer. The eastern portion would be harvested in September and October, and then resurveyed the following summer.

Because all harvest activities had been in the western portion prior to the split in 1998, the 1997/98 landings could be determined for each area by simply placing landings before the August 1998 survey into Mud Bay West, and the remaining landings for the season into Mud Bay East. Landings for the two areas were reported separately in 1998/99.

The entire area was surveyed in August 1997, with the eastern portion consisting of 13 strata totaling 12.0 ha and the western portion consisting of 19 strata totaling 14.5 ha (Table 4). Both areas were surveyed using a stratified two-stage design. Because of time constraints (daylight tides late in August were required for surveys, and all harvesting had to be complete before the survey) the entire quota was not taken, and the final harvest rate was 0.34 (Table 9).

The August 1998 survey of Mud Bay West indicated decreases in biomass for both legal Manilas (51%) and sublegal Manilas (36%) (Table 10). The 1998/99 quota was not taken entirely, and the final harvest rate for Mud Bay West was 0.39. The August 1999 survey of Mud Bay West showed further decreases in biomass of 51% for legal Manilas and 27% for sublegal Manilas. The June 1999 survey of Mud Bay East showed a decrease of approximately 30% in legal biomass, with an increase of approximately 4% in sublegal biomass.

During the experimental harvest program, legal Manila biomass at Mud Bay East decreased from approximately 31 t to 21 t (Figure 6). Over the same period, Mud Bay West demonstrated consistent decreases in Manila biomass, from approximately 60 t to 14 t for legals and from approximately 211 t to 98 t for sublegals (Figure 7). Following consultation with industry after the 1999 surveys, neither beach was harvested due to stock concerns.

Results of the 1995 survey, although not directly comparable to the 1997-99 surveys, indicate that legal stock levels in 1997 were considerably less than in 1995. Results of the 1995 survey for the entire Mud Bay site were 0.66 kg/m^2 for legals and 1.01 kg/m^2 for sublegals. In 1997, Manila biomass at Mud Bay East was 0.26 kg/m^2 for legals and 0.71 kg/m^2 for sublegals. At Mud Bay West legal biomass was 0.41 kg/m^2 and sublegal biomass was 1.45 kg/m^2. The relatively high level of sublegal biomass in 1997 at Mud Bay West did not result in legal stock increases by 1999, when legal biomass had fallen to 0.10 kg/m^2 and sublegal biomass had fallen to 0.68 kg/m^2.

Parksville

Parksville Beach (49º19'N, 124º17'W) extends from the town of Parksville on the east coast of Vancouver Island to the mouth of the Englishman River (Figure 1). Parksville was fished in the regular commercial fishery until a contamination closure was enforced in November 1995. It was a major contributor to clam production from the area, along with Craig Bay and Lasqueti Island. The survey area is a broad gently sloped beach somewhat protected from the open waters of Georgia Strait by a large natural sand berm.

Parksville was surveyed in May 1997 to establish a quota for the 1996/97 season (Table 11). The survey was a stratified two-stage design that consisted of 6 strata totaling 6.95 ha. The 1996/97 quota was taken with a final harvest rate of 0.49 (Table 4). Parksville beach was harvested co-operatively by two depuration processors, with the allocated quota divided evenly between them. The 1997 survey analysis contained an error in calculation of one stratum area. The error was carried over into subsequent analyses, and resulted in an over-estimate of abundance and biomass of approximately 5%. The estimates presented in Table 11 have been corrected; the quotas presented are those allocated based on the over-estimate of biomass; the actual harvest rates achieved are based on corrected biomass estimates.

The area was surveyed in August 1997, following completion of harvest of the 1996/97 quota, supposedly to establish a quota for the 1997/98 season. Legal Manila biomass had decreased by approximately 66%, while sublegal biomass increased by 43%. Sublegal abundance increased by 30%, indicating that the sublegal portion of the population grew without a significant number of them growing above legal size.

Industry approached DFO with the proposal that a survey following summer would result in a larger quota, and were allowed to re-survey the beach in July 1998. Legal Manila biomass had increased by 33% while sublegal biomass decreased by 22%, as a proportion of the sublegal stock grew above the legal size limit. A quota of just over 20 t was allocated, but due to a bookkeeping error in reported landings by one processor, the final harvest rate was only 0.40.

The May 1999 survey showed a decrease in legal biomass of approximately 50%, with sublegal biomass also decreasing 33%. A modest quota of 9,668 kg (split between two processors) was allocated. Attempts to harvest the quota were unsuccessful, as diggers complained that stocks were to sparse to be harvested easily. Following consultation between DFO Fish Management and industry, the beach was removed from the depuration fishery.

During the experimental harvest program, Parksville exhibited a steady decline in legal Manila biomass, from approximately 81 t to 19 t (Figure 8). the only departure from the pattern was the increase in biomass between August 1997 and July 1998, a period in which no harvests occurred.

Royston

Royston (49º39'N, 124º56'W) is a relatively large site between the breakwater on the southern side of Comox Harbour and Gartley Point (Figure 1). The site includes the estuary of the Trent River and is crossed by Roy Creek. Royston was harvested for depuration between 1992 and 1995, with total landings of approximately 100 t of Manila clams reported. Late in 1995 Environment Canada changed the classification of the beach from Contaminated to Prohibited, preventing further harvests for depuration.

A contract survey of the area was done in 1993 (Lipovsky, unpublished manuscript) which used a different methodology and a different survey area. A survey was undertaken at Royston in 1995, but this survey used different protocols, included 2.50 ha of area to the west of the wharf and covered only 8.29 ha on the east side of the wharf. Due to differences in area surveyed the results of both surveys are not directly comparable with surveys undertaken in 1997-99.

Royston was surveyed in June 1997. The survey area consisted of 12 strata totaling 10.00 ha (Table 4) on the eastern side of the wharf, ending near the mouth of the Trent River. The survey indicated that Manila stocks consisted primarily of sublegal clams; sublegals accounted for 70% of the estimated biomass and 85% of the estimated abundance (Table 12). The May 1998 survey indicated that legal Manila biomass had increased 3% while sublegal biomass had increased 50 %. The May 1999 survey showed that legal Manila biomass had increased 21% while sublegal biomass had decreased 2%.

Legal Manila biomass increased from approximately 22 t to 28 t during the experimental harvest period (Figure 9). Sublegal biomass also increased from approximately 52 t to 78 t, with a decrease to approximately 76 t in 1999.

Early surveys at Royston, although not directly comparable, indicated that Manila stocks in the area had been much larger than at the beginning of the program. In 1993, legal density was 1.27 kg/m^2 and sublegal density was 0.77 kg/m^2 (Lipovsky, unpublished manuscript). In

1995, legal Manila density was 0.30 kg/m^2 and sublegal density was 0.80 kg/m^2 (unpublished data). Manila densities from the June 1997 survey were 0.22 kg/m^2 for legals and 0.54 kg/m^2 for sublegals. Final densities at the end of the 1995 fishery are not known, but the stock had not recovered to 1992 levels in 1999, after more than 3 years of closure.

Wall Beach

Wall Beach (49º18'N, 124º17'W) is a relatively small beach south of Craig Bay (Figure 1). It has a sand/gravel substrate, crossed by freshwater runoff from a storm drain outfall. The beach was closed due to fecal contamination in the early 1990s. It was occasionally utilized by harvesters in the regular clam fishery prior to closure. It was chosen as an unharvested control for comparison to the Parksville and Craig Bay sites.

Wall Beach was surveyed in August 1997. The survey consisted of 11 strata totaling 2.18 ha (Table 4). The survey indicated that Manila clam stocks consisted primarily of sublegal clams, which accounted for 88% of total Manila biomass and 96% of total Manila abundance (Table 13). The July 1998 survey showed that legal Manila biomass had decreased 30% while sublegal biomass had decreased 17%. The July 1999 survey indicated that legal Manila biomass had decreased 51% while sublegal biomass decreased 38%.

Through the experimental harvest program, Wall Beach exhibited a strong decreasing trend in biomass of both legal and sublegal Manila clams, from approximately 4.4 t to approximately 1.5 t for legals and approximately 31 t to approximately 16 t for sublegals (Figure 10). Because there were no depuration harvests to remove stock from the beach (survey samples totaled less than 50 kg per year) and no evidence of winter kill or other catastrophic mortality, these decreases remain unexplained.

Simple Production Modeling

The simple production modeling conducted for this paper is not meant to be an extensive treatment of production from clam stocks. It makes broad assumptions about the stock response to harvest, and does not explicitly deal with natural mortality, growth or harvest history differences between beaches.

The relationship between production and legal biomass in the previous year was modeled using linear regression (Figure 11). Although the relationship was relatively poor (R^2=0.5801), there was a general increasing trend in the data. This "average production" line will be used, within the limits described above, to derive reference points for the management framework.

There was no apparent relationship between sublegal density and production, likely because some beaches exhibited poor growth: clams did not grow through the size limit in a timely fashion. Mud Bay East, Mud Bay West, Royston and Wall Beach exhibited a pattern of relatively large sublegal stocks that did not grow through to legal size during the program.

Discussion

Evaluation of Data Quality

Survey Data

As with any joint DFO–industry assessment program, there were some problems experienced. When some surveys were submitted, it was discovered that the scales used to measure both sample and individual clam weights weighed in pounds, accurate to two decimal places. The weights were then converted to grams for analysis. This incorporates a measurement error of approximately +/- 5g to each measurement, which is in addition to the sampling error represented in the confidence intervals. This error becomes very important when samples are small, or individual clams are measured. If the capacity of the balance is small, then large samples must be weighed in several batches, and the error is compounded. Before future surveys are undertaken, DFO must ensure that processors scales are of appropriate capacity and resolution for the measurements required under the protocol.

Early development of survey design occasionally resulted in decreased confidence in the results. For example, the Craig Bay survey in May 1997 resulted from an unbalanced survey design when two strata were assigned only a single first stage unit. These strata could not be analyzed using the two-stage design, as one FSU gives no degrees of freedom in the analysis. Rather than have industry incur the costs of repeating the survey, these two strata were analyzed using stratified random estimators, which allowed statistical analysis, but violated key assumptions of the model. While the mean estimates are little affected, estimates of variance, and the confidence intervals which are derived from variance, are likely inaccurate. These problems were corrected for the August 1997 survey.

There were also errors in data entry, which in most cases could be corrected during review of the data prior to analysis. In some cases, data was entered directly onto computers, then analyzed, and finally formatted to DFO standards for submission with the report. When the results of DFO analyses did not agree with industry estimates, a long process of comparing data sets and resolving inconsistencies was undertaken. In these cases there were no DFO data sheets to resolve disagreement, and the validity of a very small proportion of the data remains in question. Although somewhat tedious, the collection of data onto data sheets, followed by data entry, formatting and proofing prior to analysis ensures that a permanent record of the data exists for the resolution of questionable entries and to prevent loss due to computer drive failures.

There were often errors in the industry analyses. In most cases, these were incomplete data sets (*i.e.*, quadrats with no clams of a given species were not coded in the data as zeros, just excluded form the data set). These errors were easily rectified. In one case, Parksville, an error in measuring stratum area was made in the initial survey in May 1997, and carried forward through the 1999 survey. This had the effect of artificially increasing estimates of abundance and biomass by approximately 5%.

Estimated confidence intervals generally varied between 10 and 20% of the mean estimates of Manila biomass, except at low levels of biomass (Figure 12). Confidence intervals were consistently high at Wall Beach, ranging between 47 and 59% of the mean estimate for legal Manila biomass. Confidence intervals for sublegal Manila biomass were somewhat elevated for Mill Bay and Wall Beach. These intervals could be reduced by using bootstrap methodology to calculate confidence intervals, as in Gillespie *et al*. (1998a).

For comparison, confidence intervals for DFO surveys carried out at beach 102 on Savary Island in 1995 ranged between 11 and 28% for legal biomass and 40 and 42% for sublegal biomass, depending on the estimator used (Kronlund *et al*. 1998).

Confidence intervals are calculated from estimates of sampling variance, therefore samples that fall in areas of extremely high abundance can have as dramatic an effect as samples that fall in areas with no clams. Because clam harvesters tend to affect stock distribution primarily through depletion of areas where particularly high abundance aggregations occur, the general effect of repeated fisheries is to reduce variability on the beach, resulting in tighter confidence intervals when stock levels are uniformly low over the entire sampling area. Thus, the small confidence intervals around estimates from depleted areas, such as Craig Bay, Parksville and Royston are not surprising.

Confidence intervals at Booth Bay are relatively low for so large a stock. However, the survey design developed by the processor utilizes a relatively large number of strata for the survey area, and partitions high and low density areas very well, resulting in low variation within strata, and a low overall confidence interval. The synchronized pattern of increased or decreased legal and sublegal biomass in successive surveys might indicate some systematic bias in the surveys, as the same pattern is repeated (although not as distinctly) in littleneck estimates derived from data taken on the same surveys (Figure 13). What the nature of this bias might be, if it indeed exists, is not known.

DFO Fish Management has proposed that the depuration manager attend some surveys in 2000, to ensure that field collections are completed in accordance with approved survey protocols.

Landing Data

Reported landings were unverified, and differences in methods of estimating catch became apparent over time. Some plants were interested only in harvesting Manila clams and discouraged their diggers from keeping littlenecks. These plants reported landings of Manilas only. On other occasions, processors sorted their catch and reported separate weights for Manila and littleneck clams. In some other cases, the landings were not sorted to species, and relative composition was only roughly estimated. In most cases, it was unclear when sorting had been done, whether the weights were measured after cleaning and sorting, or, if weights were taken at the beach, what methods were used to estimate shrinkage to give a final landed weight.

In recent years processors have been allowed to stockpile harvested product by wet-storing it on beaches near their plants. Early in the program, it was unclear whether the reported landings included all clams that were taken from the beach, or whether they did not include clams that were harvested and subsequently died during wet storage. Landings are now reported at the time of harvest, prior to wet storage. Consultation with industry is required to develop standard protocols for estimating landings, or independent verification may be required.

General Trends

It is obvious that the previous strategy of linking higher harvest rates to beaches that have been "fished down" to theoretically productive levels has not worked. Even though TACs decreased as biomass decreased, harvest rates outstripped recruitment available to replenish clam populations on the beach.

Drastic population decreases were associated with three of the four 0.50 harvest rate beaches (Mud Bay East, Mud Bay West and Parksville) and two were removed from the fishery after the 1998/99 season (Table 14). Parksville was removed from the fishery after early attempts to harvest in 1999/2000 were met with digger complaints that stocks were too thin to be effectively harvested. Only Booth Bay, which supports remarkable densities of both legal and sublegal Manila clams, was able to sustain harvest rates greater than approximately 25% (Figure 14).

The two beaches harvested under a 0.25 harvest rate exhibited radically different responses. Craig Bay legal Manila biomass decreased dramatically between the 1997 and 1998 surveys, and continued to decrease during the 1998/99 harvest. Goldstream legal Manila biomass increased dramatically between the 1997 and 1998 surveys, in part because the actual harvest rate in the 1997/98 season was only 0.04, but also due to good recruitment. Legal Manila biomass remained relatively stable at Goldstream after the 1998/99 harvest, which resulted in a harvest rate of 0.23.

The control beaches exhibited a fairly wide range of changes in Manila biomass. Mill Bay showed a large increase in legal Manila biomass between the 1997 and 1998 surveys and continued to increase, although at a lesser rate, between the 1998 and 1999 surveys. Royston showed virtually no increase in legal Manila biomass between 1997 and 1998, but a moderate increase in 1999. Both legal and sublegal biomass of Manilas decreased steadily over the three years at Wall Beach.

From the responses of beaches examined it is apparent that there is no single harvest rate that can be applied to all beaches that will ensure sustainability of stock levels or production. Booth Bay shows that fairly high harvest rates can be maintained, at least for the short term, without significantly reducing stock size. However, Wall Beach shows that stock levels vary even in the absence of harvest, and stock declines may not always be linked to harvests (although continued harvest in periods of "natural" decline is not a responsible action). It should be noted as well that significant changes in substrate characteristics at Parksville (personal observation) may have contributed to stock declines, and that illegal and unreported removals at any of the sites may have contributed to stock declines.

Recruitment

One objective of the survey program was to gather information about recruitment patterns and magnitude over a variety of beaches and a number of years. Given the limited evidence that recruitment in clam populations is sporadic, three years is not an extensive data series. At Savary Island in 1995, the legal stock on the beach was dominated by the 1990 year-class, with poor recruitment for at least three years following (Gillespie *et al*. 1998b). Butter clam stocks at Seal Island only experienced significant recruitment events rarely in a data series extending back to 1940 (Kingzett and Bourne 1998). Therefore, it is optimistic to assume that recruitment patterns would be apparent from the program at this time.

It is interesting to note that two of the beaches that demonstrated a measurable recruitment to legal size were in Saanich Inlet, and the beach that maintained large legal stocks under high harvest rates, Booth Bay, was relatively close by, in an area protected from the open waters of Georgia Strait. This might support the hypothesis that recruitment may succeed or fail over relatively large areas (*i.e.*, that recruitment is not determined on a beach-by-beach basis). This is complicated, however, by the observation that recruitment events occurred only on beaches with relatively large densities of legal clams. This supports the hypothesis that recruitment is related to stock size on a particular beach, implying that a large proportion of the larvae produced on a given beach are entrained in the area, and settle on the same beach. In fact, these hypotheses are not exclusive of one another; local environmental conditions may promote successful recruitment over a fairly large area, but the magnitude of the recruitment on any beach in the area may be dependent on the size of its spawning stock.

Detailed analyses of age data from all of these beaches is required (many of the samples have not been processed or await age determination), but more information (actually detecting recruitment events on more beaches) is certainly required before the issue of spatial patterns of recruitment can be addressed, and the potential for using index beaches to assess recruitment for large areas can be evaluated.

Managers inquired as to the best way to take advantage of recruitment pulses. The first option is to increase the harvest rate in response to increased abundance, and “make hay while the sun shines”. The second is to maintain conservative harvest rates, and face less risk of depleting biomass on the beach and forcing a closure. Gillespie and Bond (1997) used simple pragmatic modeling exercises to explore expected life spans of cohorts under various harvest rates. Their model tracked the fate of the standing legal stock plus one years’ recruitment, which was modeled at high, medium and low levels. They showed that high harvest rates and 50% TACs yielded higher production, but that most of this came in the first year of harvest. Only the 0.25 harvest rate and 25% TAC were able to maintain harvests from the initial legal biomass and recruitment for more than 4 years. There is mounting evidence that significant recruitment may occur at intervals of greater than 3 years, another inducement to consider lower levels of harvest, particularly at low stock levels.

Fishery Management

Management Framework Based On Biological Reference Points

From the information gathered thus far in the experimental harvest program, it is apparent that harvest rates cannot remain constant as stock size fluctuates, but must be tied to specific reference points. Therefore, I propose a system of sliding harvest rates, with specific decision rules to be followed after the results of annual assessment surveys are received (Table 15).

Industry initiated discussions with DFO Fish Management regarding voluntary closure of several beaches after the 1999 surveys. Harvests were attempted at Parksville in September of 1999, but diggers complained that the stock density was too low to harvest effectively. Although the quota had been achieved at Craig Bay in 1998/99, the August 1999 survey indicated that legal Manila density had decreased further, and agreement to forgo harvests was reached. Similarly, suspension of harvest was agreed to in Mud Bay, after failing to achieve quota in Mud Bay East in 1997/98 or Mud Bay West in either 1997/98 or 1998/99, and after the June and August assessment surveys showed further declines in legal Manila density. Stock density had fallen below the threshold at which it was still economically viable to consider harvests. Legal Manila stock density was highest at Parksville (14.12 legal clams/m^2) and lowest at Mud Bay East (5.11 legal clams/m^2) (Table 14).

The reference point for closure to prevent economic collapse of Manila clam stocks should have a buffer zone, and the simple modeling carried out indicates that “average production” at 20 legal clams/m^2 is approximately 0 and at 30 legal clams/m^2 is approximately 9 clams/m^2 (Figure 11). Therefore, I propose that 30 legal clams/m^2 is a suitable limit reference point for closure of a beach for recovery. Under this decision rule Craig Bay, Mud Bay East, Mud Bay West, Royston and Wall Beach would have been closed for recovery when surveyed in 1997.

Booth Bay was able to maintain a strong biomass of Manila clams at harvest levels near 0.40. This stock was unique amongst beaches examined in the program in its sustained high-level production. Other beaches that had sustained long-term fishing pressure in regular commercial fisheries (Parksville) or previous depuration fisheries (Mud Bay) could not sustain high levels of production under quota management. Therefore, 0.40 should be the maximum harvest rate considered for quota-based harvests linked to annual surveys.

Stock density at Booth Bay varied between 147 and 202 legal clams/m^2 during the series of surveys. The lower 95% confidence interval of the lowest estimate is approximately 130 legal clams/m^2. Thus, the proposed threshold reference point for allowing a 0.40 harvest rate is a Manila density of greater than 130 legal clams/m^2.

At stock levels between these reference points, harvest rates will diminish in a step-wise fashion that decreases the risk of dropping below the limit for closure (Table 15). If stock levels are below the threshold for a 0.40 harvest rate, then the harvest rate will be reduced to 0.20, with the target of maintaining the beach at a high stock level and maximum production. At lower stock levels, *i.e.*, those approaching the limit reference point, additional management action is required to reduce the risk of closure, in this case reducing the harvest rate to 0.10. With the exception of Booth Bay, significant stock increase was only seen once on harvested beaches; at Goldstream between the 1997 and 1998 surveys. The harvest rate in the 1997/98 season was 0.04 and legal Manila density increased from 55 to 88 clams/m^2. The pragmatic production relationship constructed from the experimental beach data predicted an increase from 55 to 81 legal clams/m^2 (Figure 11). To compensate for the uncertainty in the simple model, and rather than tie the proposed harvest rate to a single example, a stock density of at least 70 legal clams/m^2 is the proposed threshold for increasing the harvest rate from 0.10 to 0.20. This threshold may be somewhat aggressive, as Gillespie *et al*. (1998b) recommended harvest rates between 0.13 and 0.17 for Savary Island in 1995, when legal stock density was 79.1 clams/m^2.

The recovery time for stocks to rebuild after closure cannot be determined from the limited data available. Both Mill Bay and Goldstream exhibited sizeable increases from moderate densities (38 and 55 legal clams/m^2, respectively) when unharvested, or harvested at very low rates. Thus, the proposed reference point for re-opening harvests is 70 legal clams/m^2, the same as that which would allow a 0.20 harvest rate. Note, however, that Mill Bay and Goldstream were the only sites to show significant recruitment to legal stock in the program; only two recruitment events out of 19 opportunities. A survey would be required to re-open harvest of the stock, but an annual survey need not be a DFO requirement. Industry can decide when they wish to survey and request re-opening of harvests.

Obviously, the stock levels that are proposed as reference points for reduced levels of harvest are necessarily arbitrary, given the lack of data available to set them. Unfortunately, the carrying capacity of each beach (*i.e.*, the maximum density of clams possible) is not known. However, substrate, exposure, and freshwater influence all differ from beach to beach, and are likely determinants of carrying capacity. Continued evaluation of the framework will provide information on recruitment patterns, recovery rates and the appropriateness of the proposed threshold levels.

Survey Timing

The framework proposed above requires annual decisions based on new data from annual surveys. The Parksville and Craig Bay examples show that stock abundance can be greatly reduced in only two years' harvest. Changing the requirement for annual surveys reduces the ability of the framework to respond to changes in abundance, and greatly increases the risk of having to impose more restrictive management options (*e.g.*, closure). Annual surveys also allow for timely management responses to increases in legal stock size, providing for increased production should a recruitment event occur.

In the event of a closure, a survey would be required to provide stock information indicating that recovery was sufficient to allow resumption of harvests. Although annual surveys would be beneficial from an assessment perspective, to allow tracking of recovery and provide information on the recovery process, I recognize that this is an economic burden on industry that is not offset by harvest income. The pragmatic approach would be to allow industry to decide when they wish to resume harvests, and require a survey at that time.

Constant TAC Management Framework

As mentioned previously, additional beaches harvested for depuration are managed under constant TACs developed from a single baseline survey (Table 3). Results of this review raise serious concerns regarding the harvest rates (0.50 and 0.25) used to set these TACs. Most of these beaches have not been assessed since initial surveys, some dating back to 1994. Fishery performance cannot be adequately assessed on landings alone, as there are many possible reasons for not attaining quota in a given year (*e.g.*, PSP closure, business or stock management decisions made by processors). Surveys offer the ability to directly assess stocks rather than inferring stock status through stock production or anecdotal information.

Conclusions

DFO is mandated to manage depuration fisheries for intertidal clams under conservation targets and a precautionary approach. The preliminary results of this study indicate that quotas representing only a portion of the available legal stock are not sustainable. Obviously, passive management by size limit alone has the potential to be ineffective, if digger effort and behaviour change to a more efficient fishing pattern.

The primary objective of the depuration fishery must shift from one of maximizing production in the short term to one of maintaining healthy and productive clam stocks. If stock sizes are allowed to recover by reducing harvest rates at low abundance levels, then the risk of having to close beaches for an unspecified period, obviously the last resort from a management viewpoint, is reduced.

Recommendations

The following recommendations are presented:

1. **Harvest rates currently assigned to depuration harvest beaches in the experimental harvest program should be reduced.** Performance of beaches over the first three years of the program has been mixed, but the removal of four of six beaches from depuration harvests indicates that harvest rates are generally too high.
2. **Managers should consider alternatives to constant harvest rates in the management of experimental harvest beaches.** The framework of sliding harvest rates linked to biological reference points (stock density) provide a means of moderating harvest rates in response to stock condition. This benefits the stock when abundance is declining, and benefits production when stocks are increasing.
3. **Formal protocols of establishing species composition and estimating total landings should be established for the depuration fishery.** The current practice of using a single proportion to determine landings by species is likely inaccurate. The option of using species composition from the legal biomass estimates of the most recent survey may not be any better, as digger selectivity for species is not well documented, and species composition varies by tidal height. Accurate tracking of landings by species is essential to calculate actual harvest rates, which are in turn

required for assessment of stock production characteristics under different harvest frameworks.

4. **Beaches that are managed under a constant TAC derived from a baseline survey should be reassessed, and the effectiveness of this management framework evaluated.** The results of this review raise questions as to the sustainability of the harvest rates used even with annual monitoring. Information presently available from beaches with dated baseline surveys is insufficient to allow evaluation. Surveys of beaches that have been harvested for three or more years without assessment are required to evaluate the effectiveness of this management strategy in conserving clam stocks and maintaining sustained production.

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Table 1. Annual landings (t) of intertidal clams in British Columbia, 1951-1998. 1993 through 1999 include First Nation licenced harvest in Area 7 and non-lease depuration harvests. 1997 and 1998 landings preliminary.

Year	Butter (t)	Littleneck (t)	Manila (t)	Mixed (t)	Total Steamers (t)	Razor (t)	Landed Value ($000)	Total Landings (t)	Number of Licences
1951	1,597	237	81	65	383	61	$149	2,041	NA
1952	2,490	224	184	65	473	57	$222	3,020	NA
1953	1,674	140	176	20	336	70	$127	2,080	NA
1954	1,314	66	204	5	275	123	$104	1,712	NA
1955	2,170	36	207	3	246	99	$159	2,515	NA
1956	1,454	14	99	0	113	108	$102	1,675	NA
1957	1,606	10	29	11	50	84	$102	1,740	NA
1958	987	18	15	6	39	75	$65	1,101	NA
1959	1,094	22	25	13	60	90	$75	1,244	NA
1960	1,800	41	6	23	70	101	$133	1,971	NA
1961	857	46	48	34	128	104	$76	1,089	NA
1962	1,533	92	69	43	204	77	$139	1,814	NA
1963	1,144	59	59	0	118	67	$103	1,329	NA
1964	570	69	26	1	96	48	$59	714	NA
1965	704	82	97	0	179	68	$106	951	NA
1966	831	105	149	1	255	35	$125	1,121	NA
1967	975	139	92	0	231	46	$163	1,252	NA
1968	399	91	164	15	270	12	$98	681	NA
1969	378	107	81	7	195	8	$85	581	NA
1970	792	144	79	15	238	18	$184	1,048	NA
1971	568	361	153	11	525	62	$235	1,155	NA
1972	645	631	265	1	897	17	$382	1,559	NA
1973	298	207	134	0	341	76	$196	715	NA
1974	531	328	182	0	510	69	$383	1,110	NA
1975	746	236	158	6	400	27	$333	1,173	NA
1976	655	173	199	70	442	82	$340	1,179	NA
1977	649	209	394	59	662	78	$545	1,389	NA
1978	383	159	753	245	1,157	47	$834	1,587	NA
1979	613	273	251	374	898	101	$916	1,612	NA
1980	760	358	288	151	797	75	$1,001	1,632	NA
1981	119	179	318	161	658	30	$737	807	NA
1982	102	242	598	155	995	68	$1,135	1,165	NA
1983	77	324	1,048	279	1,651	31	$1,723	1,759	NA
1984	130	294	1,677	410	2,381	100	$2,757	2,611	NA
1985	251	191	1,913	477	2,581	90	$3,288	2,922	NA
1986	158	284	1,893	371	2,548	142	$3,801	2,848	NA
1987	68	373	3,607	87	4,067	142	$6,755	4,277	NA
1988	134	290	3,909	27	4,226	155	$7,771	4,515	NA
1989	92	433	2,764	159	3,356	117	$6,955	3,565	1,870
1990	109	465	1,456	339	2,260	114	$5,279	2,483	2,068
1991	42	201	982	137	1,320	117	$3,302	1,479	1,949
1992	132	116	923	112	1,151	55	$2,720	1,338	1,814
1993	102	131	1,059	133	1,323	44	$3,371	1,469	1,639
1994	174	94	1,376	87	1,557	105	$4,410	1,836	1,844
1995	101	140	1,292	3	1,435	140	$4,724	1,676	2,448
1996	100	56	1,161	112	1,329	76	$3,847	1,505	1,906
1997	145	60	875	112	1,047	101	$3,331	1,293	1,572
1998	40	50	1,115	118	1,283	40	$3,898	1,363	907

Table 2. Annual landings from depuration facilities in British Columbia 1990-1999. Landings are from commercial fisheries only and do not include production depurated from clam leases.

	Landings (t)		
Year	Manila	Littleneck	Total
1990	n/a[1]	n/a[1]	n/a[1]
1991	-	n/a[1]	n/a[1]
1992	n/a[1]	n/a[1]	n/a[1]
1993	n/a[1]	n/a[1]	n/a[1]
1994	n/a[1]	n/a[1]	n/a[1]
1995	n/a[1]	n/a[1]	n/a[1]
1996	209.5	15.2	224.7
1997	361.7	26.2	388.0
1998	368.5	37.2	405.7
1999	352.8	27.4	380.2
Total	1,809.7	715.1	2,524.8

[1] – landings can not be released due to restrictions of the Privacy Act.

Table 3. Assessment programs for beaches harvested for depuration of intertidal clams in British Columbia.

Beach	Assessment Program	Last Assessed
Bamberton	Baseline	1995
Booth Bay	Annual	1999
Brenton-Page, Ladysmith	Annual	1999
Cachalot Inlet	Baseline	1999
Craig Bay	Annual	1999
Degnan Bay	Baseline	1996
Gartley Point	Baseline	1997
Goldstream	Annual	1999
Ivy Green	Baseline	1999
Kuper Island (6 beaches)	Baseline	1999
Lasqueti Island (2 beaches)	Baseline	1999
Long Harbour, Saltspring	Baseline	1996
Ladysmith Harbour (6 beaches)	Baseline	1994-1999
Malksope Inlet	Baseline	1998
Mill Bay	Annual	1999
Mud Bay East	Annual	1999
Mud Bay West	Annual	1999
Okeover Inlet	Baseline	1997
Parksville	Annual	1999
Royston	Annual	1999
Sooke Harbour	Baseline	1994
Sooke Basin (10 beaches)	Baseline	1994-1996
Wall Beach	Annual	1999
Willy Island (4 beaches)	Baseline	1997-1999

Table 4. Survey design, survey area, number of strata and sample sizes for beaches surveyed under the experimental harvest program for depuration harvests of intertidal clams in British Columbia.

Beach	Survey Design	Survey Area (ha)	Number of Strata	Number of Quadrats
Booth Bay	Stratified Random	3.13	16	169
Craig Bay	Stratified Two-stage	16.51	20	309
Goldstream	Stratified Two-stage	5.34	5	160
Mill Bay	Stratified Random	0.56	4	40
Mud Bay East	Stratified Two-stage	12.00	13	170
Mud Bay West	Stratified Two-stage	14.50	19	237
Parksville	Stratified Two-stage	6.95	6	232
Royston	Stratified Two-stage	10.00	12	168
Wall Beach	Stratified Random	2.18	11	112

Table 5. Survey results and actual harvest rates acheived at Booth Bay, 1996-1999.

Manilas				
Survey Date	July 1996	August 1997	August 1998	August 1999
Legal Biomass (kg)	113,247	119,551	89,845	104,165
95% CI	15,826	12,753	10,495	13,379
Sublegal Biomass (kg)	54,197	68,230	50,043	56,697
95% CI	9,216	8,807	6,228	7,745
Legal Abundance (clams)	5,454,983	6,305,904	4,597,755	5,467,653
95% CI	766,124	666,442	503,648	731,210
Sublegal Abundance (clams)	7,186,670	8,673,987	6,137,455	6,985,735
95% CI	1,511,273	1,164,579	819,450	1,064,476
Target Harvest Rate	0.50	0.50	0.50	0.50
Quota (kg)	56,624	59,776	44,923	52,083
Actual Harvest Rate	0.42	0.41	0.39	-
Change in Legal Biomass	-	+6%	-25%	+16%

Littlenecks				
Survey Date	July 1996	August 1997	August 1998	August 1999
Legal Biomass (kg)	1,922	3,580	2,511	3,150
95% CI	794	1,104	776	1,839
Sublegal Biomass (kg)	1,663	1,847	1,855	2,725
95% CI	483	766	489	1,085
Legal Abundance (clams)	70,892	136,313	89,981	117,498
95% CI	24,708	39,612	28,088	62,258
Sublegal Abundance (clams)	284,944	270,283	226,880	284,831
95% CI	83,237	116,131	70,168	120,481

Table 6. Survey results and actual harvest rates acheived at Craig Bay, 1997-1999.

Manilas				
Survey Date	May 1997	August 1997	August 1998	August 1999
Legal Biomass (kg)	113,859	105,443	40,461	35,678
95% CI	19,473	11,601	4,370	4,821
Sublegal Biomass (kg)	83,420	38,559	38,712	33,995
95% CI	20,207	5,524	4,947	4,353
Legal Abundance (clams)	5,021,592	4,982,838	1,883,960	1,656,659
95% CI	941,784	528,282	205,358	256,791
Sublegal Abundance (clams)	7,187,546	4,726,302	4,232,170	6,082,782
95% CI	1,828,170	745,744	455,699	1,122,615
Target Harvest Rate	0.25	0.25	0.25	0.25
Quota (kg)	28,465	26,361	10,115	8,920
Actual Harvest Rate	0.19	0.25	0.24	-
Change in Legal Biomass	-	-7%	-62%	-12%

Littlenecks				
Survey Date	May 1997	August 1997	August 1998	August 1999
Legal Biomass (kg)	8,895	11,264	19,995	19,283
95% CI	1,945	2,844	3,105	3,171
Sublegal Biomass (kg)	5,216	3,750	7,753	6,689
95% CI	1,413	870	985	1,174
Legal Abundance (clams)	322,524	541,035	967,178	680,783
95% CI	69,644	158,513	333,338	102,266
Sublegal Abundance (clams)	391,426	591,254	713,586	692,465
95% CI	106,890	123,747	82,039	99,203

Table 7. Survey results and actual harvest rates acheived at Goldstream, 1997-1999.

Manilas			
Survey Date	August 1997	August 1998	August 1999
Legal Biomass (kg)	62,910	101,018	98,341
95% CI	8,325	12,164	11,228
Sublegal Biomass (kg)	26,343	21,894	13,901
95% CI	3,571	3,741	2,069
Legal Abundance (clams)	2,937,250	4,698,250	4,568,990
95% CI	419,617	634,538	550,760
Sublegal Abundance (clams)	2,994,860	1,972,170	1,771,140
95% CI	408,617	326,714	298,870
Target Harvest Rate	0.25	0.25	0.25
Quota (kg)	15,728	25,255	24,585
Actual Harvest Rate	0.04	0.18	-
Change in Legal Biomass	-	+61%	-3%

Littlenecks			
Survey Date	August 1997	August 1998	August 1999
Legal Biomass (kg)	25,518	32,504	30,518
95% CI	3,867	3,908	6,113
Sublegal Biomass (kg)	18,829	19,909	22,588
95% CI	2,784	3,075	4,710
Legal Abundance (clams)	987,340	1,129,510	1,235,980
95% CI	148,315	126,278	247,112
Sublegal Abundance (clams)	2,036,970	1,935,080	2,154,270
95% CI	356,785	356,294	600,654
Target Harvest Rate	0.25	0.25	0.25
Quota (kg)	6,380	8,126	7,630
Actual Harvest Rate	0.11	0.37	0.00

Table 8. Survey results from Mill Bay, 1997-1999.

Manilas			
Survey Date	August 1997	September 1998	September 1999
Legal Biomass (kg)	4,254	7,484	7,832
95% CI	1,273	1,645	2,177
Sublegal Biomass (kg)	1,844	2,842	2,304
95% CI	499	779	857
Legal Abundance (clams)	212,600	363,680	367,720
95% CI	61,754	79,071	102,715
Sublegal Abundance (clams)	182,920	247,560	183,480
95% CI	49,562	70,995	60,801
Change in Legal Biomass	-	+76%	+5%

Littlenecks			
Survey Date	August 1997	September 1998	September 1999
Legal Biomass (kg)	214	292	348
95% CI	144	328	213
Sublegal Biomass (kg)	527	612	385
95% CI	261	357	181
Legal Abundance (clams)	9,800	12,880	13,600
95% CI	6,617	15,608	7,297
Sublegal Abundance (clams)	52,280	57,800	38,520
95% CI	26,967	36,341	21,680

Table 9. Survey results and actual harvest rates acheived at Mud Bay East, 1997-1999.

Manilas		
Survey Date	August 1997	June 1999
Legal Biomass (kg)	30,737	21,421
95% CI	6,672	4,121
Sublegal Biomass (kg)	85,544	89,304
95% CI	13,123	11,178
Legal Abundance (clams)	1,788,571	1,124,000
95% CI	459,583	236,623
Sublegal Abundance (clams)	9,965,714	10,282,667
95% CI	1,744,827	1,487,294
Target Harvest Rate	05.0	0.50
Quota (kg)	15,369	10,711
Actual Harvest Rate	0.29	0.39
Change in Legal Biomass	-	-30%

Littlenecks		
Survey Date	August 1997	June 1999
Legal Biomass (kg)	2,174	2,964
95% CI	1,253	1,517
Sublegal Biomass (kg)	2,391	2,095
95% CI	1,608	1,296
Legal Abundance (clams)	80,000	124,444
95% CI	44,895	85,773
Sublegal Abundance (clams)	255,714	205,778
95% CI	123,196	141,655

Table 10. Survey results and actual harvest rates acheived at Mud Bay West, 1997-1999.

Manilas			
Survey Date	August 1997	August 1998	August 1999
Legal Biomass (kg)	59,516	29,002	14,102
95% CI	8,564	4,538	2,146
Sublegal Biomass (kg)	210,644	134,890	98,048
95% CI	22,952	18,849	11,503
Legal Abundance (clams)	3,357,167	1,592,143	740,899
95% CI	469,897	248,473	123,962
Sublegal Abundance (clams)	26,896,738	16,371,333	11,272,222
95% CI	3,767,617	2,158,031	1,349,722
Target Harvest Rate	0.50	0.50	0.50
Quota (kg)	29,758	14,501	7,051
Actual Harvest Rate	0.34	0.39	-
Change in Legal Biomass	-	-51%	-51%

Littlenecks			
Survey Date	August 1997	August 1998	August 1999
Legal Biomass (kg)	2,782	1,841	815
95% CI	1,064	779	741
Sublegal Biomass (kg)	6,327	3,008	3,551
95% CI	1,731	821	903
Legal Abundance (clams)	121,786	82,143	34,222
95% CI	49,015	34,344	27,534
Sublegal Abundance (clams)	669,286	268,810	300,444
95% CI	184,080	65,536	73,086

Table 11. Survey results and actual harvest rates acheived at Parksville, 1997-1999.

Manilas				
Survey Date	May 1997	August 1997	July 1998	May 1999
Legal Biomass (kg)	81,273	27,925	37,191	18,573
95% CI	8,602	3,479	4,989	2,654
Sublegal Biomass (kg)	65,171	93,294	72,873	48,885
95% CI	11,153	13,681	10,924	6,931
Legal Abundance (clams)	4,556,604	1,454,394	2,009,262	981,943
95% CI	490,151	178,487	272,464	139,227
Sublegal Abundance (clams)	6,687,617	8,697,276	7,950,384	5,509,992
95% CI	1,175,563	1,337,086	1,426,337	917,162
Target Harvest Rate	0.50	0.50	0.50	0.50
Quota (kg)	42,725	15,006	20,071	9,668
Actual Harvest Rate	0.49	-	0.40	0.19
Change in Legal Biomass	-	-66%	+33%	-50%

Littlenecks				
Survey Date	May 1997	August 1997	July 1998	May 1999
Legal Biomass (kg)	-	1,303	3,372	4,989
95% CI	-	592	1,678	2,029
Sublegal Biomass (kg)	-	1,877	3,337	5,011
95% CI	-	593	1,066	1,288
Legal Abundance (clams)	-	56,401	145,848	219,594
95% CI	-	24,936	70,364	87,979
Sublegal Abundance (clams)	-	157,531	360,978	471,767
95% CI	-	47,416	105,977	113,046

Table 12. Survey results from Royston, 1997-1999.

Manilas			
Survey Date	June 1997	May 1998	May 1999
Legal Biomass (kg)	22,090	22,734	27,616
95% CI	2,511	2,500	3,168
Sublegal Biomass (kg)	51,641	77,647	76,255
95% CI	5,000	6,149	6,959
Legal Abundance (clams)	1,198,667	1,138,667	1,404,000
95% CI	133,852	130,242	164,560
Sublegal Abundance (clams)	6,602,667	9,182,667	8,540,000
95% CI	595,042	744,820	786,697
Change in Legal Biomass	-	+3%	+21%

Littlenecks			
Survey Date	June 1997	May 1998	May 1999
Legal Biomass (kg)	1,256	744	3,636
95% CI	497	481	3,665
Sublegal Biomass (kg)	3,469	3,854	4,150
95% CI	678	613	981
Legal Abundance (clams)	58,667	29,333	82,667
95% CI	22,198	17,306	41,409
Sublegal Abundance (clams)	348,000	496,000	477,333
95% CI	61,408	73,884	98,059

Table 13. Survey results from Wall Beach, 1997-1999.

Manilas			
Survey Date	August 1997	July 1998	July 1999
Legal Biomass (kg)	4,406	3,094	1,510
95% CI	2,201	1,832	706
Sublegal Biomass (kg)	31,308	26,111	16,172
95% CI	7,782	7,324	3,551
Legal Abundance (clams)	242,270	176,040	127,170
95% CI	123,310	98,050	92,901
Sublegal Abundance (clams)	5,200,430	5,473,370	3,697,950
95% CI	1,104,014	1,168,852	814,116
Change in Legal Biomass	-	-30%	-51%

Littlenecks			
Survey Date	August 1997	July 1998	July 1999
Legal Biomass (kg)	238	262	927
95% CI	115	140	622
Sublegal Biomass (kg)	386	169	927
95% CI	311	83	459
Legal Abundance (clams)	7,140	8,560	9,750
95% CI	3,540	4,720	5,742
Sublegal Abundance (clams)	52,960	46,200	174,850
95% CI	29,408	22,945	69,898

Table 14. Annual harvest rates and Manila clam density for beaches in the experimental harvest program, 1996-1999.

Beach	Season	HR	Survey Densities (# clams)	
			Legal	Sublegal
Booth Bay	1996/97	0.42	174.55	229.96
	1997/98	0.41	201.77	277.54
	1998/99	0.39	147.11	196.38
	1999/2000	-	174.95	233.52
Craig Bay	1996/97	0.19	29.80	42.65
	1997/98	0.25	28.87	27.38
	1998/99	0.24	11.41	25.63
	1999/2000	(X)	10.03	36.84
Goldstream	1997/98	0.04	55.05	56.13
	1998/99	0.23	88.05	36.96
	1999/2000	-	85.63	33.19
Mill Bay	1997/98	0.00	37.96	32.66
	1998/99	0.00	64.94	44.21
	1999/2000	0.00	65.66	32.76
Mud Bay E	1997/98	0.29	14.90	83.05
	1998/99	(X)	9.37	85.69
Mud Bay W	1997/98	0.34	23.15	185.49
	1998/99	0.39	10.98	112.91
	1999/2000	(X)	5.11	77.74
Parksville	1996/97	0.49	65.52	96.06
	1997/98	0.40	28.89	114.32
	1998/99	0.19 (X)	14.12	79.23
Royston	1997/98	0.00	11.99	66.03
	1998/99	0.00	11.39	91.83
	1999/2000	0.00	14.04	85.40
Wall Beach	1997/98	0.00	11.14	239.10
	1998/99	0.00	8.09	251.65
	1999/2000	0.00	5.85	170.02

Table 15. Proposed Limit and Threshold Reference Points and associated target harvest rates for beaches in the experimental harvest program.

Reference Point	Type	Harvest Rate
< 30 legals/m^2	Limit	0.00 (Close for Recovery)
< 70 legals/m^2	Threshold	0.10
< 130 legals/m^2	Threshold	0.20
≥ 130 legals/m^2	Threshold	0.40

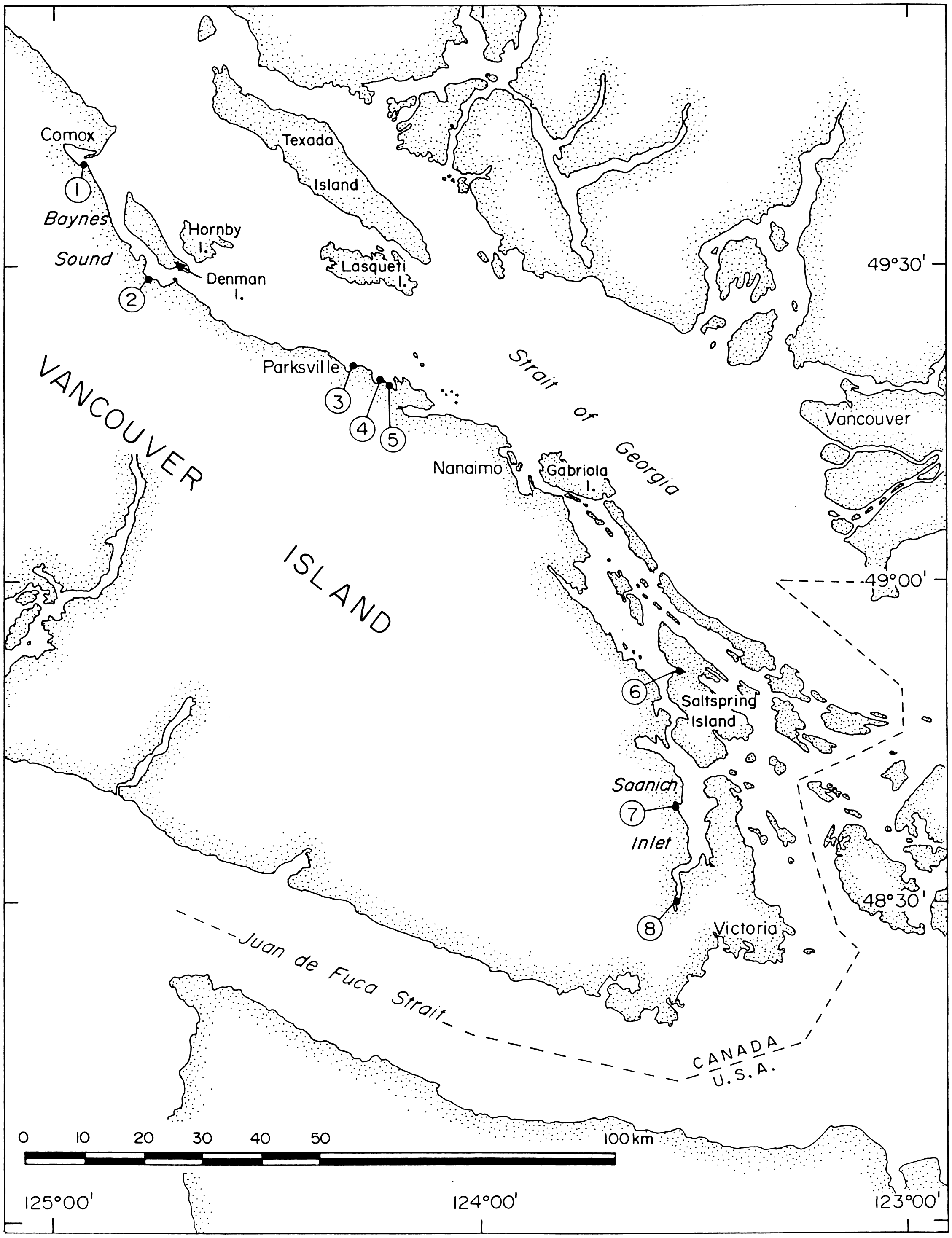


Figure 1. Location of depuration beaches in the experimental harvest program.
Legend: 1-Royston; 2-Mud Bay; 3-Parksville; 4-Craig Bay; 5-Wall Beach; 6-Booth Bay; 7-Mill Bay; 8-Goldstream.

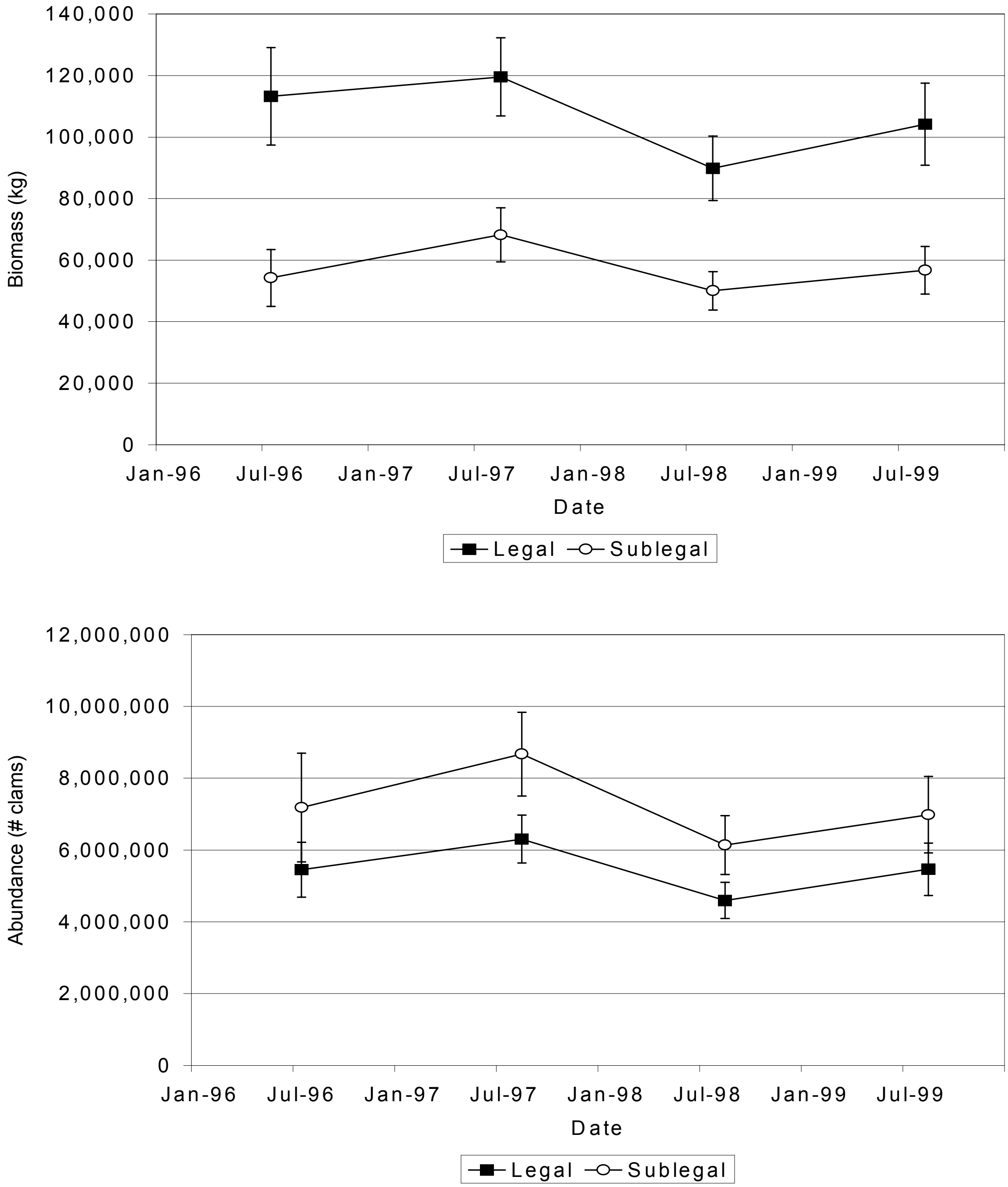
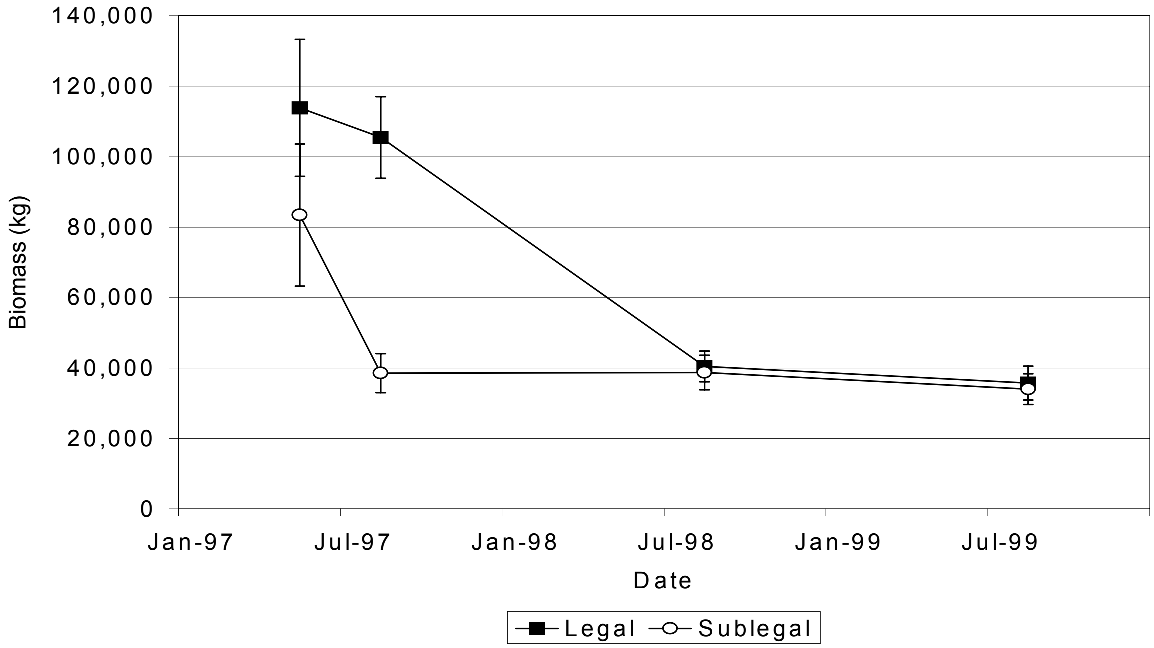


Figure 2. Manila clam stock trajectory at Booth Bay, 1996-1999.



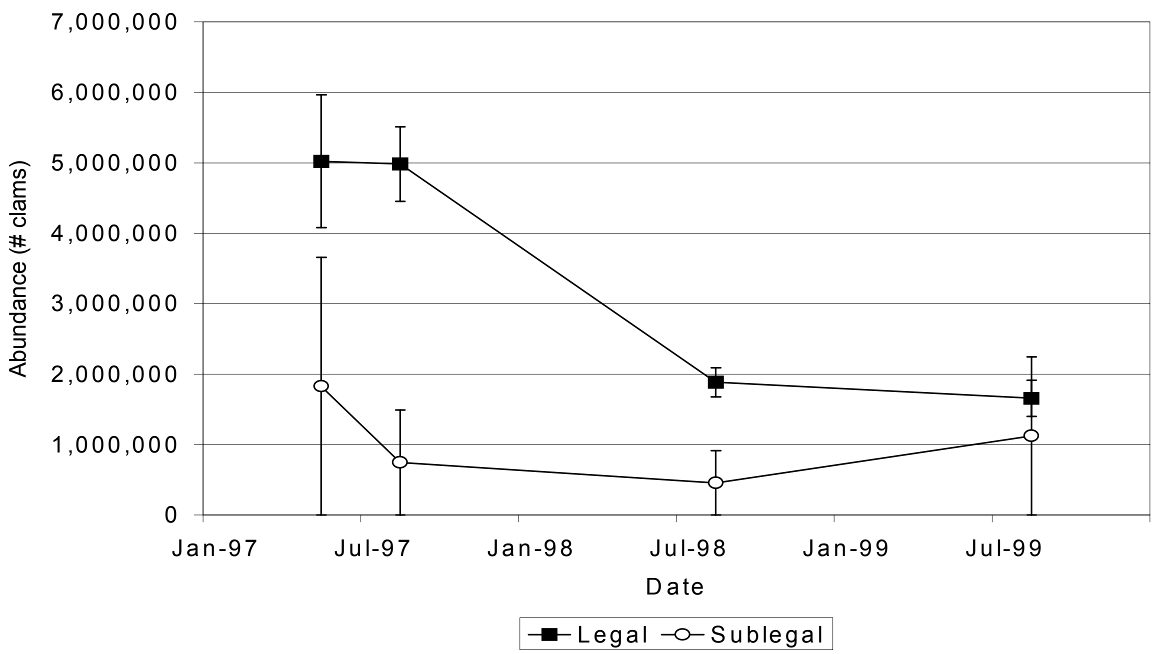


Figure 3. Manila clam stock trajectory at Craig Bay, 1997-1999.

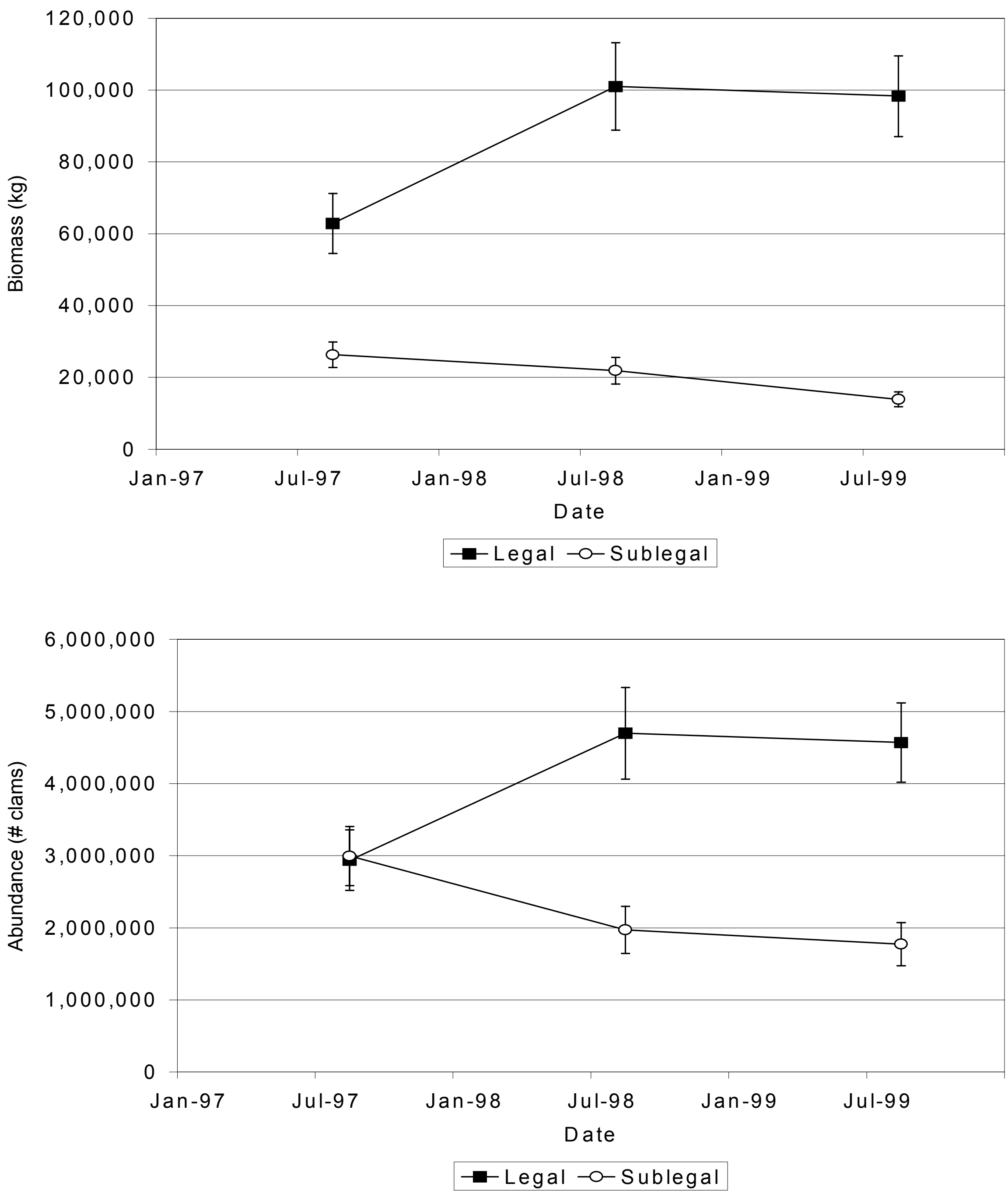


Figure 4. Manila clam stock trajectory at Goldstream, 1997-1999.

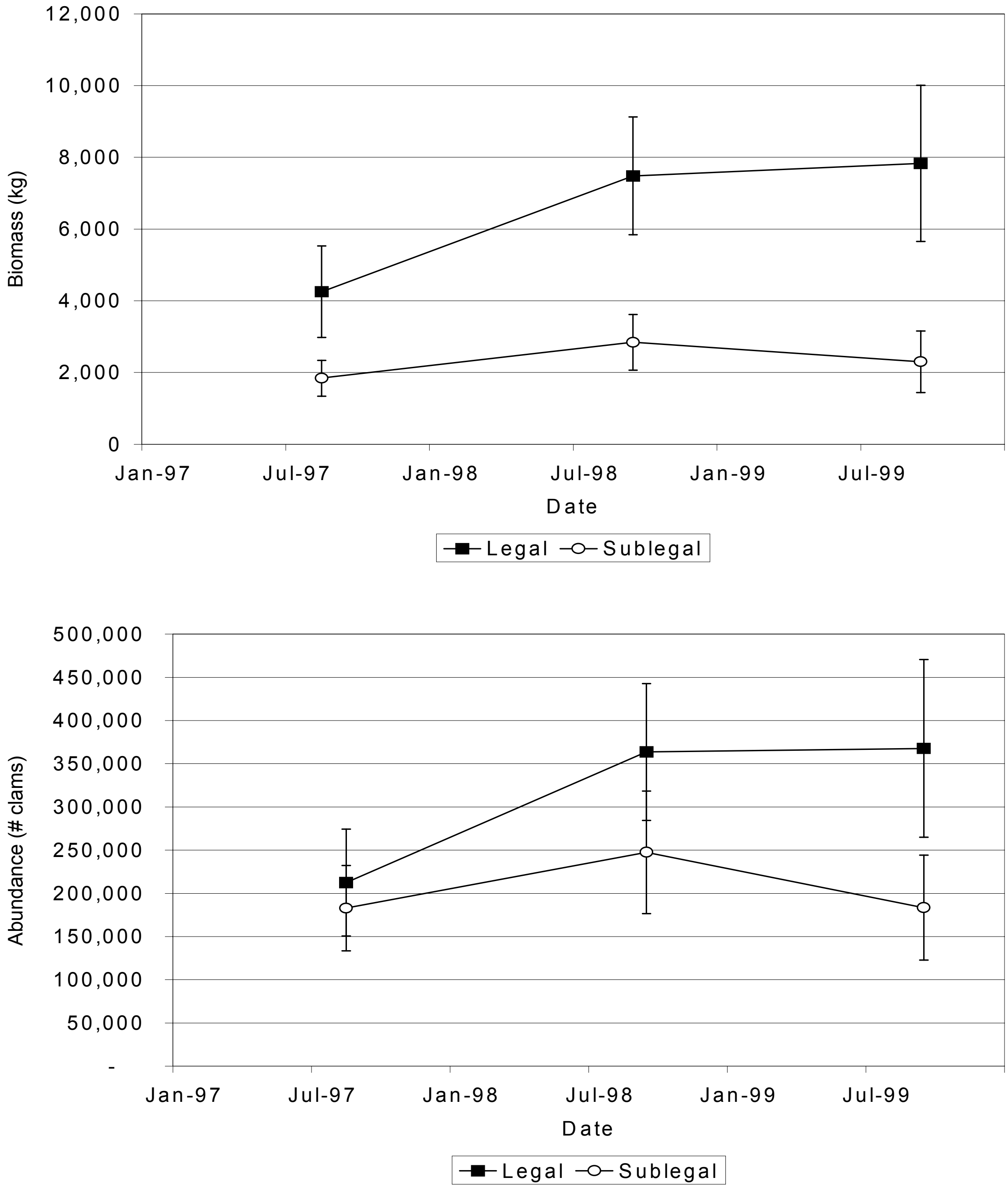


Figure 5. Manila clam stock trajectory at Mill Bay, 1997-1999.

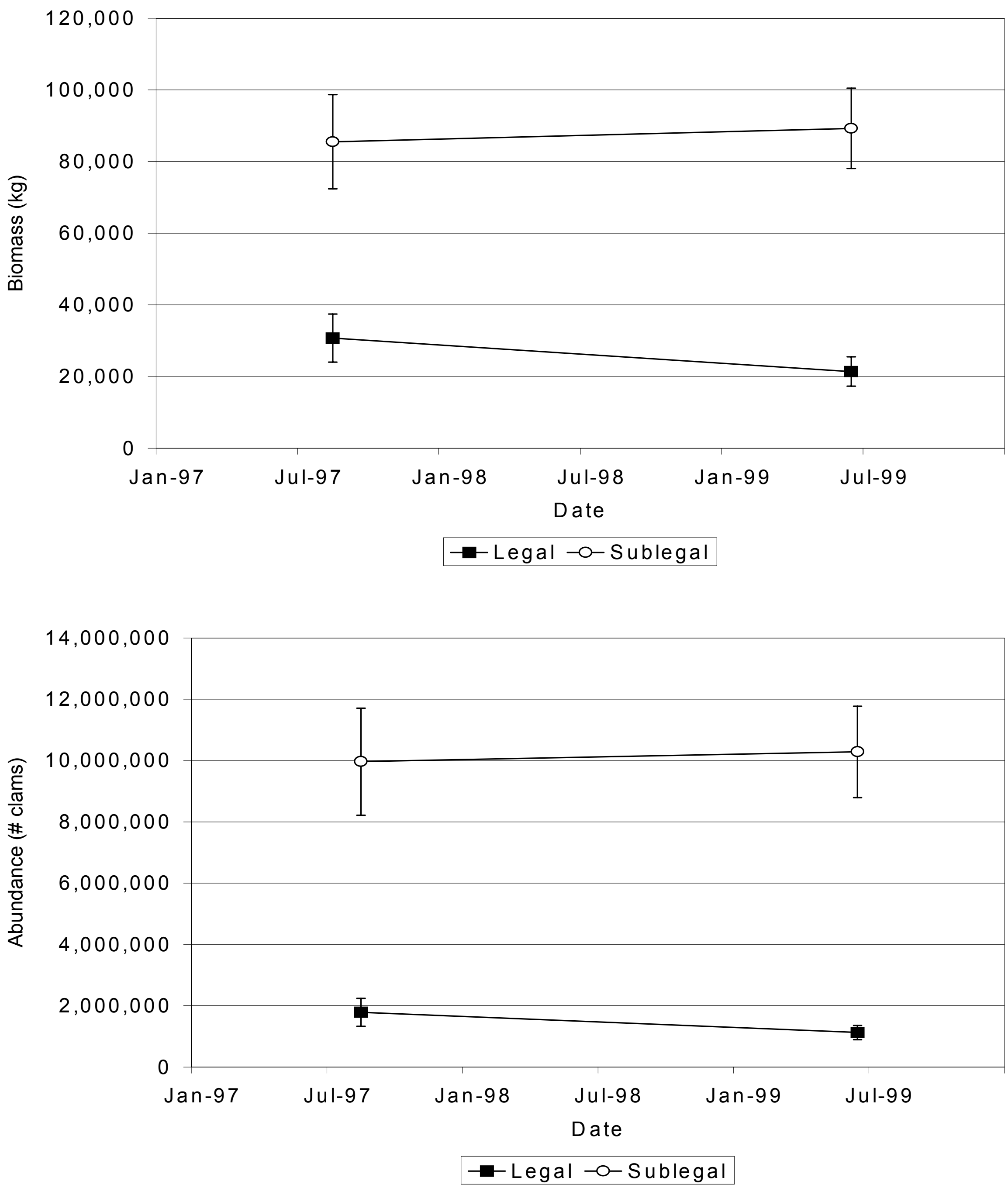
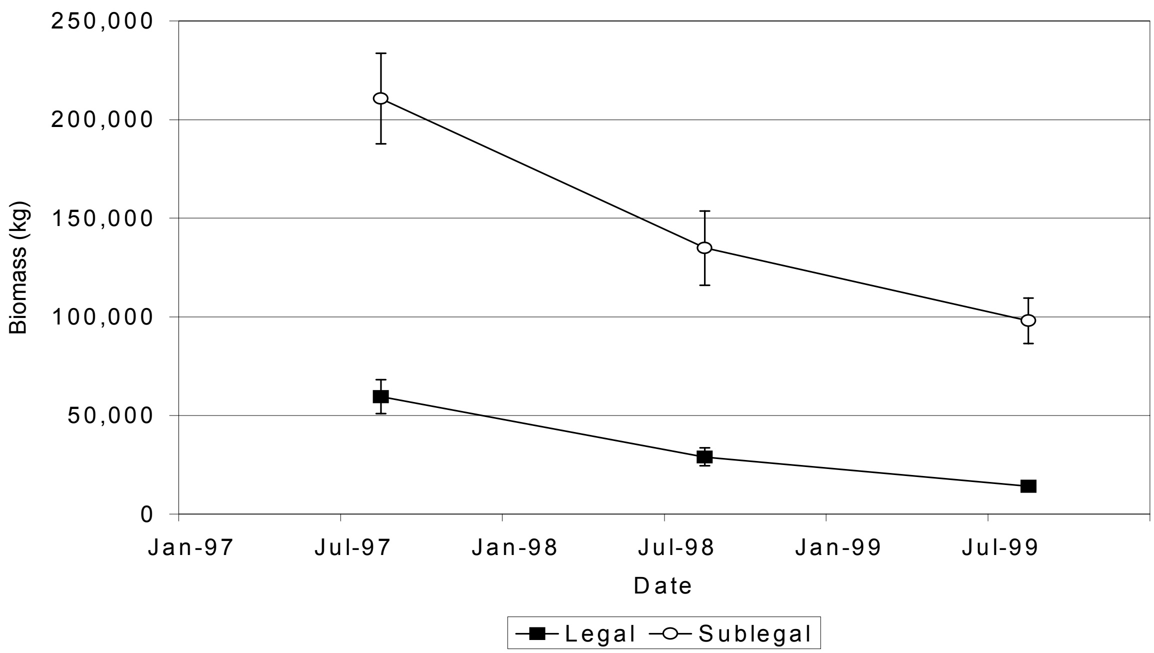


Figure 6. Manila clam stock trajectory at Mud Bay East, 1997-1999.



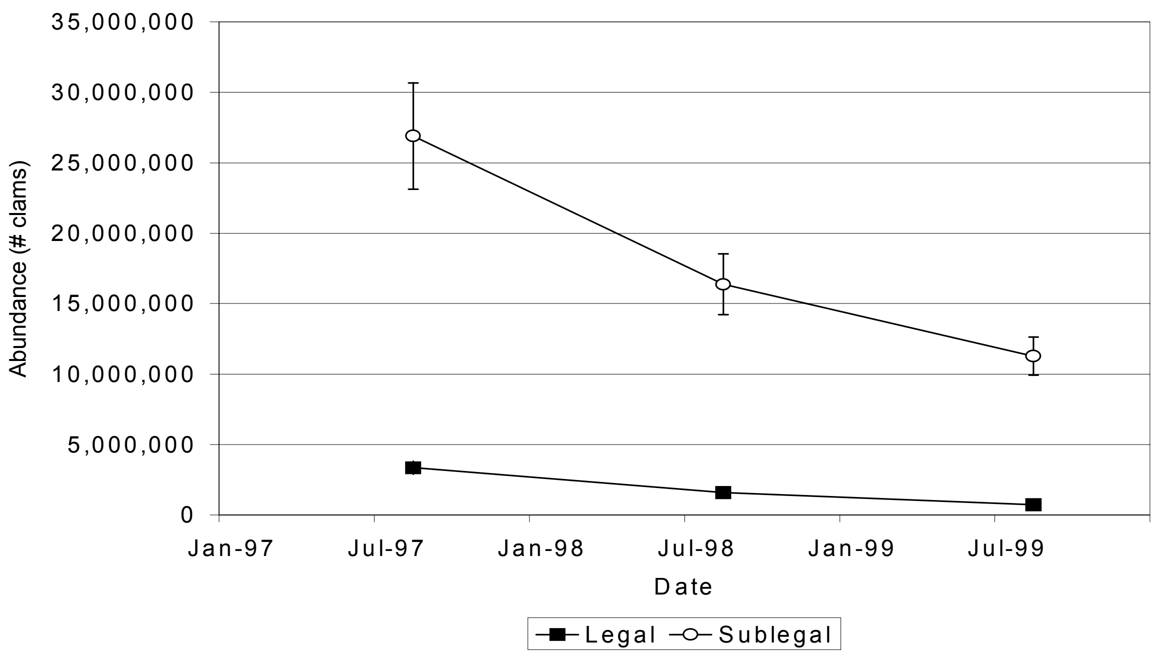
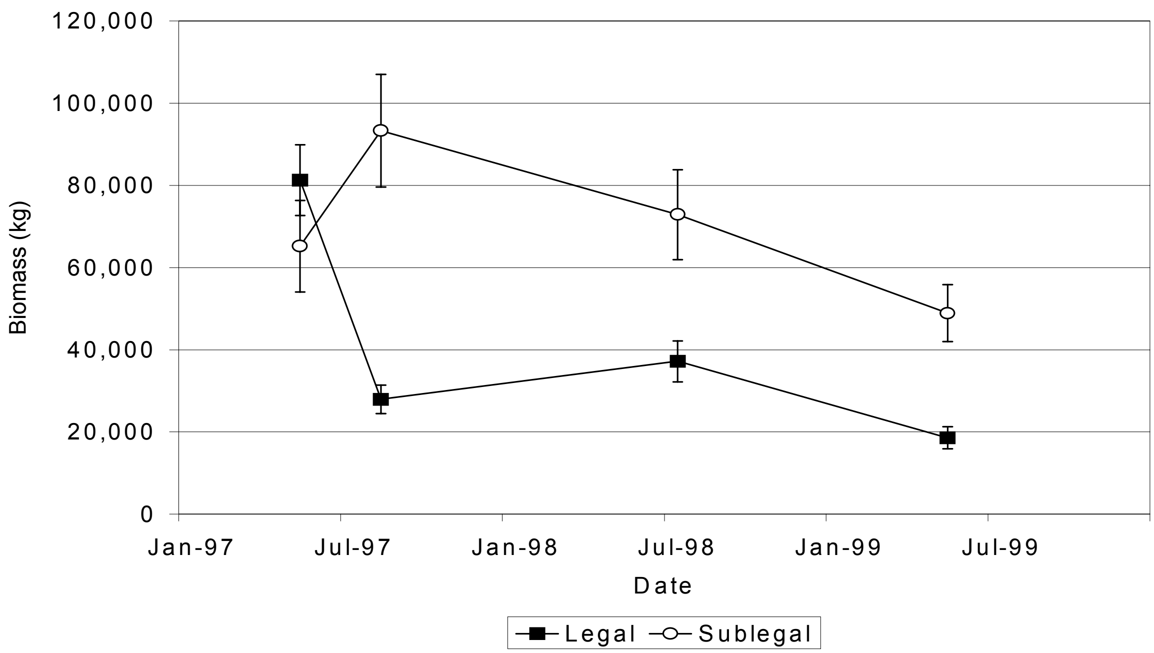


Figure 7. Manila clam stock trajectory at Mud Bay West, 1997-1999.



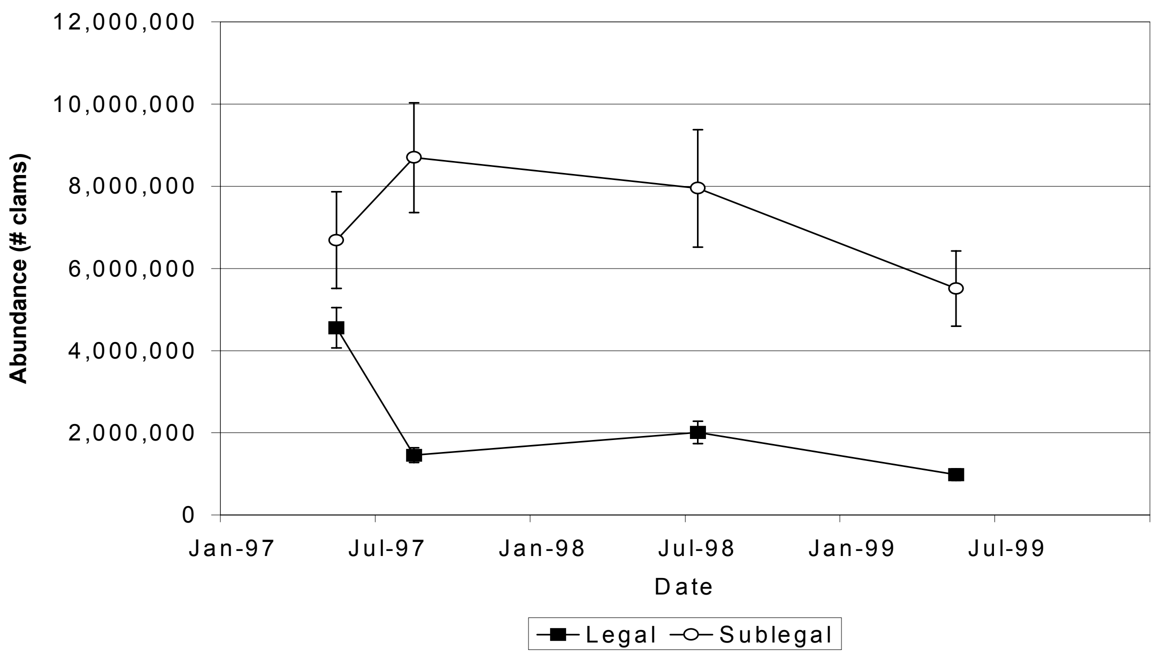


Figure 8. Manila clam stock trajectory at Parksville, 1997-1999.

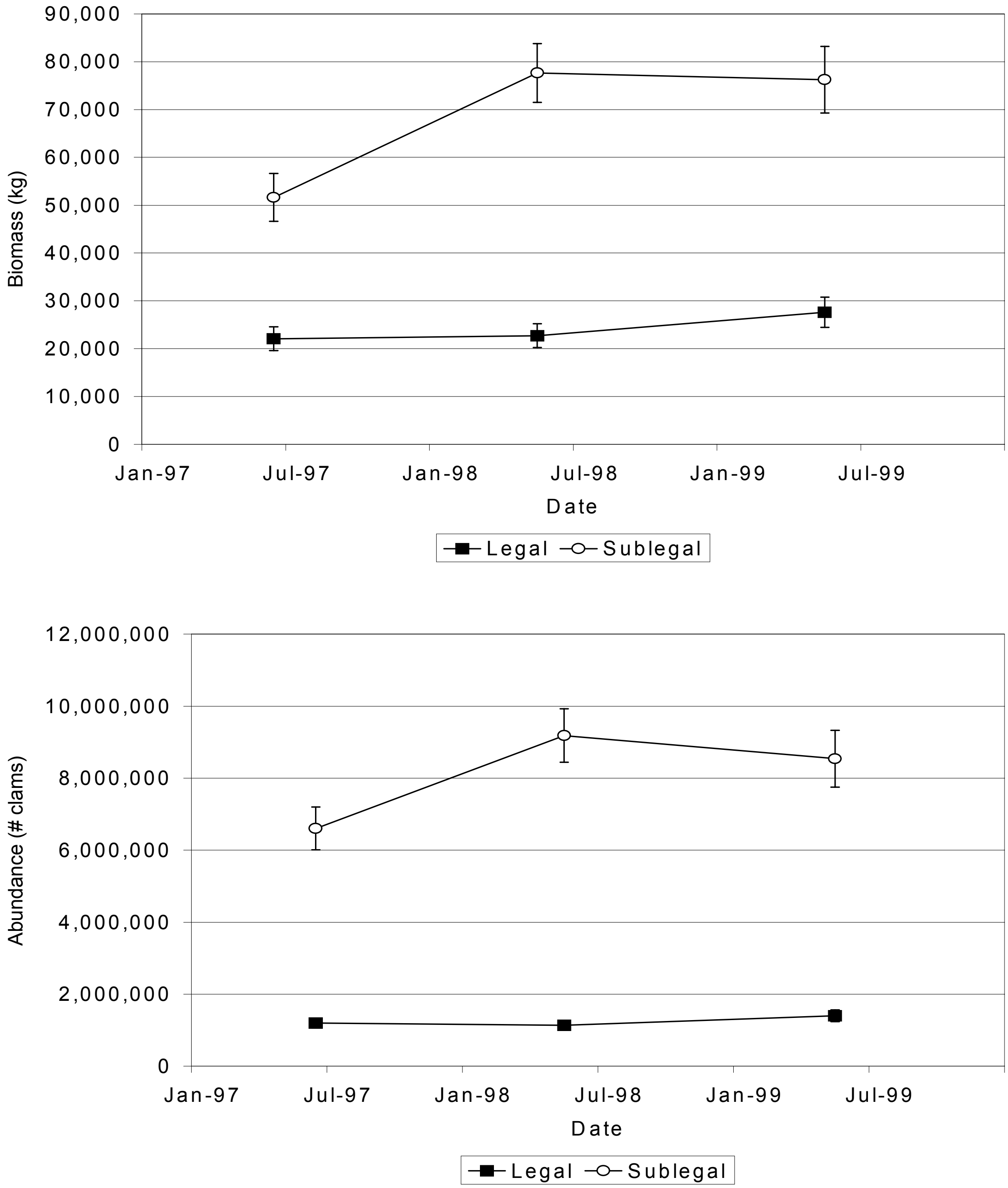


Figure 9. Manila clam stock trajectory at Royston, 1997-1999.

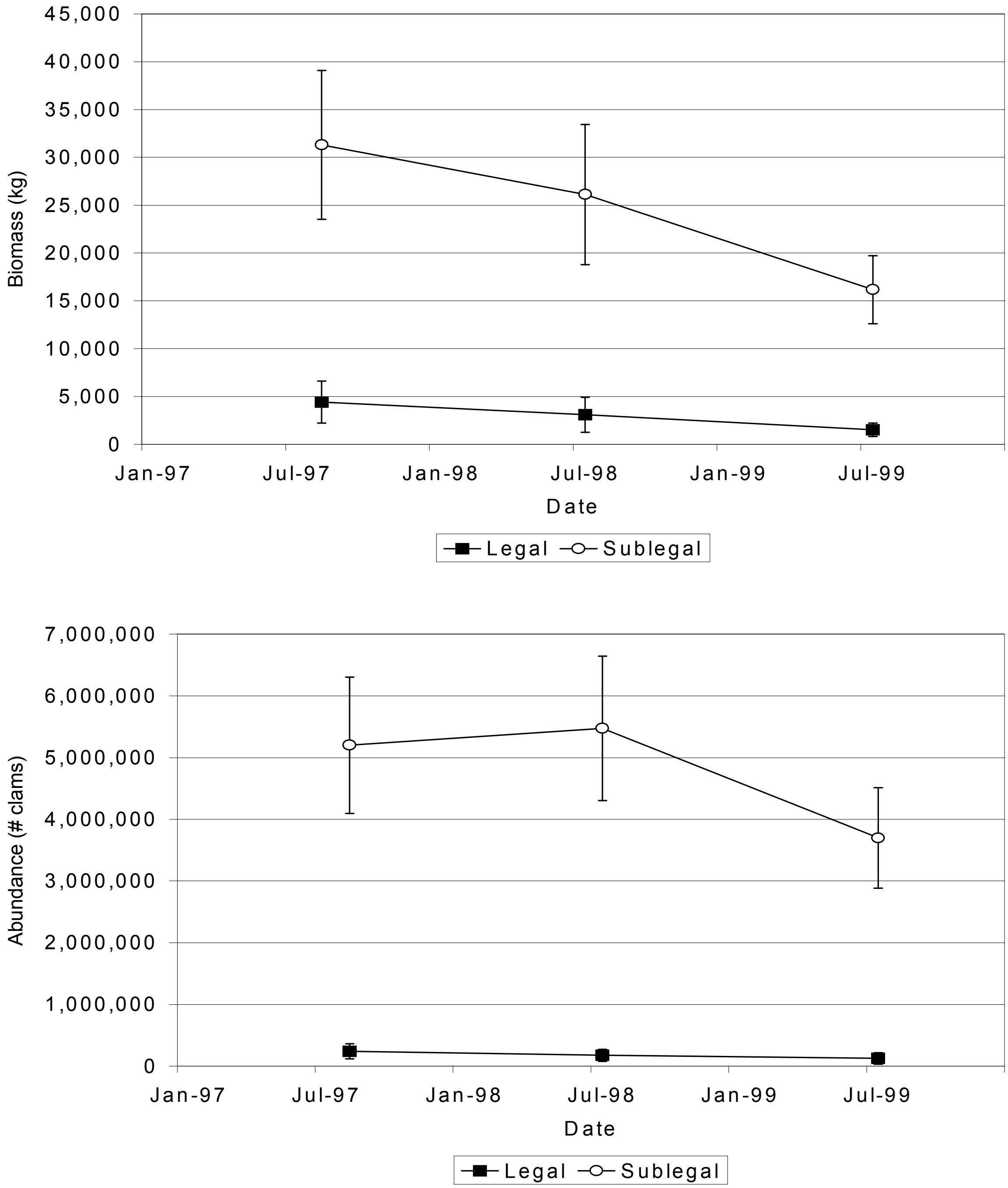


Figure 10. Manila clam stock trajectory at Wall Beach, 1997-1999.

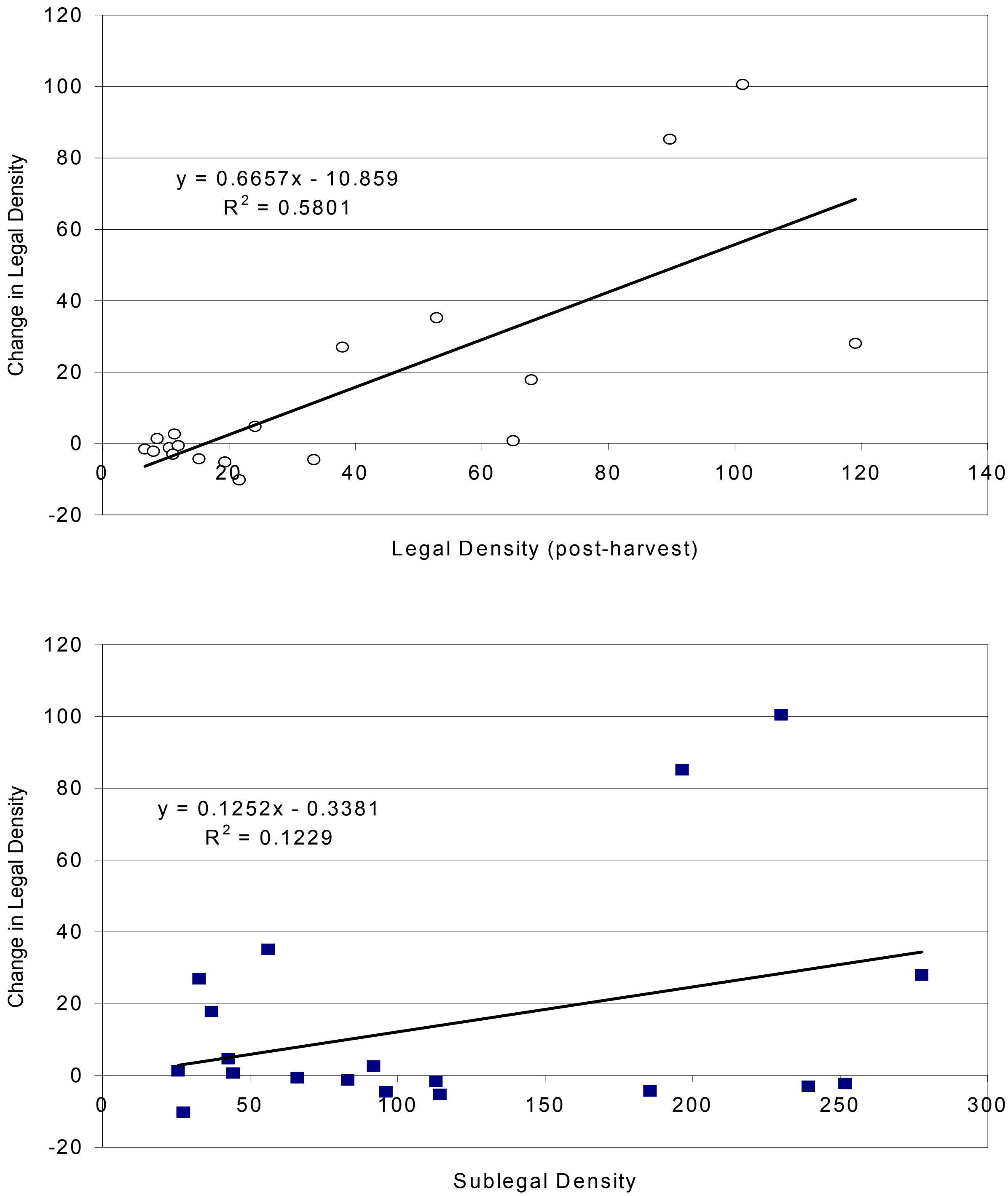
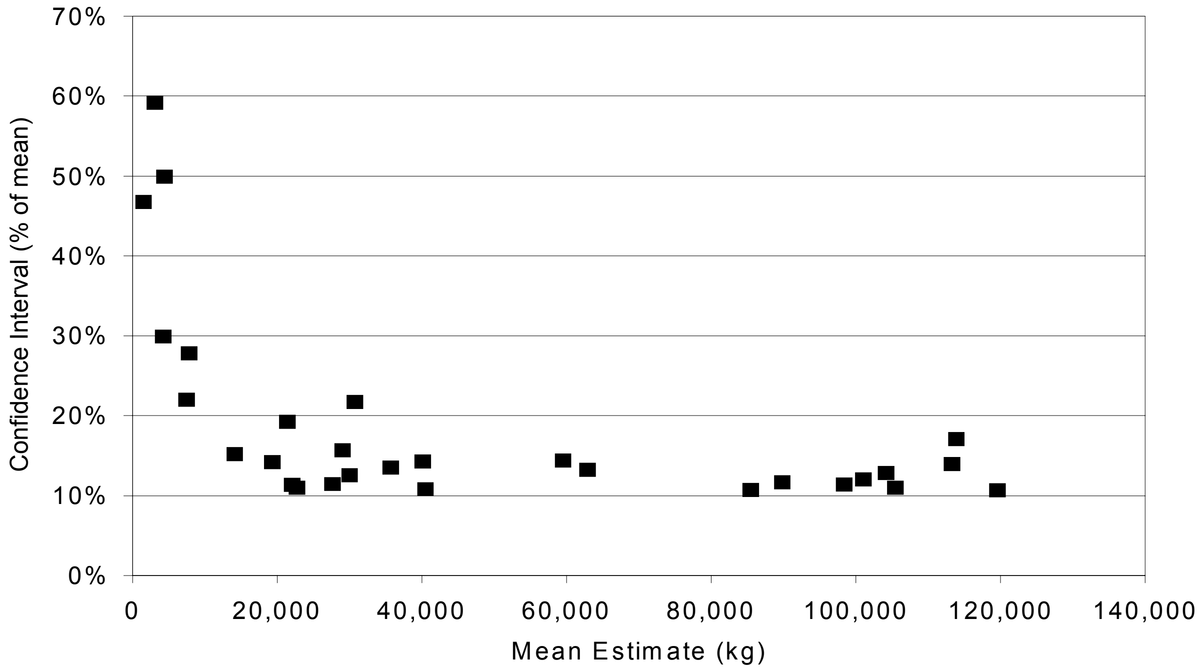


Figure 11. Simple production models relating change in legal density (clams/m^2) to post-harvest legal density (upper panel) and sublegal density (lower panel) for the previous year from beaches in the experimental harvest program.



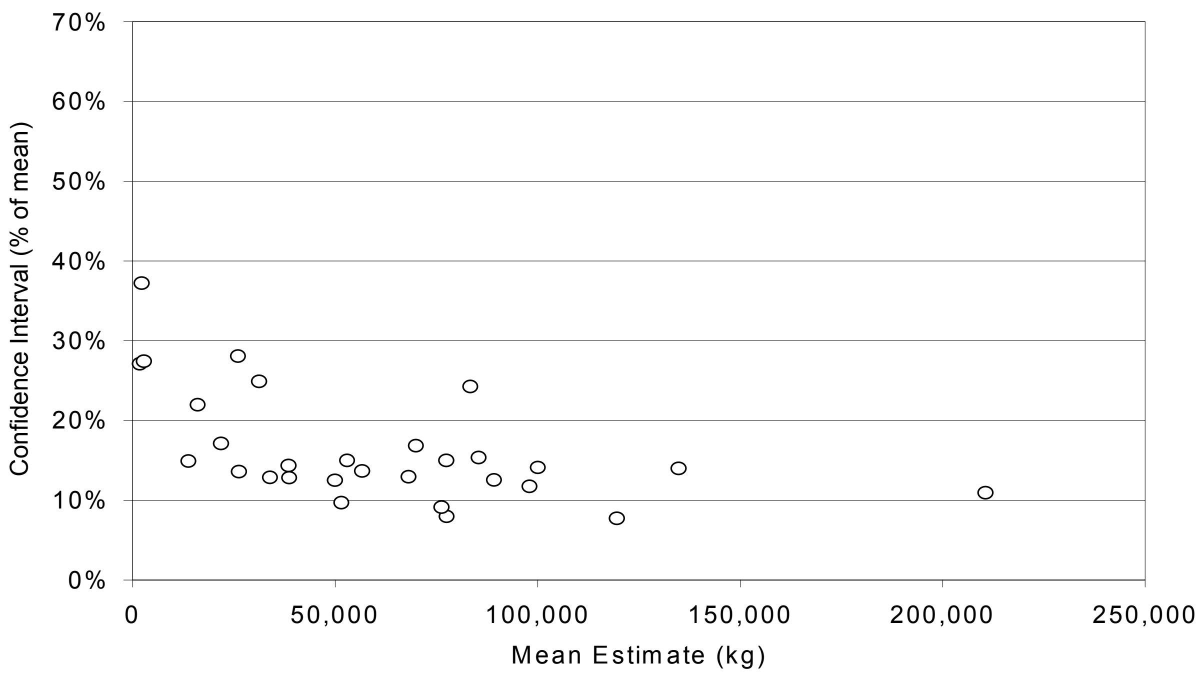


Figure 12. Relationship between estimated total legal (upper panel) and sublegal (lower panel) Manila clam biomass (kg) and width of the associated confidence interval for beaches in the experimental harvest program, 1997-99.

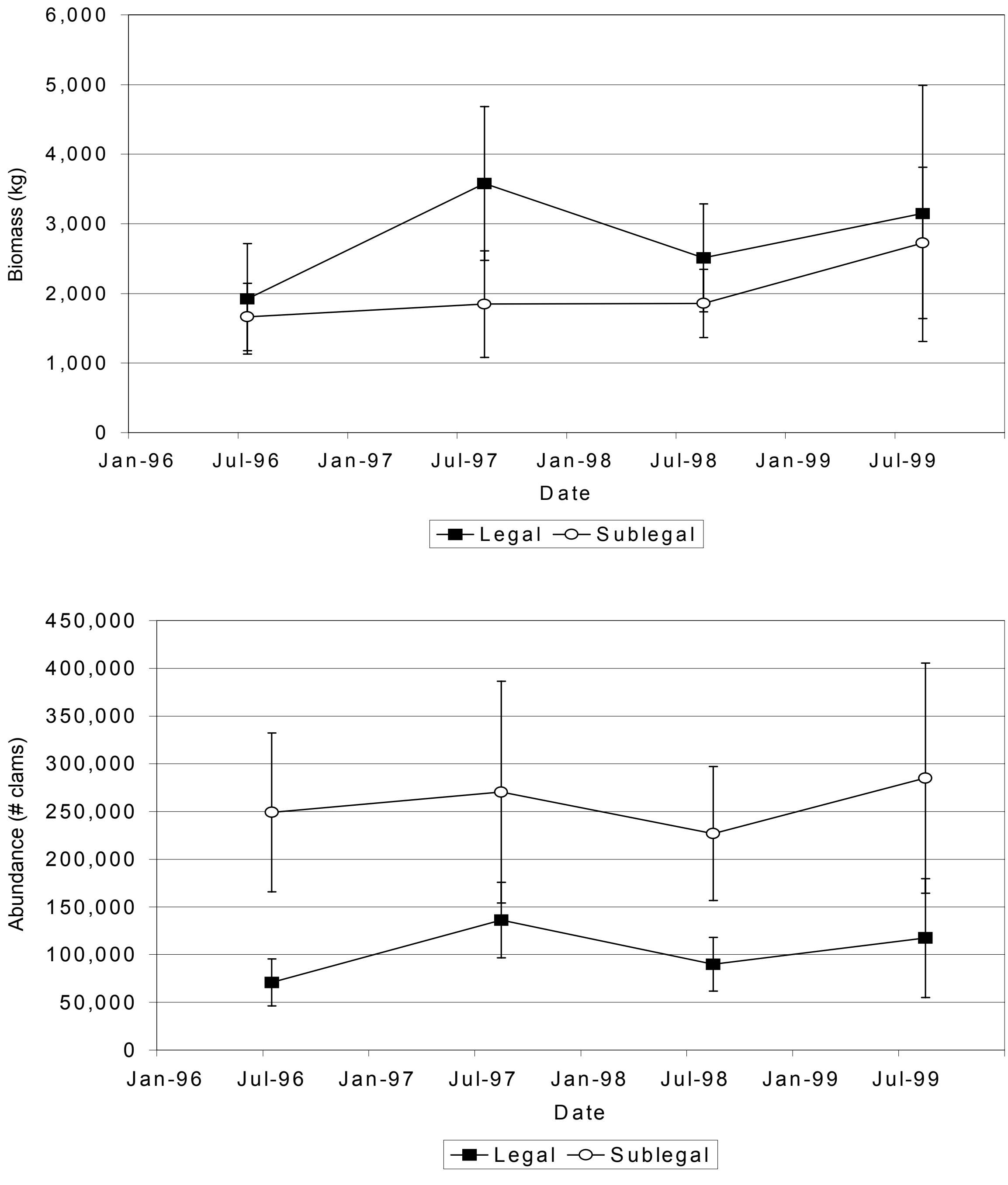


Figure 13. Littleneck clam stock trajectory at Booth Bay, 1996-1999.

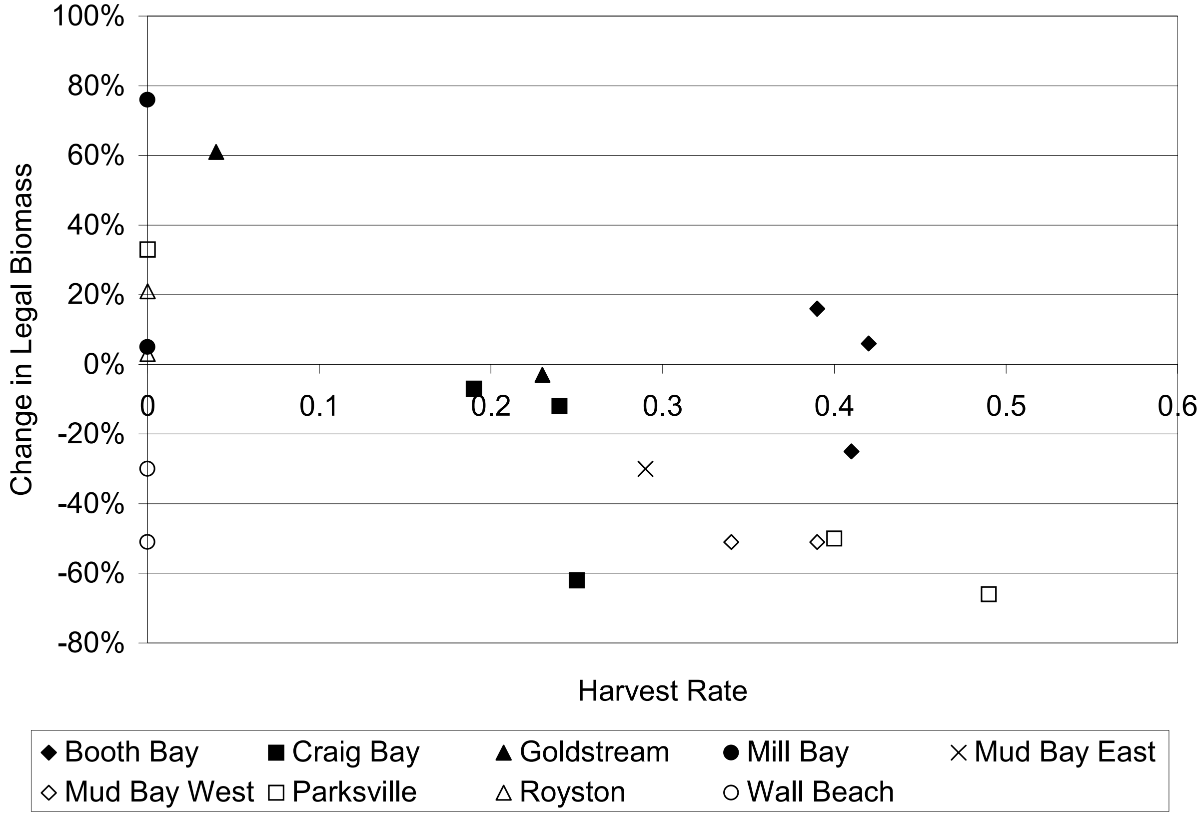


Figure 14. Relationship of harvest rate to change in biomass of legal Manila clams from experimental harvest program beaches, 1996-1999.

Appendix 1

Request for Working Paper

PSARC INVERTEBRATE SUBCOMMITTEE

Request for Working Paper

Date Submitted: March 3,2000

Individual or group requesting advice:

- Randy Webb/Gerry Kelly/ Rick Harbo- Resource Management; Depurator's Association of B.C. (DABC)

Proposed PSARC Presentation Date:

- June 20000

Subject of Paper (title if developed): Review of Experimental Harvest Rates in the Clam Depuration Fishery

Lead Author(s): Graham Gillespie

Fisheries Management Author/Reviewer: Randy Webb and Rick Harbo

Rationale for request:

- Much of the survey work has been funded by industry
- Harvest rates (0%-control beaches to 50% of the legal biomass) have been under review for 3 years (1996 to 1999). Surveys have been undertaken at since 1991 (see earlier PSARC WP).
- Quotas and harvests have decreased in some areas since initial review
- Review will facilitate implementation of a long term strategy utilising reference point management

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

- What is the *quality of data* from industry surveys ? It should be noted that no verification has been undertaken to date (this has been proposed for 2000). What are the confidence levels around biomass estimates from industry surveys and how do they compare with DFO surveys?
  - Can we document the harvest strategy and behaviour differences in depuration fisheries (similar to a lease ?) compared to a competitive "wild" fishery. Digger behaviour and efficiency is different in a quota fishery.
- Does evidence exist to determine a sustainable harvest rate for the Depuration fishery? What are *ranges of sustainable harvest rates*?
- What biological reference points will trigger a management review of current harvest rate?
- How often do surveys need to be conducted to provide reliable fish management data? We currently have annual surveys at some beaches and others where only an initial survey is required. We need to identify the current management and assessment frameworks.
- How does recruitment (do we also want to look at growth, knowing growth rates may change across the beach?) vary from location to location and from control beaches (0%) to heavily harvested beaches? Are "index beaches"

possible or is recruitment too localized and variable to rely on index beaches?

- How do we take advantage of pulses of recruitment under the survey/management frameworks?
- What are the criteria for closing a beach to harvest? What are minimum biomass thresholds or other biological reference points (eg. signs of recruitment?) that should be used to close beaches? How long should a beach be closed for “rebuilding of stocks” and to what level?

Objective of Working Paper: To determine biological and management reference points (in addition to size limits) for intertidal clam fisheries. What are sustainable harvest rates in the Depuration and “wild fisheries”? Are index beaches possible? How often should beaches be surveyed?