SUMMARY REPORT
Task Title: Gravid Female Dungeness Crab Habitat

Study Project Partners:
Snohomish County Marine Resources Committee
Stef Frenzl, Jen Sevigny
Washington Department of Fish and Wildlife (WDFW)
Don Velasquez
Natural Resources Consultants, INC
Jeff June, Scott Goodman

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Project Background

Dungeness crab is an important species ecologically and economically in the Puget Sound region. However, little is known about gravid female Dungeness crab habitat preferences in the marine environment in Snohomish County. Two years ago, Don Velasquez, WDFW Biologist, approached the MRC requesting help in determining where gravid female Dungeness crabs prefer to settle along the nearshore. Due to skyrocketing harvest rates over the past few years, Dungeness crab stewardship had been prioritized as a primary goal of the MRC since 2003, so the MRC readily agreed to work on the project. The Gravid Female Dungeness Crab Habitat Study was developed to further our understanding of Dungeness crab habitat availability and needs in Snohomish County, and to promote appropriate means of protection for productive gravid female crab habitat.

Project Objectives

The Gravid Female Dungeness crab Habitat Study was originally intended to investigate the extent and productivity of marine habitat for gravid female Dungeness crab in Snohomish County. The initial study was divided into three Phases:

Phase I: Identify potential brood habitat areas from existing data

Phase II: Conduct underwater surveys of six potential areas with Tulalip dive teams

Phase III: Complete data analysis and final report

This project was originally anticipated to begin work in 2006; however, Tulalip Tribes has had staffing challenges that prohibited them from partnering with the MRC on this project. In January 2007, the MRC decided to contract as much work as possible to Natural Resources Consultants, Inc (NRC), with an understanding that completing field surveys would not be possible because gravid crabs use the sandy substrate during the winter months, and a contract wouldn't be completed until April. Additionally, our original budget was significantly under-budget for completing field surveys via consultant instead of working in partnership with the Tulalip Tribes.

The MRC revised its goals to the following:
<u>Phase I Goals:</u>

1) Develop a series of GIS maps and data that show potential gravid female crab habitat in the waters of Snohomish County, in addition to a final report that describes the GIS mapping methodology employed and the source of the data products used.
2) Develop a detailed gravid female survey protocol to field verify the completed preliminary GIS map described above. The survey protocol will incorporate shallow water (<105 ft) diver, deep water Remote Operating Vehicle and investigate possible bottom trawl sampling options.
3) Develop a budget narrative for completing Phase II (surveys and analysis), underwater surveys of mapped areas to locate gravid crabs and to identify habitat types selected by gravid females.

The MRC applied for funds from the 2007-2009 NWSC Grant to implement Phase II of this project (field surveys and analysis).

Project Implementation

Jen Sevigny (MRC), Stef Frenzl (MRC) Don Velasquez (WDFW), and Natural Resources Consultants developed the Phase I Scope of Work (attached to this summary report).

Goal 1: Develop a series of GIS maps
NRC developed the GIS maps. The following maps were generated, and are attached to this summary report:

1) Snohomish County Marine Waters- Bathymetry
2) Snohomish County Marine Waters- Less than 120 feet depth
3) Snohomish County Marine Waters- Potential Dive Survey Area (Skagit Bay & Port Susan)
4) Central Snohomish County marine waters potential dive survey areas (Everett area).
5) North Snohomish County marine waters potential ROV survey areas.

Goal 2: Develop gravid female survey protocol
NRC developed the draft protocols, which received review by the MRC, WDFW and Snohomish County Surface Water Management habitat biologists. The protocol is attached to this summary report.

Goal 3: Develop Phase II budget and narrative
NRC developed the budget and narrative for Phase II (field surveys and analysis) implementation (see attachments).

Discussion
Although we faced a roadblock with the Tulalip Tribes due to unforeseen staffing circumstances, we feel that this project was highly successful in accomplishing our revised goals. NRC has supplied the necessary maps, protocols and anticipated budget to help us ensure that the field survey work and following analyses will result in high-quality data and usable GIS layers.

The partnership between the MRC and WDFW continues to be strong, especially surrounding Dungeness crab stewardship. WDFW is anticipating incorporating the final data into the Priority Habitat & Species recommendations document to help protect gravid female Dungeness crab habitat.

Recommendations

Because this project entails relatively expensive research on habitat that previously has been unidentified, we feel that the phasing approach works rather well. The MRC originally anticipated a complete survey with the original budget. Because we were able to phase the project, we now know that our original plan and budget was unrealistic. Phasing the project gave us the opportunity to investigate how best to approach the survey work based on scientific literature searches, interviews with researchers and resource managers, and compiling existing mapping data. Without this process, the end product may have not had such a high chance of success and partner collaboration.

Resources/References

See Attached Phase I Scope of Work and Survey Protocol for references.

Attachments (see following page)

- Gravid female Dungeness crab Phase I Scope of Work
- Gravid female Dungeness crab Phase I map series
- Gravid female Dungeness crab Phase II survey protocol
- Gravid female Dungeness crab Phase II budget and narrative

Schedule A
Scope of Work

Gravid Female Dungeness Crab Habitat Study
Phase I Scope of Work

Prepared by:
Jen Sevigny, Snohomish County MRC
Don Velasquez, Washington Department of Fish and Wildlife
Stef Frenzl, Snohomish County

March 2, 2007

Introduction
In 2001, the Snohomish County Marine Resources Advisory Committee (MRC) identified Dungeness crab stewardship as a high priority for marine resource conservation in Snohomish County. This decision was based on the social, economic, and ecological importance of the crab fishery to a broad range of stakeholders within the local community. In pursuit of answers to questions about how to sustain this fishery, the Snohomish County MRC, Tulalip Tribes, and Washington Department of Fish and Wildlife (WDFW) identified a number of scientific data gaps. As legal co-managers of the local crab fishery, the Tulalip Tribes and WDFW began addressing these data gaps by designing and implementing a collaborative study of local juvenile crab habitat using limited financial assistance from the Snohomish County MRC. In addition to juvenile crab habitat, gravid female habitat was also identified as a data gap by the above-mentioned entities.

The MRC now proposes a two-phase project to identify gravid female crab habitat areas in Snohomish County. Phase I of this project involves the Snohomish County MRC, Tribes, and WDFW partnering to 1) develop a survey protocol to identify and map gravid females, 2) generate a GIS map of potential brood habitat and future survey sites, and 3) generate a budget narrative for actual survey work. Phase II of this project will require underwater surveys of mapped areas to locate gravid crabs and to identify habitat types selected by gravid females.

These data can then be used to promote appropriate means of protection for productive gravid female crab habitat. Findings from this study will help the co-managers and other stakeholders understand the ecological dynamics of local Dungeness crab populations and make informed decisions about how to manage commercial, recreational, subsistence and ceremonial harvest of this valuable marine resource. Study results will also help increase public understanding of the role of local nearshore habitat in sustaining Dungeness crab productivity in Snohomish County.

Brief Summary of Dungeness Crab Biology
Dungeness crabs usually mate from March through June in Washington waters (Cleaver 1949; D.A. Armstrong, unpubl. data). The male crabs are polygamous--each male crab may mate with more than one female crab (Cleaver 1949). Male crabs mate only with female crabs that have just molted (shed their old exoskeleton). Fertilization of the eggs does not occur at the time of mating. The female crab stores the sperm until her eggs are fully developed (Snow and Nielsen 1966). The eggs are fertilized when the female extrudes them under her abdomen where they are carried until hatching (MacKay 1942; Stevens 1982).

After hatching in early spring, the young crabs are planktonic and swim freely away from the female. Larval development takes approximately four months in Puget Sound waters. Larvae develop through six successive stages (5 zoea and 1 megalopa) in the plankton before they molt into the first juvenile stage (Poole 1966). Early juveniles settle within inter-tidal habitats, up to the +5 MLLW tide height (Paul Dinnel, pers. comm.) Crabs along the Washington coast molt about 6 or 7 times in their first year of life (Stevens and Armstrong 1984). During the first two years both sexes grow at similar rates. Juveniles with less than 30 mm carapace width predominantly occupy inter-tidal habitats and prefer some form of cover (Butler 1956). After two years, most crabs approach sexual maturity, and female crabs begin to grow more slowly than the males (Butler 1960). At 4 to 5 years of age, a male

Dungeness crab can be over 6 $^{1}/_{2}$ inches in shell width and weigh between 2 and 3 pounds. It generally takes about 13 or 14 molts for a settling megalops larvae to achieve the legal size of 6 $^{1}/_{4}$ inches in Washington state (Orensanz and Gallucci 1988). A large male Dungeness crab can exceed 10 inches in shell width and the estimated maximum life span is between 8 and 13 years (Alaska Department of Fish and Game 1994).

Gravid Female Biology and Habitat Preference

Mature female crabs generally molt between May-August, and mating occurs immediately after the female has molted and before the new exoskeleton hardens. In October or November, eggs are fully developed and the eggs are extruded and fertilized (Mayer 1973; MacKay 1942). Eggs remain attached to the female's abdomen until hatching in winter (December – February in Washington State). Females are often buried in sand as the eggs develop (Stevens 1982). An egg mass may contain from one to two million eggs (Wild 1983a) and a large female crab can carry 2.5 million eggs (Alaska Department of Fish and Game 1994). Eggs are orange at extrusion and become darker in color as they develop (Cleaver 1949). Change in water temperature is thought to have a considerable influence on the rate of egg development and mortality after fertilization and spawning (Wild 1983b). As water temperature increases, the rate of egg development increases, but so does the mortality rate.

Very little data exist for gravid female habitat distribution or preference in Puget Sound, and there are currently no data for Snohomish County waters. Limited data exist for gravid females caught in commercial crab pots, however precise crab locations are not available. The current belief is that most gravid females use eelgrass beds during egg development (Norris et al. 2001) with some females moving to deeper waters as eggs approach hatching.

Given the lack of knowledge on gravid female crab habitat selection, the objectives of this project are to map the location of relative densities of gravid female Dungeness crab and identify selected habitat types. The intent is to document the position of the gravid female crabs observed with relative accuracy so comparisons can be made between location types. The final product would be a GIS map overlay of the relative density of gravid crab over a given area within and beyond diver depth. There are two phases to this project - this scope of work and associated contract covers Phase I only.

Phase I Objectives:

1) Develop a protocol for identifying and mapping gravid female Dungeness crabs in Snohomish County marine waters.
    - Protocol will be derived from methodologies developed by Gordon 2002, Kenyon et al. 2004, and Kenyon et al. 2006, Roelfsema et al. 2006, Spencer et al. 2005, and finalized with input from the Snohomish County MRC, Tribes, Consultant, and WDFW.

2) Generate a preliminary map of potential brood habitat and future survey areas for gravid female Dungeness crabs. The following GIS layers (identified through Stone and O'Clair 2002) will be incorporated (where possible) in the development of this map.

    Essential Layers:
    - Bathymetry
    - Substrate Type
    - Sediment Grain Size
    - Slope
    - Water Temperature
    - Salinity

    Non-Essential Layers:
    - Intertidal eelgrass
    - Subtidal eelgrass
    - WDFW sport trap data
    - Derelict Gear pot trap data

3) Develop a Budget Narrative for the underwater gravid female survey effort, data analysis, and final report preparation.

Volunteers

Phase I will require volunteer support from Snohomish County MRC members, and the Tulalip and Stillaguamish Tribes in the form of project planning and data sharing. There will be no volunteer support during Phase II due to the nature of the fieldwork.

Phase I: Deliverable Products

This scope of work and associated contract covers Phase I of the project only. The Consultant will produce the following deliverables:

1) The Consultant will provide a series of GIS maps and data that show potential gravid female crab habitat in the waters of Snohomish County, in addition to a final report that describes the GIS mapping methodology employed and the source of the data products used. The Consultant will incorporate existing available scientific data and identify additional sources to develop the map, and will obtain the County's GIS standards to submit maps with required projections, size, formatting and metadata for all GIS products. Deliverables will be phased into a low-resolution map and data set and high-resolution map and data set.

2) The consultant will develop a detailed gravid female survey protocol to field verify the completed preliminary GIS map described above. The survey protocol will incorporate shallow water (<105 ft) diver, deep water Remote Operating Vehicle and investigate possible bottom trawl sampling options. The consultant will review the latest transect survey methodology and statistical analyses and provide recommendations for discussion of the best methods available to accomplish the desired survey results. Development of survey protocol will be in coordination with the County, WDWF Shellfish Biologist, MRC members, and Tribal Biologists.

3) The Consultant will develop a budget narrative for completing Phase II, underwater surveys of mapped areas to locate gravid crabs and to identify habitat types selected by gravid females. The budget estimates will include costs of the surveys as described above, analyzing the data, completed GIS products and producing a final report.

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GIS Mapping of Potential Survey Sites - Overview

Snohomish County marine waters enclose an area of approximately 240 square kilometers of Central Puget Sound (Figure 1). This marine area shares a water boundary with four other counties including Skagit County to the north, Island County to the west, Kitsap County to the southwest and King County to the south. With the exception of Kitsap County, these boundaries split important shallow water habitat for Dungeness crab. A comprehensive survey of gravid female Dungeness crab in these areas would not be limited by county lines and would ideally be undertaken as a multi-county effort to include all areas of interest.

Objectives to design a mapping protocol for potential and actual survey sites will include essential and non-essential GIS layers. Preliminary mapping presented here focuses on bathymetry as the main essential layer – as the major determining factor to provide a scope of area (square kilometers of depth zones) and type of survey by depth zone (dive or ROV).

Bathymetry – Survey Areas and Type

Dive surveys in county waters could be undertaken in marine areas of 120 feet depth or less. County marine waters from 0 to 120 feet comprise approximately 100 square kilometers. Three main areas make up the large majority of this including county waters in Skagit Bay, north Port Susan, and north Possession Sound due west of Everett. Tulalip Bay and the area immediately south of Gedne Island are both smaller but have significant shallow water habitat (Figure 2).

Skagit Bay waters within Snohomish County are made up of shallow intertidal areas much of which is mud and sand flats that become very shallow or dewater at low tides. The outer region of this area is a potential dive survey region mostly in 30-40 foot water of approximately 6 square kilometers (Figure 3). Port Susan waters within Snohomish County have a broader depth spectrum from intertidal flats to areas of greater than 120 feet. Dive survey areas outside of the intertidal mud flats comprise approximately 12 square nautical miles (Figure 3).

Potential dive survey areas in and around north Possession Sound are shown in Figure 4. The main area directly outside of the Everett marina is large and measures approximately 16 square kilometers. This area is also a very high effort sport crab pot area, especially in the southwest portion. The Tulalip Bay dive area is approximately 1.1 square kilometers and includes most of the inner bay and a small zone just outside the bay. Gedne Island dive areas are south of Gedne and enclose approximately 3.3 square kilometers of water

ROV survey areas for gravid Dungeness crab females would extend from the outer dive area depths (120 feet) deeper to approximately 240 feet. These

areas make up 14.1 square kilometers within Snohomish County marine areas and are shown in Figure 5. The narrow depth band covers a broad area north to south in the county waters and focusing survey effort along this range would be likely limited to known areas of crab density from dive surveys where depths go beyond diver limits.

Other Essential Layers

Substrate type will be included in detail in final potential survey mapping. NOAA nautical charts will be overlain and all known bottom types will be digitized and considered. University of Washington oceanographic research maps depicting bottom types in areas of interest will also be included. Sediment grain size will not likely be available to incorporate in survey area design until some dive surveys have been completed. Slope considerations can be derived from known bathymetry and higher resolution bathymetry will lend to this and also be included in the final map summaries. Water temperature and salinity will likely be incorporated on a limited basis. Preliminary dive surveys or field sampling will likely provide some of this information.

Non Essential Layers

Intertidal and subtidal eelgrass layers available at this time are rudimentary. Polyline GIS files of simple shoreline coverages (presence/ no presence) will be expanded upon in final mapping. The inclusion of sport pot/trap data will be helpful in some of the larger potential survey areas where known mixes of both sex crabs are typically captured. WDFW will be compiling and providing whatever data is available for final mapping. NRC has a significant database of information regarding derelict crab pots in Snohomish County that will be included in final mapping. While sex and maturity information of Dungeness crab is not part of this data, the high effort fishing areas are readily known and can be used to focus survey effort.

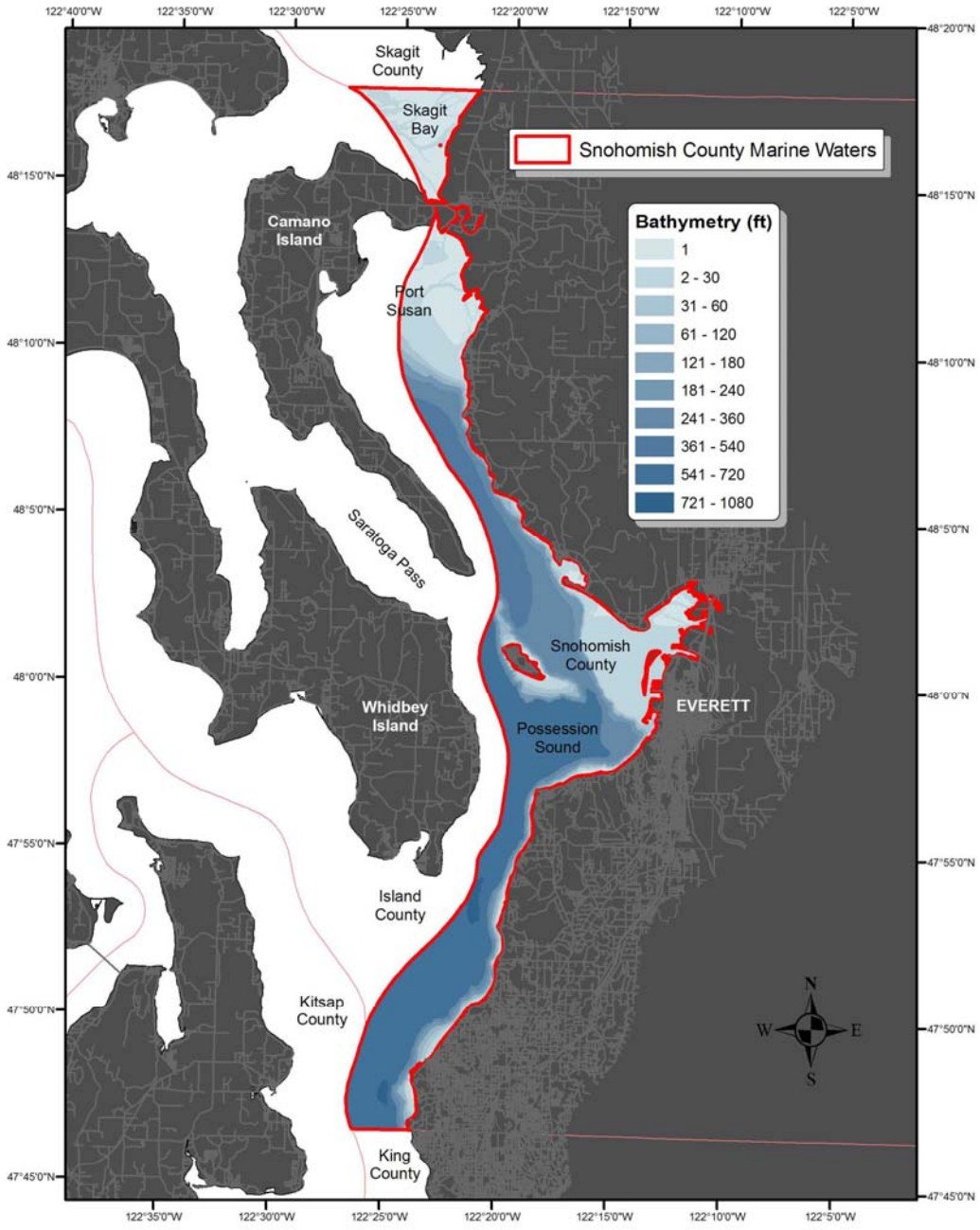

Figure 1. Snohomish County marine waters.

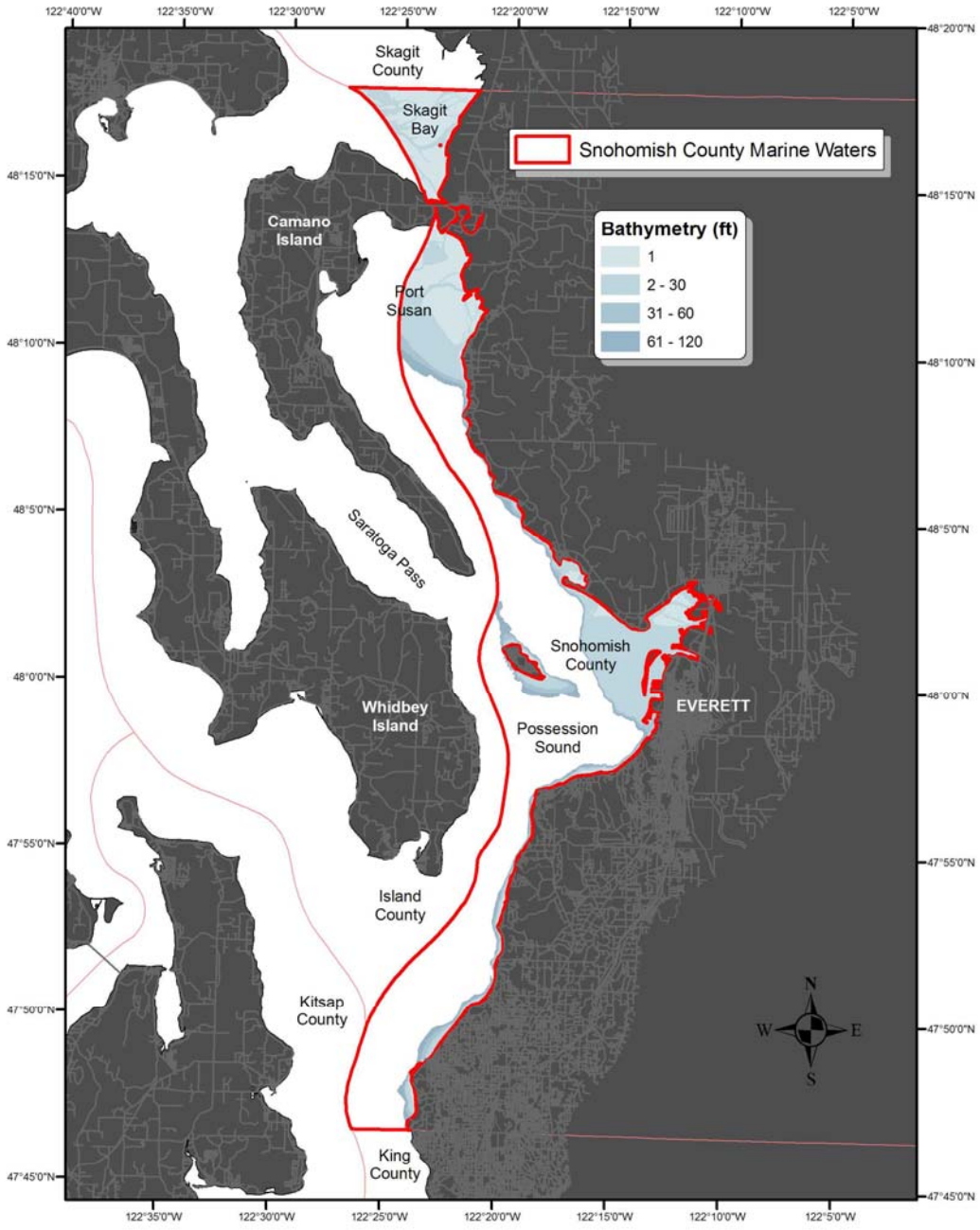

Figure 2. Snohomish County marine waters less than 120 ft depth.

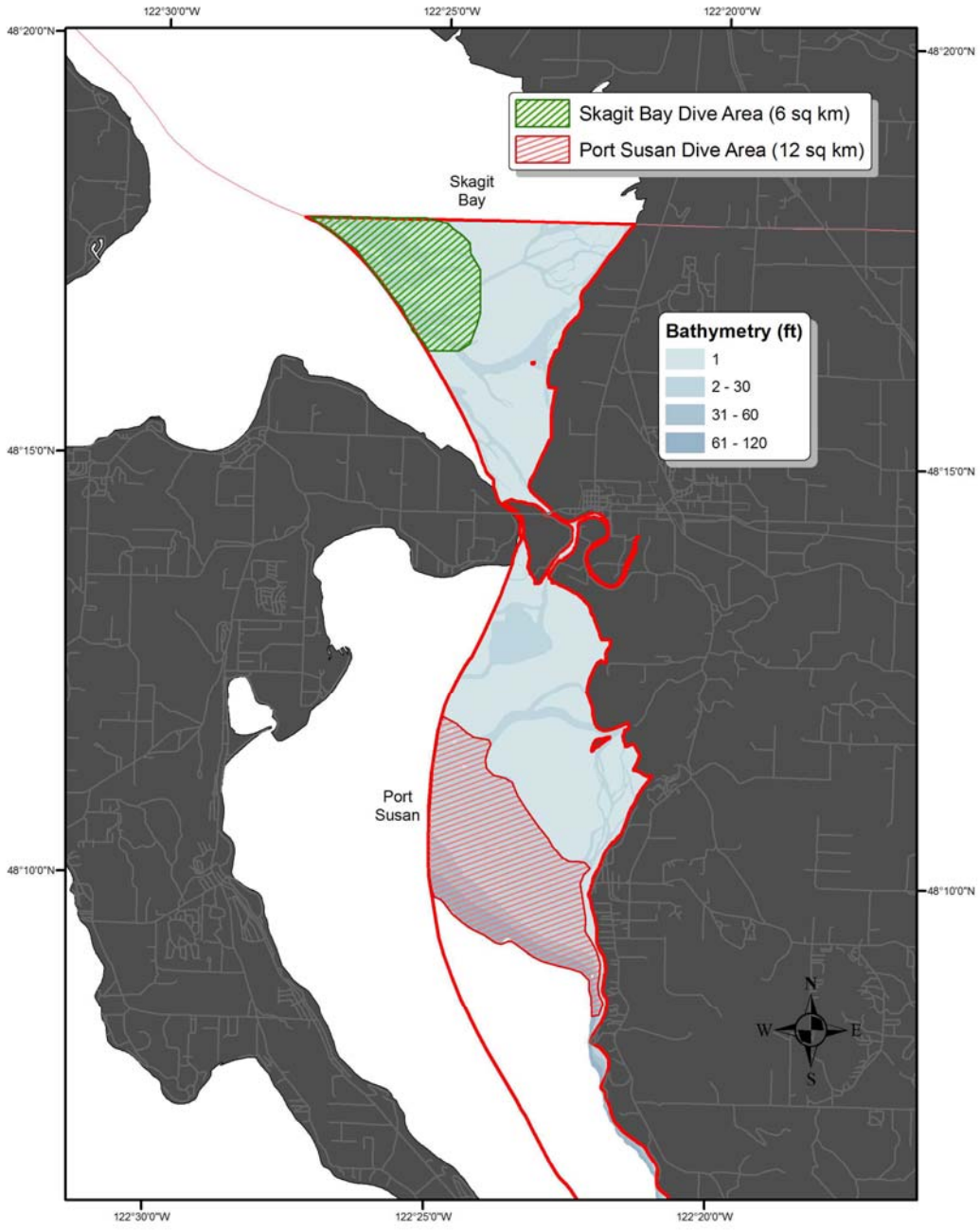

Figure 3. North Snohomish County marine waters potential dive survey areas (Skagit Bay and Port Susan).

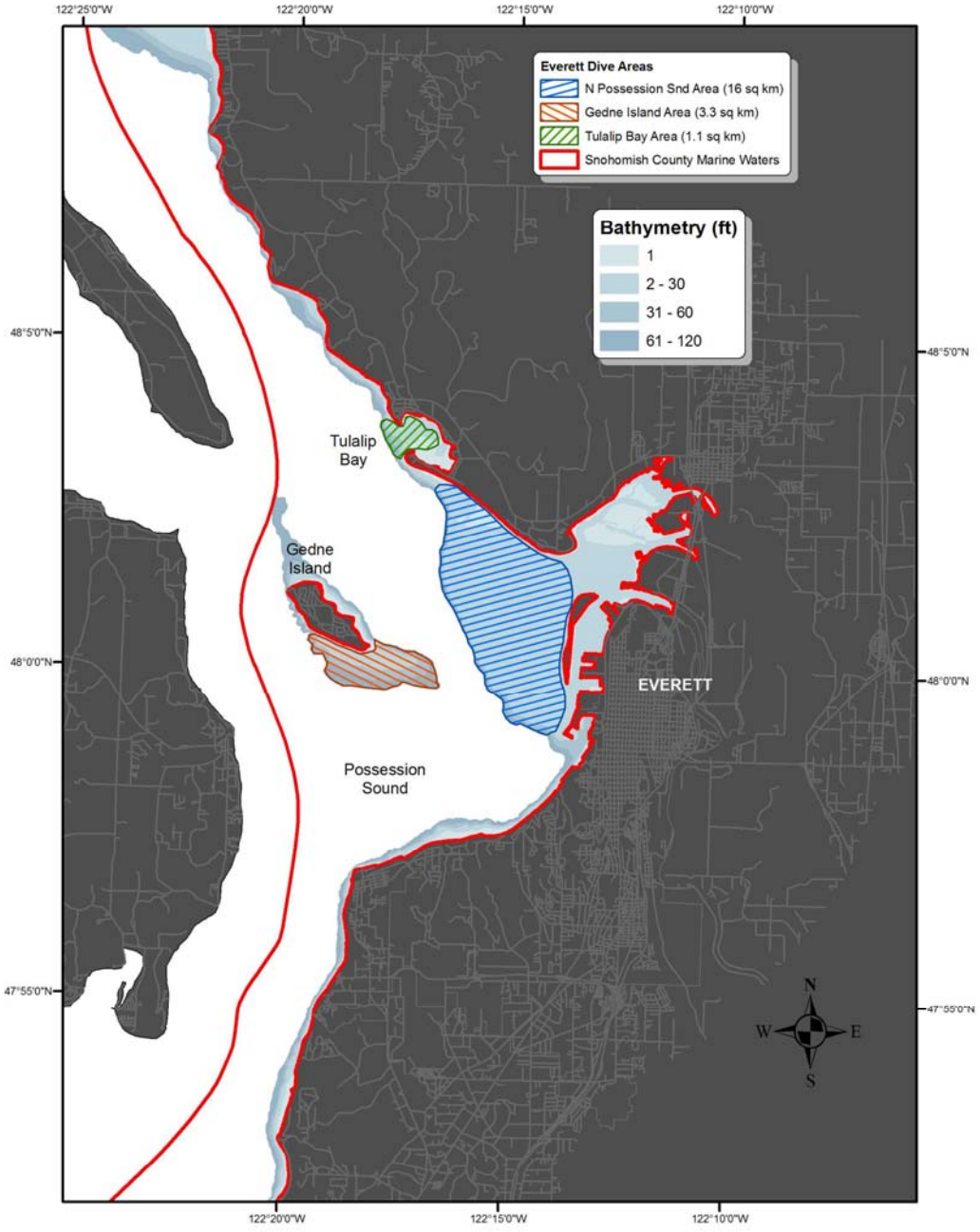

Figure 4. Central Snohomish County marine waters potential dive survey areas (Everett area).

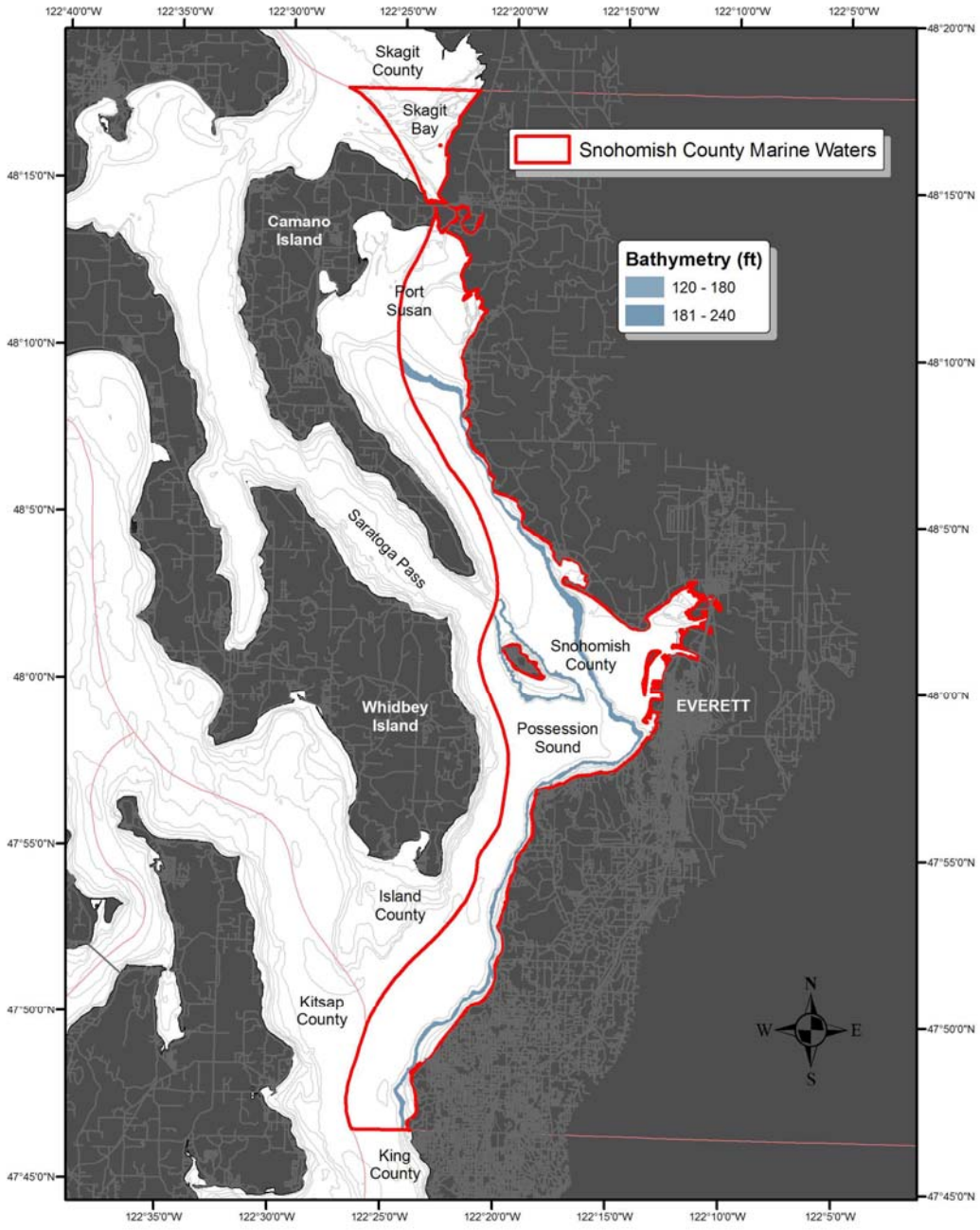

Figure 3. North Snohomish County marine waters potential ROV survey areas.

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Gravid Female Dungeness Crab Survey Protocol

Prepared for
Snohomish County

Prepared by
Natural Resources Consultants, Inc.

June 27, 2007

Background

In 2001, the Snohomish County Marine Resources Advisory Committee (MRC) identified Dungeness crab stewardship as a high priority for marine resource conservation in Snohomish County. This decision was based on the social, economic, and ecological importance of the crab fishery to a broad range of stakeholders within the local community. In pursuit of answers to questions about how to sustain this fishery, the Snohomish County MRC, Tulalip Tribes, and Washington Department of Fish and Wildlife (WDFW) identified a number of scientific data gaps. As legal co-managers of the local crab fishery, the Tulalip Tribes and WDFW began addressing these data gaps by designing and implementing a collaborative study of local juvenile crab habitat using limited financial assistance from the Snohomish County MRC. In addition to juvenile crab habitat, gravid female habitat was also identified as a data gap by the above-mentioned entities.

The MRC now proposes a two-phase project to identify gravid female crab habitat areas in Snohomish County. Phase I of this project involves the Snohomish County MRC, Tribes, and WDFW partnering to 1) develop a survey protocol to identify and map gravid females, 2) generate a GIS map of potential brood habitat and future survey sites, and 3) generate a budget narrative for actual survey work. Phase II of this project will require underwater surveys of mapped areas to locate gravid crabs and to identify habitat types selected by gravid females.

These data can then be used to promote appropriate means of protection for productive gravid female crab habitat. Findings from this study will help the co-managers and other stakeholders understand the ecological dynamics of local Dungeness crab populations and make informed decisions about how to manage commercial, recreational, subsistence and ceremonial harvest of this valuable marine resource. Study results will also help increase public understanding of the role of local nearshore habitat in sustaining Dungeness crab productivity in Snohomish County.

Snohomish County contracted with Natural Resources Consultants, Inc., (NRC) of Seattle to assist in the development of the GIS products under Phase I of the project and to develop a gravid female Dungeness crab field survey protocol. This document provides an overview of the products anticipated from the Phase I analyses and a recommended survey protocol for the Phase II field sampling of gravid female Dungeness crab in Snohomish County.

Phase I Products

Phase I of the project involves developing GIS layers of data elements that may be important determinant factors in preferred habitats for gravid female Dungeness crab. Available data on what is believed to be essential and non-essential habitat characteristics will be plotted on a navigation charts. The essential habitat characteristics are based on analyses conducted by Stone and O'Clair (2002) on gravid female Dungeness crab preferred habitat in a southeastern Alaska estuary. Non-essential data layers are information available that may assist in refining the selection of areas of preferred habitat for gravid female crab.

Essential Layers:

- Bathymetry
- Substrate Type
- Sediment Grain Size
- Slope
- Water Temperature
- Salinity
-

Non-Essential Layers:

- Intertidal eelgrass
- Subtidal eelgrass
- WDFW sport trap female crab catch data
- Derelict Gear pot trap female crab catch data

Crab experts from Snohomish County, local Tribes, WDFW and other organizations will review the results of the Phase I GIS to hypothesize the habitat characteristics believed to be preferred by gravid female Dungeness crab. The GIS layers will be queried in ArcInfo® for overlaps of areas of habitat characteristics (depth, substrate type, sediment grain size, slope, temperature and salinity) meeting the hypothesized preferred habitat characteristics. Non-essential GIS layers will be overlain on the hypothesized preferred habitat to indicate if gravid female catch data and eelgrass distribution support the distribution of the hypothesized preferred habitat areas. Areas will be earmarked for Phase II field surveys of habitat type and gravid female crab relatively abundance in order to test the preferred habitat hypothesis.

Phase II Survey Protocol

Purpose, Goals, and Anticipated Deliverables

Very little data exist for gravid female habitat preference in Puget Sound, and there are currently no data for Snohomish County waters. Limited data exist for gravid females caught in commercial crab pots, however precise crab locations are not available. The current belief is that most gravid females use eelgrass beds during egg development (Norris et al. 2001) with some females moving to deeper waters as eggs approach hatching. The purpose of the proposed Phase II gravid female Dungeness crab survey is to test the hypotheses of preferred habitat characteristics and increase information about gravid female crab distribution relative to habitat type in Puget Sound and specifically Snohomish County. If the preferred habitat characteristics of gravid female crab can be determined, the GIS products from Phase I of the project should provide the distribution and abundance of preferred habitat in Snohomish County and lend additional information on important habitat for Dungeness crab throughout Puget Sound.

Given the lack of knowledge on gravid female crab habitat selection, the goals of the project are to map the location of relative densities of gravid female Dungeness crab,

describe their observed preferred habitat characteristics and test the hypothesis of preferred habitat developed by regional experts. The final product would be a GIS map overlay of the relative density of gravid crab, descriptions of habitat characteristics over the areas surveyed and a statistical test of the hypothesized preferred habitat use by gravid female Dungeness crab. Data collected during the survey may also provide for additional statistical analyses to further refine preferred habitat parameters.

Survey Methods

Two types of survey methods are anticipated for the Phase II field survey, a towed diver survey of shallow water (<90 ft) and a remote operated vehicle survey of deeper water (90 to 250+ ft). Both surveys will employ a fixed transect approach, in that transect lines will be predetermined and closely followed. Transects will be determined from Phase I GIS layers to cover hypothesized preferred and non-preferred gravid female Dungeness crab habitat. Generally, transects will be designed to cover similar habitat (depth, substrate type and size, and slope) within a particular transect. Transects may vary by length depending upon the continuity habitat characteristics. Each transect will be considered a separate sample.

Diver Survey

A diver equipped with SCUBA gear will be towed behind a 200-300 lb clump weight suspended under the survey vessel. The heavy weight of the clump will allow it to be positioned a known fixed distance (layback distance) from the onboard differentially corrected GPS antennae. A low light underwater video camera system equipped with optional underwater lighting system will be attached to the clump weight to record seabed habitat characteristics along the survey track line. Two laser range finders will be positioned so that the laser image on the seabed is visible in the video image and allow the survey crew on the vessel to determine the height of the clump weight off the seabed and depth of field of the video image. The height of the clump weight off the bottom will

be constantly controlled on the survey vessel with an onboard winch using the laser range finders displayed on the onboard video feed as an indication of the distance between the clump weight and the seabed.

The image from the video will be recorded on the survey vessel on a digital recorder either on tape or on a hard drive. A date and time stamp, latitude and longitude and water depth will be overlain on the recorded video image. The diver will be equipped with a two-way communication system with the survey vessel. The divers audio feed will also be recorded on the digital videotape recording.

The survey transects will be programmed into a hydrographic survey navigation software package (Hypack® or other) and the course of the vessel accurately (<1 m) monitored and tracked during the survey with a high-end GPS system. The survey vessel will approach the start of the transect line and deploy the clump weight to the proper depth off the seabed (5 to 10 ft depending upon visibility). The diver will then enter the water and position him/herself behind the clump weight and conduct an equipment check. The boat crew will advise the diver when the transect line is started and the diver will begin surveying for gravid female Dungeness crab. Typically, only the crab's eye stocks and mouthparts are visible. Divers should have experience identifying buried crab.

The survey vessel will proceed along the transect line at approximately 1 to 1.5 nautical miles per hour (knots). The vessel employed must have low speed course keeping capabilities (bow thruster or twin engine). Based on previous experience, depending upon water clarity and light conditions, a single diver should be capable of visually surveying 15 ft on either side of the transect centerline for Dungeness crab. However, the diver will provide an estimate of the visual survey range to either side of the transect line for each survey transect conducted. The survey will cover approximately 8,500 m^2/hr (0.0025 nm^2/hr).

Gravid female Dungeness crab are typically buried in soft substrate. Upon seeing a buried crab the diver will report the relative position of the crab to the clump weight when the crab is perpendicular to the survey line (distance in feet or meters and left or right of the clump weight). The diver will leave the clump weight and quickly inspect the crab to see if it is gravid, report habitat characteristics of the location (depth, sediment type, relative sediment grain size and the presence of absence of eelgrass or other vegetation) and rejoin the clump weight to continue the survey. The vessel may slow or stop the survey while the diver leaves the clump weight or temporarily suspend the survey and make a turn and rejoin the survey line and pick up the diver to continue the survey. The location (latitude, longitude, distance and direction from the transect line and water depth) of gravid female crabs observed will be recorded on the survey vessel. Transect lengths will vary but be limited by available diver dive time. The vessel will have a minimum crew of three divers who will double as surface vessel operators and data recorders.

Remote Operated Vehicle Survey

Diver surveys deeper than 90 ft are greatly limited by dive time and the potential for decompression dives raises safety issues. Remote operated vehicles (ROV) have been proven effective for deepwater surveys in a variety of applications. The basic methodology for the ROV survey is similar to that used for the diver survey. Survey transects are laid out in a hydrographic navigation software package. A clump weight is deployed and the ROV is positioned behind the clump weight. An acoustic tracking device is positioned on the ROV to constantly measure the position relative to the onboard GPS antennae.

The ROV is equipped with two low-light video cameras that overlap their images on the center line and have a field of view of about 15 ft (similar to the divers view range) to the left and right. Laser range finders are positioned to show the field of view and maintain the distance between the clump weight, ROV and the seabed. Additional lighting can be

provided on the ROV video cameras, if necessary. The vessel tows the clump weight and ROV along the transect line and the video image, time stamp, latitude and longitude and depth are recorded onto a digital recorder. A voice track of the survey operator can also be recorded on the digital video image.

When a crab is sighted, the location along the transect line is noted, the survey is stopped and ROV can be released from the clump weight and maneuvered to the location of the buried crab. A manipulator arm or a scoop ring installed on the ROV can be used to disturb the crab and assess whether it is a gravid female Dungeness crab. The ROV then returns to the position on the clump weight, the vessel is repositioned at the previous position on the transect line and the survey continued. The survey crew, using the video cameras on the ROV can assess the habitat characteristics at the location of the gravid female crab and collect similar information provided by the divers, This information can be recorded in a written log and verbal observations recorded on the digital video recording.

ROV operations can be conducted at depths of up to 600 ft, but from a practical standpoint, 250 ft is a reasonable maximum depth for crab surveys using an ROV. The ROV will survey at a speed of about 1 knot, similar to the speed of the diver survey, cover a similar path width along the transect line and cover approximately the same 8,500 m^2/hr (0.0025 nm^2/hr) area per hour of survey time.

Other Potential Survey Data

Since the precise location of each gravid female Dungeness crab encountered on a survey transect will be recorded, it will be possible to return to the location and collect additional habitat information, either on the same day as the survey or at a later time. CTD units could be used to measure temperature and conductivity (salinity). Sediment samples could be collected, either by divers or with a surface deployed sediment sampler for sediment type, grain size and compaction analyses. Slope angle can also be determined

either by taking depth soundings along a transect line or by a diver reporting depths at different distances away from the crab location.

Data Products, Analyses and Deliverables

Both surveys will provide density estimates (number of crab per unit area surveyed) of gravid female Dungeness crab and observed habitat characteristics by transect sample. Post-survey processing of the digital video recordings will allow a thorough review of the habitat characteristics. The hydrographic navigation software will provide the track line and the seabed area covered during the survey. A habitat expert reviewing the videotapes can produce a running habitat type analyses that is geo-located using the position information recorded on the videotape. This information can be input into a GIS system to ground truth the habitat layers produced in Phase I. Habitat type between the transect lines can be extrapolated using standard GIS interpolation processes to produce an overall area habitat type map.

Final project products will include a GIS layer showing the area surveyed, counts and densities of gravid female Dungeness crab by survey transect, a GIS layer showing the location of observed gravid female Dungeness crabs, a table listing the locations (latitude and longitude) of locations of gravid female Dungeness crabs and habitat characteristics observed at those locations and a statistical analysis testing the hypothesis that the hypothetical preferred habitat had significantly higher density of gravid female Dungeness crab than hypothetical on-preferred habitat.

Equipment

Vessel

Survey vessel with station-keeping capabilities, able to support both divers and ROV operations. Minimum of 40 ft length, 12 ft beam, working deck space, twin engine or single engine and bow thruster.

Additional Vessel Equipment:

Generator 7Kw or larger

Depth Sounder (Echo Track 3 or similar with NEMA output)

Differentially corrected/WAAS GPS (Trimble DSC232RTK or similar)

Chart Plotter (Garmin, Nobeltec or similar)

ROV winch and umbilical handling system (350 ft minimum)

Clump weight winch with depth control (300 ft minimum)

Electronic equipment rack (weather protected with electrical and data connections)

Hydrographic navigation software (Hypack or other)

Acoustic tracking system surface equipment (Linkquest USBL or other)

Computers (2)

Remote Operated Vehicle

The ROV should be capable of working in moderate currents common to Puget Sound. At a minimum the ROV should be capable of 2 HP forward thrust and ½ HP lateral thrust.

Additional ROV Equipment:

Two (minimum) high-resolution digital video cameras (DV25, HD or machine vision grade) with housings and lights to 300 ft depth

Single function manipulator

Scanning sonar (MS 100 or other)

Range finding lasers (2)

Biaxial clinometers (Applied Geomechanics, Microstrain or other)

Data acquisition cards, video overlay board, cables, monitor, etc.

Acoustic tracking device (Link

Depth sounder (with bottom type discrimination if available)

Water temperature probe

Diver Equipment

SCUBA equipment for three divers with backup gear. Standard equipment for Puget Sound waters, dry suit, weight belt, buoyancy compensator, dive computer, SCUBA tank and regulator, wireless communication system.

Other Possible Equipment

CTD

Sediment sampler

Anticipated Costs

Diver Survey

Diver survey cost for three divers and the vessel should be approximately $2,860 to $3,000 per survey day. If a project manager/biologist is included the cost would be an additional $660 per survey day.

ROV Survey

The ROV equipment cost is typically charged a 1% of equipment value per survey day. The ROV equipment value necessary for the gravid crab survey is estimated at $270,000 resulting in a daily equipment charge of $2,700 per day. The vessel/crew charter costs are about $2,200/day. The typical charge for an onboard project manager is $660 per day. Total daily cost for the ROV survey would range from $5,000 to $5,500 per day.

Analyses and Reporting

Costs are dependent upon the level of analyses desired. To develop the table and GIS layers of observed habitat characteristics and crab locations, conduct the statistical analyses and produce a final report would probably run $3,500 to $5,000. More extensive statistical analyses such as principal components or cluster analyses would probably add another $3,000.

Safety Plan

The contractor hired for the survey work should submit a safety plan for both the diver and ROV survey components. Each company typically has their own safety plan format. However, at a minimum the safety plan should include the following:

All diving operations must be in compliance with the diving safety requirements of the appropriate State (WISHA) or Federal (OSHA) Agency.

At a minimum, dive team members shall have experience working in confined space environments and overhead obstructions. All personnel associated with the diving operation shall have current training in CPR, first aid, and emergency oxygen administration. Emergency oxygen must be available on the survey vessel.

Diving operations will be confined to depths less than 100 feet of water and within the no-decompression limits of the US Navy Standard Air Tables.

All dive operations should be fully explained in a dive plan read and understood by all divers prior to starting daily operations. A dive supervisor should be identified to be responsible for all daily dive operations.

An emergency medical evacuation plan should be developed and maintained on the vessel. The medical evacuation plan should include a description of available evacuation methods (helicopter, fast boat, etc.), the closets medical facilities available for both general medical assistance and dive-related injuries (decompression chamber). Contact numbers for all evacuation means and medical facilities should be available. The plan should designate an emergency medical evacuation supervisor and a backup person.

A detailed plan for vessel operation procedures while divers are in the water should be developed. The plan should address potential dangers to divers from vessel operations and provide policies and procedures to eliminate accidents.

A ROV operations safety plan must be prepared providing procedures to follow during ROV operations. Particular attention should be paid to winch operations and high-

voltage use. The plan should designate an ROV supervisor to control all aspects of the ROV operation.

References

Stone, R.P. and C.E. O'Clair. 2002. Behavior of female Dungeness crabs, *Cancer magister*, in a glacial southeast Alaska estuary: homing, brooding-site fidelity, seasonal movements, and habitat use. J. of Crustacean Biology, 22(2): 481-492.

Anticipated Costs to Conduct a Gravid Female Dungeness Crab Survey in Snohomish County

Diver Survey

Diver survey cost for three divers and the vessel should be approximately $2,860 to $3,000 per survey day. If a project manager/biologist were included the cost would be an additional $660 per survey day for a total of $3,520 to $3,660 per day.

ROV Survey

The ROV equipment cost is typically charged a 1% of equipment value per survey day. The ROV equipment value necessary for the gravid crab survey is estimated at $270,000 resulting in a daily equipment charge of $2,700 per day. The vessel/crew charter costs are about $2,200/day. The typical charge for an onboard project manager is $660 per day. Total daily cost for the ROV survey would range from $4,900 to $5,560 per day.

Analyses and Reporting

Costs are dependent upon the level of analyses desired. To develop the summary table and GIS layers of observed habitat characteristics and crab locations, conduct the statistical analyses and produce a final report would probably cost $3,500 to $5,000. More extensive statistical analyses would probably add another $3,000 to the final reporting cost.

Total Survey Cost

Divers should be capable of conducting six to eight, 30 minute or longer transects per day. ROV operations should be capable of completing four to six deepwater survey transects each day. The number of survey days and transect samples necessary will depend upon the variability of gravid female Dungeness crab density observed and the number of habitat types or variables statistically analyzed.

The following table provides a hypothetical survey budget for collecting about 20 survey transect samples in both deep and shallow water.

Survey Method	Number of Days	Number of Samples	Daily Cost	Total Cost
Diver	3	20	$3,660	$10,980
ROV	4	20	$5,560	$22,240
Total	7	40		$33,220
Analyses and Reporting				$ 8,000
			Total Survey Cost	**$41,220**