# PROCEDURES TO DETERMINE INTERTIDAL POPULATIONS OF *PROTOTHACA STAMINEA*, *TAPES PHILIPPINARUM*, AND *CRASSOSTREA GIGAS* IN HOOD CANAL AND PUGET SOUND, WASHINGTON

By

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# ABSTRACT

To fulfill its management obligations the Washington Department of Fish and Wildlife (WDFW) conducts intertidal bivalve population surveys on selected Washington public beaches in Hood Canal and Puget Sound. The agency has been conducting intertidal shellfish population assessments since 1986 and during this time has developed a set of standard sampling methods. The information collected enables state and tribal managers to effectively assess the existing clam and oyster resources upon which a sustainable harvest is based. Surveys are conducted on an annual basis during the summer low tides using a typical systematic random sampling design.

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# INTRODUCTION

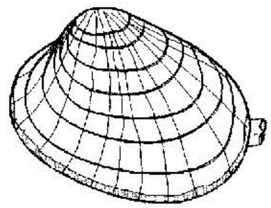
The intertidal shellfish project is responsible for determining clam and oyster populations on selected public beaches in Hood Canal and Puget Sound. The information collected during population surveys is used to determine allowable harvest levels from which harvest allowances for commercial and recreational harvest are set. This paper describes the survey methods, the reasons these methods are used, sampling efficiency, and the step by step procedures involved. Data recording, storage, and summary protocols are also discussed. The sampling strategy WDFW currently uses has been adapted from methods developed in 1986. Methods were updated in 1991 in recognition of the need to improve sampling design and to best use the staff and information available. Changes in the methodology implemented in 1991 preclude comparisons of population estimates with prior years. Methods described here are subject to change as management objectives evolve.

Methods used are consistent with those described in statistical references (Scheaffer, Mendenhall and Ott 1979; Seber 1973; Hilborn, Walters 1992).

# SPECIES DESCRIPTION

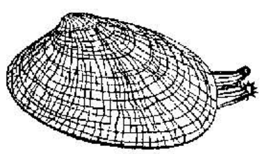
WDFW sampling protocols were developed to target native (*Protothaca staminea*) and Manila (*Tapes philippinarum*) littlenecks and the Pacific oyster (*Crassostrea gigas*).

A brief description of the above species follows:



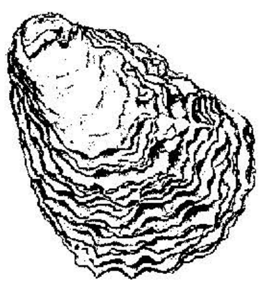
Native littleneck clam
*Protothaca staminea*

Average size 1-2", up to 2½". Rounded shell with concentric and radiating lines. Typically found at a depth of 1" to 5".



Manila littleneck clam
*Tapes philippinarum*

Average size 1-2", up to 2½". Oblong, with concentric and radiating lines. May have colored, patterned shells. Typically found at a depth of 1" to 5".



Pacific oyster
*Crassostrea gigas*

Irregular, chalky-white shell. Often found in groups attached to one another or a solid object.

In addition to these species, populations of butters (*Saxidomus giganteus*), cockles (*Clinocardium nuttallii*), and eastern softshells (*Mya arenaria*) are also examined. Because procedures were developed to target native and Manila littlenecks and Pacific oysters, sampling error associated with other species is higher.

## Habitat Types

Although the native and Manila littleneck clams are generally found in protected situations where the substratum is composed primarily of gravel mixed with sand or mud, both species can be found in areas where large cobble or even boulders predominate. Native littlenecks prefer low mid-intertidal zones while Manila littlenecks prefer the higher tidal zones. However, native and Manila littlenecks often occur together and can be found throughout the intertidal.

The Pacific oyster, also targeted by current sampling procedures, can tolerate a broad range of salinity levels and is therefore found from an extremely high intertidal zone to a low intertidal zone. Oysters tend to attach to hard substrates and are found on boulders, cobble and logs. Clusters of oysters can be found on gravel, sand, mud and shell.

# MATERIALS AND METHODS

## SAMPLING DESIGN

Beach surveys are carried out using a systematic random design. The beach is sampled at the same density from boundary[1] to boundary, from the top of the clam or oyster band to the water or in some cases the bottom of the clam or oyster band. Samples are taken during a four hour period centered on low tide. Clam surveys are conducted on those days when the low-tide is equal to or lower than -1.0 ft. MLLW. For oyster surveys, days with a low tide of -0.6 ft. or lower are used. These tidal heights were selected to ensure the resource is exposed, allowing complete sampling of the band.

**Sampling Densities** - The minimum sampling density for clams is eleven samples per acre, which equates to taking one sample per 4,000 $ft^2$ blocks. If the number of required samples is too large to sample with given staff resources, exceptions may be made and the sampling density reduced. This usually occurs when the beach exceeds 10 acres and the precision remains within an acceptable range.

The sample block size for clam surveys is defined as the area of beach ($ft^2$) associated with a single sample; a block size of 4,000 $ft^2$ translates into 11 samples per acre (transects every 100 ft and samples taken every 40 ft down the transect; 11 samples x 4,000 $ft^2$/sample = 44,000 $ft^2$). The block size is chosen to produce the most accurate population estimate possible given clam/oyster distribution patterns, staff, and budgetary constraints. Precision of a population estimate is calculated from the mean density and variance from the survey data. Minimum sample size is calculated using the data from the previous year's survey. Bounds on the error of our estimates are set by restricting the predicted 95% confidence interval to be within 30% of the mean. The optimal block size is then determined so that the estimate is within these bounds.

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1 Boundary as defined by management need for a particular beach (legal boundary, plot boundary). The beach is not defined as the "productive area".

and:

$\hat{T}$ =estimation of population in sampled area

$N$ =# $ft^2$ on the beach

$\hat{\sigma}^2$ = estimated variance of the samples

$\hat{\mu}$ =mean # of clams per sample

B =bounds on the error of the estimate (i.e., one half the length of 95% confidence interval)

These calculations are used to determine how many samples need to be taken from a given beach to produce a population estimate which is within the calculated error range (bounds) 95% of the time.

**Note:** When the sampled area is the entire productive area, then $\hat{T}$ = Total Population. When the sampled area is not the entire productive area[4], then $\hat{T}$ = Harvestable Population.

## SURVEY METHODS

Field crews typically consist of one surveyor and one or two technicians. The surveyor identifies sample "plot" locations on the beach in accordance with predetermined protocols while a technician(s) digs sample holes. The substrate from the sample hole is placed onto a board and sorted. All clams are retained to determine length and weight of each specimen. On beaches sampled for oysters, the surveyor performs counts of oysters within the sample plot and technician(s) measure the oysters in a predetermined subset of sample plots.

The following methods are used for both clam and oyster population surveys, but the discussion here is geared more to clam surveys. Both clam and oyster survey methods are similar, but have the deviations specific to clam or oyster surveys are sample placement, area sampled, and methods used to obtain samples and record sample data.

Prior to surveying a beach, field packets are prepared. These field packets contain:

1. Beach maps
2. Beach boundary descriptions
3. Description of enhancement plot where applicable
4. Directions to the beach
5. Sample block size
6. Expected number of samples
7. Tidal correction (time and height)
8. A copy of the survey notes from the most recent survey

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[4] This occurs occasionally when available tides restrict the survey area.

The default block size[2] (11 samples per acre) is used on beaches where no previous data is available.

To calculate minimum sample size the following procedure is used[3]:

The estimated population total is calculated as:

$$\hat{T} = N\hat{\mu}$$

The estimated variance around this total is:

$$\hat{V}(\hat{T}) = N^2\left(\frac{\hat{\sigma}^2}{n}\right)\left(\frac{N-n}{N}\right)$$

The finite population correction factor $\left(\frac{N-n}{n}\right)$ can be ignored for these studies since it is essentially equal to one.

The bound on the error surrounding the estimate can be set to 2 standard deviations from the estimate, thereby assuring the population estimate is within these limits 95% of the time. This limit on the error associated with the estimates is:

$$2\sqrt{\hat{V}(\hat{\tau})} = 2\sqrt{N^2\frac{\hat{\sigma}^2}{n}} = B$$

Lastly, the number of samples which should be taken from a beach to reach a given level of precision is:

$$n = \frac{N^2\hat{\sigma}^2 4}{B^2}$$

2 This is the mean block size based on analysis of previous beach surveys.

3 Scheaffer, Mendenhall, Ott 1979.

Other Survey gear include:

9. Thirty to 50 surveyor's flags
10. Clipboard with attached random number table
11. Numbered tags[4], bags, extra tags and bags
12. Compass
13. Pencils and a permanent marker

Each sampling season, beaches are scheduled to be surveyed on days which have minus tide heights comparable to the tide heights of surveys conducted on previous years. Year to year comparisons of beach area and density associated with that area can then be made. The variable nature of tides and the limited number of available field days allow few beaches to be sampled at the same tidal height as in previous years. Variation in tidal height between years is minimized by careful planning prior to the sampling season.

Since smaller beaches can take less than four hours to survey, an evaluation is made in advance to determine the total time needed to complete the sampling. This allows the survey to be centered on low tide. The survey usually begins two hours before low tide and is conducted in the same direction and using the same starting point as previous surveys. The survey is completed no more than two hours following low tide.

Prior to the field season, and at least twice during the season, field personnel determine their pace length by pacing a pre-determined distance three times and recording the number of paces each time. Then the distance paced is divided by the number of paces to determine the number of feet in each pace. The average foot pace is used. Trials are conducted on several different substrate types. The distance paced off on a beach determines (ultimately) the area of the beach which in turn determines the total population. If the surveyor's paces are of variable length or poorly recorded, the estimated area of the beach, and hence the estimated resource, can vary significantly. This introduces unnecessary variation into the population estimate.

Once on the beach, the surveyor locates the beach boundary[5] by studying maps and field notes from the previous survey. All boundary information including landmarks, distinguishing features, and compass bearings are recorded on data sheets. Compass bearings are taken on large distant immobile objects which are identifiable on a map. Two or more sightings are used to determine a boundary or locate a point on a map. For use in triangulation, bearings are taken at least 45° apart and 90° from the orientation of the beach being surveyed.

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4 Tags are used for sample tracking. These tags are consecutively numbered in advance with the surveyors initials. No two samples have the same letter-number combination within a field season.

5 Ownership boundary except where otherwise determined.

A "best fit" compass bearing is taken along the long axis of the beach from boundary to boundary (Figure 1). This is the line which best describes the overall direction of the beach. Transects are laid out at a 90° angle to this line. The exact bearing is determined by adding or subtracting 90° from the best fit bearing[6].

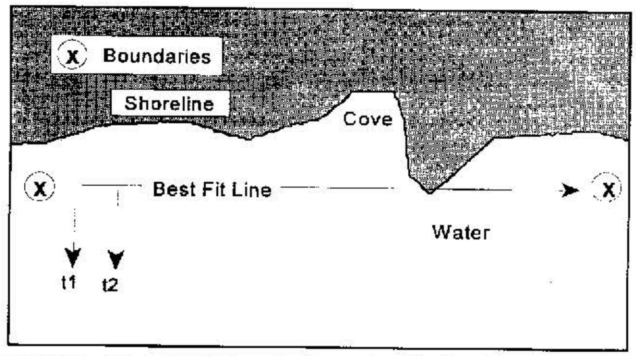

**Figure 1.** The best fit follows the long axis of the beach.

The top of the clam band is located by digging test holes. The distance from the high bank to the top of the band is paced and recorded by the surveyor. The surveyor begins each transect at the top of the clam band and surveys to the water. The first transect is laid at a random number of paces from the boundary, along the best fit line. All information is recorded on the data sheets.

The transect bearing is determined and a random number is selected within the specified block size and then that distance is paced by the surveyor. The first sample is placed at this point with a tagged bag. Samples are consistently placed at the right boot toe to reduce the introduction of subconscious bias. The sample number and the number of paces to the sample location are recorded on the data sheets.

The second sample (and all others along the transect) are a predetermined number of paces along the transect. The number of paces between the last sample and the water are recorded on the data sheets.

The next transect (and all remaining transects) are a fixed distance apart as determined by the preset block size. The first sample on every transect is a random number of paces down the transect, followed by samples placed at regular intervals.

When a sample falls on hardpan, a boulder, or "half on and half off" a boulder the sample is still taken as described above. The surveyor paces on the transect line without deviating and places samples as indicated by the specified block size. The surveyor then returns to the top of the transect and verifies there are no missing or out of order samples. With this done, errors can be

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6 The acronym RALS (Right Add Left Subtract) will help the surveyor remember when to add and when to subtract 90° from the best fit line. When the water is on your right, add. When the water is on your left, subtract.

identified and corrected on the spot[7]. The surveyor then continues along the beach on the best fit bearing.

Pacing along the best fit bearing (or along a transect) may require pacing over beach debris, through water, or over the top of banks and berms. This is done unless it imposes a danger to the surveyor or prohibits accurate pacing. When the beach curves or for other reasons it is impractical to pace along the best fit bearing to the next transect the surveyor paces along the last transect to a location where pacing can continue along the best fit bearing. The surveyor then continues along this offset best fit bearing to the next transect (Figure 2). This is referred to as a "stair-step" and is discussed later. All movements (paces, directional changes) are recorded on the data sheets. See Appendix 1 for examples.

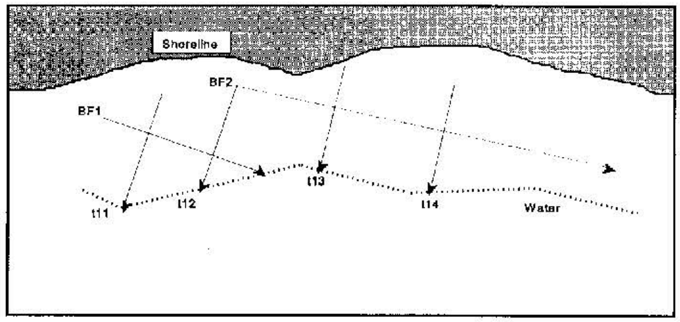

**Figure 2.** A stair step allows the surveyor to avoid obstacles and maintain square blocks.

Distinguishing landmarks on a beach are recorded on the data sheets. These include boat ramps, docks, bulkheads, pilings, enhancement plots etc. These are used to "anchor" the survey to maps, since these landmarks do not vary from year to year. They are also used when beach boundaries change to compare the previous year's data with current data.

Because flooded sample holes collapse easily, care is taken when placing samples in water. During the second half of the survey, when the tide is coming in, samples are placed so that they can be dug before the water reaches them. A surveyor uses personal judgement in this determination. Factors considered by the surveyor include speed of the incoming tide, type of substrate, and how long until a technician can reach the sample location. If a sample placed by the surveyor is flooded, the technician retrieves the sample bag and notifies the surveyor. The flooded sample is recorded as such on the surveyor's field sheet. If samples are flooded frequently or if productive tideland is being covered by the incoming tide, the surveyor may assign a technician to first dig samples closest to the incoming water or decide to continue the survey on a future tide day.

On beaches with standing water inside the intertidal (shallow tide pools), the surveyor does not

7 Problems are easily corrected in the field, but may be impossible to correct at a later date.

place a sample in more than one inch of water. If a sample falls in an area with greater than one inch of water, the surveyor records the sample as flooded.

If the beach boundary is closer than a next transect, no further transects are laid and the remaining shore paces are recorded on the data sheets. Boundary information is recorded as done for the first boundary.

**Enhancement Plots** - As with all landmarks on or near the beach, clearly marked enhancement plot boundaries are noted on the field sheet. In addition, any samples that fall within the boundaries of the enhancement plot are noted. This allows enhanced populations to be separated from the rest of the beach.

In some situations, a surveyor may increase sampling densities in order to accurately estimate a population of enhanced stock. This can only be accomplished in areas which are clearly marked as enhancement plots.

**Survey Variations-Curves, Turns, Spits, Peninsulas, and Islands** - When the shoreline makes significant directional changes such as those occurring on an island or a spit, special procedures are used. As with all beaches, the intertidal area is divided into square blocks and data are recorded on the surveyor's data sheets.

When a beach curves to the inside, a compass bearing is taken which runs completely across the curve from one side to the other. This best fit bearing may extend through water. Regardless, the surveyor paces along the best fit line to where the next transect is located. The surveyor determines the transect direction, locates the top of the clam band and lays out samples as normal. The surveyor then returns to where the best fit line intersects the transect and resumes travel along the best fit. If water or another obstacle will be encountered prior to the next transect, the surveyor moves along the last transect completed to a point where, if travel were to resume along the best fit line the obstacle could be avoided. Travel is resumed along the off-set best fit. This is called a stair-step and should only be done to avoid an obstacle (Figure 2). If performed correctly, this method divides the beach into square blocks throughout any curve of a beach (Appendix 1).

For a beach that curves to the Outside, the general methods described above are used. In general, a best fit line can be laid low in the intertidal zone which may intersect the bottom of the transects. Or, a best fit can be laid high in the intertidal zone which may intersect the top of the transects and possibly cross an upland area. Either method is acceptable (Appendix 1).

When a shoreline makes a significant turn, procedures become more complicated (Figure 3). For an outside turn, the last transect before the turn is surveyed as usual. The reciprocal of this transect bearing becomes the new best fit and the old best fit becomes the new transect bearing.

The new best fit line will run roughly parallel to the shoreline. Stair-steps are performed if obstacles such as water are encountered. The survey continues as usual but samples are not placed above the last transect on the old best fit (this area was covered by the preceding transect, Appendix 1).

An inside turn is surveyed similarly to an outside turn (Figure 3). At the point of the turn, a transect is laid out as usual. The direction of this transect becomes the new best fit direction, and the reciprocal of the old best fit will become the new transect direction. The surveyor moves to the top of the clam band along the last transect associated with the old best fit. Proceeding on the new best fit line the surveyor moves to the next transect as usual. In doing this, the surveyor is pacing down the last transect laid out on the old best fit. For the first transect on the new best fit, samples are placed along the transect as normal until the old transect line is encountered. All movements are recorded on the data sheet in a similar manner as when reaching the water line. This procedure is followed until water is encountered at the bottom of the old transect (Appendix 1).

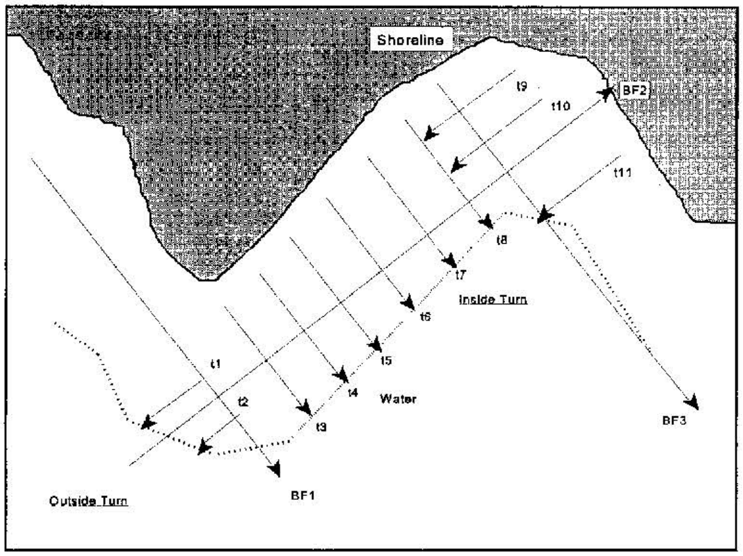

**Figure 3.** An outside and inside turn. Note the orientation of transects.

Peninsulas are surveyed as though they were two outside turns (Appendix 1).

Islands are surveyed as though they were three or more outside turns (Appendix 1, example 2).

When the surveyor reaches the base of a Spit, the best fit is changed so that it runs down the center of the spit. This may require pacing several block lengths over to center the new best fit on the spit. The survey of the spit begins at this point. Transects are placed on both sides of the spit, starting with a random number of paces to the first sample on each side. Samples are positioned as usual (Appendix 1, example 2).

**Data Recording** - Considerable emphasis is placed on proper completion of field data sheets. Properly completed survey data can later be plotted using a GIS mapping system. Plots allow managers to identify patterns of resource on individual beaches or to re-section the beach according to Department of Health (DOH) certifications or other management concerns. If a surveyor fails to record even a small item such as direction of the survey it becomes impossible to plot the beach without consultation with the surveyor. Given the seasonal nature of staff, consultation can be difficult or impossible.

Most beaches require more than one survey sheet. For each sheet, all the header information is completed (Appendix 1). This provides redundancy in data recording which gives staff the ability to check for and correct possible mistakes or to locate missing data. The survey form prompts the surveyor for all necessary information. Also, the form has a comments section, in which the following information is recorded:

| Comment | | Note |
|---|---|---|
| 1 | Beginning Boundary Description | |
| 2 | Ending Boundary Description | |
| 3 | Overall Substrate Type | Deviations from this are recorded next to individual sample numbers. |
| 4 | Missing Sample Numbers | Whenever a number or series of numbers is missing. |
| 5 | Flooded Sample Numbers | Whenever a sample is placed on the beach and is not taken by a technician (whatever the reason. |
| 6 | Miscellaneous | Anything the surveyor feels may be important for reconstruction of the survey when returning to the lab. |

As stated above, deviations from the overall substrate type are recorded on data sheets next to individual sample numbers. Substrate designations are boulder, gravel, cobble, sand, sand/gravel, sand/mud, mud/gravel, mud, eelgrass, and hardpan. Combinations of substrate types should be given in order of dominance. For example, if a substrate consists of sand and gravel with sand being more prevalent, the substrate is recorded as sand/gravel (S,G). No other substrate designations are used unless noted and defined in the comments section.

When recording the occurrence of a stair-step, the notation is placed on the transect affected by the change. This is done even though the actual pacing occurs on the transect last completed (see Appendix 1 for an example).

**Staff Allocation Information** - Information such as number of surveyors, crew members, vehicles, and boats are tracked throughout the season. This information is used by staff to schedule up-coming field seasons and develop budgets for seasonal staff and equipment. This information is collected by the surveyor (Appendix 7).

## SAMPLING METHODS

Clam and oyster sampling methods differ somewhat due to the nature of the resource. Survey methods do not differ.

**Clams** - As the surveyor places samples, a technician(s) follows and collects them. A 1ft$^2$ hoop is centered over the survey flag, the sample bag is removed, and the hole is evacuated to the size of the hoop (with straight sides), to a depth of 12 inches and placed on a sorting board. In some substrates the hole is dug quickly to prevent the sides from collapsing into the sample. If the sides do collapse, only clams which were known to be in the sample before the collapse are retained.

The substrate on the board is sorted back into the hole. Most clams are easy to recognize by shape although this is not always the case and care is taken to sort through the substrate thoroughly. All the clams (all sizes and species) are retained and placed in the sample bag with the sample tag. Clams which are embedded in the sides of the sample hole are taken only if they extend more than half way into the sample hole. The hoop is used to check this before the clam is taken.

Sample plots which fall on hardpan or large boulders are evacuated. Often this type of sample contains crevasses or depressions which contain clams. At times, excavating the sample may be accomplished using hands, a small trowel, or a gardeners fork. If a sample plot is half on a boulder, the other half of the sample is evacuated.

All sample bags collected during the survey are placed in a larger plastic bag and labeled with the following information:

1. BIDN
2. Date
3. Beach name
4. Surveyors initials
5. Diggers initials
6. Sample range
7. Bag number (e.g. 1 of 5)

Samples are returned to the work station and frozen. The number of large bags and all pertinent beach information is recorded in the freezer log (Appendix 2).

**Oysters** - Beaches are surveyed using the same methods as clam surveys. Oysters are sampled from the upper limit of the oyster band to the lower limit of the oyster's distribution. The following equipment is used:

1. Compass
2. Clipboard
3. Map packets
4. Random number table
5. One or two surveyor's flags
6. Hoops (2)
7. Calipers
8. Data sheet

During oyster surveys, the surveyor conducts counts of oysters while technicians measure oysters on a predetermined number of transects. The number of transects on which oysters are to be measured is determined by the density of oysters recorded during the previous year's survey, with a target of 300 or more measurements per beach. On the remaining transects, all oysters greater than or equal to 2.5 inches(63mm) in height within the hoop are counted (Figure 4).

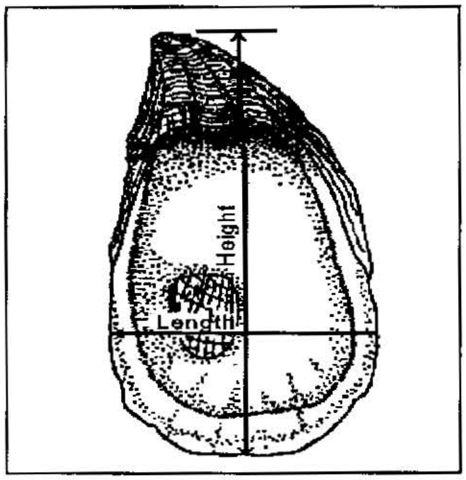

**Figure 4.** Oyster valve height measurements (Kent, 1988).

The sample area is defined using hoops 2ft$^2$. On "measure" transects, all oysters within the hoop are measured to the nearest 5mm and their attachment substrate is recorded. Attachment substrates are important because oysters are harvested differently on different substrates.

Attachment substrates fall into two general categories: oysters which can be taken off the beach (attached to nothing, each other, or loosely attached to rocks or other material), and oysters which are firmly attached to materials such that removal of the oyster would break the oyster shell or otherwise cause the oyster's death. Attachment definitions are as followed:

| **Single Oysters** | |
|---|---|
| S | Not attached, or attached to very small pebbles which have been overgrown. |
| H | Attached to rocks or other substrate from which they are easily removed. |
| R | Attached to rocks or substrate from which they cannot be removed. |
| M | Attached to shell (usually applies to spat (young-of-year). |

| Clusters of Oysters | |
|---|---|
| C | Not attached, or attached to very small pebbles which have been overgrown by oysters. |
| K | Attached to rocks or other substrate from which they are easily removed. |
| A | Attached to rocks or substrate from which they cannot be removed. |

If a harvester is able to get a clean blow to the oyster with a hammer or other implement, the oyster is classified as easily removed. If the oyster looks like it cannot be removed without damage, but a harvester may attempt to knock it off, it is recorded as easily removed. A key has been developed to aid the sampler in determining attachment type (Appendix 5).

**Data Recording** - There are two separate data sheets for oyster surveys. The first is the surveyor's field sheet. It is used as a record of the survey and for oyster counts. The second data sheet is to record oyster measurements. See Appendix 2 for examples of these forms.

The survey sheet is filled out in the same manner as a clam survey except the sample number is recorded on the left of the transect line and the sample count falls on the right side of the line.

All information at the top of the measurements form is completed. Each column on this form represents one sample. At the top of the column the transect number, the number of paces to the top of the oyster band[8], the random number, and the sample number are recorded.

Occasionally, technicians assigned to measure oysters may also conduct a count on a "count only" transect. In this case, all oysters 2.5 inches in height and greater (Figure 4) are counted and the total number is written in the column and circled. This is written in large numbers so it is not missed or mistaken as a measured sample. The surveyor notes on the survey field sheet when counts are performed by technicians. On measure samples, one person measures all the oysters in the sample and determines into which attachment category the oyster falls. The data recorder places a tally mark in the appropriate height box along with the attachment letter (the size ranges are indicated at the side of the page). Additional oysters in the same height and attachment category are tallied next to the attachment category letter. Care is taken in recording data for ease in interpretation of data.

At the bottom of the column the number of paces to the bottom of the oyster band, the number of paces to the water, and the time at the water are all recorded.

8 A positive number [+] indicates the oyster band is above the best fit, a negative number [-] indicates the band is below the best fit.

A tally of the number of clusters is kept at the bottom of the sample column on the data sheet (See Appendix 2 for additional detail).

## SURVEYING AND SAMPLING - GENERAL

The size of the beach and the number of days available for the survey are factors that influence the number of people assigned to complete a survey. A surveyor can, under normal circumstances, place up to 75 samples and a technician can dig as much as 30 holes per tide. Additional samples can be collected by adding additional technicians. Once 75 or more samples are to be collected in one tidal day, a second surveyor is added. On an oyster crew, 2 crew members can measure from 300 to 400 oysters per tide day.

In 1994 the average number of clam samples per beach was 155, with surveys ranging from 36 samples (requiring 1 surveyor, 1 technician, and 1 day) to 592 samples (requiring 3 surveyors, 6 technicians, and 3 days).

All random numbers are obtained from a random number table (Rohf, Sokol 1981; table 10, page 11). The surveyor enters the table at a random point. Two digits are taken from the table with each use (Example 1).

**Example 1**

**58237 81333 12573 36181 84900 39614 61303 05086 97670**

The random number sequence would be as follows for this line:

58, 23, 78, 13, 33, 12, 57, 33, 61, 81, 84, 90, 03, 96, 14 and so on.

When a random number is outside the desired block, the number is crossed out and the next number is selected. This is done until the number falls into the needed block size. Double zeros are not used as a random number.

## GLOBAL POSITIONING SYSTEMS (GPS)

Beginning in 1996, WDFW will begin field testing a GPS. This system will enable WDFW staff to associate shellfish resources to a specific sample location and provide a Geographic Information System(GIS) map, will reduce data entry time, and will reduce data summary errors. Also, GPS will enable WDFW to identify shellfish resources associated with changes in DOH certification lines and separate enhancement plots from natural populations.

Procedures for use of GPS equipment in conducting shellfish population surveys and preliminary results may be available in Fall, 1996.

## SAMPLE PROCESSING

Samples collected during clam population surveys are processed at the lab on higher tide days or as time permits on field days. Samples to be processed are signed out and removed from the freezer by the technicians processing them. Samples are processed in teams of two technicians.

Extreme care is taken when completing the processing data sheet. This is critically important. This is the first and best place to look for missing and lost samples.

The samples are processed while still frozen[9]. Macomas are not measured but total number and weight are recorded. All other clams are sorted by species and measured to the nearest 0.1mm and weighed to the nearest .01 gram. Clams are processed from largest to smallest, in the following order: Manilas, natives, butters, cockles, horse clams, eastern softshells, and macomas. Clams which are broken but can be accurately measured (for example only one valve is broken) are measured, not weighed, and the weight is recorded as BR (indicating broken). When length can not be accurately measured, an estimate is made regarding size. When this is done, the specimen is listed as > 1.5 or < 1.5 inches and weight is recorded as EST (estimate). If all that is present is the neck, a piece of shell or some other fragment which positively does not belong to any other clam and which can not be measured then the specimen is recorded as BR-BR for length and weight. This is also true for clams that have been crushed to a degree which prohibits accurate measurements.

Importance is placed on recording order and sizing of each clam. Clams are measured, numbered, and then recorded consecutively from largest to smallest in each species. This system allows identification and probable correction of mis-recorded data and errors. In the event an error is identified and the correction cannot be found, the entire sample and any others which may have been affected are discarded.

Sample tags are compared against the data sheets for each bag of samples processed. The tags are saved in the order in which they are processed and kept until all the data has been entered and proofed. Cover tags are made for each beach specific bundle of tags. The BIDN, sample range, and date the beach was sampled is recorded on the cover tag. This makes future identification easier if they are needed for solving data problems. Despite the availability of these sample tags, length/weight data sheets are used to complete a sequence checklist (Appendix 2). This checklist

9 Tests were performed which indicate that the weight of live clams and the weight of frozen clams are not statistically significant. Clams which have been frozen and thawed do weigh significantly less than either fresh or frozen clams. Population totals and harvest quotas are weight based. Hence, processing of clams are done while clams are either live or frozen.

is completed for each beach after the samples have been processed to account for missing sample numbers. The sequence checklist is then attached as a cover sheet to the completed length/weight data sheets.

**Redundancy** - A system of checks and cross-references has been developed which allows tracking and possible correction of mis-recorded data and other errors. To the untrained individual these checks may appear redundant and unnecessary. While it is true there is significant redundancy in every aspect of shellfish population assessment, it is also true that this redundancy has saved hundreds of hours of work. Very often, after surveyors and crew members have left for the season, problems occur with the data that must be solved by staff that was not present during surveying, sampling, or processing. Problems such as mis-recorded sample numbers, missing samples, illegible survey or processing data sheets, and even missing beaches occur frequently. Nearly all problems can be solved using this redundancy built into the system.

## DATA ENTRY

Data is entered into standard Paradox® files throughout the field season as it is collected. This is done to allow biologists to produce population estimates as soon as possible following the field season.

For clam data, three files exist: the field survey file, the length/weight file, and a data checking file. The field survey (map) file is **YYBCHRAW.db**. This file contains all the information on the surveyors field sheets. The next file is the clam length/weight file, **YYSFRAW.db**. This file contains all the information on the lab processing data sheets. The last file is a file which is used to check for inconsistencies in the length/weight file, **YYNUM.db**.

The field survey file (YYBCHRAW.db) is set up in Paradox® with the following variables:

| | | | | | | |
|---|---|---|---|---|---|---|
| BIDN | SURVEYOR | TRANSECT | SHOREPAC | SAMPNO | TRANSPAC | PACE |
| DATE | LOW WATER | BESTFIT | AZIMUTH | HIGH DRIFT | TO CB | SUBSTRATE |
| TIME | MOVE BF | | | | | |

The lab processing data (YYSFRAW.db) is also imputed into Paradox® with these variables:

| | | | | | |
|---|---|---|---|---|---|
| BIDN | SAMPNO | SPECIES | LENGTH | WEIGHT | FLAG |

The length / weight check file (YYNUM.db) is imputed into Paradox® with these variables:

| | | | |
|---|---|---|---|
| BIDN | SAMPNO | SPECIES | NUMBER |

For oyster data, there are two data files, the population file **YYOYSPOP.db** and the height file **YYOYSHGT.db**. The population file contains survey information and counts. The height file contains all height information collected on measure transects.

The population file (YYOYSPOP.db) is set up in Paradox® with the following variables:

| BIDN | SURV | DATE | TRAN | SHPAC | SFTPAC | SAMPNO | TRPAC | TRFTPAC | NUMBER |
|---|---|---|---|---|---|---|---|---|---|

The height file (YYOYSHGT.db) is also input into Paradox® with these variables:

| BIDN | DATE | TRAN_ | SAMPNO | SZCLASS | NO_OYS | ATTCHMNT |
|---|---|---|---|---|---|---|

For specific step-by-step examples of how values are extracted from field sheets and entered into the above Paradox® variables, see Appendix 3.

Additional details for all the above variables can be found in Appendix 6.

## DATA PROOFING

YYBCHRAW.db and YYSFRAW.db are run through a series of Paradox® Queries[10] that are designed to minimize the time required to proof the data. Also, Paradox® length/weight files are read into a statistical software package (SAS®) to perform the final data proofing activity. The SAS® program examines individual lengths and weights of every clam found in the Paradox® file and generates a list of all clams falling more than two standard deviations away from the predicted length or weight based on species specific regression curves for each beach or region. This list is compared with the raw data sheets by hand and errors are corrected.

All data files other than YYSFRAW.db are checked and corrected line by line by hand.

With all of the above completed, the data is summarized.

## DATA SUMMARY

Both clam and oyster Paradox® files are converted to dbase® III files and imported into SAS® which generates population and allowable harvest estimates. The program generates this data and stores it as a SAS® data file which can be easily converted to dbase® or ASCII files. All data from 1990 to the present are stored in identical files and file formats.

For clam data, each clam is assigned a "flag" which identifies its physical condition (flags indicate whether it was a whole clam, a length-broken, an estimated length, a missing length, or a broken-broken clam). A set of regressions is used to predict weights for clams which were measured but have no weight. These regressions are species-and beach-specific on all beaches with sufficient numbers of clams. The regressions are based on lengths and weights of clams

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10 Copies of Paradox® Queries are available upon request.

collected from 1987 through 1993. On beaches with insufficient data to generate a significant regression, an overall species specific regression curve which pools clams from all beaches is used. Clams with flags indicating either length or weight are missing have that missing values replaced using the regression equations. The broken-broken (BR-BR) clam's length and weight are replaced with the mean length and weight of that species on that beach.

The number (and weight) of native littlenecks and Manila clams greater than or equal to 20 mm are then counted in each sample. The mean number of clams per sample is calculated to give the mean number of clams per square foot and the mean weight per square foot. The same procedure is used to determine the number of harvestable sized 38mm clams per square foot.

For both clam and oyster beaches, the productive area of the beach is calculated by converting transect and shore paces to feet using the surveyors pace to foot conversion factor. The area associated with each sample quadrant is then calculated (shore feet * transect feet), and the quadrant areas are summed over the entire beach. This gives the entire area of the beach which was surveyed in square feet.

For clams, the mean number (weight) per square foot is multiplied by the productive beach area to generate total number and weight of clams of each species on the beach. For oysters, the number of oysters in samples is converted to number of oysters per square foot then multiplied by the productive beach area to generate a total number. This is the population estimate. For clams, 20mm and the 38mm populations are calculated separately. The precision of these estimates are also calculated as previously noted (see sampling design).

Data collected within enhancement plots are summarized as independent units.

**Harvest Rates**[11] - Clams are assigned to a length class by species. These classes are: Natives: 1 = less than 29mm, 2 = 29mm to 38.9mm, 3 = 39mm to 47.9mm, and 4 = 48mm and greater. For Manilas: 1 = less than 27mm, 2 = 27mm to 35.9mm, 3 = 36mm to 42.9mm, and 4 = 43mm and greater. The number of clams in each class is determined and the proportion in the 2nd and higher classes is calculated.

The harvest rate for clams is calculated as:

$$h = \frac{s^3}{(1-p)(s^3+s^2+s+1)}$$

[11] Based on the Iterative Method of Determining Allowable Harvests.

where $s$=the survival rate of class 2 and greater clams, and $p$=the proportion of the population in the class 2 ($p=1-(p_{3yr}+p_{4yr}$; where $p_i$=proportion of clams in the $i$th class)[12]. If the harvest rate is greater than 50% then the harvest rate is set to 50%. The harvest rate is applied to the 38mm (for Manilas, natives, and butters) population to determine the next year's allowable harvest.

The harvestable population of oysters is a percentage of the 2.5 inch and greater population for the beach. The harvest rate for oysters is calculated as:

$$h = 0.1399 \times (\text{Percent of total population 65mm and greater})^{-1.0086}$$

Harvest rates on beaches with known enhancement stock and without significant natural recruitment are typically set at 50%.

# RESULTS

On clam beaches surveyed in 1995, the average number of samples per surveyed acre was 14.61 when the total beach was less than 10 acres. When the beach exceeded 10 acres the average number of samples dropped to 10.84. This was due to limitations in available staff and time to complete the survey.

For all species in 1995 surveys, approximately 50% of beach surveys produced population estimates with a 95% chance of being within 50% of the parametric population total. On beaches with both Manila and native populations, the population estimate for one or both species was within 30% on 23 of 58 surveys (40%) and 40% on 30 of 58 (52%).

When acreage of the beach is significant and fewer samples are taken the average precision degrades (Figure 8).

In general for clam beaches, the average precision for Manilas and natives tends to be slightly higher than for butters (Figures 5,6, and 7). Native littlenecks are surveyed with the greatest precision. The accuracies presented here are resultant of the combined effects of natural variability in the populations and sampling error. It is not possible to separate these errors at this time, and not without additional field studies. Increasing the samples per acre is not expected to increase survey precision substantially (Figure 8).

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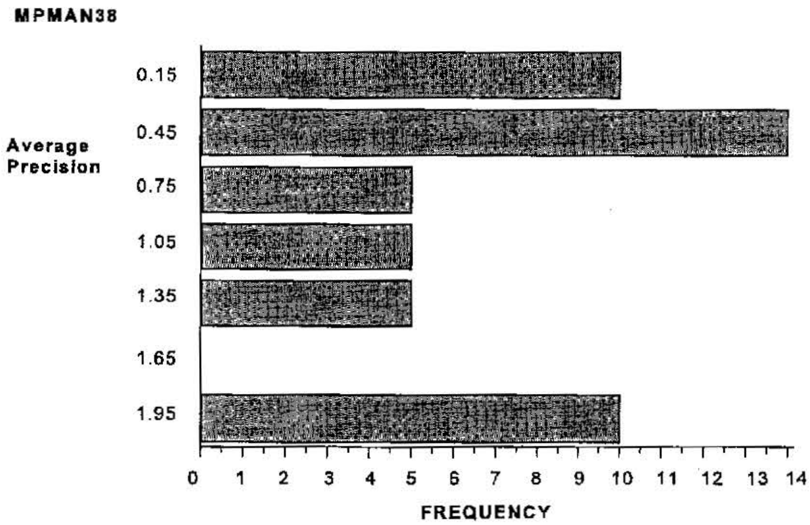
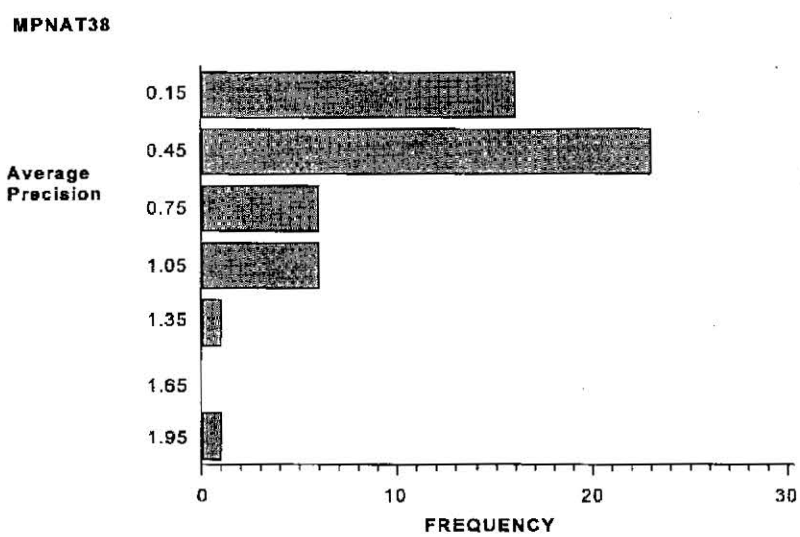
12 This is an equation for the calculation of harvest rate taken from an analysis of the iterative methods done by Bob Conrad of the Northwest Indian Fisheries Commission in 1990.



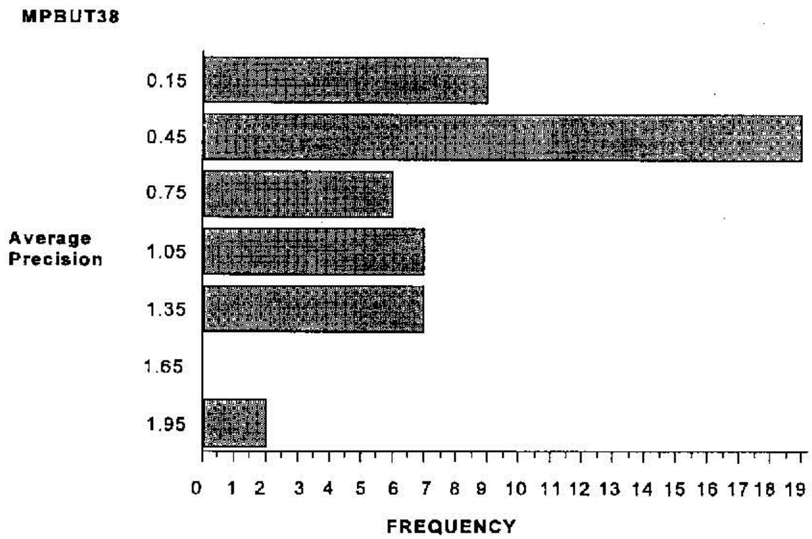

| FREQ. | COM. FREQ. | PCT | COM. PCT |
|---|---|---|---|
| 10 | 10 | 20.41 | 20.41 |
| 14 | 24 | 28.57 | 48.98 |
| 5 | 29 | 10.20 | 59.18 |
| 5 | 34 | 10.20 | 69.39 |
| 5 | 30 | 10.20 | 79.59 |
| 0 | 39 | 0.00 | 79.59 |
| 10 | 49 | 20.41 | 100.00 |

**Figure 5.** The average precision for surveys conducted on manilas between April and August 1995.




| FREQ. | CUM. FREQ. | PCT. | CUM. PCT. |
|---|---|---|---|
| 16 | 16 | 30.19 | 30.19 |
| 22 | 39 | 43.40 | 73.58 |
| 6 | 45 | 11.32 | 84.91 |
| 6 | 51 | 11.32 | 96.23 |
| 1 | 52 | 1.09 | 98.11 |
| 0 | 52 | 0.00 | 98.11 |
| 1 | 53 | 1.89 | 100.00 |

**Figure 6.** The average precision for surveys conducted on natives between April and August 1995.




| FREQ. | CUM. FREQ. | PCT. | CUM. PCT. |
|---|---|---|---|
| 9 | 9 | 18 | 18 |
| 19 | 28 | 38 | 56 |
| 6 | 34 | 12 | 68 |
| 7 | 41 | 14 | 82 |
| 7 | 40 | 14 | 96 |
| 0 | 40 | 0 | 96 |
| 2 | 50 | 4 | 100 |

**Figure 7.** The average precision for surveys conducted on butters between April and August 1995.

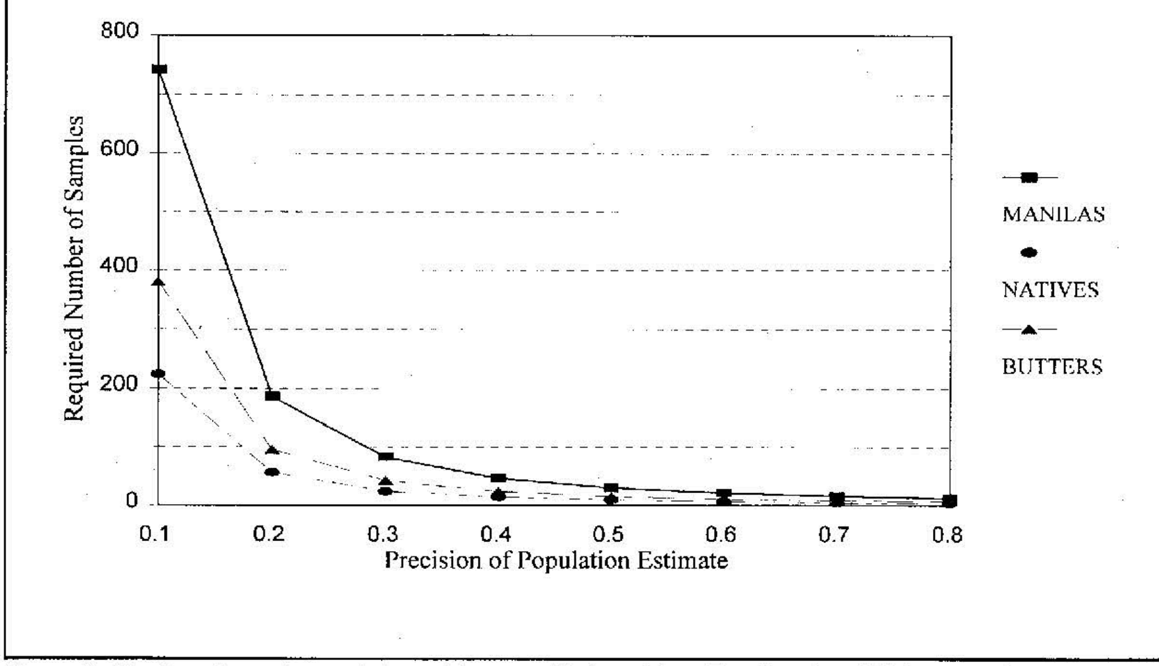



**Figure 8.** Number of samples needed to achieve specified precision. Data based on 1994 survey of BIDN 270442.

As Figure 8 illustrates, a substantial increase in samples must be taken to increase survey precision from .2 to .1. For Manilas, to achieve this, an additional 555 samples must be taken. Similarly, an increase in precision from .3 to .2 would require only 103 additional samples (Figure 8 is a representation of BIDN 270442 only).

Due to the significant difference in required samples to achieve a small increase in precision, WDFW surveys beaches to achieve the best precision possible given limitations in resources and available tides. Typically, this precision is approximately .2 to .4.

## 1995 CLAM SURVEY AVERAGES

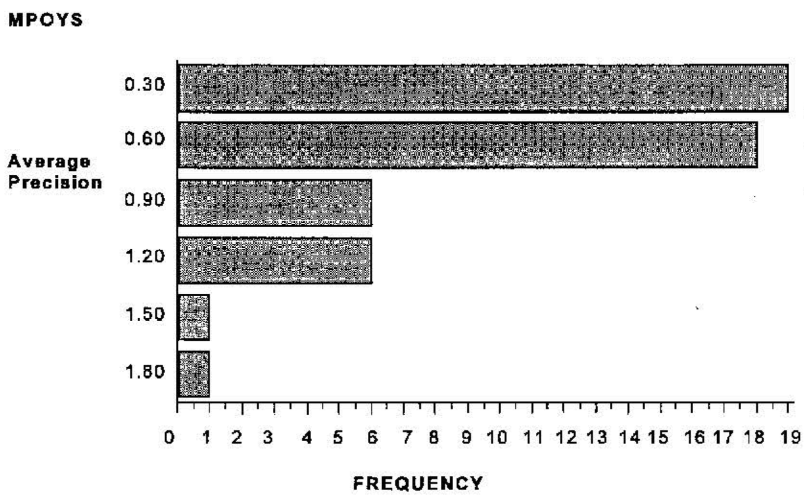
Averages associated with completion of a clam beach from survey to final data set follow. Hours reflect time required for one staff person.

| | |
|---|---|
| Mean staff per beach(per acre) | 5.70(.43) |
| Mean surveyors per acre | .13 |
| Mean surveyors per beach | 1.68 |
| Mean technicians per acre | .30 |
| Mean technicians per beach | 4.02 |
| Mean time on beach (in hours) | 5.91 |
| Mean size of beach (in acres) | 13.25 |
| Mean samples per beach | 149.66 |
| Mean processing time per beach (in hours) | 13.55 |
| Mean data entry per beach (in hours) | 6.43 |
| Mean proof time per beach (in hours) | 4.69 |
| Mean total time per beach (in hours) | 67.40 |
| Mean total staff hours per acre | 5.09 |

On oyster beaches, the average number of samples per surveyed acre is 22.76 when the total beach is less than 10 acres. When the beach exceeds 10 acres the average number of samples drops to 6.97. As with clam beaches, this is due to limitations in available staff and time to complete the survey.

When acreage of the beach is significant and fewer samples are taken the average precision degrades. This can be seen in Figure 9 where 15.68% of surveyed oyster beaches had an error factor of 1.21 or greater.

On all surveyed beaches, 37.25% had a precision of 45% or less.




| Average Precision | FREQ. | CUM. FREQ. | PCT. | CUM. PCT. |
|---|---|---|---|---|
| 0.30 | 19 | 19 | 37.25 | 37.25 |
| 0.60 | 18 | 37 | 35.29 | 72.55 |
| 0.90 | 6 | 43 | 11.76 | 84.31 |
| 1.20 | 6 | 49 | 11.76 | 96.08 |
| 1.50 | 1 | 50 | 1.96 | 98.04 |
| 1.80 | 1 | 51 | 1.96 | 100.00 |

**Figure 9.** The average precision for surveys conducted on Pacific oysters between April and August 1995.

## 1995 OYSTER SURVEY AVERAGES

Averages associated with completion of an oyster beach from survey to final data set follow. Hours reflect time required for one staff person.

| | |
|---|---|
| Mean staff per beach(per acre) | 3.78(.54) |
| Mean surveyors per acre | .17 |
| Mean surveyors per beach | 1.19 |
| Mean technicians per acre | .37 |
| Mean technicians per beach | 2.59 |
| Mean time on beach (in hours) | 3.88 |
| Mean size of beach (in acres) | 6.99 |
| Mean data entry per beach (in hours | 3.20 |
| Mean proof time per beach (in hours) | 1.85 |
| Mean total time per beach (in hours) | 27.70 |
| Mean total staff hours per acre | 3.96 |

# DISCUSSION

Methods described in this paper are generally acceptable for the targeted species and their habitats. But, as with any effort to estimate populations, bias or other inaccuracies can significantly degrade the results.

Over years of conducting population surveys of shellfish we have found six noteworthy difficulties. The first four are associated with surveying the beach and taking the sample. The remaining two deal with tides and sampling design.

1. The first difficulty is soft substrates. In soft substrates the sides of the sample hole tend to collapse. As the sample is sorted the hole becomes increasingly larger. This forces the technician to use best judgement to determine when to no longer remove clams from the hole. This is a problem because populations can be over or under estimated significantly if the technician digging the sample hole fails to use good judgement.

2. The second difficulty occurs if the surveyor gets too far ahead of the technicians digging sample holes during an incoming tide, samples located near the water may become flooded. If a sample becomes flooded, data extracted from the preceding sample is used to determine population for a larger area thereby reducing precision.

3. The next problem is that sample efficiency drops significantly at clam sizes below 20mm. The smaller the specimen, the more difficult it is for a technician to visually see and extract from the substrate. Generally, anything larger than 20mm is retained.

4. The fourth problem is associated with pacing. Pacing errors can increase or decrease the area of the beach and thereby increase or decrease the total population of the beach. This error is reduced by determining foot/pace conversion factors several times during the field season. Alternative technologies such as GPS could be employed to improve precision.

5. The fifth difficulty is tidal height. Tide height can significantly increase or decrease total area of the beach from year to year. To reduce this error, sampling must occur on a similar tide height each year.

6. The sixth and last difficulty is that the sampling design has been tailored to the distribution patterns of native and Manila littlenecks and Pacific oysters. If a slightly higher error factor is acceptable, these methods can also be used for butter clams. Because distribution patterns are significantly different for horse clams, this sampling design is not acceptable for that species.

Errors associated with these problems are reduced by conducting an extensive three to five day training program prior to taking the first sample. Training includes guidance on how to sample in various substrates, how to pace over different types of substrate, how to sort samples, and when not to take the sample due to conditions which prohibit accurate sampling. This training is continued throughout the sampling season to ensure adherence to proper protocols and continued sample quality.

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# COMPUTER PROGRAMS CITED

Borland Paradox. 1993. Release 4.5. Scott's Valley, CA: Borland. On 9 computer disks: 3½ inch: Accompanied by: 5 reference guides. System requirements: VGA driver, 6 megabytes of RAM.

The SAS system for information delivery. 1994. Release 6.10. Cary, N.C.: SAS Institute inc. On CD ROM or 3½ inch disks: Accompanied by: installation instructions. System requirements: DOS 5.0 or later, Windows 3.1 or later, Intel compatible 80386-33Mhz or higher CPU, a math co-processor, minimum 8 megabytes of RAM.