Regional Information Report No. 1J07-14

Project Operational Plan: Marine Invertebrate (Sea Cucumber, Red Sea Urchin, and Geoduck) Stock Assessment, 2007

by

Marc Pritchett

and

Zachary Hoyt

September 2007

Alaska Department of Fish and Game **Division of Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_{2}, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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By
Marc Pritchett
Alaska Department of Fish and Game, Division of Commercial Fisheries, Douglas
and
Zachary Hoyt
Alaska Department of Fish and Game, Division of Commercial Fisheries, Petersburg

Alaska Department of Fish and Game
Division of Commercial Fisheries
Publishing Office Address

September 2007

The Regional Information Report Series was established in 1987 and was redefined in 2006 to meet the Division of Commercial Fisheries regional need for publishing and archiving information such as project operational plans, area management plans, budgetary information, staff comments and opinions to Board of Fisheries proposals, interim or preliminary data and grant agency reports, special meeting or minor workshop results and other regional information not generally reported elsewhere. Reports in this series may contain raw data and preliminary results. Reports in this series receive varying degrees of regional, biometric and editorial review; information in this series may be subsequently finalized and published in a different department reporting series or in the formal literature. Please contact the author or the Division of Commercial Fisheries if in doubt of the level of review or preliminary nature of the data reported. Regional Information Reports are available through the Alaska State Library and on the Internet at: http://www.sf.adfg.ak.us/statewide/divreprots/htlm/intersearch.cfm.

Marc Pritchett,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
802 3rd St., P. O. Box 110024, Douglas, AK 99811-0024, USA

and
Zachary Hoyt
Alaska Department of Fish and Game, Division of Commercial Fisheries,
16 Sing Lee Alley, Petersburg, Alaska 99833, USA

This document should be cited as:
Pritchett, Marc, S., Zachary,Hoyt. 2007. Project Operational Plan: Marine Invertebrate (Sea Cucumber, Red Sea Urchin, and Geoduck) Stock Assessment, 2007. Alaska Department of Fish and Game, Regional Report Series No. 1J07-14, Douglas.

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ABSTRACT

This document describes stock assessment and research plans for sea cucumbers, red sea urchins and geoducks for the 2007 field season. Populations of each species are monitored as separate projects, but combined into one Project Operational Plan due to similarity of stock assessment methods and field schedules that frequently overlap or call for simultaneous surveys.

Sea cucumber assessment surveys have been conducted in Southeast Alaska on a systematic basis since 1990. These surveys are supported by general funds of the State of Alaska and Southeast Alaska Regional Dive Fisheries Association (SARDFA) sea cucumber assessment funds generated by industry. Sampling and analytical methods are the same as those used in 2006.

Red sea urchin assessment surveys were initiated in Southeast Alaska in 1994. No commercial red sea urchin areas are scheduled for the 2007 survey season; only the two control areas will be surveyed. Assessment methods are the same as those used in 2006.

Geoduck biomass surveys are supported by NOAA Federal Marine Research VII and VIII. Surveys for traditional commercial areas fished since the mid-to late 1980's are supported by State of Alaska general funds. It is anticipated that geoduck survey methods will be similar to the method used in 2006, but we will continue implementation of an alternative method to potentially improve survey variance.

Key words: 2007 dive surveys, Southeast Alaska, sea cucumber, red sea urchin, geoduck clam

SEA CUCUMBER

INTRODUCTION

This section describes the research and assessment program needed to support the commercial sea cucumber (*Parastichopus californicus*) fishery in Southeast Alaska. The fishery is managed under a conservative policy of sustained yield. Harvest quotas are described in the management plan for sea cucumbers developed in 1990 (ADF&G 1990) and adopted into regulations (5AAC 38.140.) by the Alaska Board of Fisheries (ADF&G 1991, 1992). The management plan calls for an assessment of the population size in each harvest area prior to the opening of the fishery. This document describes the methods and locations of the assessment surveys that will be conducted and statistical methods used to estimate the biomass, associated precision of biomass estimates, and resulting commercial fishery quotas for 2007–08 season.

This document also describes a continuing program for sampling five control sites; located in refuges near Ketchikan, Craig, Sitka, Whale Pass, and Hydaburg. Commercial harvest of sea cucumbers is prohibited in all control areas. Controls are needed to monitor changes in population size that are not influenced by commercial fishing. Controls are expected to be important for distinguishing effects of commercial harvest from other factors affecting populations in harvest areas, e.g., long-term population trends, climate changes, and recruitment failures.

OBJECTIVE

The overall objective of sea cucumber stock assessment surveys is to monitor changes in density and biomass in both control and commercial harvest areas, and to determine a biologically and statistically acceptable quota for areas opened to commercial fishing.

Sampling Methods

Density Estimates: the SCUBA Survey Method

Density estimates are made via SCUBA along 2-meter-wide strip transects oriented perpendicular to shore. A set of paired transects (two 2-meter-wide transects for each sampling location) serve as the primary sampling unit. Transects extend from zero to 15 m (50 ft) fsw below mean lower low water (MLLW). Transect length varies depending on slope of the bottom. It is desirable to limit exposure to depths greater than 18.5 m (60 fsw) because deeper dives severely limit total bottom times for SCUBA divers and pose safety risks when conducted repetitively over several days. The majority of habitat worked by commercial divers is less than 15 meters.

A variety of techniques may be used to complete the transect pairs. Either one or both divers swim along the transect holding a 2-meter-rod (a 2.1 cm diameter white PVC tube) in a horizontal position, perpendicular to the census path. Transect direction is maintained by reference to a compass mounted on the rod. If the transect is exceptionally long, both divers generally swim with transect rods and count sea cucumbers, resulting in the transect pair being completed as divers swim in one direction. If the transect is relatively short, or a large sample of sea cucumbers needs to be collected for weight measurements, one diver will often complete both transect pairs (shore to depth and return). The second diver collects the sea cucumbers needed in the weight sample and assists the first diver in making the counts. Two divers may swim from shore to depth and return using one transect rod with each diver counting all individuals on one side (one-half) of the transect rod if there is a large amount of kelp, large numbers of sea cucumbers, or additional counting of sea urchins is required. If transects are conducted by swimming from shore to depth and return, the second transect in each pair is approximately 20 meters to the left (when facing shore) of the first transect. If each transect in a pair is completed concurrently by each diver swimming in one direction, the divers are separated to the limits of visibility and safety.

When an area is initially surveyed, extensive data is collected on transect length, cucumber density, substrate type, and vegetative cover. These data will not be collected for areas previously surveyed, but only for an area’s initial survey. However, divers will record data on depth, predominate vegetative cover and substrate types, the presence of other species of interest, including sea urchins and abalone, and any other interesting observations. Presence of vegetation in each segment is recorded as "percent cover" for up to two types (Appendix A). Substrate type is recorded for the two most common types on each segment, with the most prevalent type listed first (Appendix B). The beginning and ending times for each transect are recorded to allow for later standardization to MLLW.

Location and Number of Transect Samples

Stock assessment of sea cucumber populations in 2007 will be in areas that were sampled in 2004. These areas will include all or portions of Subdistricts 101-11-002, 101-23, 101-44, 45, 46 and 48, 101-80, 106-10, 20 and 22, 103-11 and 15, 103-50, 102-10, 102-40, 102-50, 111-50, 112-18, 19, 80 and 90, 112-12, 13, and 50, 112-15, 61 and 114-25, 113-40, 42 and 43, and 113-55, 56, 57 and 58. Control areas will include all or portions of Subdistricts 101-27, 103-40, 103-60, 106-30, and 113-40. Potentially, three additional new areas will be surveyed pending SARDFA input and funding.

Transect locations will be the same as the 1995, 1998, 2001 and 2005 transect locations. The sampling method will allow a comparison of densities in which the variability due to location is minimized. The original transect pairs were systematically distributed along the shorelines of each harvest area. Location of the first transect pair was randomly chosen, and subsequent transect pairs were located at equal intervals along the shoreline. The distance between transect pairs equals the total length of shoreline divided by the number of transect pairs allocated to each area. Transects will be located using nautical charts showing transect locations and differential GPS. Based on previous survey's precision estimates, many areas may require an increase in transect number to achieve statistical objective. Available resources preclude additional survey time; therefore only those transects surveyed previously will be surveyed in 2007.

Average Weights

Samples will be taken to determine the average weight of cucumbers. Collection of individual sea cucumber weights in an area addresses two objectives: 1) comparison to previously sampled sea cucumbers and their average weights will determine if any significant change in size has occurred; and 2) conversion of population estimate from number of sea cucumbers to biomass in pounds. In commercial harvest areas approximately 15 sea cucumbers will be collected from all odd numbered transects (i.e. half the transects). In control areas, 30 sea cucumbers will be collected from each of six previously selected sites within each control area. Individual sea cucumbers will be eviscerated, drained, and then weighed to the nearest gram.

Statistical Analysis

Average number of sea cucumbers per linear meter of shoreline is calculated as

$$d = \sum_{i=1}^{n} \frac{C_i}{4n} \tag{1}$$

where:

d = average number of sea cucumbers per linear meter of shoreline,

i = individual transect,

C_i = the total count of sea cucumbers in a transect pair, and

n = the number of transect pairs.

The 4 reflects 2 transects of 2 meters width each.

The variance of the mean, σ_d^2, is estimated as

$$\sigma_d^2 = \frac{\sum_{i=1}^{n} \left(d - \frac{C_i}{4} \right)^2}{(n-1)n} . \tag{2}$$

Confidence limits about d are calculated using the appropriate t-value with n-1 degrees of freedom.

Average weights for transect j (W_j) and associated variance of the mean weight (σ_W^2) within a transect for *m* sea cucumbers sampled in a transect are estimated as

$$W_j = \sum_{i=1}^{m} \frac{w_{ij}}{m} \qquad (3)$$

$$\sigma_W^2 = \frac{\sum_{i=1}^{m} \left(W - w_{ji}\right)^2}{(m-1)m} \qquad (4)$$

The estimated mean weight for the entire sub-district (W_A) and associated variance of this mean weight is:

$$W_A = \sum_{j=1}^{t} \frac{W_j}{t} \qquad (5)$$

$$\sigma_{W_A}^2 = \frac{\sum_{j=1}^{t} \left(W_j - W_A\right)^2}{(n-1)t} \qquad (6)$$

where t is the number of transects where a sea cucumber sample was taken for weight measurements. A t-test will be used to determine if there has been a significant change in average weight for each of the transects where samples were collected in 2004 and 2007, and the paired t-test will be used to determine if a significant change in average weight has occurred over the entire subdistrict. The average weight and precision of this estimate is necessary for expanding the estimated number of sea cucumbers in an area to the biomass of the population.

Biomass estimates and associated precision will be made based on a product of two random variables formula (Goodman, 1960). The total number of sea cucumbers in a sub-district (N_c) is the product of the average number of sea cucumbers per meter of shoreline and the total estimated length of shoreline (L). Note that no variability is associated with the estimate of shoreline.

$$N_C = Ld \qquad (7)$$

and

$$\sigma^2_{N_C} = \sigma^2_d L^2 \qquad (8)$$

where d and σ^2_d equal the average number and variance, respectively, of sea cucumbers per linear meter of shoreline (Equations 1 and 2).

The biomass (B_c) of the sea cucumbers and associated variance is:

$$B_C = N_C W_A \qquad (9)$$

and

$$\sigma^2_{B_C} = (\sigma^2_d W^2_A + \sigma^2_{W_A} d^2 - \sigma^2_d \sigma^2_{W_A}) L^2 \qquad (10)$$

Although the variance can be estimated for the biomass, the degrees of freedom associated with the t-value for the precision is not known, but can be estimated through simulation.

The quota is calculated as per 5 AAC 38.140.(h).

Commercial Catch Sampling

No commercial sampling of sea cucumbers will occur during the 2007-08 season.

RED SEA URCHINS

INTRODUCTION

This section describes research and assessment programs in Southeast Alaska needed to support the commercial red sea urchin (*Strongylocentrotus franciscanus*) fishery. The red sea urchin fishery is managed under a conservative policy of sustained yield. The management plan calls for an assessment of the population size in each harvest area prior to the opening of the fishery. This document describes the methods and locations of the assessment surveys that will be conducted in 2007.

This section also describes a sampling plan for control areas in refuge areas where commercial harvest of sea urchins is prohibited. Control areas are needed to monitor changes in population size that are not directly influenced by commercial fishing. Control areas are expected to be important for distinguishing effects of commercial harvest from other factors affecting populations in harvest areas, e.g., long-term population trends, climate changes, and recruitment events or failures.

OBJECTIVES

During the 2007 red urchin stock assessment surveys will be conducted in Subdistricts 101-27 and 104-30 (controls). No commercial harvest areas are currently scheduled for dive surveys. The objective is to conduct surveys in control areas that can be used to monitor changes in densities of red sea urchin populations across years in the absence of commercial harvest. The long-term objective is to collect a time series of density data from unfished areas that can be compared to data from fished areas to infer whether potential changes are due to commercial harvest, or to other causes.

SAMPLING METHODS

Density Estimates

Density estimates are made via SCUBA along 1-meter-wide strip transects running perpendicular to shore. The transects serve as the primary sampling unit. Transects extend from zero to 10 meters (33 fsw), 12 meters (40 fsw) and 15 meters (50 fsw) of depth corrected for mean lower low water (MLLW). Transect length varies depending on steepness of the bottom. Dives are limited to a maximum depth of 21 m (70 fsw) because deeper dives severely limit total bottom time for scuba divers and pose safety risks when conducted repetitively over several days.

Two divers swim as a team along each transect, with each diver holding a 1-meter-rod (a 2.1 cm diameter white PVC tube) in a horizontal position, perpendicular to the census path. Transects within a pair are separated by 5 to 10 meters. Transect direction is maintained by reference to a compass mounted on the rod. Each diver counts the number of red sea urchins with diameters equal to or greater than 60 mm (2.4 in) passing under their rod. Information is written onto a slate that is attached to the survey rod.

Methodology for Bee Rocks (subdistrict 101-22) varies from the technique used for the majority of the red sea urchins transects due to the lack of visible shoreline. Divers will locate the beginning of the transect using GPS, descend to depth and will survey north for 30 m using a compass mounted on the survey rod. Distance will be maintained by using a 10 m string that is attached to the survey rod. The end of the 10 m string will have a lead weight attached to it that is left at the beginning of the transect. Three 10 m sections will be counted for a total of 30 m.

After recording the count, divers record data on depth, substrate, vegetative cover, and the presence of other species of interest, including green sea urchins, geoduck clams, sea cucumbers and abalone. Substrate type is recorded for the two most common types that represent the entire dive, with the most prevalent type listed first. Possible substrate types include rock, boulder, cobble, gravel, sand, mud, shells and shell remnants, and woody debris (see Appendix B). Presence of vegetation for the dive is recorded as "percent cover" for up to two types, including *Alaria*, *Agarum*, *Fucus*, *Nereocystis*, *Ulva*, *Zostera*, coralline algae, filamentous algae, fir kelp, hair kelp, large brown kelp, leafy red algae, and red hair kelp (see Appendix A). Data are recorded at the end of each dive prior to surfacing and reflect the dive as a whole.

The beginning and ending times for each transect are recorded to allow for later standardization to the MLLW tidal stage. Transects are paired so that a dive team censuses one strip while conducting a dive.

Diameter Estimates

Average size of urchins are estimated for each area to convert densities to biomass and to monitor changes in urchin size. During each transect, divers stop at one randomly chosen location between 2 and 15 m (MLLW) along transects to collect urchins to obtain measurements of diameter. Either shallow, middle or deep locations are chosen, varying each dive. A sample of 30 urchins is collected as close as possible to this sample site. The urchins are placed into bags, taken to the dive skiff to be measured and are placed back into the water as close to the sample site as possible.

BIOMASS ESTIMATES

Red urchin biomass is estimated as a product of the estimated population size and the average mass of urchins for each subdistrict. The calculation begins with estimates of urchin population densities made by scuba divers counting urchin on meter-wide transect pairs.

Average Density

Average density, d, is estimated in units of urchins per meter of shoreline length for each subdistrict:

$$d = \frac{\sum \sum c_i / m}{n} \qquad (1)$$

where c is the count of sea urchins ≥ 60 mm diameter on each transect i for i = 1 to m (m is at most 2 transects per pair), and n_t is equal to the number of transect pairs.

Shoreline lengths in each subdistrict are measured using GIS computer software and scanned NOAA Nautical Charts.

Average Mass

Average diameter of urchins will be estimated for each area to convert densities to biomass. Approximately 30 red sea urchins per transect will be collected. This sample size is sufficient to meet the statistical objective using equation 1.2, where t_α is the two-sided critical t value for a 100(1-α)% confidence level, the precision (p) is 90%, and the coefficient of variation (CV) is 40%, estimated from pilot samples collected in 1994 (ADF&G unpublished data). Individual red sea urchins will be measured to the nearest millimeter.

Outside test (shell) diameters are measured to the nearest millimeter with calipers, excluding the spines. If conditions permit, urchins are measured immediately aboard the skiff and returned to the general area from which they were removed.

Average mass (g) for each area is estimated from average test diameter (mm) within that area. A multiplicative model was used to describe the relationship between weight and diameter:

$$\text{mass} = 0.001238 * \text{diameter}^{2.7117}. \qquad (2)$$

The R-squared statistic indicates the model explains 92.92% of the variability in weight (Table 1, Figure 1).

Equation 2 was used for the first time in 2005. This formula was estimated from 2,142 urchins, sampled from Districts 101,102 and 104 in 2003 and 2004, using a log transformed regression. The equation was applied to each urchin sampled for size.

The average mass (W) for each subdistrict is estimated as:

$$W = \frac{\sum_{j=i} \sum w_i / \sum o_i}{n_j}$$

Where w_i is the estimated weight (based on Equation 2) of all urchins in sample greater than $\geq$ 60 mm i, o_i is the count of all urchins $\geq$ 60 mm in the sample, and n_j is the total number of weight samples taken in subdistrict $j \geq$ 60 mm.

Population Size and Biomass

The population size or biomass of urchins ≥ 60 mm diameter in each subdistrict is calculated as the product of average density (urchins per meter of shoreline), and the total available habitat (meters of urchin-compatible shoreline).

Total biomass (b) for each subdistrict is calculated as:

$$b_j = \bar{d}_j W_j l_t , \qquad (4)$$

where l is the length of shoreline in a subdistrict. The lower bound of the biomass estimate is calculated as the percent precision (Equation 5) times the biomass.

Confidence limits for the biomass estimates are based on an estimate of the variance of the biomass. A variance-of-products formula (Goodman 1960) is used to calculate a variance estimate for the product of mean density and mean weight per geoduck clam. Assuming that there is no correlation between density and weight then the variance of the biomass is:

$$\delta_B^2 = D^2 \frac{\delta_w^2}{n_w} + W^2 \frac{\delta_D^2}{n_D} - \frac{\delta_D^2 \delta_W^2}{n_D n_w} , \qquad (7)$$

where:

δ^2_B = variance of biomass, B,

D = mean density of red urchins,

W = mean weight,

δ^2_D = variance of mean density,

δ^2_W = variance of mean weight,

n_D = number of transects,

n_W = number of geoduck clams weighed.

In general, a sample goal of 15 to 25 transect pairs has been established for each area. This sample size is expected to achieve 60 to 70% precision (defined in Equation 5 below) based on information from prior urchin surveys. This sampling goal is greater in control areas to increase the precision of the estimate. In non-control areas where precision from past surveys fell below the target, the number of transect pairs was increased to between 18 and 35. The index is equal to the lower bound of the one-sided 90% confidence interval expressed as a percent of the average biomass:

$$\text{Percent precision} = 100\left(1 - t_\alpha \frac{SE}{\bar{b}_j \sqrt{n_j}}\right), \tag{5}$$

where t is the t-value from Student's distribution for a one-sided interval with significance level $\alpha = 10\%$, SE is the standard error of the biomass among n transect pairs.

The (Guideline Harvest Level) GHL for each subdistrict is calculated as the product of the percent precision, biomass and 6% harvest rate:

$$GHL = 0.06 b_j P \tag{6}$$

Where P is the precision estimate.

Location and Number of Transects

Transects that were completed during previous surveys will be sampled at the same locations. The sampling method will allow a paired comparison of densities in which the variability due to location is minimized (Woodby et al. 1993). The original transect pairs were systematically distributed along the shorelines of each harvest area. Systematic sampling is preferred over random sampling due to simplicity of design and because estimates are generally efficient relative to random sampling, provided that there is no spatial pattern in the distribution of the sample organism at the same scale as the sampling. Location of the first transect pair is randomly chosen, and subsequent transect pairs are located at equal intervals along the shoreline. The distance between transect pairs equals the total length of shoreline divided by the number of transect pairs allocated to each area. Transect sites will be located using nautical charts showing transect locations, aided with GPS equipped with electronic charts of the area.

The number of transects sampled in each area will be the same as in 2003.

Commercial Catch Sampling

No commercial sampling of red sea urchins will occur during the 2007–08 season.

GEODUCK CLAMS

INTRODUCTION

This section describes the research and assessment program needed to support the commercial geoduck clam (*Panopea abrupta*) fishery in Southeast Alaska. The fishery is managed under a conservative policy of sustained yield. Harvest quotas are described in the Board of Fisheries adopted management plan for geoduck clams (RIR 1J99-39 and 5 AAC 38.142). The management plan calls for an assessment of the population biomass in each harvest area prior to the initial opening of a geoduck clam fishery and a maximum of 12-harvest years between assessments. This section describes the objectives, methods, and locations of assessment surveys that will be conducted during the 2007 survey season.

OBJECTIVES

The objectives for the 2007 geoduck clam survey season are:

To monitor the geoduck clam control area,

1) Resurvey areas currently open to commercial harvest to improve survey precision,
2) As time permits, survey a new area within Southeast Alaska, in conjunction with input from the SARDFA Geoduck Committee, for potential geoduck clam commercial fisheries. These new areas result from contracted industry reconnaissance surveys.
3) Investigate and improve geoduck clam survey methodology.

METHODS

Current Methods

Density estimates are completed by scuba divers along two-meter-wide strip transects. There are two types of transects that may be used depending on the area; these transects serve as the primary sampling unit. The first type run perpendicular to the shore and are used along straight shorelines (not coves or bays). Transects extend to a minimum target depth of 17 meters (55 fsw) depth below mean lower low water (MLLW). Dives to the target depth include the majority of habitat in which commercial divers normally operate. Dives are limited to a maximum depth of 21 m (70 fsw) because deeper dives severely limit total bottom time for scuba divers and pose safety risks when conducted repetitively over several days. Transect length varies depending on the slope of the bottom. Type one transects are used in areas such as the Goddard area fisheries and Cone Island fisheries.

Two divers swim as a team along each transect, with one diver holding a two-meter rod (a 2.1-cm diameter white PVC tube) in a horizontal position, perpendicular to the census path. Transect direction is maintained by reference to a compass mounted on the rod. The diver carrying the rod counts the number of geoduck clams passing under one side of the rod (usually the left) while the second diver counts geoduck clams on the other side (usually the right). Alternatively, each diver may carry a one-meter rod, but under no circumstances will a diver count an area wider than one meter.

The second type of transect is used in coves and embayments where a reasonable estimate of sea bed area could be made. A buoyed anchor is dropped on a transect location where divers descended and survey a measured distance. A 1 m^2 PVC square is used, beginning at the anchor, to count geoduck clams per meter square. The square is flipped in the direction of the transect and sequential counts made for the length of the transect. Type two transects are used in Ulitka Bay.

A variation of both type one and two transects involves using a 1-meter square that is placed at the beginning of the transect, counts are made within the square, then the square is flipped in the direction of the transect and density is again estimated. The square is continually flipped until either the target depth (Type I) or target distance (Type II) is reached. This method has the advantage of focusing the divers estimates into a well defined area and may achieve a higher within diver precision (though this has not been tested). The disadvantage is the cumbersome use of the square, particularly in dense kelp, and the somewhat longer time it takes to complete the transect.

In addition to recording the geoduck clam count for each transect, divers also will record data for start and stop depths, substrate type, percent vegetative cover, vegetative type, and the presence of other species of interest including sea urchins, sea cucumbers, abalone, and *Sargassum muticum*. Vegetative type will be recorded for the two most common types on each transect, with the most prevalent type listed first. Substrates are coded using a key that groups various algae and intertidal plant species into categories (Appendix A). Similarly, substrate type was recorded as "percent cover" for up to two types and was coded (Appendix B).

The beginning and ending time for each transect is recorded by a dive tender to allow for standardization to the mean lower low water (MLLW) tide stage. Preferably, shoreline (type-one) transects are paired (sides A and B) so that a dive team would census one strip while descending, and then a second strip when returning to shore. The second transect in each pair is approximately 10–15 m to the left (when facing shore) of the first transect. This is the preferred method but may not be practical when a gentle slope requires extended bottom times, with multiple dives often necessary to complete one transect. It is left to the divers discretion as to whether a paired transect is appropriate for a particular transect site. The appendices list whether a transect was paired or not.

Density estimates for each linear shoreline (Type I) are calculated as the average number of geoduck clams per meter of shoreline length:

$$d_1 = \sum_{i=1}^{n} \frac{L_i}{kL_t} c_i \qquad (1)$$

where:

d_1 = estimated number of geoduck clams per meter of shoreline,

i = transect index,

c_i = count of geoduck clams on each transect *i*,

L_i = shoreline segment length associated with each transect *i*,

L_t = total shoreline length,

n = number of transects,

k = either 2 or 4 depending on transect width.

The variable k in Equation 1 is equal to 2 when only side A is counted on a type 1 transect, or equals 4 when both sides A and B are counted, and corrects for the 2-meter width of each transect side.

Where a reasonable measurement of sea bed area could be made (Type II transects), the density per square meter of sea bed is estimated:

$$d_2 = \frac{1}{Tn} \sum_{i=1}^{n} c_i \qquad (2)$$

where:

d_2 = estimated number of geoduck clams per square meter,

i = transect index,

c_i = count of geoduck clams on each transect *i* from 1 to n,

T = transect length,

n = number of transects,

Uncertainty in the density estimate is expressed as the percent precision. The index is equal to the lower bound of the one-sided 90% confidence interval expressed as a percent of the average density and calculated as:

$$P_D = 100\left(1 - t_\alpha \frac{s}{D\sqrt{n}}\right), \quad (3)$$

where:

P_D = percent precision of the density estimate,

t_α = t-value from Student's distribution for a one-sided interval with significance, level α = 10%,

s = standard deviation of the mean,

D = estimated density of geoduck clams,

n = number of transects.

In a perfectly precise estimate, P_D would equal 100%; decreasing numbers indicate increasing uncertainty.

Potential Method Improvement

ADF&G and SARDFA jointly contracted with Dr. Chris Siddon, through the University of Alaska, to investigate potential improvements to the department's geoduck clam survey methodology. Dr. Siddon's results have been completed and generally recommend a transition to an area estimate (Siddon 2005). The results of this analysis may be integrated into the current survey method. Method details and a comparison with current methods will be thoroughly discussed in the 2006 geoduck season report.

Geoduck Clam Weight Estimates

Limited resources and need for efficiency dictates that geoduck clam weight estimates are made using data collected from previous commercial fisheries and assessment surveys. All data available from specific surveyed areas are combined and applied to the biomass estimate for that area. In new areas where no data have been collected, all data available from Southeast Alaska are averaged and used to estimate the biomass. After the fishery has occurred, data collected for that area's commercial fishery will be averaged and used to recalculate the biomass estimate. If there are significant differences in an area's weight estimate, an adjustment may be made to the biomass estimate and applied to future GHLs for that area. This method of estimating geoduck clam weight for an area increases the efficiency of geoduck clam surveys.

Mean weight per geoduck clams within a given area is estimated as:

$$W = \frac{\sum w_i}{n_w}, \qquad (4)$$

where:

W = estimated mean weight per geoduck clam,

w_i = weight of the *i*th geoduck clam from the available data,

n_w = sample n for weight.

Geoduck Clam Biomass Estimate

Geoduck Clam Biomass Estimate

The estimate of total geoduck clam biomass in an area is calculated as:

$B_{bed} = (D_1)(W)(S)$ or, 5)

$B_{bed} = (D_2)(W)(A)$ 6)

where:

B_{bed} = estimated total geoduck clam biomass per defined area,

D_1 = estimated density of geoduck clams per linear meter of shoreline,

D_2 = estimated density of geoduck clams (number per square meter),

W = estimated mean weight per geoduck clam (in pounds),

S = total estimated shoreline length (in meters),

A = total estimated bed area (in square meters).

Confidence limits for the biomass estimates are based on an estimate of the variance of the biomass. A variance-of-products formula (Goodman 1960) is used to calculate a variance estimate for the product of mean density and mean weight per geoduck clam. Assuming that there is no correlation between density and weight then the variance of the biomass is:

$$\delta_B^2 = D^2 \frac{\delta_W^2}{n_W} + W^2 \frac{\delta_D^2}{n_D} - \frac{\delta_D^2 \delta_W^2}{n_D n_W}, \qquad (7)$$

where:

δ^2_B = variance of biomass, B,

D = mean density of geoduck clams (D_1 or D_2),

W = mean weight (pounds per geoduck),

δ^2_D = variance of mean density,

δ^2_W = variance of mean weight,

n_D = number of transects,

n_W = number of geoduck clams weighed.

Uncertainty in the biomass estimate is expressed as the percent of precision. The index is equal to the lower bound of the one-sided 90% confidence interval expressed as a percent of the biomass. This index, similar to P_D (equation 2), is calculated as

$$P_B = 100\left(1 - t_\alpha \frac{s}{B_{bed}\sqrt{n}}\right), \tag{8}$$

where:

P_B = percent precision of the density estimate,

t_α = t-value from Student's distribution for a one-sided interval with significance level $\alpha = 10\%$,

s = standard deviation of the mean biomass estimate (δ_B, from equation 7),

B_{bed} = estimated total geoduck clam biomass per defined area,,

n = number of transects.

The GHL for biomass estimates is calculated using a precision adjusted biomass.

$$B_{adj}=P_B*B_{bed} \tag{9}$$

where:

B_{adj} = precision adjusted biomass estimate (used to calculate GHL),

P_B = from equation 8, above,

B_{bed} = from equation 5 or 6, above.

Geoduck clams can be difficult to count when they are hidden below the substrate. For this reason the true clam density may be underestimated. The method described below, used to estimate the true density of geoducks from visual counts, is patterned after that used by the Washington Department of Fish and Wildlife (Bradbury et al. 2000). This method was originally introduced by Goodwin (1977) who coined the term "show factor." A "show" is either a siphon visible above the substrate or a depression in the substrate that can be identified as having been made by a clam siphon.

The show factor, F, is the ratio of geoduck clam shows visible during a single observation of any defined area and the true abundance of harvestable geoducks within that area:

$$F = n / N, \tag{10}$$

where:

n = the number of visible shows within a defined area (show plot),

N = the absolute number of harvestable geoducks within the area.

The guideline harvest levels for Southeast areas open during the 2003/2004 season were adjusted for a show factor as:

$$GHL_F = \frac{GHL_{bed}}{F}, \tag{11}$$

where:

GHL_F = show factor adjusted guideline harvest level (GHL) estimate,

GHL_{bed} = geoduck GHL estimate,

F = show factor, from Equation 10.

A value of 0.80 will be used for the show factor in equation 11 for all open areas.

Location and Number of Transects

Surveys for potential commercial harvests will be in the following locations:

1) Northern Noyes Island to include Little Steamboat Bay, Ulitka Bay, and Steamboat bay; and
2) If time and resources permit, an additional area may be wholly or partially surveyed.

Depending on the time needed to survey the area, and if resources are available, an additional as yet unidentified area may be surveyed.

Type-one transects will be systematically distributed along the shorelines of each harvest area[1]. Location of the first transect in each area will be randomly chosen, and subsequent transects located at equal intervals along the shoreline in a general west-to-east, south-to-north direction. A standard transect interval of 200 meters will be used. Where shoreline length is insufficient, resulting in a limited number of transects, an interval of 100 meters will be used. There are no permanent markers at the transect sites to show the survey team where to dive; rather, transect sites will be located using DGPS (differential global positioning system) and nautical charts showing transect locations with approximate latitude and longitude provided. Where a

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[1] Systematic sampling is preferred over random sampling due to simplicity of design and because estimates are generally efficient relative to random sampling, provided that there is no spatial pattern in the distribution of the sample organism at the same scale as the sampling frequency. Our surveys have indicated that there are no repeating patterns of abundance in geoduck clam distributions at the scale of our surveys.

reasonable estimate of sea bed area can be made (type-two transects), a grid of approximately equal columns and rows is randomly constructed over the area to be surveyed. These grid intersections become the transect locations. This method provides for a random yet systematic placement of transects. There are obviously no permanent markers associated with these transects. Each transect latitude and longitude is determined using nautical charts then located using DGPS on the dive skiffs.

Control Surveys

Control areas can be used to monitor changes in densities of geoduck clam populations across years in the absence of commercial harvests. The long-term objective is to collect a time series of density data from unfished areas that can be compared to data from fished areas to infer whether a decline is due to fishing, or to other causes. Formal surveys will be conducted to estimate geoduck clam density and biomass once suitable areas are defined and as time allows. Control sites will also be an excellent location for the long term placement of show plots.

Currently, two control sites have been established: one near Craig in Port Mayoral, and one in Blank Inlet south of Ketchikan. These sites are closed to commercial harvest.

Divers and Geoduck Clam Survey Experience

Geoduck transects almost always contain other animals whose siphons may be confused with geoducks by inexperienced divers. Density estimates will be biased if divers misidentify animals as geoducks or if they fail to count geoducks under the assumption they are something else. Field experience is crucial when identifying geoducks. New department divers can gain experience when diving with experienced surveyors but counts may be suspect. Inexperienced diver's counts will not be included in the density (and thus, biomass) estimates until, in the estimate of the project leader, the new divers has adequately demonstrated proficiency with geoduck identification. Appendices C and D may be used to increase the efficiency of geoduck recognition by new divers.

COMMERCIAL CATCH SAMPLING

Commercially harvested geoduck clams will be sampled at dockside in each management area upon landing. A goal of 100 geoduck clams will be sampled per commercial bed per season. If possible, samples within each subdistrict will be obtained from multiple vessels. Sampling will include the weight to the nearest whole gram. Identifying information shall include the harvest date, subdistrict, bed, and any other available pertinent information (e.g. latitude and longitude of harvest, depth of harvest, substrate).

2007 FIELD SCHEDULE

During the 2007 field season sea cucumber, red sea urchin and geoduck clam population assessment surveys will require approximately 80–85 vessel days including travel (excluding herring surveys, Appendix 5). Actual number of days for each project will depend on weather, travel, over-lapping projects, and coordination among herring diving projects.

OTHER NECESSARY RESOURCES

The *R/V Kestrel*, based in Petersburg, will be used as the support research vessel and base dive platform for sea cucumber, red sea urchin and geoduck clam assessment surveys. This is a 105 ft steel displacement hull vessel capable of accommodating six divers in addition to vessel officers.

Six divers will be assigned to each cruise, allowing two dive teams to operate simultaneously. If six divers are not available, a vessel crew member may tend one dive team (each dive team requires a tender to operate the skiff). Another tender will be required if vessel personnel are not available.

The support research vessel will be accompanied by two 19’ aluminum skiffs that have been enhanced for diving purposes. Skiffs will be transported by the support vessel to the project site. All diving will be conducted from these skiffs.

Due to the nature of the described dive surveys (multiple divers per day, reverse-profile to 70 fsw, multi-day diving), 36% Enhanced Air Nitrox will be used for all diving. Nitrox is produced onboard via a membrane equipped compressor. All diving will be in accordance with the Department’s Dive Safety Manual.

DATABASE AND SOFTWARE REQUIREMENTS

The vessel is equipped with a late model computer and color printer with battery backup unit. All transect data will be entered and stored in a Microsoft Access database. Microsoft Excel will be used for the data analysis. Data will be entered by dive team members within the same day of data collection (if possible) to maximize recall of dives. Ideally, the collectors of data will enter the data. Commercial landing data will be entered into the Alexander database system.

REFERENCES CITED

ADF&G 1990. Interim management measures for the red sea cucumber fisheries in Southeast Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau. Regional Information Report 1J90-30.

ADF&G 1991. Commercial Shellfish Regulations. Regulations of the Alaska Board of Fisheries for Commercial Fishing in Alaska. Alaska Department of Fish and Game, Juneau.

ADF&G 1992. Commercial Shellfish Regulations. Regulations of the Alaska Board of Fisheries for Commercial Fishing in Alaska. Alaska Department of Fish and Game, Juneau.

Bradbury, A., B. Sizemore, D. Rothaus, and L. Timme. 2000. Stock assessment of subtidal geoduck clams (*Panopea abrupta*) in Washington. Marine Resources Unit, Fish Management Division, Fish Program, Washington Department of Fish and Wildlife.

Cochran, W. G. 1977. Sampling Techniques 3rd Edition. John Wiley & Sons, New York. 428 pp.

Goodman, L. A. 1960, On the exact variance of products. American Statistical Association Journal 55: 708–713.

Siddon, C. 2005. Evaluation of the Southeastern Alaska Geoduck (*Panope abrupta*) Stock Assessment Methodologies. University of Alaska-Fairbanks. School of Fisheries and Ocean Sciences. Juneau. Alaska

Thompson, S. K. 1992. Sampling. John Wiley & Sons, New York. 343 pp.

Woodby, D.A., G.H. Kruse, and R.H. Larson. 1993. A conservative application of a surplus production model to the sea cucumber fishery in Southeast Alaska. Pages 191–202 in: G. Kruse, D.M. Eggers, R.J. Marasco, C. Pautzke, and T.J. Quinn II [eds.]. Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations. Alaska Sea Grant College Program Report No. 93-02, University of Alaska Fairbanks.

Table 1.–Regression of red sea urchin weight (g) vs. diameter (mm).

Multiplicative model: $Y = a*X^b$

Coefficients

Parameter	Least Squares Estimate	Standard Error	T Statistic	P-Value
Intercept	-6.69412	0.073387	-91.2167	0.0000
Slope	2.71168	0.016179	167.61	0.0000

Analysis of Variance (Note: intercept = ln(a)

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	1677.25	1	1677.25	28093.03	0.0000
Residual	127.765	2140	0.059703		
Total (Corr.)	1805.01	2141			

N = 2,142 red urchins

Correlation Coefficient = 0.964

R-squared = 92.9%

Standard Error of Est. = 0.244

Mean absolute error = 0.1530

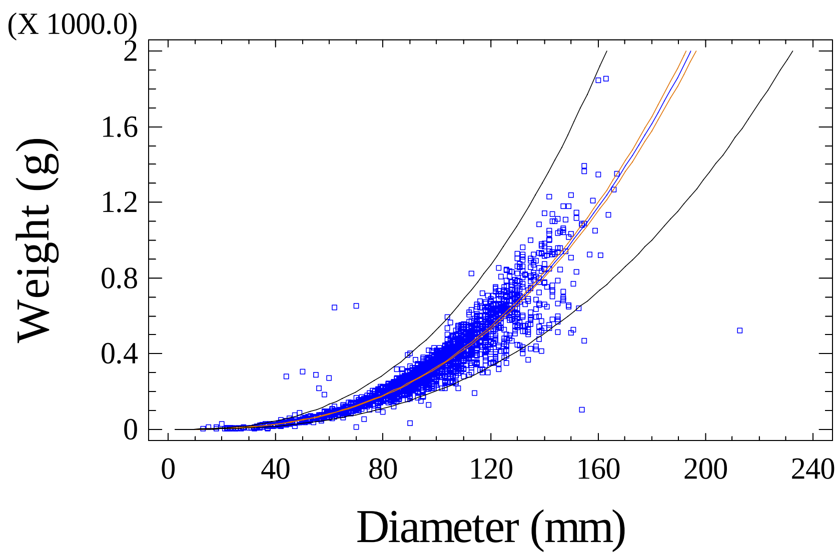


Figure 1.–Plot of fitted model for red sea urchins: mass = 0.001238 * diameter$^{2.7117}$.

APPENDIX

Appendix A.–Key to vegetative substrate types used for all marine invertebrate surveys.

Code	Expanded code	Species included	Latin names
AGM	Agarum	Sieve kelp	*Agarum clathratum*
ALA	Alaria	Ribbon kelps	*Alaria marginata, A. nana, A. fistulosa*
ELG	Eel grass	Eel grass, surfgrasses	*Zostera marina, Phyllospadix serrulatus, P. scouleri*
FIL	Filamentous red algae	Sea brush, poly, black tassel	*Polysiphonia pacifica, P. hendryi, Pterosiphonia bipinnata*
FIR	Fir kelp	Black pine, Oregon pine (red algae)	*Neorhodomela larix, N.oregona*
FUC	Fucus	Rockweed or popweed	*Fucus gardneri*
HIR	Hair kelp	Witch's hair, stringy acid kelp	*Desmarestia aculeata, D. viridis*
LAM	Laminaria	split kelp, sugar kelp, suction-cup kelp	*Laminaria bongardiana, L. saccharina, L. yezoensis (when isolated and identifiable)*
LBK	Large Brown Kelps	Five-ribbed kelp, three-ribbed kelp, split kelp, sugar kelp, sea spatula, sieve kelp, ribbon kelp	*Costaria costata, Cymathere triplicata, Laminaria spp., Pleurophycus gardneri, Agarum, Alaria spp.*
MAC	Macrocystis	Macrocystis	*Macrocystis integrifolia*
NER	Nereocystis	Bull kelp	*Nereocystis leutkeana*
RED	Red algae	All red leafy algae (red ribbons, red blades, red sea cabbage, Turkish washcloth)	*Palmaria mollis, P. hecatensis, P. callophylloides, Dilsea californica, Neodilsea borealis, Mastocarpus papillatus, Turnerella mertensiana*
ULV	Ulva	Sea lettuce	*Ulva fenestrata, Ulvaria obscura*
COR	Coralline algae	Coral seaweeds (red algae)	*Bossiella, Corallina, Serraticardia*

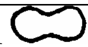
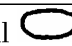
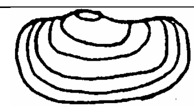
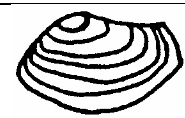
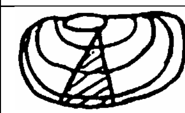
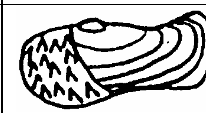
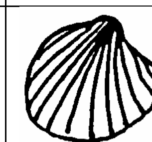
Appendix B.–Key to bottom types used for all marine invertebrate surveys.

Code	Expanded code	Definition
RCK	Bedrock	Various rocky substrates > 1 meter in diameter
BLD	Boulder	Substrate between 25 cm and 1 meter
CBL	Cobble	Substrate between 6 cm and 25 cm
GVL	Gravel	Substrate between 0.4 cm and 6 cm
SND	Sand	Clearly separate grains of < 0.4 cm
MUD	Mud	Soft, paste-like material
SIL	Silt	Fine organic dusting (very rarely used)
BAR	Barnacle	Area primarily covered with barnacles
SHL	Shell	Area primarily covered with whole or crushed shells
MUS	Mussels	Area primarily covered with mussels
WDY	Woody debris	Any submerged bark, logs, branches or root systems

Appendix C.–Identification and comparison of siphon shows for geoduck and selected clams.

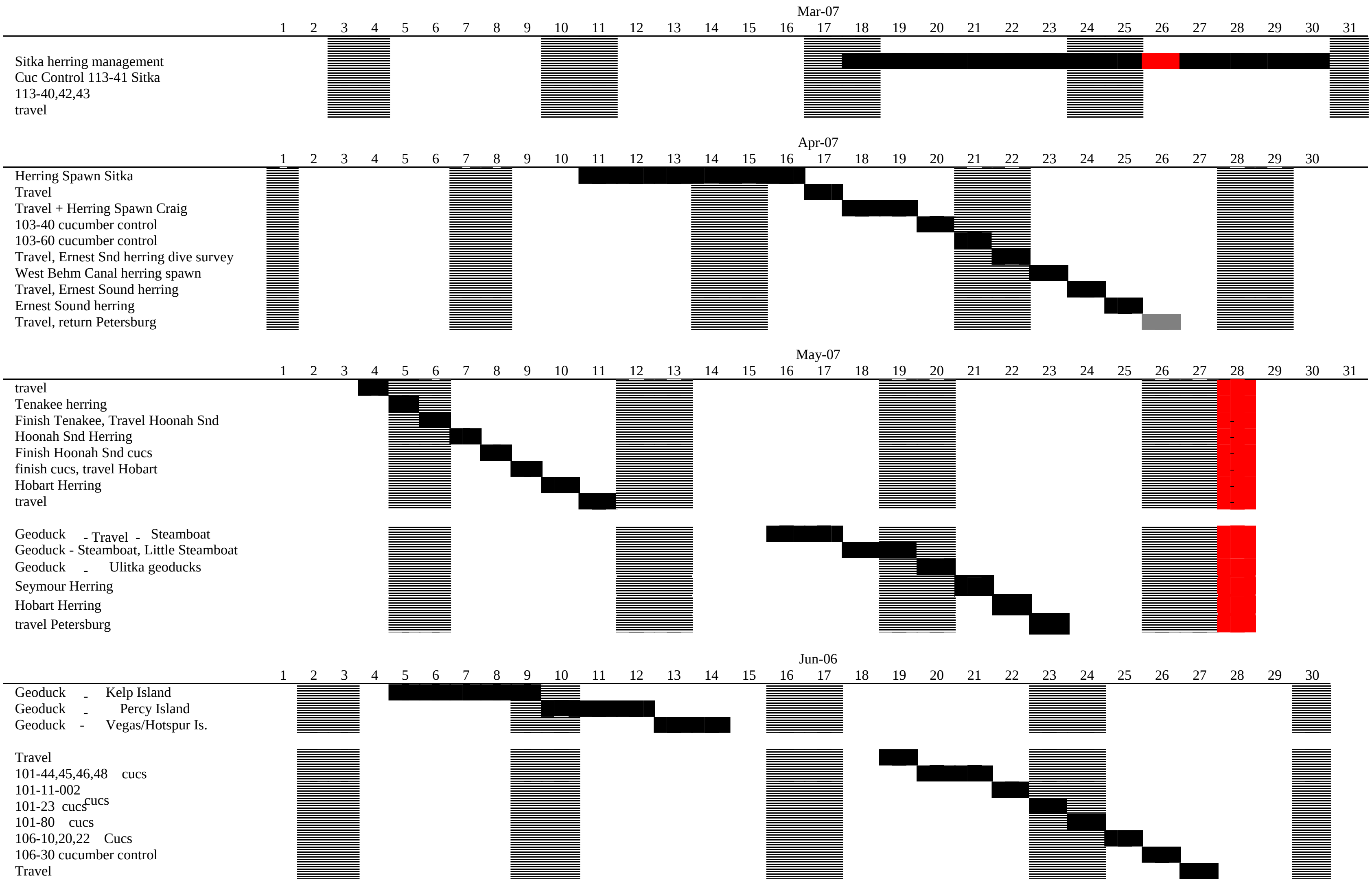
Geoduck clam beds almost always contain other clams whose siphons or shows may be confused with geoduck clams by inexperienced divers. When geoduck siphons are exposed above the substrate and pumping water, they are easily recognized by their large size, elliptical or oblong shape, a flat (rather than rounded) siphon, the absence of tentacles along the inner portion of either siphon opening, and both siphon openings are the same size. When partially retracted, geoduck siphons may be identified by their elliptical or oblong shape, flat siphon tip, and sometimes by the presence of pellet-like particles of undigested particulate matter (psuedofeces) laying on the surface near the siphon tip. Geoduck siphons have a soft leathery texture (as opposed to a slimy feel) with no horn plates on the siphon tip; but this may be difficult to discern while wearing heavy neoprene gloves. When probed, geoducks typically retract their siphons slowly, rarely expelling a jet of water. Probably the most easily confused with geoducks are horse clams (*Tresus capax* and *T. nuttallii*). When horse clam's siphons are open and pumping, the presence of an inner ring of tentacles can be seen.. Obviously these can not be seen when the siphon is closed. Typically, horse clam siphons are oval or nearly round in cross-section, while geoduck siphons are elliptical. Horse clams generally retract their siphons faster than geoducks when disturbed, expelling a jet of water. Also, horse clam pseudofeces are thin and stringy rather than pellet-like. False geoducks (*Panomya* sp.) are generally smaller than geoducks, and have a distinctive siphon tip with a thin pink or red ring encircling each siphon hole, though the color may not be apparent. *Panomya* siphon tips are rounded in cross-section, as opposed to geoduck siphons, which are essentially flat when view from the side. *Panomya* can also be distinguished by their thinner siphon membranes and because the incurrent siphon, when open and pumping, is noticeably larger than the excurrent siphon. Truncated softshell clams (*Mya truncate)* are usually much smaller than geoducks, and have a thin, dark-brown, wrinkled siphon with leathery flaps at the tip. Piddocks (*Zirphaea* sp.) are distinguished from geoducks by their bifurcated ("double-barreled") siphons, maroon siphon tips, and a distinctive white and black pattern on the siphons. Piddock siphons are also very thin-walled and have a slimy, smooth feel unlike the leathery siphon covering of geoducks. Piddocks are boring clams, and are therefore found only in clay, wood, or rock substrates, although this may not be readily apparent if there is a thin surface layer of sand or mud. Cockles (*Clinocardium nuttallii*) are readily distinguished by their white, "hairy" siphon tips and can be easily dug by hand to verify their identity (Bradbury et al, 2000, Harbo 1997).

Appendix D.–Descriptions of common bivalves in Southeast Alaska. Adapted from Bradbury et al. 2000.

SPECIES	Geoduck	Horse Clam	*Mya truncata*	*Panomya sp.*	Piddock	Cockle
siphon shape	elliptical 	oval  round hole	round 	figure 8 	oval 	two circles 
tentacles	absent	present/distinct	present/fine frills or small bumps	present/fine	present/distinct	present/distinct
substrate depth	l8 to 36 inches	8 to 15 inches	8 to 10 inches	8 to 15 inches	8 to 20 inches	surface
substrate type	all (except clay)	gvl/cbl/sand	mostly mud/sand	all (except clay)	clay/rock/wood	sand/sand-mud
shell						
siphon color	brown with	grey/blue orange	dark brown	red and white	mottled reddish	creamy brown
	cream interior	tentacles	"wrinkled skin"	"circled siphons"	brown and white	
other distinguishing features	large siphon, smooth/soft, pseudo feces	horny plates on siphon, encrustation on plates	leathery flaps like horse clam usually without encrustation	large siphon, smooth/soft, pseudo feces	bifurcate siphon shotgun like, slimy thin feel	"furry" look to siphon, very shallow, heavy round shell

Appendix E.–Survey schedule for the 2007 survey season.

For clarity, herring spawn deposition survey schedule is included as several sea cucumber surveys will be completed between herring surveys. Black boxes are scheduled survey days. Vertical bars indicate weekends. Red indicates holidays.



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Appendix E.–continued (page 2 of 2)