2005 BIVALVE MANAGEMENT PLAN FOR PUBLIC TIDELANDS IN REGION 6: CENTRAL PUGET SOUND

Introduction

This Bivalve Management Plan for public beaches describes available clam and Pacific oyster resources, harvest shares, population assessment methods, and management activities for these species for the period January 1, 2005 through December 31, 2005 in Region 6. Region 6 includes all public tidelands within the marine waters enclosed by the following prescribed boundary: South of a line projected from Apple Cove Point to Point Edwards and north of a line projected from the ferry dock at Point Southworth to Brace Point (Figure 1).

The inter-tidal fisheries subject to this Plan include non-Treaty recreational and commercial fisheries, Treaty commercial fisheries, Treaty subsistence fisheries, and Treaty ceremonial fisheries. The species affected by this Plan include Manila littleneck (*Venerupis philippinarum*), native littleneck (*Protothaca staminea*), butter clams (*Saxidomus giganteus*), and Pacific oysters (*Crassostrea gigas*), native oyster (*Ostrea conchaphila),* softshell clam*, (Mya arenaria*), cockle (*Clinocardium nuttallii),* mussel (*Mytilus spp.),* horse clam (*Tresus spp.*), and geoduck (*Panopea abrupta).* This list may be expanded in the future to reflect new fisheries that evolve.

Tables 1 and 2 summarize available resource information for littleneck clams. The parties may develop additional management and allocation information for any other inter-tidal bivalves to be added to this Plan by written agreement.

Scope of Plan

This Plan establishes the non-Treaty and Treaty harvest shares for 2005 from the beaches specified herein. Consistent with conservation needs, harvest will occur only on public beaches identified within this Plan or by an agreed supplement or amendment to this Plan.

No Waiver or Admission of Usual and Accustomed Areas

No party hereto waives any claims concerning the location, boundaries, scope or use of usual and accustomed grounds and stations. This Plan does not constitute an admission that a particular area used for management is an accurate description of usual and accustomed grounds and stations, their location, boundaries, scope or use.

The terms of this Plan shall never be used as evidence in any tribal, state or federal court of administrative or quasi-judicial proceeding concerning the location, boundaries, scope or use of usual and accustomed grounds and stations of the breadth or limit of usual and accustomed areas.

If a tribe not party to this Plan should have rights to harvest inter-tidal bivalves from any beach addressed herein, then any amount actually taken by that tribe on the beach shall count against the planned tribal share and the state retains all rights to its share.

Application to Federal Court Revised Shellfish Implementation Plan

1. This Plan is intended to be consistent with the Federal District Court's order dated December 20, 1994, and all subsequent implementation orders in United States v. Washington, No.9213, Sub-proceeding 89-3.

2. The parties agree that they remain bound by ¶ 1.6 of the court's Revised Shellfish Implementation Order of April 8, 2002, continuing the application of the Consent Decree on Shellfish Sanitation Issues (May 5, 1994). Additionally, this Plan shall not be construed to be a waiver of any requirements of the Consent Decree, or be construed to be an agreement by the State Department of Health for sanitation matters. The undersigned State agencies do not represent the Department of Health.

3. This Plan shall not apply to property leased from the State and held by a lessee. Such property, including renewals of leases for such property, is controlled by applicable provisions of the court's orders. Except as provided for herein, the State retains the right to lease additional property which could remove the property from planning and harvest. Provided, however, the State will comply with all applicable parts of the court's order relevant to the State leasing or releasing or property.

4. Nothing in this Plan is intended to preclude any party from asserting a right to take harvestable shellfish that another party is unable to harvest or has chosen not to harvest, nor is it intended to preclude any party from asserting that no such right exists with respect to shellfish. The parties agree that this issue is not addressed in this Plan and each party may assert its position without prejudice from any provision of this Plan.

Management Goals and Objectives

The management goal of this Plan is to preserve, protect, and perpetuate inter-tidal bivalve resources; provide for their sustainable harvest; provide for stable annual fisheries; protect the habitat necessary to sustain these harvests; and minimize bycatch mortalities of other species. The parties will manage inter-tidal harvests on a beach-by-beach basis unless otherwise agreed.

Beach Management Categories

Beaches will be assigned to one of three management categories during the planning process for the Region 6 Management Plan depending on the management need for each species on that beach. The three categories are: (1) primary active management, (2) secondary active management, and (3) passive management. Beaches can be changed from one category to another during the planning process or inseason by amending the tables if the affected parties agree.

1. Primary beaches will meet the following criteria:

    - Demand for littleneck clams, Pacific oysters, or another inter-tidal bivalve species approximates TAC, or is expected to approximate TAC.

    - The annual variability in TAC may also be high.

    - Population assessments will be conducted on primary beaches every year except where the parties agree to an alternate schedule.

    - Commercial, ceremonial, and subsistence (C&S), and recreational fisheries may occur on these beaches.

2. Secondary beaches will meet the following criteria:

    - Demand for littleneck clams, Pacific oysters, or another inter-tidal bivalve species is less than on primary beaches, and does not approximate TAC, or is not expected to approximate TAC. Availability/vulnerability of these resources to fishing is moderate.

    - The annual variability in TAC may also be moderate.

    - Population assessments will be conducted on these beaches every other year, or otherwise by agreement.

    - Commercial, C&S, and recreational fisheries may occur on these beaches.

3. Passively managed beaches will meet the following criteria:

    - Beaches/species in this category are not designated as primary or secondary active management. Available information on recreational and C&S harvest does not indicate the need for resource surveys or a TAC on these beaches at this time.

    - C&S and recreational fisheries may occur on these beaches.

    - No allocation is specified for either party.

    - Population assessments are not required but may be made periodically on selected beaches.

    - Where management needs require more intensive management, beaches may be placed in either the primary or secondary active management category.

Population Assessments

Tables 1 and 2 identify the beaches included in this Regional Plan. Table 1 identifies the party that will conduct population assessments on the identified beaches. Population assessments will follow the procedures outlined in either Appendix 1 or "Procedures to Determine Intertidal Populations of *Protothaca staminea*, *Tapes philippinarum*, and *Crassostrea gigas* in Hood Canal and Puget Sound, Washington", by William Campbell, WDFW, unless other methodologies are developed and agreed to by the parties. The parties agree to investigate alternative methodologies for population assessments during the term of this Plan and implement agreed-to methods where appropriate. If any party to this Plan is not able to complete their scheduled population assessments as identified in Tables 1 and 2, that party shall try to notify the other Plan parties in a timely fashion to allow the other parties to conduct the missed assessment(s), if possible.

Estimates of Total Allowable Catch

The parties will establish the annual TACs on a beach-by-beach basis for primary and secondary management beaches. New population assessment and TAC estimation methods will be reviewed and approved by the affected parties in a timely fashion before being placed in use.

1. Natural Stocks TAC

   The TAC for native littleneck clams will be up to 25% by weight of clams equal to and greater than 38 mm, and for Manila clams the TAC will be up to 33% by weight of clams equal to and greater than 38 mm, except where agreed otherwise. For each year there is no new population survey on a primary or secondary active management beach the previous year's TAC will be reduced by 25%, except as otherwise agreed. If a beach is not surveyed for multiple years there will be multiple TAC reductions of the most recent survey.

2. Enhanced Stocks TAC

   The parties will jointly establish each year which beaches will be included as currently enhanced, based on the following factors: 1) The time interval since the most recent enhancement event; 2) The magnitude of enhancement efforts; 3) Any evidence related to the success of enhancement efforts; 4) Expected grow-out time at the specific location. Bivalve stocks that are enhanced will have TACs established at 50% of the total harvestable stock, unless otherwise agreed. For those beds not assessed for population size every year, the TAC will be 75% of the previous year's TAC, unless agreed otherwise. For each year there is no new population survey on a primary or secondary active management beach the previous year's TAC will be reduced by 25%, except as otherwise agreed. If a beach is not surveyed for multiple years there would be multiple TAC reductions of the most recent survey.

Harvest Shares

Unless otherwise agreed, each Treaty and non-Treaty harvest share is calculated as 50% of the TAC for each primary and secondary active management beach (Table 1). Treaty and non-Treaty allocations are not established for passively managed beaches (Table 2). Passively managed beaches are open year-round to subsistence, ceremonial, and recreational fisheries subject to specific Tribal and State regulations. Fisheries occurring on beaches containing natural and artificial stocks will be designed and conducted so that the total harvest of natural and artificial stocks does not exceed any party's share on any one beach, unless agreed otherwise.

1. Adjustment Provisions To Prevent Over-harvest of Agreed Harvest Levels**:**

   The parties agree to design fisheries and utilize appropriate management tools that will prevent over-harvest of agreed harvest levels and protect the shellfish resource. Where any over-harvest of the Treaty or non-Treaty share of a species occurs on a beach, the total amount of that species over-harvest shall be subtracted from the offending party's share for that beach in the following year, or as otherwise agreed. This provision is not intended to prejudice any claims by either party with respect to paragraph 4 under the section: Application to Federal Court Revised Shellfish Implementation Plan**.**

2. Studies To Determine Effects of Different Harvest Strategies on Adult Recruitment

   Any party to this Management Plan may propose to investigate different harvest strategies, such as periodic harvest rotation schedules, on any primary or secondary beach identified herein in an effort to determine the effects of changing harvest rates on the rate of adult recruitment. Any such proposal will be distributed to all parties to this Plan, and a consensus between the parties will be required before such proposals are implemented.

Fishery Monitoring and Catch Accounting

The parties agree to monitor fisheries, maintain harvest records, and report harvest information as described below. Harvest will be reported on an annual basis no later than 15 days after the end of the term of the current year's plan. A preliminary report of catch will be due at least 30 days before the end of the term of the current year's plan.

1. Tribal Commercial Fishery

   Beach specific records of Tribal commercial harvest by species will be recorded on Tribal fish tickets. Tribal commercial catch will consist of catch reported on Tribal Fish Receiving Tickets modified by fishery monitor data if necessary. In addition, all Tribal commercial clam fisheries will occur with a Tribal fisheries monitor to observe the fishery and record catch as it is removed from the beach. On those beaches where catch and effort rate is low, an on-site monitor may not be required. Tribal commercial clam fisheries that occur without an on-site monitor will be controlled by regulation and Tribal fisheries staff to ensure the harvest is from a certified area and that all catch is recorded and tagged as it is removed from the beach.

2. Tribal Ceremonial and Subsistence Fisheries

   Tribal fishery managers will account for Tribal ceremonial harvest by species from catch records of each specific opening. Subsistence catch accounting methods used by the Tribes are described below.

   Suquamish Tribe - The Suquamish Fisheries Department issues ceremonial harvest permits for each ceremonial harvest which specify the harvesters, species, location and amount to be harvested. Subsistence harvest quantity is reported to the fisheries office within twenty-four hours of the fishery, as required by Tribal Ordinance

   Tulalip Tribes - Tribal ceremonial fisheries will be accounted for from permit information of each specific opening. Subsistence fisheries will occur based on a permit system with an associated catch reporting requirement. Harvesters are required by regulation to have a valid subsistence permit in their possession during each subsistence harvest. The subsistence permit will have the date of harvest and maximum daily harvest amount listed on each permit for each species. A limited number of permits are issued to any one individual per year so not to exceed a total harvest per person per year. The maximum daily harvest quantity listed on the permit is the amount of shellfish recorded as the actual subsistence harvest. In addition, beach creel surveys of tribal harvests may be conducted as a comparison between the actual harvest and the harvest estimate.

   Muckleshoot Tribe – If the Muckleshoot Tribe opens ceremonial or subsistence fisheries in Central Puget Sound during 2005, the Tribe will provide the other parties to this Plan with their catch accounting methods prior to any opening.

3. Recreational Fishery

   The recreational fishery will be monitored and catch estimates will be based on scientific sampling, analyses, and methods. A description of these procedures is described in Appendix 2.

4. Non-Treaty Commercial Fishery

   Beach specific records of non-Treaty commercial harvest, excluding leased beaches, will be recorded on WDFW Fish Receiving Tickets. In addition to fish ticket catch accounting, all non-Treaty commercial clam or oyster fisheries will occur with a State fisheries monitor to observe the fishery and record catch as it is removed from the beach.

<u>Fishery Regulations</u>

The parties to this Plan will promulgate and enforce regulations that provide for orderly fisheries designed not to exceed their respective agreed share for each beach. Such regulations shall include, but not be limited to, the following provisions as they may apply to a particular party's fishery.

1. Regulations that apply to all fisheries:

   a. The dates and hours the fishery will be open.
   b. The beach(s) open for harvest.
   c. The type of fishery to be opened.
   d. The target species.
   e. Minimum size limits (Minimum size limits for Manila, native littleneck, butter, and cockle clams is 38mm (1.5 inches) across the longest dimension of the shell, unless otherwise agreed.)
   f. The gear allowed. (In general, clams may be dug by hand or hand-operated fork, pick, rake, or shovel. Oysters may be picked by hand or with the aid of a hand-held prying tool that minimizes damage to the non-harvested oysters.)
   g. Daily harvest limits, if any.
   h. Clam diggers must refill holes and flatten mounds to original beach level.

2. Regulations that apply to non-Treaty recreational fisheries:

   a. Seasons - Seasons may vary in length for each beach and are designed not to exceed the non-Treaty share where applicable. Season length may be adjusted in-season to ensure that the applicable non-Treaty share is fully utilized but not exceeded.
   b. Oysters must be shucked on the beach and the shells replaced at the same tide height as taken.

3. Regulations that apply to non-Treaty commercial fisheries:

   Regulations that will govern non-Treaty commercial fisheries, in addition to those described in Section 1, are contained in State contracts opening specific beaches. In addition, the State party proposing a commercial opening shall provide notice to all affected parties at least two full working days before the opening for primary management beaches and at least one full working day for secondary beaches.

4. Regulations that apply to Treaty fisheries:

   The Tribes will specify on a beach-by-beach basis regulations that will govern Treaty commercial, ceremonial, and subsistence fisheries, in addition to those described in Section 1. In addition, Tribes proposing a commercial opening shall provide notice to all affected parties at least two full working days before the opening for primary management beaches and at least one full working day for secondary beaches.

Oyster and Shellfish Transfer Permits

Beaches which have infectious diseases or significant shellfish predators will carry the following restrictions: 1) Each tribal commercial fishery on these beaches will specify by regulation the agreed-to conditions under which inter-tidal bivalves may be transferred to another area. The described transfer conditions will be designed to prevent the introduction and spread of disease and predators. 2) Non-Treaty commercial harvesters will be required by state regulation to have oyster transfer permits or a system to regulate transfers. The permit or regulation will include provisions that specify transfer routes and conditions that prevent the spread of disease and predators. Transfers will not occur between beaches with infectious diseases or predators and beaches void of these problems. 3) Current beaches within Region 6 that have documented infectious diseases or significant shellfish predators, along with the associated WAC reference, are as follows:

1) Liberty Bay west from Tower Point to Keyport (WAC 220-72-011(7)) restricted for Japanese oyster drills.
2) Dyes Inlet west from Rocky Point to Tracyton (WAC 220-72-011(8)) restricted for Japanese oyster drills.

Enforcement

The parties agree to support and conduct effective enforcement activities required to maintain orderly fisheries and ensure compliance with the provisions of this Plan and the Consent Decree. The Tribes and the State further agree that they will take meaningful and substantial enforcement actions if Treaty or non-Treaty harvesters violate their respective regulations.

The parties agree that any party to this plan may personally observe any or all harvest operations of another party, with prior notification.

Property Boundary Issues

The parties will attempt to resolve property boundary issues on public beaches by utilizing the following process (these two steps may or may not occur in one planning year):

1. The agency that owns the tideland will provide available agency information describing the boundaries of the beach to the affected parties to this Plan. The agency will support or work with other parties to contact the private tideland owner(s) as applicable, and assist the other parties in resolving outstanding boundary issues.

2. If no resolution occurs in Step 1, an on-site meeting will be scheduled with staff from the agency, the private tideland owner(s), and Tribal management staff to designate agreed-to interim boundaries that will allow shellfish harvesting to occur.

Changes to the Plan

All affected parties may make changes to this Plan only upon written agreement. Where there are exclusive Usual and Accustomed (U & A) fishing places within Region 6 and where a change to this Plan occurs only within that exclusive U & A, the affected Tribal party shall be the Tribe having the adjudicated exclusive U & A.

Authorized Signatures for the 2005 Central Puget Sound Intertidal Bivalve Plan

This Plan is made by the following parties, and the undersigned persons have authority to enter this Plan under ¶ 4.5 of the federal court's order.

FOR THE WASHINGTON DEPARTMENT OF FISH AND WILDLIFE

________________________________(name)

________________________________(title)

________________________________(date)

FOR THE DEPARTMENT OF NATURAL RESOURCES

________________________________(name)

________________________________(title)

________________________________(date)

FOR THE TULALIP TRIBES

________________________________(name)

________________________________(title)

________________________________(date)

FOR THE SUQUAMISH INDIAN TRIBE

________________________________(name)

________________________________(title)

________________________________(date)

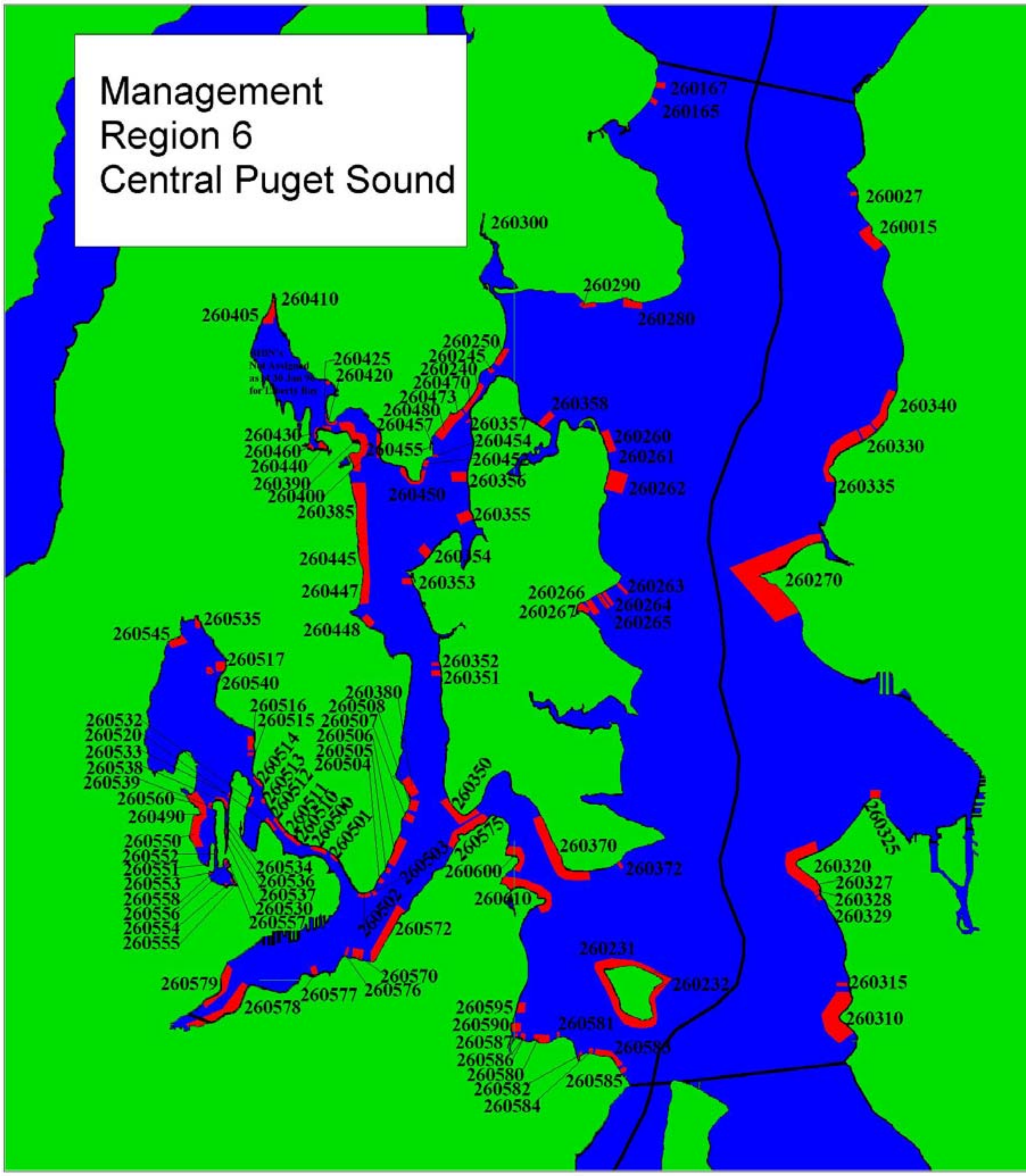
FOR THE MUCKLESHOOT TRIBE

________________________________(name)

________________________________(title)

________________________________(date)

Figure 1



(Region Map)

Appendix 1

Surveying Intertidal Clam Populations
and
Assigning an Annual Harvestable Biomass

2002 Revision

1. Surveying for Intertidal Clams - An Overview

Any natural resource which is subjected to significant harvest, should regularly be monitored to assess the status of that resource. Clam populations, which are relatively immobile, readily lend themselves to surveys. Surveys for intertidal clams take one of two basic forms, a baseline survey or a full survey.

A baseline, or reconnaissance survey, is used to determine the following: if a particular stretch of beach has clams, which species are predominant, whether these are relatively dense or sparse, how pervasive they are, and generally whether the large ones are reaching a size indicative of a productive environment. This type of survey is relatively simple, consisting of walking the portion of the beach in question during a low tide (-1 foot or lower), with a clam fork, rake or shovel, and digging ‘test’ holes at a number of randomly selected locations on the beach. Neither the clams nor the holes are counted or measured. The status of the clam population is then subjectively assessed, based on what is seen, and how it relates to other beaches, previously examined in greater detail, by the surveyor. The surveyor’s experience is obviously valuable to such an assessment and this type of survey is highly recommended prior to performing a full survey, as it provides a good, qualitative picture of the status of the clam population, with relatively little effort.

Full surveys are conducted to more accurately determine the size and status of the population. Instead of using randomly located sample sites, a full survey consists of a predefined sample density, with samples positioned precisely, in a random, or stratified random manner. Beach size is measured, sample holes are of a specific size, and all clams of interest are collected from each hole, identified to species, counted and measured.

The resulting data can be used to determine mean clam density, productive beach area, number and biomass of clams on the beach, relative dispersion and size distribution. Any of a number of methods can then be employed to predict a sustainable harvest rate for the beach. Depending on the potential harvest effort and the importance of adhering to the predicted sustainable harvest rate, a number of management controls are then employed to target that rate.

2. Conducting a Full Survey

a. Pre-survey Preparation

A full survey is very labor intensive and should not be undertaken lightly. Once the decision is made to conduct a full survey, considerable forethought and planning are required. Spring is the best time of year to schedule beach surveys since this is when extreme low tides occur during the daylight hours. Though extreme low tides also occur during the fall, these are at night, and can be much less efficient. Conducting such surveys at night, in the cold, during the rainy season, is less productive, and probably results in less reliable data.

Since intertidal beach surveys are by definition, highly dependent upon the tides, detailed information on the tidal cycles for the planned survey location, on the days in question, is highly beneficial. It should be noted that though tide tables contain relatively reliable, precise predictions of tidal conditions, based upon years of past data, local environmental conditions, accompanied by high or low barometric pressures, can drastically alter actual tidal conditions. This aside, the computer software program titled TideMaster, is very useful for this purpose, being able to provide tide cycle projections, at fifteen minute intervals, for more than one hundred sites around Puget Sound. The survey-days' chart(s) should be printed ahead of time, for use in the field. Be sure to note of the time at which the tide will be at the -1 foot level.

There are many pieces of equipment which should be gathered and packed at least one day before the planned survey. Five gallon plastic buckets are ideal for transporting most field equipment to the survey site. Zip lock bags are also ideal for holding and isolating the clams excavated from each sample hole, and a large number should be packed. Numerous preprinted labels, preferably on waterproof paper (e.g., 'Rite in the Rain') should be taken, as well as several sharp pencils. One or two large field tape measures or laser range finders is/are also essential, unless distances will be paced, and the pace of each 'pacer' has been calibrated. If paces will measure distance, include a couple of ropes, at least as long as the longest transect, to help keep transect lines straight. Stakes (wood or thick wire), of two distinct types (possibly denoted by different colored surveyors tape tied to one end), should also be taken. A couple of sample templets, preferably made of thick wire, in the shape of either a circle or a square, of one or two square foot area, are also necessary. Square templates are best if digging is to be done with a clam fork or rake, while round templates are preferred for use with a shovel (A strip of surveyor's tape attached to the template makes locating it on the beach much easier, should it be momentarily misplaced). A fork/rake is more versatile when digging clams, and works best when the substrate includes cobble. Pack at least two forks/rakes or shovels. A clip board with waterproof paper and/or preprinted data sheets, and a compass or two, round out the pack.

The survey crew should consist of at least two people. Additional personnel are particularly useful to speed up sample collection, however, their assistance in actually setting up the transects and sample sites will be limited, and a greater overall coordination will be required. The survey crew should verbally ‘walk through’ the survey process at least one day before the survey, if they have not worked as a team previously.

b. The Survey

The survey can commence any time after the tide has begun to fall, and part of the clam zone has become exposed. Starting at one end of the beach, one or two people should walk the upper level of the beach, digging several ‘test’ holes to subjectively determine the upper limit of clam distribution. At regular intervals, of a distance less than the intertransect distance (e.g., 50ft.), stakes should be inserted into the substrate, to mark the upper clam boundary (UCB). One type of stake (type I) should be used to mark the UCB.

Only if the survey crew is very familiar with this beach and they feel confident locating the UCB with limited test digs, should they omit the step above, and proceed directly to positioning the stakes that signify the start of each transect, as described below.

While this is occurring, another surveyor should get positioned at the spot where the end of the beach and the upper clam boundary meet. If transects are to be 50 feet apart, using a random number table, or similar method, select a random number (0-49). Measure this distance in feet, along the UCB (denoted by stakes), and place one of the second type of stakes or type II stakes (i.e., different from the UCB stakes) into the substrate at this point. Transect ‘A’ will be established from this point down to the water, making it perpendicular to the water line. Return to the starting point, and take a compass bearing to the stake at transect ‘A’, and a second bearing directly to the water’s edge.

The area which will be between this end of the beach and transect ‘A’, is the first buffer zone. At this point it would be good to make use of the clipboard. Either write this information in the appropriate area on preprinted data sheets or sketch the beach and transect locations: draw a straight line across most of a page, representing the UCB and draw two perpendicular lines at one end of the UCB line, representing one end of the beach and transect ‘A’. Write down the width of the buffer and the two compass bearings just noted, in the appropriate location. Also, write ‘A’, where the stake at transect ‘A’ would be, if the beach is being sketched.

From stake ‘A’, measure 50 feet along the UCB, if transects are to be 50 feet apart and place stake ‘B’ (type II) into the substrate. Either return to stake ‘A’, take a compass bearing to ‘B’ and note it on the clipboard, or have another surveyor perform this task. Proceed along the UCB locating the uppermost end of each transect line with type II stakes, and noting the compass bearing to each, from the previous transect's stake.

While this is proceeding, keep track of when the tide appears to be half to three quarters of the way out. At this time, individual transects and sample sites can be established. The element of randomness introduced into locating sample sites along each transect can be introduced by a number of means. NOTE: While the distance from the end of the beach to transect 'A' was randomly located, establishing all samples in a uniform pattern relative to each other hardly qualifies as random sampling. At minimum, one more element of randomness should be introduced, and this is the methodology which will be described here.

To establish transect 'A', a surveyor should be positioned at the stake representing the top of transect 'A'. Using a field tape measure or rope, lay down a line from the stake directly to the water line. From stake 'A', take a compass bearing on this line, and note it on the clipboard. If sample frequency along transects is to be one sample every 50 feet, randomly select a number from 0-49 and make note of this number. From stake 'A', measure that number of feet down the transect line and place a type-II stake. The sample taken from this location will be labeled A1. Measure 50 foot intervals down the transect line placing type II stakes at sample locations A2, A3, etc. until the water's edge prevents location of another stake. Completion of transect 'A' must wait until the tide extends below the -1 foot level.

Sample locations along transect 'B' can be established simultaneously, or after transect 'A' is laid out. The location of the first sample along transect 'B', should be established by selecting a new random number, and measuring that distance down to the water. Similarly, new random numbers should be generated for the placement of the first sample site on each subsequent transect. Be sure to note the compass bearing of each transect, down to the water.

The most time consuming component of a full beach survey, is digging samples, and this is where a greater number of assistants is most beneficial. The size of each sample is one or two square feet. This size is suggested as a matter of practical convenience and has not been statistically determined to be the optimal size for these species (see J.M. Elliott, 1977, to determine how the most statistically appropriate sample size can be calculated). Sample digging should begin any time after the first part of transect 'A' has been laid out.

The effect of the next high tide should be considered when deciding whether to continue locating all sample sites, or to locate them just prior to digging. The beach will probably not be completely surveyed in one low tide cycle and some stakes are likely to be dislodged if left over night, due to tidal changes or curious passersby, so sample location should probably not get too far ahead of sample digging.

When digging a sample, the sample template should be positioned consistently, relative to the stake, throughout the whole survey, e.g., a template might be always centered on the line, on the shoreward side of the stake, or possibly always centered over the stake. As diligently as possible, attempt to make sides of the excavation hole perpendicular to the beach surface, removing all clams which fall within the area framed by the template. Excavation should be as deep as the clams could reasonably be found (8-12 inches for littleneck and manila clams). Discretion should be used, to exclude any clams which accidentally fall into the hole, should the sides cave in, as is often the case. Since even careful sample collection appears to greatly undersample clams less than one inch long, the recommended method for calculating harvestable biomass (discussed later) is based only on a legal sized clams, and those less than 1 inch in length could be returned to the holes without being counted or measured, if so desired. All clams between one inch and the legal size should probably be retained with the sample, to serve as an indicator of the year-class strength for the following year.

Clams from each sample should be placed in a zip lock bag with a completed sample label, written in pencil (ink may run). At a minimum, sample labels should contain the transect letter and sample number. Because samples have a way of getting mixed together, including the date and beach name or number, on each sample label, is highly advisable.

While this is proceeding, the time should be regularly monitored, and one person should be prepared to stop current activities, when the tide reaches the -1 foot level, as determined by TideMaster or similar such information. At this point, type I stakes, similar to those used to mark the UCB, should be inserted in the beach, along the water line, in a manner similar to that used for the UCB. These stakes will mark the lower clam boundary (LCB). Next, each transect which was short of this LCB, should be extended, in a straight line down to the LCB, and the total length of each transect written in the appropriate location on the clipboard. One additional sample should be collected for each 50 foot increment (in this example), similar to earlier sample site selection, and these samples also noted on the clipboard, e.g., A8, A9, and A10. Sample sites on the lower beach will be the first to be covered by the incoming tide, and will be exposed for the lease amount of time. Every effort should be made to ensure that these samples are collected while the tide permits.

The -1 foot survey boundary is suggested after consideration of a number of factors. Simply extending transects down to the waterline without regard for the changing tide, results in sequentially longer, then shorter transects, as the tide drops, then rises during the survey process, skewing results. A beach which is surveyed completely in one day will have the center of the beach disproportionately sampled. This method also results in differing measurements of beach area, from year to year, effectively turning a constant into a variable, which reflects neither population strength, nor the effectiveness of management action. Choice of a specific tidal height is a trade off between surveying the maximum beach area available (waiting until the lowest tide of the year), which overestimates the size of the population being harvested (few harvesters will ever access the lower beach), and the other extreme, in which case surveys would only extend to the zero tide or less (+ 1ft, etc.), which underestimates the size of the population being harvested, and unduly reduces annual harvest amounts.

Sample site location and sample collection should continue until the whole beach or area of interest is surveyed. It is important to realize that a beach is not a precise unit and if only two or three discrete areas on a specific beach contain sufficient clams, restricting surveys to these areas may be a more efficient way to survey the beach. Later extrapolation of densities found in these areas, should obviously only extend to the area covered by the surveys. If used appropriately, this will result in only a slightly smaller allowable harvest, while greatly reducing the effort necessary to survey areas which would likely have limited harvest anyway.

3. Sample Analysis

If samples are to be stored, freezing for a short time is adequate. When ready for processing, the contents of each sample should be identified to species, and all clams counted. For the species of interest, each clam length should be measured to the nearest millimeter (mm) and recorded. Actual lengths may be written or, if a preprinted sheet, containing a column of sequential numbers, representing mm length increments is available, checks could be marked beside each, as a clam of that size is measured and the total of each length frequency tallied at the end. Though measurements may be done on site, they may be more precise, and records better organized, if this were to occur in the lab or office.

Weighing each clam is generally not necessary, as water loss is likely to be responsible for much of any difference in weight between two clams of identical length. Also, considerable length / weight data have already been collected, and this relationship can be used to eliminate the need for weighing each individual.

That said, it should be acknowledged that many factors can cause two clams of the same length to be of different weights. A clam of length ‘x’ will generally weight more in late summer than another clam of the same length, toward the end of winter, since the former has likely been feeding for weeks, while the latter has likely been living off of some of it’s nutritional reserves. Also, the productivity of different bodies of water varies, and so clams on one beach may have more body mass than clams of identical size on another beach, since they each have different amounts of food available to them. Further, where a clam is on a beach, relative to tidal height, is another variable which affects body mass, as those clams which are lower on a beach, spend more time submerged, and thus are able to spend more time feeding.

The above situations all explain weight differences due to body mass, but shells of the same length, also vary in weight, further impacting total weight. For example, one clam may have optimal growing conditions (food supply, water temperature, etc), and reach size ‘x’ in ‘y’ years. Another clam, being in less than optimal conditions, may only reach size ‘x’ in ‘y’ + 3 years. Though the body mass of the former may be greater, the latter, having laid down 3 extra year’s worth of shell layers, will have a thicker shell. Which clam weighs more will depend on the relative impact of these two components of total weight. An awareness of such variables, and how they impact the weight of clams of a given size, should increase the value of any weight data which are collected.

If the extra effort is made to weigh each clam, particular care should be given to the potential effect of water loss, between the time a sample is collected and when it is weighed. Simply freezing clams will not prevent this, as moisture can be lost from the frozen sample, through evaporation, a process commonly referred to as ‘freezer burn’.

4. Data Analysis

The Northwest Indian Fisheries Commission has developed a spreadsheet in Lotus 123, to analyze these data and this spreadsheet has been successfully ported to MicroSoft’s Excel. While the spreadsheet currently requires some small initial instruction to operate, it has been used successfully for a number of years.

The frequency, by millimeter, of each size class of manilas and littlenecks, should be entered into a table in the spreadsheet. Using the length/weight data for manila clams presented in Anderson, Miller and Chew (1982), and length/weight data for littleneck clams, provided by the Washington Department of Fish and Wildlife (WDFW), the spreadsheet converts length frequencies to weights. Total weights for each species are calculated and displayed, as are weights for only those clams which are 25+ mm (1+ inches), and weights for only those clams which are 38+ mm (1.5+ inches). WDFW considers 38 mm (1.5 inches) to be the minimum legal size for littlenecks and manilas, since this size allows at least one reproductive cycle before exposure to the fishery.

Since the field sample design previously described accounts for curves in the upper and lower clam boundaries, beach area computation is complex, and best left to a computer. Beach survey data, such as compass bearings and transect lengths are entered into another region of the spreadsheet, and the surveyed area of the beach is calculated.

In a third region of the spreadsheet, the number of samples and the area of each sample, e.g., 2 square feet, are entered.

Extrapolation of weight, by species, for harvestable clams (38+ mm) per x-number of samples, yields the weight of each species, for the whole surveyed beach.

5. Annual Harvestable Biomass

The 1.5 inch (38 mm) minimum legal size is supported here, for the reason stated above and because of the exponential relationship between length and weight. Essentially, weight increases greatly for every additional mm in length and since growth is rapid and mortality is limited at this size, there is great benefit to not harvesting the smaller sizes.

The following fixed harvest rates are suggested to be initially applied to the entire population which meets the minimum legal size: 25% for littlenecks and 33% for manilas. These harvest rates are based on a 1989 report by the Washington Department of Fish and Wildlife (WDFW), which recommends their use when sample data is limited and ". . . the data was considered to be indicative of a good population."[1] Since these rates are recommended for use with limited data, they are assumed to be conservative and should be reassessed after approximately 5 years.

There are some basic differences between a natural or lightly harvested population, and one which is regularly harvested at levels which approach a maximum sustainable yield. An unharvested population consists of many age classes which are, to some extent, reflected in a wide size range. After 5 years of moderate harvest, clams which were of harvestable size when the fishery began, will have been exposed to as much as 5 years of harvests and all will likely have been removed from the population. This will have two distinct results, which become more pronounced, as the harvest rate increases:

a) It will cause the fishery to be more dependent upon recent recruits[2]. This will have the effect of destabilizing the fishery, and;

b) It will cause large, heavy clams to be replaced by smaller, lighter ones. This will have the effect of magnifying the impact of 'a' above;

The evolution of these results can be illustrated by the following example, which begins with a previously unharvested beach:

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[1] This report appears as Appendix A in a 1989 Shellfish Management Agreement and Plan, between the State of Washington and the Suquamish Indian Tribe. A 1989 Shellfish Management Agreement and Plan, between the State of Washington and the Point No Point Treaty Council contains identical recommendations.

[2] Recruits, as used here, refers to recruits into the fishable population, i.e. 38mm+.

Example

Initially, harvest consists of clams of many size and year classes, which reflects the population size/age structure. When higher harvest rates are used, clams are less likely to escape harvest for many years and large/old clams will be quickly eliminated from the population.

At very high harvest rates, the fishery will be focused mostly on recruits of the year and possibly, to a lesser extent, on recruits of the previous year. Since a large clam can weigh as much as 3 times more than a recent recruit, after a short period, many more clams must be harvested to maintain the biomass which was harvested when large clams were available. This further focuses effort on recent recruits. Should there be a poor larval set, or high seed mortality[3] in any one year, recruitment for that year could be virtually eliminated, thus eliminating the fishery for that year. Seafood markets are highly dependent upon a supplier's ability to consistently supply product and one failed year could result in the permanent loss of buyers as they scramble to meet their customers' needs. Also, this would likely significantly hamper efforts to achieve a premium price, for years to come.

The annual harvestable biomass should be recalculated (e.g., 25% x total legal-sized biomass) each year, based upon annual population surveys. If this amount is harvested each year, a trend may become evident after about 5 years. Little confidence should be placed in apparent trends based upon fewer years of harvest data, since population estimates have wide confidence intervals, larval sets vary greatly from year to year, and survival of young clams is highly variable from year to year.

After 5 or more years of harvest, if the annual harvestable biomass appears to be lessening over time, i.e., population biomass decreasing, despite a constant harvest rate, then this harvest rate is likely to be above a sustainable level, and it should be reduced. If the annual harvestable biomass appears to remain constant, or is increasing, then the harvest rate may be either appropriate, or less than that which the population could support, and an increase of 5-10% should be explored. Every three to five years afterward, this harvest rate should be reassessed, particularly if significant, large scale events may have impacted the population on that particular beach, in the interim.

6. Exceeding Recommended Harvest Rates

Since the recommended 25% harvest rate for littlenecks (and 33% for manilas) will generally be conservative, the temptation will be great, to initially harvest at a higher rate, with the intention of reducing that rate if it later appears to be too

[3] As could result from prolonged subzero temperatures during a winter low tide cycle

high. The rational is, if the suggested rate turns out to be low, some harvest has unnecessarily been forgone. Realistically, however, those clams are not ‘lost’ (aside from a limited natural mortality), but continue to grow, to be harvested another year. Though, harvest is certainly not maximized by initially adopting a conservative harvest rate, attempting to reach a maximum sustainable yield in the first year of a fishery is a risky strategy.

The risk lies not in the likelihood of permanently damaging the population, since repopulation is almost exclusively a function of distant clam beds, which will presumably continue to reseed the beach in question, after an excessive harvest occurs. The real problem with an excessive harvest rate is in the difficulty faced when later trying to reducing it. As discussed above, a trend in the population biomass, over time, cannot be reassessed with any confidence, until after several years (e.g., 5+ years) at that harvest rate have passed. After five years or so of excessive harvest, the beach under management will have been producing progressively less harvestable product. Without a harvest rate adjustment, future production will likely be lesser still. Under these circumstances, it can then become very difficult to implement a lower harvest rate, since this will temporarily reduce harvestable biomass even further.

Given the limited potential benefit of pursuing an initial harvest rate which is higher than the recommended level, verses the significant difficulty in later reducing that level if it should prove to be excessive, prudent management suggests a conservative rate should initially be used.

7. References

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Appendix 2 (to Bivalve Region 6 Plan)

INTERTIDAL SHELLFISH HARVEST ESTIMATION PROCEDURES FOR THE RECREATIONAL FISHERY IN BIVALVE REGIONS 1, 5, 6, 7 & 8

Introduction

Annual estimates of the recreational catch of clams and oysters on public beaches are required by regional state-tribal bivalve management plans. Under terms of these regional bivalve plans, Washington Department of Fish and Wildlife (WDFW) estimates recreational effort and catch on all primary and secondary management public beaches where such harvest occurs, and total effort is reported on many passively managed beaches. Besides meeting the requirements of federally mandated shellfish management plans, estimates of recreational effort and harvest are used to help recommend seasons and other regulations for the recreational fishery.

Harvest estimates are generated annually for Manila clams, native littleneck clams, butter clams, cockles, horse clams, geoducks, eastern softshell clams, and Pacific oysters. Harvest estimates are generated from two primary field activities: **(1)** Creel surveys, which are conducted on selected beaches to determine catch per unit effort (CPUE, or pounds caught per harvester-day) by species; and **(2)** Aerial surveys, which are conducted from fixed-wing aircraft to estimate total effort (total harvester-days). Additional sampling activities, which have been conducted to refine harvest estimates, include low tide counts, ingress surveys, plus-tide surveys, and winter-harvest surveys.

This appendix describes the methods used by WDFW researchers to assess the recreational harvest of clams and oysters in Bivalve Regions 1 (Strait of Juan de Fuca), 5 (Admiralty Inlet), 6 (Central Puget Sound), 7 (South Puget Sound), and 8 (Hood Canal). The sampling design and methods for creel, aerial and ingress surveys are presented. These methods are currently under review and will be updated and improved in the future.

General Sampling Design

Recreational harvest (in pounds) on a given beach is estimated for species ***h*** as the product of total fishing effort (as harvester-days on the beach) and catch-per-unit-effort for species ***h*** (CPUE, as pounds per harvester-day on the beach).

Standardized sampling methods have been established to estimate fishing effort and CPUE on public beaches. Sampling of recreational effort is stratified by tide height and day of the week (tide-day strata). These strata were selected based on analysis of flight data from 1994-2001 which showed that variation in fishing effort is related to differences in tide height and day of week. A detailed written description of these analyses will be available soon. The three tide-day strata currently in use are described in Table 1. All available daylight tides from March through September < 2.0 feet are grouped according to tide-day strata, and sampling dates are randomly selected from available tides within each of the three strata.

Table 1. Tide-day sampling strata for recreational effort on intertidal beaches. Extreme low tides = -2.0 ft and below; low tides = -0.1 to –1.9 ft; high tides = 0.0 to 1.9 ft. "Weekend" includes holidays.

Stratum	Description
ELOW	Weekend extreme low tides
LOW	Weekday extreme low tides, weekend low tides
HIGH	Weekday low tides, weekend and weekday high tides

Estimating total recreational harvest of clams on a beach involves the following sequence of steps:

1) An instantaneous count of recreational clam and oyster harvesters is obtained by flying over the beach close to low tide and counting harvesters. Each primary and secondary beach is flown roughly 45 times from March through September. Effort counts are stratified by the three tide-day strata shown in Table 1. Ground-based effort counts ("low tide counts") are used to augment the flyover counts.

2) The instantaneous count of harvesters for each flight is expanded with an ingress ratio to provide an estimate of the total number of harvesters on the beach for the entire day. An ingress ratio is the expected proportion of harvesters present on an "average beach" at the time during the low tide cycle when the instantaneous count was made from the air. Ingress ratios are calculated based on a series of ingress surveys during which observers counted all harvesters using the beach during the entire low tide cycle, and recorded the number of harvesters present at each half-hour interval during the cycle.

3) An estimate of the mean number of harvesters per day is calculated for each of the three tide-day strata. These three estimates of daily effort are multiplied by the number of available clamming tides (days) within each of the three strata. These three products are summed, providing an estimate of the total number of harvesters using the beach from March through September (except on "plus tides").

4) An estimate of the number of harvesters using the beach on "plus tides" (those tides >=2.0 and < 4 feet) is added to the effort estimate calculated in Step 3 above. Effort on plus tides is assumed to be 16.0% of the unstratified mean daily effort on all surveyed tides on the beach. This assumption is based on an analysis of flight data collected during plus tides in 1993 and 1994.

5) On certain beaches, where winter harvest has been observed in the past, an estimate of the number of harvesters using the beach during the winter months (October through February) is added to the effort estimate. Effort during the winter on these beaches is assumed to be 5.0% of the total effort from March through September (including plus-tide effort).

6) Catch per unit effort (CPUE) is estimated for each species on the beach from creel surveys. During each creel survey, all (or most of) the harvesters leaving the beach are interviewed, and their catch is sorted by species and weighed. For each creel survey, the daily CPUE is the average number of pounds (by species) taken per harvester.

7) An estimate of the average season-long CPUE on the beach (again, for each species) is made by averaging all the creel survey data from the most recent three years of data available for that beach.

8) An estimate of total harvest on the beach (by species) is calculated by multiplying total estimated effort on the beach (including plus-tides and winter use, if applicable) by CPUE for the species.

Estimation of Catch Per Unit Effort (CPUE)

Creel Surveys

Creel surveys are conducted for a four-hour period straddling the local time of low tide. Only harvesters who have completed their day's harvest are interviewed, and whenever possible, all harvesters exiting the beach during this four-hour time period are interviewed. The total weight and number of each species harvested is recorded. Broken clams are counted but not weighed, and are noted as broken so that an estimated weight can be used as a surrogate during analysis. The number of harvesters per party are also recorded.

The daily *CPUE* for each species on a beach is estimated for each creel survey day by dividing the total daily catch (pounds per species for clams, or number of oysters) by the total number of harvesters interviewed:

$$CPUE_s = \frac{\sum catch_i}{\sum harvester_i}$$

where $CPUE_s$ is the daily *CPUE* on day s, and $catch_i$ is the catch (in pounds) by the *i*th harvester on day s. A separate $CPUE_s$ is calculated for each species (Manilas, native littlenecks, cockles, butter clams, geoducks, etc.).

The mean season-long *CPUE* for each species on a beach is estimated as a three-year running mean, averaging all the estimates of $CPUE_s$ for the previous three years in which creel surveys were performed on the beach:

$$\overline{CPUE} = \frac{\sum_{t=1}^{3} CPUE_{s,t}}{\sum_{t=1}^{3} n_t}$$

where

$\overline{CPUE}$ = the mean season-long *CPUE*

$CPUE_{s,t}$ = the daily *CPUE* on day s of year t

n_t = the number of days the beach was sampled by creel survey in year t

The variance of the mean season-long *CPUE* is estimated as:

$$Var\overline{CPUE} = \frac{\sum_{n=1}^{s} \left(CPUE_s - \overline{CPUE}\right)^2}{n-1}$$

where n = 1 to s surveys over the past three creel-survey years are averaged.

Estimation of Effort

Observers in fixed-wing aircraft monitor fishing effort on public beaches along the shorelines of the Strait of Juan de Fuca, Puget Sound, and Hood Canal, targeting areas where significant recreational harvest is known to occur. A single flight route has been developed to encompass all beaches in WDFW Region 6 (which includes Bivalve Regions 1, 5, 6, 7 and 8) that are important from a management perspective. The route was designed to ensure that all flight counts would occur close to the absolute minimum daily low tide. Flight counts must be made within a two-hour window centered on low tide. The route starts at Sequim Bay and follows the falling tide as it progresses towards South Puget Sound (Figure 1). Barring adverse wind conditions, the survey starts at Sequim Bay exactly at local low tide and ends at Frye Cove in South Sound two hours later, again exactly at local low tide.

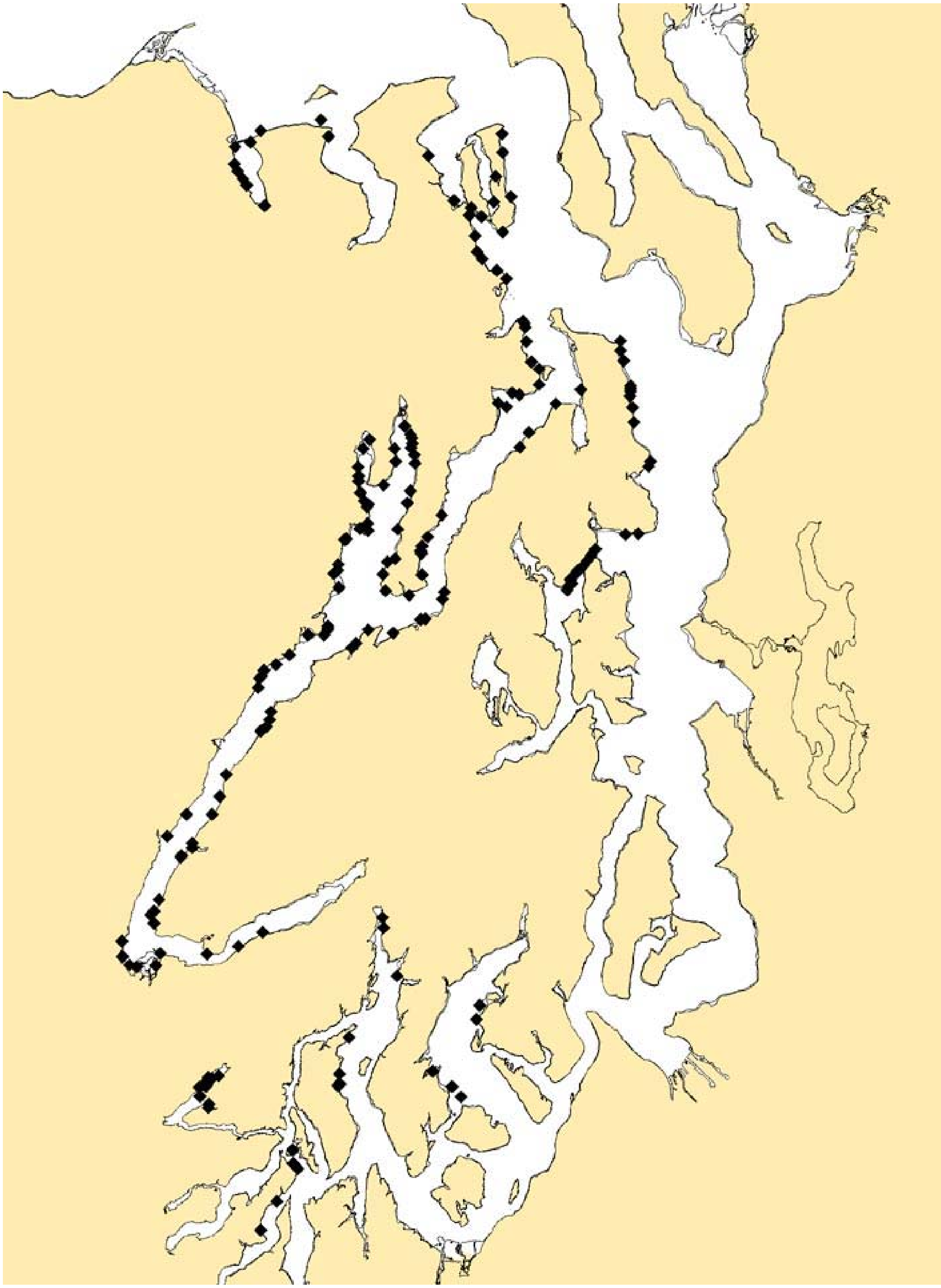

Figure 1. Map showing WDFW Region 6 beaches (black diamonds) covered on the 2002 flight route. The route starts at Sequim Bay and ends at Frye Cove in South Puget Sound.

Flight surveys provide an instantaneous count of all harvesters on a beach at a given moment during the tide cycle. Harvesters are counted from fixed wing airplanes flying at 70-120 knots at an altitude of 300-500 ft. The distance flown from the shore is approximately 200 ft from the line of low water, but varies with the width of the intertidal zone to ensure complete coverage of the tidelands and nearshore area.

Only those people actively engaged in clam or oyster harvesting, or those clearly equipped to do so, are counted during aerial surveys. This includes people with shovels and buckets leaving or entering the beach. Clam and oyster harvesters are not separated in the flight counts because the two user types cannot be differentiated during flyovers; it is also common for a harvester to switch at some point in the day from taking oysters to clams, or vice versa. The number and type of harvesters on each beach is recorded directly on computer generated flight maps, along with the time the count was made. Commercial harvesters, tribal harvesters and WDFW personnel are counted and labeled separately on the maps to ensure that individuals participating in these activities are distinguished from recreational harvesters. The summation process only includes individuals whom the surveyor determines to be actively engaged in recreational clam or oyster harvesting.

Flight surveys are assigned to one of the three tide-day strata described in Table 1 above. These strata are based on a comprehensive analysis of all flight data and low tide count data from 1994 through 2001. Cluster analysis, Monte Carlo simulations, and analysis of variance (ANOVA) concluded that the three tide-day strata shown in Table 1 produce estimates of total effort with equal or higher precision than the former twelve strata scheme. Flight dates are randomly assigned among the three strata based on an optimum allocation formula (Thompson 1992, page 107) and on the number of days available each month within the strata designations. More flights are scheduled during the months May-July simply because more tide-days are available within each stratum during this period.

Low Tide Counts

Low tide counts are used to supplement aerial survey data in cases where additional data are needed to estimate harvest rates. Insufficient sample sizes in flight counts can occur when the airspace above a beach is temporarily restricted, when seasons are very short, when seasons end early in the year, or when very high variance in historical counts on a beach dictates that increased sampling is needed. Low tide counts are conducted at the time of the local low tide by a ground observer (e.g. park ranger, WDFW surveyor) who records the data on a computer-generated map of the beach area. Low tide counts are recorded in the same manner as flight counts, with separate designations for recreational, tribal and commercial harvesters.

Ingress Ratios

The count of harvesters obtained from flights or low-tide counts is obviously an instantaneous count, and it is not likely to represent the total number of harvesters using the beach over the entire day. An expansion factor is therefore used to generate an estimate of total all-day use from each instantaneous effort count.

The effort-expansion ratio is currently based on a single pooled model for an "average beach." The model is a curve relating the number of harvesters present at any one time during the tide cycle to the total all-day effort. An ingress ratio is therefore a simple proportion of total effort present at a particular time relative to Seattle low tide. The model is based on harvester behavior at ten WDFW Region 6 beaches recorded during ingress surveys in 1990 and 1992. Ingress surveys were conducted within a six-hour time block centered on the time of low tide. The total number of shellfish harvesters entering the beach all day (i.e., during the six-hour time block) was recorded, along with instantaneous counts of the number of harvesters present on the beach at each half-hour interval (relative to Seattle low tide). All 80 ingress surveys were pooled to generate the ingress model. Using the pooled data from all beaches to represent the "average beach", the ingress ratio for any given half-hour increment is calculated as:

$$R_t = \frac{H_t}{H_s}$$

where

R_t = the ingress ratio for time t (the proportion of all-day effort present at time t)
t = the time (in minutes) relative to Seattle low tide (e.g., at local low tide, $t = 0$; one half-hour later, $t = 30$; one hour prior to Seattle low tide, $t = -60$)
H_s = the total number of harvesters observed entering ("ingressing") the beach all day (i.e., during the six-hour time interval spanning Seattle low tide)
H_t = the total number of harvesters observed on the beach at time t

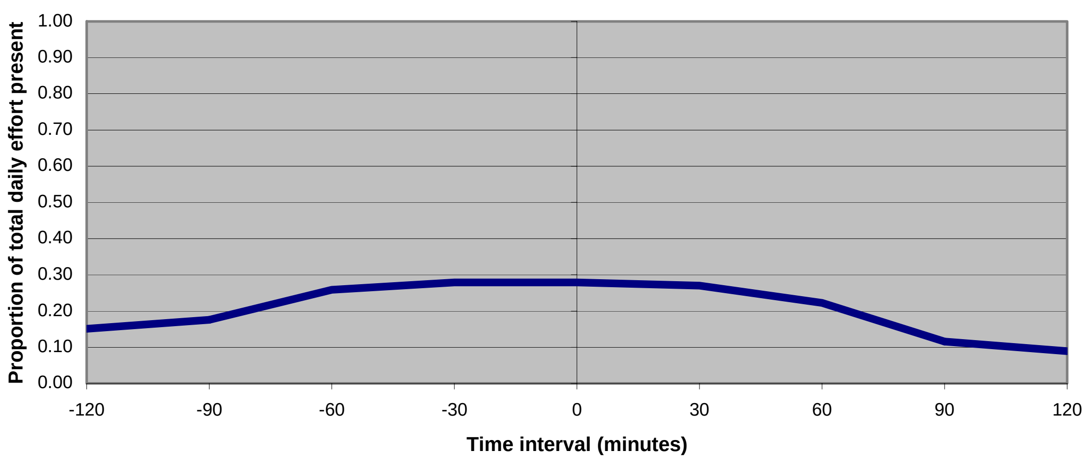

Figure 2. Ingress model for recreational clamming effort, showing the expected proportion of all-day effort present during a four-hour period surrounding low tide. Time intervals are shown as minutes before and after Seattle low tide. The vertical line represents the time of Seattle low tide (zero minutes). Data for the model are pooled from ingress surveys conducted on selected WDFW Region 6 beaches in 1990 and 1992.

Model points were interpolated for times between the observed half-hour survey increments so that an ingress ratio could be calculated for any minute during the six-hour time block straddling low tide.

A separate ingress model has been generated for beaches that have only oyster harvest. The current clam ingress model, truncated to show only the four-hour period surrounding low tide, is shown in Figure 2. The ingress ratio exactly at Seattle low tide (R_0), for example, is 0.28; the ingress ratio 90 minutes before low tide (R_{-90}) is 0.18. Variance is not currently estimated for points along the ingress curve.

We are currently analyzing roughly 370 daily ingress surveys conducted in 1998, 1999, and 2000 on 36 beaches in WDFW Region 6. Following analysis, we may use these data to generate a new ingress model, or possibly several new beach-specific ingress models. We also plan to estimate variance for points along the ingress curve(s).

Estimation of Total Effort on a Beach

Total effort on a beach during a sampled day is estimated by dividing the instantaneous count of harvesters that day (obtained from either a flyover or low-tide count) by the ingress ratio corresponding to the time of the instantaneous count:

$$E_{s,h} = \frac{E_{t,h}}{R_t}$$

where

$E_{s,h}$ = estimated total number of harvesters using the beach on day s in tide-day stratum h
$E_{t,h}$ = observed instantaneous count of harvesters at time t on day s in tide-day stratum h
R_t = the ingress ratio (expansion multiplier) for time t, based on the current ingress model

Variance of $E_{s,h}$ cannot currently be calculated since, as noted above, no variance estimate of R_t is currently available.

Total season-long (March-September) effort on a beach is estimated using the standard formula for stratified random sampling (Thompson 1992, page 102). The mean daily effort within each of the three tide-day strata is given by:

$$\overline{E}_h = \frac{1}{n_h}\sum_{i=1}^{n_h} E_{s,h}$$

where

$\overline{E_h}$ = the mean daily effort in tide-day stratum h
n_h = the number of sampled days in tide-day stratum h
$E_{s,h}$ = estimated total number of harvesters using the beach on day s in tide-day stratum h

The total season-long effort within tide-day stratum h given by:

$$\overline{E}total_h = N_h \overline{E}_h$$

where

$\overline{E}total_h$ = total season long effort within tide-stratum h
N_h = the total number of available harvest days (tides) on the beach within stratum h
$\overline{E_h}$ = the mean daily effort in tide-day stratum h

The estimate of total season-long effort on the beach is the sum of the three individual tide-day stratum estimates:

$$\overline{E}total = \sum_{h=1}^{3} \overline{E}total_h$$

where $\overline{E}total$ is the estimated total effort on the beach from during period March-September and on tides lower than 2.0 feet. Variance of the estimated total effort is estimated as:

$$Var\overline{E}total = \sum_{h=1}^{3} N_h \left(N_h - n_h\right) \frac{s_h^2}{n_h}$$

where

$$s_h^2 = \frac{1}{n_h - 1} \sum_{i=1}^{n_h} \left(E_{s,h} - \overline{E}_h\right)^2$$

is the sample variance of mean daily effort in tide-day stratum h. Note, however, that this estimate of sample variance tacitly assumes that the values of $E_{s,h}$ are observed values of daily effort rather than estimates expanded with an ingress ratio. The variance of the ingress ratio is ignored because estimates of this variance are currently unavailable, as noted above. Thus, variance estimates for both mean daily effort and total season-long effort ignore the un-calculated variance of the ingress ratio.

<u>Plus Tide Effort Estimates</u>

Effort on plus tides (tides >=2.0 feet and < 4 feet) is estimated for each beach as 16% of the unstratified mean daily effort on the beach:

$$\overline{E}plustides = 0.16\left(\frac{1}{n}\sum_{1}^{n} E_s\right)$$

where

n = the total number of effort samples in all three strata
E_s = the estimated total number of harvesters using the beach on day s

Effort on plus tides is added to the total effort estimate ($\overline{E}total$) on tides < 2.0 ft for an estimate of total effort on all clamming tides. The 16% figure is based on an analysis of effort data collected on plus tides flight surveys in 1993 and 1994.

Winter Effort Estimates

Low tides occur primarily during daylight hours from March through September, but during the rest of the year, low tides suitable for shellfish harvest occur mostly at night. Creel surveys conducted by WDFW from November 1994 through February 1995 confirmed that wintertime recreational harvest occurred on 24 of the beaches included on the 2002 flight route (Figure 1).

These surveys indicated that winter harvest represents a very small proportion of the overall yearlong harvest. Based on these data, winter effort is estimated as 5% of the March – September total effort (including plus-tide effort). This effort is added to the total effort estimate for all clamming tides for an estimate of yearlong effort on a beach.

<u>Estimation of Total Harvest on a Beach</u>

Total harvest on a beach by species is estimated as the product of total effort on the beach and CPUE for the species:

$$\overline{C}_h = \overline{E}total\left(\overline{CPUE_h}\right)$$

where

$\overline{C}_h$ = total estimated harvest of species *h* on the beach
$\overline{E}total$ = total estimated season-long effort (harvester days) on the beach

$\overline{CPUE_h}$ = estimated mean CPUE (pounds per harvester) of species *h* on the beach

Variance of total harvest is estimated as a variance of products (Goodman 1960):

$$Var\overline{C_h} = \overline{CPUE_h}^2\left[Var\overline{E}total / n_E\right] + \overline{E}total^2\left[Var\overline{CPUE_h} / n_{CPUE}\right] - \left[Var\overline{E}\ Var\overline{CPUE_h} / n_E n_{CPUE}\right]$$

where

n_E = the sample size for the estimate of total effort on the beach (the sum of effort sample days in all three tide-day strata)

n_{CPUE} = the sample size for the estimate of mean season-long CPUE for species h (the sum of creel survey sample days in the past three years)

Note again, however, that the above estimate of variance of total harvest ignores variance of the ingress ratio.

The standard error (SE) of total harvest of species h on a beach is given by:

$$SE\left(\overline{C}_h\right) = \sqrt{Var\overline{C}_h}$$

The 95% confidence bound of total harvest of species h on a beach is given by:

$$\overline{C}_h \pm \left(t_{0.05,2,v}\right) SE$$

where

$t_{0.05,2,v}$ = tabled t-value, $\alpha = 0.05$, two-tailed, v = df (degrees of freedom)

Confidence bounds on the estimate of total harvest are not calculated due to the lack of a variance estimator on the ingress ratio. Work is currently underway to estimate variance on ingress ratios.

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