CANADIAN POLICE RESEARCH CENTRE
CENTRE CANADIEN DE RECHERCHES POLICIÈRES
THE SCIENCE OF SAFETY AND SECURITY
LA SCIENCE DE LA SÉCURITÉ
www.cprc.org

TR - 09 - 2002

DETERMINATION OF TIME OF DEATH FOR HUMANS DISCOVERED IN SALTWATER USING AQUATIC ORGANISM SUCCESSION AND DECOMPOSITION RATES

Date: 2002

Authors:

Gail S. Anderson, M.P.M., Ph.D.
and
Niki Hobischak, B.Sc.(Honours), M.P.M.

TECHNICAL REPORT
CANADIAN POLICE RESEARCH CENTRE

DETERMINATION OF TIME OF DEATH FOR HUMANS DISCOVERED IN SALTWATER USING AQUATIC ORGANISM SUCCESSION AND DECOMPOSITION RATES

Gail S. Anderson[1], M.P.M., Ph.D.

and

Niki Hobischak[2], B.Sc.(Honours), M.P.M.

[1] Diplomate American Board of Forensic Entomology, Associate. Prof. School of Criminology, Director, Forensic Entomology Laboratory, Simon Fraser University, Forensic Entomology Consultant

[2] Research Coordinator, Forensic Entomology Laboratory, Simon Fraser University.

EXECUTIVE SUMMARY

Forensic entomology is the study of insects associated with a dead body in order to determine time since death, which may be used to assist in human death investigations. This concept has recently been applied to aquatic environments to determine elapsed time since submergence. Many dead humans are found in the ocean, either as drowning victims, or as homicide victims that have been disposed of in what appears to be a convenient area for such dumping. In order for this concept to be of value, data must be generated on aquatic organism succession and decompositional stages on carrion in the context in which it is to be used. Therefore this marine research was conducted over 2 years, examining different seasons near Popham Island in the Howe Sound area of British Columbia, Canada. This research investigated faunal colonization and decompositional changes on carrion in spring and fall. These data can now be used in human death investigations in this region of Canada for marine cases.

DETERMINATION OF TIME OF DEATH FOR HUMANS DISCOVERED IN SALTWATER USING AQUATIC ORGANISM SUCCESSION AND DECOMPOSITION RATES

Gail S. **Anderson**, M.P.M., Ph.D., and Niki **Hobischak**, B.Sc. (Honours), M.P.M.,
School of Criminology, Simon Fraser University, Burnaby, B.C.

ABSTRACT

Research to establish a database of aquatic organism succession on carrion in the marine environment was conducted in spring and fall 2000 and extending to spring 2001. Pig carcasses were used as human models and were placed out near Popham Island in the Howe Sound area of British Columbia, Canada. Invertebrate succession and decompositional descriptions were observed for two seasons, spring and fall. These data may assist in determining time of submergence; hence time of death, in human death investigations, particularly homicides.

ABSTRACT (Non-Technical)

Forensic entomology, or the study of the insects which colonize human remains, can be used to accurately determine time elapsed since death up to a year or more after death. It has proven invaluable in many homicide cases. However, insect colonization rates and patterns vary from environment to environment. Therefore, data from a terrestrial scenario can not be applied to a marine environment. Pig carcasses were submerged off the coast of Vancouver, B.C. to establish a database including invertebrate succession and decompositional descriptions. This research is immediately valuable in analyzing cases currently pending, as well as future cases.

INTRODUCTION

Forensic entomology is the study of insects associated with a dead body in order to determine time since death, which may be used to assist in human death investigations. Insect colonization on carrion in terrestrial environments has been extensively researched, particularly in British Columbia; however, little is known about the fauna colonization in the marine environment.

One of the most understudied areas, forensically, is that of the marine environment. British Columbia has a vast coastline, which is used extensively for recreation, and of course, for criminal purposes as well. Therefore, the Vancouver region is the obvious area to begin research on submerged carrion, due to the proximity to the ocean, and the high numbers of remains recovered from this area.

A human corpse goes through a range of rapid and complex chemical and biological changes during decomposition, from immediately after death to months and even years after death. In a terrestrial situation, different species of insects are attracted to different stages of decomposition, at different times after death. From an analysis of the insects on the remains, and the insect evidence left by previous insect species, an entomologist can determine the elapsed time since death in terrestrial environments. This technology is now commonly used in homicide investigations across North America (Anderson & Cervenka 2001, Anderson 2001, Anderson 1999, Anderson 1995).

Literature on human remains in the marine environment is very limited (Sorg *et al.* 1997) and mostly consist of forensic casework (Kahana *et al.* 1999, Boyle *et al.* 1997, Ebbesmeyer and Haglund 1994, Haglund 1993, Davis 1992). At the present time, there are no effective methods for determining time of death of human or any mammals found

in water. Also decompositional rates and patterns have not been studied in marine environments. Insect succession on homicide victims is now commonly used to determine elapsed time since death in Canada. Most recently, a preliminary database for carrion in freshwater habitats has been created (Hobischak and Anderson 2002, Hobischak 1997, MacDonell 1997). In addition to invertebrate succession, time of submergence determinations, and decompositional rates in freshwater, a comparison was made with human death investigations (Hobischak and Anderson 1999, Hobischak 1997). The results indicated that there was almost no understanding of decomposition in water, and pathologists usually determine time of death simply by determining when the person was last seen alive, which may be extremely inaccurate, particularly in a homicide case.

Bodies in marine situations often do not refloat, depending on depth, as pressure from the water prevents the expansion of gases (Teather 1994). There are a few examples of case studies using aquatic insects (Hawley *et al.* 1989; Siver *et al.* 1994) but these are rare, and frequently inaccurate due to a lack of correct data. There have been little published case histories using marine invertebrates, and little information on marine taphonomy (Boyle *et al.* 1997, Sorg *et al.* 1997). No experimental work has been performed on the actual aquatic succession on corpses in marine environments, despite the fact that the potential is enormous.

There are several factors that could potentially be used in determining the length of time of submergence including succession of invertebrate fauna on the remains, presence of specific life stages of invertebrates or structures associated with them (Sorg *et al.* 1997). In particular, in the marine environment, skeletonization may be very rapid depending on factors such as season, organisms present, depth, clothing, presence or

absence of wounds *etc*. After skeletonization, some species may find that bones themselves are an inviting substrate (Sorg *et al.* 1997).

Aquatic ecology studies indicate that organisms colonize a substrate dependent on many measurable factors, such as size of object, texture, position, flow of water, water temperature, current speed, water depth, presence of aquatic flora and fauna etc. (Sheldon 1984). Some marine organisms involve a free swimming larval stage, which will settle on a suitable object and moult to the adult sessile stage. They will remain on this substrate for the rest of their lives, growing incrementally and predictably, ie. a barnacle. The growth of this organism may indicate a time since skeletonization and hence assist in determining time since submergence.

The marine environment is the only habitat which is not dominated by insects, however, it is home to a vast array of close relatives, the invertebrates. It is very probable that these will colonize remains in a predictable sequence in the same manner as insects. The objectives of this study were to develop a system to determine time of death on bodies disposed of in the ocean, using arthropod succession. As well, this work will address decompositional rates and patterns of remains in water as this is a vastly under-studied area.

METHODS AND MATERIALS

Research Site

The location of the research was approximately 30 minutes from Horseshoe Bay, by boat. The individual carcass sites were away from the shoreline of Popham Island, which is a research site, operated by the Vancouver Aquarium Marine Science Centre

(Figure 1). This area is privately owned by Mr. Rudy North and closed to the public. This research examined carrion decomposition at two depths, approximately 7.6 m (25 ft) referred to as shallow and 15.2 m (50 ft), deep. However, these depths altered anywhere from 1.5-3 m (5-10 ft) due to the high and low tides. Description of site, sediment type, depth of anchor placement, average depth and pig weight are summarized in Table 1.

Research Proposal

Pigs (*Sus scrofa* L.) were used as models for human decomposition as they are omnivorous, with a digestion very similar to that of human. They are relatively hairless and have skin so similar to that of humans that it can be used in human skin grafts. A 23 kg pig has traditionally been used as a model because it's a convenient size to carry, equivalent to an average adult male torso which is the main site of decomposition and insect colonization, and is recognized as an excellent human decompositional model (Catts and Goff 1992). Pigs used for these experiments were between 20 – 25 kg (44 -55 lbs) as suggested by the Vancouver Aquarium staff to avoid over stimulation of the environment. However larger pigs may have given a representation of decomposition in the marine environment.

Pigs were sacrificed by the butcher, using a pin gun which did not involve draining the blood. These freshly killed pigs were driven to the dock where the RCMP's Nadon (Figure 2) immediately transported the pigs and divers to Popham Island (Appendix I). Then smaller vessels, the Nadon's Zodiac (Figure 3) and the Aquarium research boat (23 ft Kellehan aluminum work boat) (Figure 4), were used to transport the pig carcasses to the research sites. Three carcasses were placed in the shallow sites and

three at deep locations. Each naked pig carcass was bound with nylon rope (Figure 5, 6) and anchored to the sea floor by concrete blocks, which were placed previously (Figure 7). An additional 2 m (6ft) of nylon rope attached to each carcass allowed the body to float or rest on the sediment, depending on decompositional stage. This set-up procedure (Appendix I) was repeated with the experiment beginning October 14, 2000. Summary of site and carcass specifics for the fall experiment is located in Table 2.

Examination and Sampling

The carcasses were visited at varying frequencies depending on decompositional rate, diver availability (Figure 8) and boat accessibility (Figure 9-12). Generally, each carcass was photographed, video taped, and visually examined *in situ* by divers to prevent any unnecessary disturbances to the fauna. For the experiment beginning May 16, 2000, carcasses were sampled at 6-7 h elapsed time since submergence (ETSS), 12-13 h, 21-21.5 h, 3 days, 11, 30, 40, 47, 54, 116, and 140 days ETSS.

For the experiment beginning October 14, 2000, carcasses were examined at 19 days, 26, and 33 days using the same manner. At 35 days, 12S was photographed and visually examined *in situ*, put into a plastic container and then brought to the surface for a more thorough examination (Figure 13). At this time microscopic organisms were collected and preserved for later identification (Figure 14). At 48 days, 10D was examined in the same manner as above.

On the termination day of both experiments, October 14, 2000 and May 26, 2001, all sites were visited and remains were photographed, bagged, and brought to the surface. On the shore, the remains were closely examined, photographed, and macroorganisms

were collected with forceps then preserved in ethanol. All remains and collected organisms were transported to the laboratory for proper identification and storage.

At the laboratory, all remains were rinsed with distilled water, and examined with a microscope. All organisms were collected and preserved in alcohol. The rinsate from the remains was also examined under the microscope for microorganisms. All organisms were identified using appropriate keys (Sept 1999, Harbo 1997, Jensen 1995, Gotshall 1994, Kozloff 1987, Lamb and Edgell 1986, Griffith 1967). Remains were organized by site and photographs were taken. Bones were then placed in plastic bags and frozen for any future examinations.

RESULTS

Results and discussion are focused mainly on the summer experiment due to the more frequent sampling dates. If observations and statements refer to the fall experiment these will be indicated as such.

Decomposition

Decomposition in salt water appeared much slower than in terrestrial environments. Typical decompositional characteristics associated with aquatic habitats were observed including lividity, bloating, marbling, hair shedding, skin sloughing, scavenging, adipocere formation, flesh decaying, exposure of internal organs, algae accumulation, silting, disarticulation of bones, and algae staining on bones (Hobischak and Anderson 2002) (Table 3 and 4). Decompositional stages that were clearly observed on all carcasses in the spring experiment included fresh, bloat, active decay and remains;

however sequence of decomposition is not exclusive to only these stages. Differences were observed between decomposition of carcasses which floated versus those that had contact with the sediment for the majority of the experiment.

For the summer 2000 experiment, by 6-7 hours ETSS, one pig carcass in each "habitat" shallow and deep water was not floating and had contact with the sediment. These two pig carcasses (1S, 4D) had contact with the sediment for the remainder of the experiment (Table 3). One pig carcass (5D), floated immediately and remained floating until day 47, when its nose made contact with the sediment; however the rest of body remained floating until the following sampling date. Two carcasses, (2S, 6S) had sunk by 12-13 hours; however, by day 30, they were observed floating again. By day 47, 2S had sunk back to the sediment but 6S remained floating along with 3D. No comment can be made on when 3D "refloated" due to technical difficulties; 3D was not observed on day 47. Carcass 6S and 3D were observed on the sediment on day 54.

Due to problems obtaining divers, the first sampling date for the fall experiment beginning October 14, 2000 was 19 days; therefore no comment can be made on whether the carcasses immediately floated or sank. By day 19, 11D and 12S were still floating, and there was no observation for 7S. Carcass 8S had its head wedged between two rocks and 10D had its head in the sediment. Carcass 9D was the only one observed at this time lying on the sediment. By day 33, carcass 7S was the only one to have complete contact with the sediment. Carcass 9D was floating; however the nose had contact with the sediment. All other carcasses were floating at the extent of the rope at this time. The next sampling date was day 225 or the recovery date; therefore no further comment can be made regarding the refloat of the carcasses.

By 6-7 hours, 4 carcasses were floating, 2 had contact with the sediment and one pig exhibited lividity on its back (Table 3). By 12-13 hours, all coagulated blood from the wound on each pig was removed. Pigs still looked fresh and two pigs showed lividity. Silt was starting to accumulate on carcasses. By 21-21.5 hours, carcasses were covered in silt and one carcass had reds marks on the back of the hocks, possible feeding damage. By day 3, most carcasses had white "frayed" margins on ears and some bloating was evident. One carcass had a white "digested" area on rear end, (possible scavenging by sea stars 2 days prior). Small crabs were observed tearing the flesh off one pig carcass. By day 11, flesh was decaying, significant scavenging had occurred, ears were scavenged; bare patches, exposed bone, hair shedding, and skin sloughing were observed. Two carcasses had noses with contact with the sediment and adipocere appeared to be forming. Three carcass had varying degrees of bloat. Silt and algae were accumulating on the carcasses (Table 3).

For the fall experiment, by day 19, two carcasses were observed floating. All carcasses were scavenged with some skeletonization of the skull, and one had its internal organs exposed (Table 4). Skin sloughing was significant and carcasses had varying degree of silt and algae accumulation.

By day 30, three carcasses were floating, two carcasses had contact with the sediment and one carcass was gone (Table 3). The carcasses that were floating consisted of skull, spine, torso, intestines and leg bones. Very little skin with hair held the structure together. Those carcasses that had contact with the sediment were only skeletal remains with an intact abdomen, very little skin and hair remained. Decomposition appeared more rapid when carcasses had contact with the sediment.

For the fall experiment, by day 33, only one carcass was lying on the ground and one had its nose in contact with the sediment (Table 4). The remaining carcasses were all floating. Extremities were scavenged but the majority of tissue on the torso was intact. On day 35, one carcass was brought to the surface for a thorough examination. It was still bloated and adipocere was coating most of the lower abdomen. There was surface scavenging on the lower abdomen, hind quarter and neck. On day 48, another carcass was brought to the surface. The carcass was still bloated and the hair was mostly gone. The head was partially skeletonized also the muscle tissue and spinal column was exposed (Table 3).

By day 54, all carcasses had contact with the sediment. Disarticulation was evident to some degree on all carcasses. By day 116, the three remaining carcasses were completely skeletonized, and the bones were cleared of tissue and had a brown algae staining.

By day 140, there was only bones left at 4 of the 6 sites. Bones were not recovered from 1S or 5D. Carcass 2S (Figure 15) had the most bones remaining with 59 followed by 4D (Figure 16) with 57 bones. Carcass 6S had the least amount of bones recovered with 12 (Figure 17) followed by 3D (Figure 18) with 24 bones.

For the fall experiment, bones were collected from 4 of the 6 sites also (Table 4). Bones were not recovered from 12S and 11D. Carcass 8S had the most bones remaining with 57 (Figure 19). Carcass 9D had 28 bones recovered (Figure 20) and 10D had 27 bones remaining (Figure 21). Carcass 7S had the least amount of bones recovered with only 4 ribs (Figure 22).

Fauna

By 6-7 hours ETSS, no fauna was observed on any carcasses at the shallow depth (8.5–8.8 m) (Table 3). Wrinkled Amphissa (*Amphissa columbiana*), green sea urchin (*Strongylocentrotus droebachiensis*) (Figure 23), red sea star (*Mediaster aeqalis*) (Figure 24), Western Lean Nassa (*Nassa mendicus*), red rock crab (*Cancer productus*), blue mud shrimp (*Upogebia pugettenis*) were found on the carcasses at the greater depth (12.8–15.5 m). By 12-13 hours, carcasses at the shallow sites were visited only by small amphipods and larval herring. Those carcasses at the greater depths had numerous organisms observed including small and large amphipods (Figure 25), red sea star (*Mediaster aeqalis*), coon striped shrimp (*Pandalus danae*) (Figure 26), Alaskan pink shrimp (*Pandalus eous*), wrinkled amphissa (*Amphissa columbiana*), western lean nassa (*Nassa mendicus*), larval herring, Oregon triton (*Fusititron oregonensis*) (Figure 27), and sunflower sea star (*Pycnopodia helianthoides*) (Figure 28).

At 21-21.5 hours, the only organisms observed were on carcasses at the greater depths and included sunflower sea stars (*Pycnopodia helianthoides*) and the red sea star (*Mediaster aeqalis*). By day 3, carcass 2S was observed to have Oregon triton (*Fusititron oregonensis*), and mottled sea star (*Pisaster bervispinus*) visiting and carcass 6S had amphipods. Oregon triton (*Fusititron oregonensis*) and red sea star (Mediaster aeqalis) were observed on 3D and 4D and a red rock crab (*Cancer productus*) was sighted on 5D. By day 11, a leather star (*Dermasterias imbricata*) and sand dabs (*Citharichthys* sp.) were the only organisms visible on one carcass at the shallow depths. Sunflower sea star (*Pycnopodia helianthoides*) was found on two deep carcasses; as well as, a hermit crab (*Pagurus beringanus*) and sand dabs (*Citharichthys* sp.) each found on

one carcass. By day 30, the sunflower sea star (*Pycnopodia helianthoides*) was observed on two deep carcasses; in addition to a red sea star (*Mediaster aeqalis*) which was found on only one carcass. By day 47, very few organisms were observed only barnacles on one shallow carcass and a sunflower sea star (*Pycnopodia helianthoides*) and a halibut near a deep carcass. By day 54, mussels and little fish were observed at the shallow sites; whereas, the deep sites seemed to attract seastars (*Pycnopodia helianthoides* and *Henricia aspersa*) and small fish including gobies and sculpins. On day 116, the only organism observed was a ling cod on carcass 5D.

On the recovery date, 140 days, the largest number of organisms were collected, observed, and noted (Table 3). Organisms collected from the shallow sites included marine oligochaetes (Family Enchytraeidae), bloodworms (*Euzonus* sp.) (Figure 29), juvenile red rock crab (*Cancer productus*), blue mud shrimp (*Upogebia pugettensis*), *Nereis vexillosa*, *Nereis* sp., *Pandora* sp., scaleworm, Aleutian Macoma (*Macoma lama*), Sitka periwinkle (*Littorina sitkana*), periwinkle (*Littorina scutulata*), unidentified limpet, *Diastylis rathkei*, *Ammotrypane aulogaster*, copepods, nematodes, ostracoda, wrinkled amphissa (*Amphissa columbiana*), and a Sitka shrimp (*Heptacarpus sitchensis*). Organisms collected from the deep sites included Red rock crab (*Cancer productus*), Pacific lyre crab (*Hyas lyratus*), Pacific red hermit (*Elassochirus gilli*) (Figure 21), proboscis worm (*Glycera* sp.), bloodworms (*Euzonus* sp.), marine oligochaetes (Family Enchrytraeidae), scaleworm, giant Western Nassa (*Nassarius fossatus*), *Ammotrypane aulogaster*, nematodes, and copepods.

Depth may have contributed to the kinds of organisms found on the carcasses. Scaleworm (*Arctonoe* sp.) was the only species found at the shallow depths at more than

one site in the spring/summer experiment (Table 5). Many species were found multiple times at the deep sites. These included proboscis worms (*Glycera* sp.), Oregon triton (*Fusititron oregonensis*), Western lean nassa (*Nassarius mendicus*), copepods, red rock crab (*Cancer productus*), coon striped shrimp (*Pandalus danae*), sunflower sea star (*Pycnopodia helianthoides*), red sea star (*Mediaster aeqalis*). Marine oligochaetes (Family Enchytraeidae), bloodworms (*Euzonus* sp.), sea lice and larval herring were the only species found at both shallow and deep depths during the summer experiment (Table 5).

For the fall experiment, fewer species seemed to be "depth specific". Chalky macoma (*Macoma calcarea*), leafy hornmuth (*Ceratostoma foliata*), and barnacles were consistently found at shallow depths (Table 6). Whereas, sea strawberry (*Gersemia rubiformis*) (Figure 30), sea star (*Henricia aspersa*), feather star (*Florometra serratissima*) and sunflower sea star (*Pycnopodia helianthoides*) were found at the greater depths 15.2 m (50 ft). No organisms were consistently found at both depths (Table 6).

Sediment type seemed to have an influence on the fauna observed and collected from the carrion. Those species that visited the carrion (more often) with a sediment type of rock included the Oregon triton (*Fusititron oregonensis*), sunflower sea star (*Pycnopodia helianthoides),* the pile worms (*Nereis* sp.), sea strawberry (*Gersemia rubiformis*), leafy hornmouth (*Ceratostoma foliata*), smooth cockle (*Clinocardium blandum*), chalky macoma (*Macoma calcarea*), oysters (*Ostrea* sp.), and mussels. Those species that were mostly or exclusively found on the carcasses in the sand included the

coon striped shrimp (*Pandalus danae*), sea star (*Henricia aspersa*) sand dabs (*Citharichthys* sp.), and gobies.

Season also seemed to have an influence on the fauna observed and collected from the carrion. There were more species of fauna that were only seen in spring/summer experiment. These species included scaleworms (*Arctonoe* sp.), Western Lean Nassa (*Nassarius mendicus*), Oregon Triton (*Fusititron oregonensis*), hermit crab (*Pagurus beringanus*), red rock crab (*Cancer productus*) pacific lyre crab (*Hyas lyratus*), blue mud shrimp (*Upogebia pugettenis*), coon striped shrimp (*Pandalus danae*), sand dabs (*Citharichthys* sp.) and other small fish. Those species that were exclusively seen in the fall included the sea strawberry (*Gersemia rubiformis*), sandworms (*Nephtys* sp.), chitons, leafy hornmouth (*Ceratostoma foliata*) (Figure 31), and most of the mollusks.

DISCUSSION

The biggest problem with this research was the sampling depended on diver availability. For the first experiment, divers from the RCMP dive team were readily available. Also staff from the Vancouver Aquarium were in the vicinity doing their own research and frequented our pigs when RCMP members were not available. Observations from the fall experiment were totally dependent on the Canadian Coast Guard and members of Canadian Amphibious Search Team (CAST). During the time of the fall experiment the Canadian Coast Guard were disbanded and not allowed to dive; therefore observations did not occur during this time. Members of CAST (a volunteer group) tried to observe the carcasses during this time of disbandment; however obtaining transportation to the sites limited their observation and sampling dates.

Decomposition

Decompositional stages that were clearly observed on all carcasses included fresh, bloat, active decay and remains; however sequence of decomposition is not exclusive to only these stages. Sorg *et al*. (1997) suggest keys to interpreting the length of the postmortem interval: Phase 1: loss of soft tissue and Phase 2: Bone Modification. Phase 1 consists of whether soft tissue is present, soft tissue absent: crania, distal extremities or soft tissue absent: torso, proximal extremities, cartilage present or absent, decomposition odor present or absent, and adipocere present or absent (Sorg *et al*. 1997). Phase 2 consists of abrasion absent or abrasion/dissolution present: cancellous bone exposure or abrasion/dissolution present: marrow cavity exposure, bioerosion present or absent, dissolution absent or present, encrustation absent or present (see Appendix II for definitions). A comparison of this research with this model outlined by Sorg *et al*. (1997) will be the focus of a future paper.

Primary flotation is caused by gases which are formed in the digestive tract (Teather 1994). The gases form quickly and affect the buoyancy of the body in the first 24-72 hours. In total 4 out of 6 carcasses in the spring/summer experiment immediately floated. Teather (1994) states factors that affect primary flotation include the variety and distribution of bacteria which forms the gases and composition of the most recent meal consumed by the individual.

Regardless of depth, one pig carcass in each habitat immediately sank to the sediment while the other two carcasses floated to the extent of the rope. The weight of the carcass did not seem to be a factor in whether it floated or not, as the pig at the

shallow depth was the lightest pig at 20.9 kg (46 lbs) and the pig at the greater depth was the heaviest pig at 25 kg (55 lbs).

Secondary flotation occurs when bacteria present within the body produce gas at sites other than the gastrointestinal tract (Teather 1994). Two carcasses which had sunk by 12-13 hours ETSS had been observed floating again by day 30. In the fall experiment more pigs, 5 out of 6 carcasses seemed to refloat around day 33.

Depth is suggested to affect time of refloat. At a greater depth the volume of gas produced is considerably less, in addition to the gases high solubility in water and surrounding tissues; therefore resulting in a deterrent to reflotation (Teather 1994). Higher water temperature is also assumed to increase and quicken gas production and hence result in a shorter submergence time before refloat (Teather 1994); therefore, temperature may inhibit decomposition gas formation (Schafer 1978). Both of these assumptions were not observed in these experiments as more carcasses refloated in the fall experiment.

A warm, moist, anaerobic environment favours adipocere development, a rancid, greasy, wax-like substance and was created when the carrion was in contact with the sediment. Also, adipocere is formed from fats contained within the body (Teather 1994); therefore pig carcasses should promote adipocere formation unlike emaciated bodies. Adipocere formation was observed on the nose of a pig that had contact with sediment on day 11 compared to the earliest observation of complete adipocere formation appearing within only 22 days (Simonsen 1977). Dix (1987) reported minimal adipocere in 3 weeks also. By 41 days, one carcass exhibited significant adipocere on hind quarter and abdomen.

Fauna

The Phylum Mollusca contains many species which possess a mouthpart (radula) consisting of a ribbon of chitinous teeth. These species, including chitons and snails, were observed on numerous carcass and are thought to have produced "bore" holes in many of the carcasses. These wounds were very visible when the carcass was brought up to the surface for examination (Figure 32). These bore holes were quite common and could be confused with perimortem wounds. If wounds are suspected to be the act of violence, a marine biologist should be consulted to rule out animal scavenging.

Sorg *et al.* (1997) conveniently divided marine crustacean scavengers into 2 ecological groups 1) macroscavengers including large shrimp, lobsters, crabs and large species of peracarids, particularly amphipods and isopods and 2) microscavengers, less than 2 cm in length including amphipods (beach fleas, scuds), small isopods (sea lice and gribble), and small shrimp which usually are in large numbers when attracted to carrion. Both ecological groups were evident in these experiments. Significantly more macroorganisms associated with scavenging (i.e. crabs, sea stars) were found on the carcasses at the deeper depths versus shallow depths. These macroscavengers shredded the skin and underlying tissue exposing viscera and other organs to future attack and were very important in accelerating the decomposition process. The microscavengers were not in significant enough numbers to alter or affect the decomposition rate of the carrion.

At least one specimen from each of the five extant groups in the Phylum Echinodermata were observed in these experiments. These included Crinoidea (feather stars) (Figure 33), Asteroidea (sea stars), Ophiuroidea (brittle star) (Figure 34) , Echinoidea (sea urchin) and Holothuroidea (sea cucumber). Feather stars and the sea

cucumber are known to be suspension feeders or deposit feeders and do not affect scavenging activity. However, feather stars are known to use clothing or portions of skeletal remains as a substrate for attachment and sea cucumbers have been known to occur on clothing, body parts, or in the sediment collected within the clothing (Sorg *et al.* 1997). Sea stars, brittle stars, and sea urchins are scavenging species which would utilize the carrion as an energy source.

Sculpins and gobies were present throughout these experiments. These species are known to be scavengers on organic debris in addition to feeding on live prey primarily polychaetes, mollusks, and small crustaceans (Sorg *et al.* 1997). Therefore, it could not be determined whether the fish were present at the carrion, for the carrion itself or for the microorganisms associated with the carrion.

There was significant difference in the number of species (and which ones) that were associated with a specific depth (either shallow or deep) between spring and fall experiments. This may be due to the inconsistent method of sampling and also duration between sampling dates. Due to boat and diver limitations, less frequent sampling occurred in the fall experiment.

The fall pigs had various wounds including a cut ear, prolapsed bowel, and sores on shoulders and hind quarters. None of these wounds seemed to attract any fauna specifically; however 19 days was the first observations after carcass placement. In the summer experiment, carcasses were frequently visited after initial placement and no fauna was specifically attracted to the bullet hole in the head. At 6-7 hours ETSS, wounds were free of coagulated blood and looked fresh. No fauna was in the vicinity of the wounds. Although by this time, whelks had created several wounds on the body and

one whelk was inside the nostril. Wounds on the carrion do not seem to attract fauna unlike the terrestrial environment, where Dipteran larvae are first attracted to wound sites, followed by natural orifices.

Sorg *et al.* (1997) suggests the great potential of using sessile forms of organisms, which literally attach themselves to the remains, to determine time of death. Theoretically, this sounds great, and there is extensive literature on the development times of these sessile organisms; however, very few of them were observed throughout these experiments. For example, at day 47, a barnacle was visible in a left eye; however, it was not present the next sampling date to bring back to the lab for closer examination. At day 225 ETSS, barnacles were observed on a tag that was used to restrain the pig carcass, however, these were not located directly on the remains. Mussels were also observed in the vicinity of carcass but not on carrion. Only one other example of a sessile organism was evident, a sea strawberry was established on a scapula bone at day 225 ETSS, on carcass 9D.

CONCLUSIONS

Although no definitive time of submergence can be determined, there were observations which may be useful in suggesting or eliminating an approximate time of submergence. Seasonal differences in fauna and duration of decompositional stages may assist in determining time of submergence. Fauna specific to spring/summer included scaleworm (*Arctonoe* sp.), Oregon Triton (*Fusititron oregonensis*), Western Lean Nassa (*Nassarius mendicus*), coon striped shrimp (*Pandalus danae*), red rock crab (*Cancer productus*), and red sea star (*Mediaster aeqalis*). Species common to fall included sea

strawberry (*Gersemia rubiformis*), feather star (*Florometra serratissima*) and brittle star (*Ophiopsilla* sp.).

Weight of the carcass and depth of carcass placement did not influence primary flotation. This research did not support the assumptions that higher water temperatures resulted in shorter submergence times before refloat and greater depth delays carcass reflotation. Floating carcasses had longer decompositional stages compared to those carcasses that had contact with the sediment.

Sediment type dictated the fauna present in the vicinity of the carcass. A greater number of scavenging organisms including crabs (*Pagurus* sp. and *Elassochirus* sp.), red rock crab (*Cancer productus*), Pacific lyre crab (*Cancer productus*), and coon striped shrimps (*Pandalus danae*) were found on carcasses on the sandy sediment. These scavengers removed tissue quickly increasing the decompositional rate compared to those carcasses on rocks. In addition to the sediment type, depth also affected the decompositional rate. Significantly more scavenging organisms occurred on carcasses at the greater depth than the shallow sites.

Adipocere formation can drastically interfere with the normal rate of decomposition. If adipocere formation occurred before the majority of the tissue was removed, it would preserve the carcass in a fatty substance making it uninviting to those scavengers who typically feed on the carrion. Without the rapid removal of this tissue the decompositional stages are delayed.

Unlike the terrestrial environment, wounds on the carrion in marine conditions do not seem to attract fauna. On land Dipteran larvae are attracted to wound sites before they will colonize natural orifices.

ACKNOWLEDGEMENTS

This work was supported and partially funded by the Canadian Police Research Centre, Ottawa, Ontario. This research could not have been done without the hundreds of hours of in kind support in the form of boats, divers, and field technicians by the RCMP, Vancouver Aquarium, and the Canadian Amphibious Search Team (CAST). We would particularly like to thank Ms. Julie Graham and Cpl. Bob Teather (retired) for their support and encouragement throughout this research.

RCMP

Sgt. Ken Burton, Skipper of "Nadon"
Cpl. Dave Smith
Cpl. Bruce Ward
Joyce Kwan, Ident (civilian)
Lloyd Smith (retired)
David Burton

Canadian Coast Guard

Tim MacFarlane - diver
Luciano Nisi – diver
Stu Simms – diver
Julie de Grandpere - diver
Captain Sue Pickerell
Captain Brian Wooten
Navigator Jeff Nemrava
Navigator Craig Rachman
Navigator Bruce Briggs
Pilot – Karl Seseleja
Rick Foreman - Osprey
David Gonzalez (piloted small zodiac)
John Merrett
Joss Hallier (Tofino)

Aquarium

Dr. Jeff Marliave
John Fisher
Jeremy Heywood (diver)
Jennifer Norton (diver)

Nathan Taylor (diver)
Andrea Park (diver)
Other research divers
Andy Lamb – identifications of whelks

C.A.S.T.

Tim McFarlane
Troy Attfield
Dan Hilderbrand
Brad Falconer
Andy Meeher
Sean Stevenson
Greg Ipatowicz
Lynn Hurren
Tony Reynolds
Ian Campbell
John Merrett

S.F.U.

Bruce Leighton – identifications of marine oligochaetes
Amanda Ward – Field Assistant
Jodie Warren - Lab Assistant

Media Coverage

Marianne Meadahl – SFU News
Mark Miller – Discovery
Kevin Mills - Discovery

REFERENCES CITED

Anderson, G.S. 2001. Insect succession on carrion and its relationship to determining time of death IN Forensic Entomology The Utility of Arthropods in Legal Investigations. Byrd, J.H. and Castner, J.L. (Eds.). Boca Raton, CRC Press. 418 pp.

Anderson 1999. Chapter 20 Forensic Entomology: The use of insects in death investigations IN Forensic Osteological Analysis A book of case studies. Fairgrieve, S. (Ed.). Springfield, Charles C. Thomas. 340 pp.

Anderson, G.S. 1995. The use of insects in death investigations: an analysis of forensic entomology cases in British Columbia over a five year period. Can. Soc. Forensic Sci. J. 28:277-292.

Anderson, G.S. and Cervenka, V.J. 2001. Insects associated with the body: Their use and analyses IN Advances in Forensic Taphonomy Method, Theory, and Archaeological Perspectives. Haglund, W.D. and Sorg, M. (Eds.). Boca Raton, CRC Press. 507 pp.

Boyle, *et al.* 1997 IN Forensic Taphonomy The postmortem fate of Human Remains. Haglund W.D., Sorg M.H. (Eds.). Boca Raton, CRC Press. 636 pp.

Catts, E.P. and Goff, M.L. 1992. Forensic entomology in criminal investigations. Ann. Rev. Entomol. 37:253-272.

Davis, J.H. 1992. Bodies in water. Solving the puzzle. J. of the Florida Med. Assoc. 79(9):630-632.

Dix, J.D. 1987. Missouri's lakes and the disposal of homicide victims. J. Forensic Sci. 32(3):806-809.

Ebbesmeyer, C.C., and Haglund, W.D. 1994. Drift trajectories of a floating human body simulated in a hydraulic model of Puget Sound. J. Forensic. Sci. 39(1):231-240.

Gotshall,, D.W. 1994. Guide To Marine Invertebrates Alaska to Baja California. Sea Challengers, Monterey, CA. 105 pp.

Griffith, L. M. 1967. The Intertidal Univalves of British Columbia. Handbook No. 26. British Columbia Provincial Museum Department of Recreation and Conservation, Victoria, BC. 101 pp.

Haglund, W.D. 1993. Disappearance of soft tissue and the disarticulation of human remains from aqueous environments. J. Forensic Sci. 38(4):806-815.

Haglund and Sorg 2002. Humans Remains in Water Environments IN Advances in Forensic Taphonomy Method, Theory, and Archaeological Perspectives. Haglund, W.D. and Sorg, M. (Eds.). Boca Raton, CRC Press. 507 pp.

Harbo R.M. 1997. Shells & Shellfish of the Pacific Northwest. A Field Guide. Harbour Publishing, Madeira Park, BC. 270 pp.

Hawley, D.A., Haskell, N.H., McShaffrey, D.G., Williams, R.E., and Pless, J.E. 1989. Use of aquatic insects in determining submersion interval. J. Forensic Sci. 34:622-632.

Hobishcak, N.R. 1997. Freshwater invertebrate succession and decompositional studies on carrion in British Columbia. Masters of Pest Management Thesis, Department of Biological Sciences, Simon Fraser University, Burnaby, BC.

Hobischak, N.R. and Anderson, G.S. 2002. Time of submergence using aquatic invertebrate succession and decompositional changes. J. Forensic Sci. 47(1):142-151.

Hobischak, N.R. and Anderson, G.S. 1999. Freshwater-related death investigations in British Columbia in 1995-1996. a review of coroners cases. Can. Soc. Forensic Sci. J. 32 (2 & 3):97-106.

Jensen, G.C. 1995. Pacific Coast Crabs and Shrimps. Sea Challengers, Monterey, CA. 87 pp.

Kahana, T., Almog, J., Levy, J, Shmeltzer, E, Spier, Y, Hiss, J. 1999. Marine taphonomy; adipocere formation in a series of bodies recovered from a single shipwreck. J. Forensic Sci. 44(5):897-901.

Kozloff, E.N. 1987. Marine Invertebrates of the Pacific Northwest. University of Washington Press, Seattle, WA. 511 pp.

Lamb, A. and Edgell, P. 1986. Coastal Fishes of the Pacific Northwest. Harbour Publishing, Madeira Park, BC. 224 pp.

MacDonell, N.R., and Anderson, G.S. 1997. Aquatic Forensics: determination of time of since submergence using aquatic invertebrates. Canadian Police Research Centre, Ottawa, ON.

Schafer, W. 1978. The Ecology and Paleoecology of Marine Environments. University of Chicago Press, Chicago, IL.

Sept, J.D. 1999. The Beachcomber's Guide to Seashore Life in the Pacific Northwest. Harbour Publishing, Madeira Park, BC. 235 pp.

Sheldon, A.L. 1984. Colonization dynamics of aquatic insects, pp. 401-429 IN Ecology of Aquatic Insects. Resh, V.H. and Rosenberg, D.M. (Eds.). Praeger Publishers, New York. 625 pp.

Simonsen, J. 1977. Early formation of adipocere in temperatre climate. Med. Sci. Law 17:53-55.

Siver, P.A., Lord, W.D., and McCarthy, D.J. 1994. Forensic Limnology: the use of freshwater algal community ecology to link suspects to an aquatic crime scene in southern New England. J. Forensic Sci. 39(3):847-853.

Sorg M.H., Dearborn J.H., Monahan E.I., Ryan H.F., Sweeney K.G., David E. 1997. Forensic Taphonomy in marine contexts IN Forensic Taphonomy The postmortem fate of Human Remains. Haglund W.D., Sorg M.H. (Eds.). Boca Raton, CRC Press. 636 pp.

Teather, R.G. 1994. Encyclopedia of Underwater Investigations. Best Publishing Company, Flagstaff, Arizona. 186 pp.

LIST OF FIGURES

Figure 1. Map of Popham Island

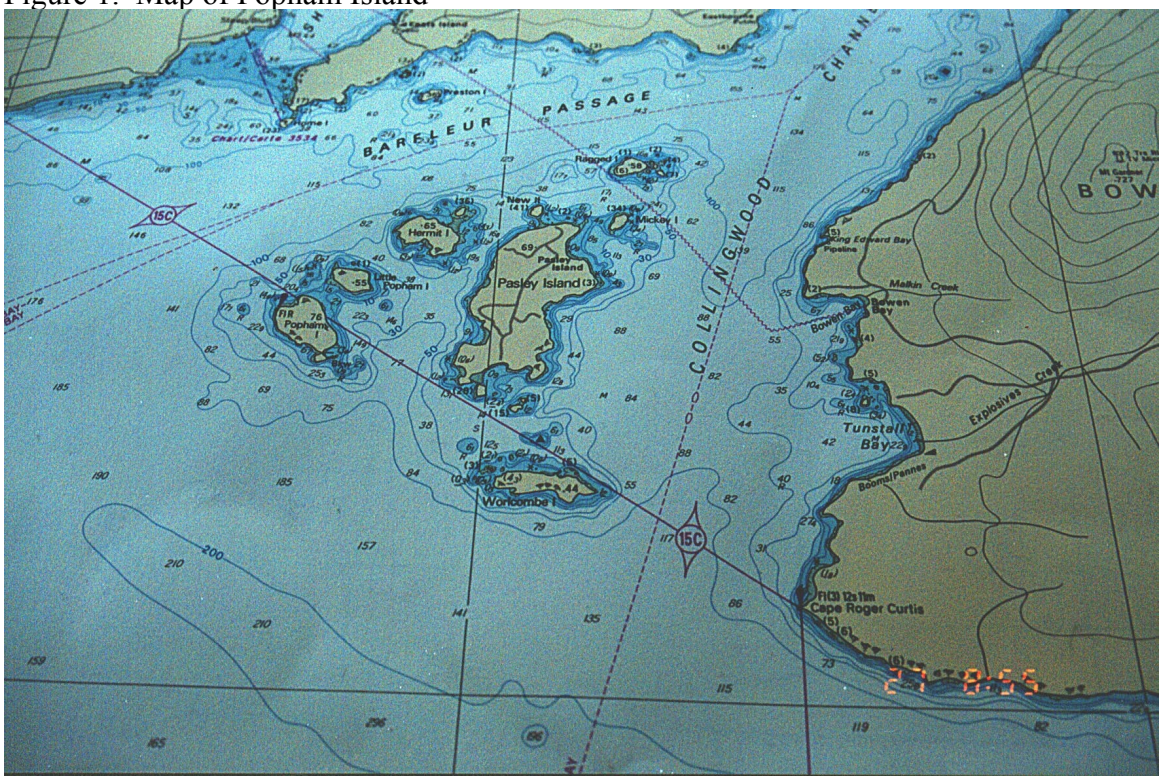

Figure 2. RCMP Nadon at dock on Popham Island

Figure 3. RCMP Zodiac tied up at dock on Popham Island

Figure 4. Aquarium vessel, a 23 ft Kellehan

Figure 5. Bound pig

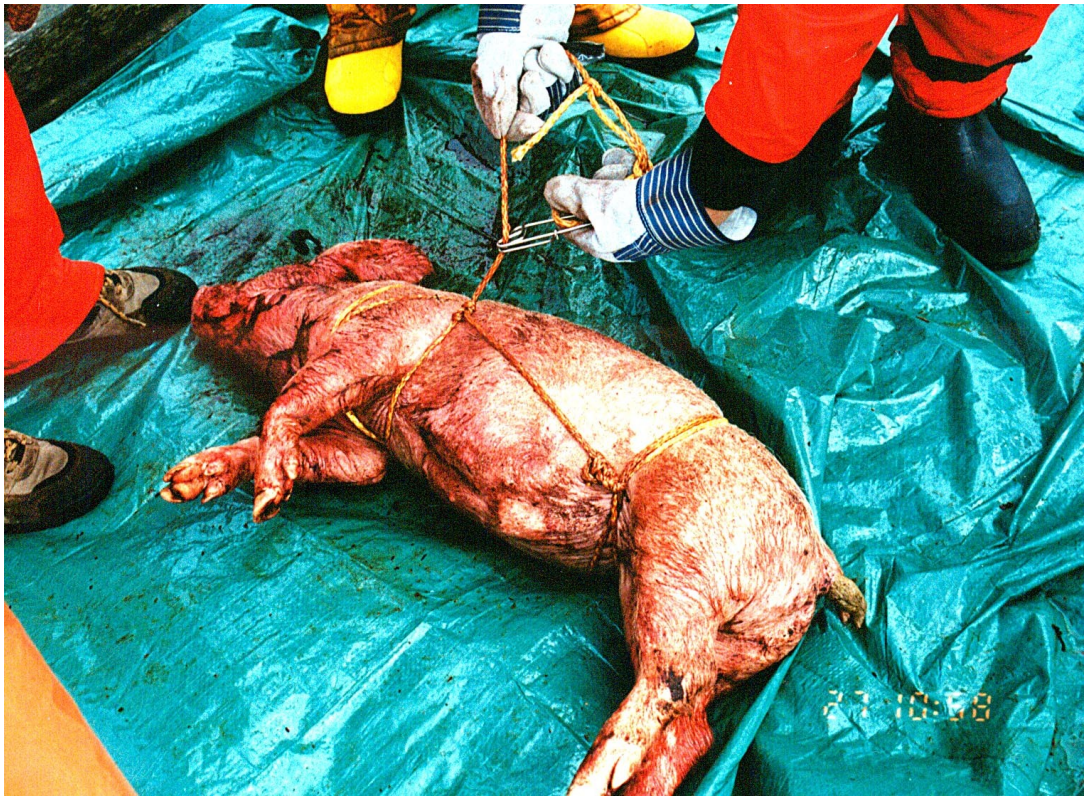

Figure 6. All carcasses ready to go out

Figure 7. Concrete block set up

Figure 8. Divers and CAST boat

Figure 9. Canadian Coast Guard vessel – Siyay

Figure 10. Canadian Coast Guard small hovercraft

Figure 11. The “Tofino”, manned by the Canadian Amphibious Search Team (CAST)

Figure 12. Members of the Canadian Amphibious Search Team unloading their boat

Figure 13. Pig was removed from water in plastic container, 35 days ETSD

Figure 14. Pig at surface being examined for organisms

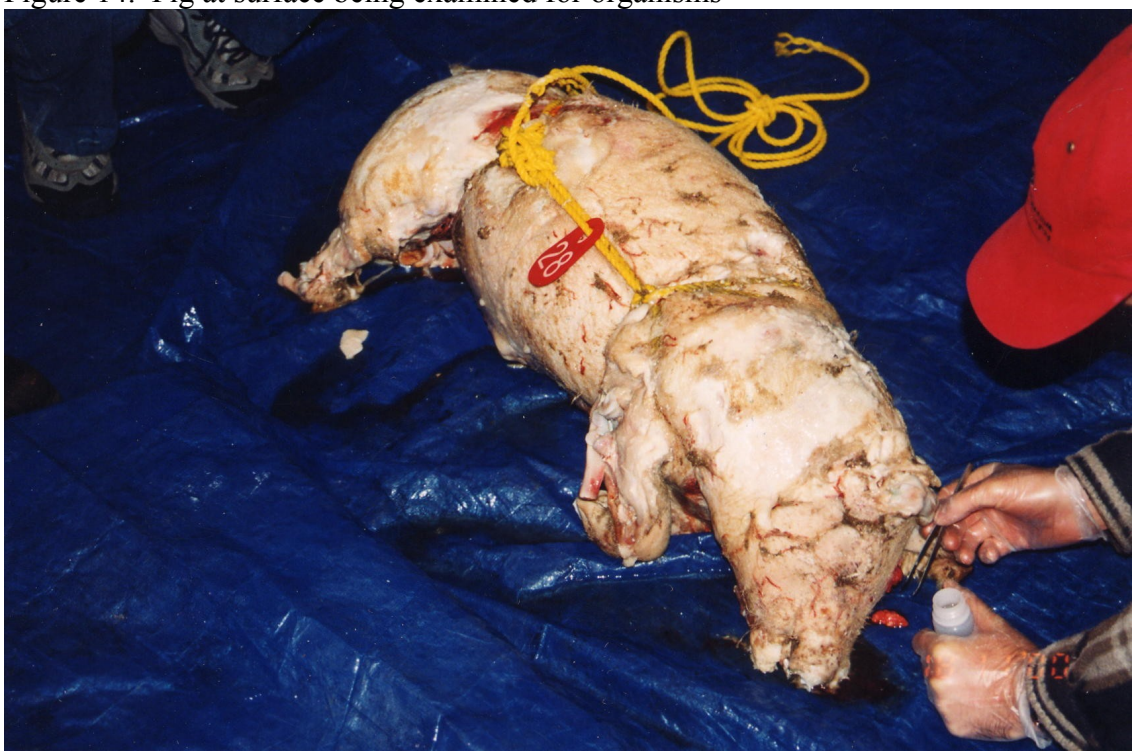

Figure 15. Bone recovery for site 2S

Figure 16. Bone recovery for site 4D (improperly labeled 4S(1) and 4S(2) on the photographs)

Figure 17. Bone recovery for site 6S

Figure 18. Bone recovery for site 3D

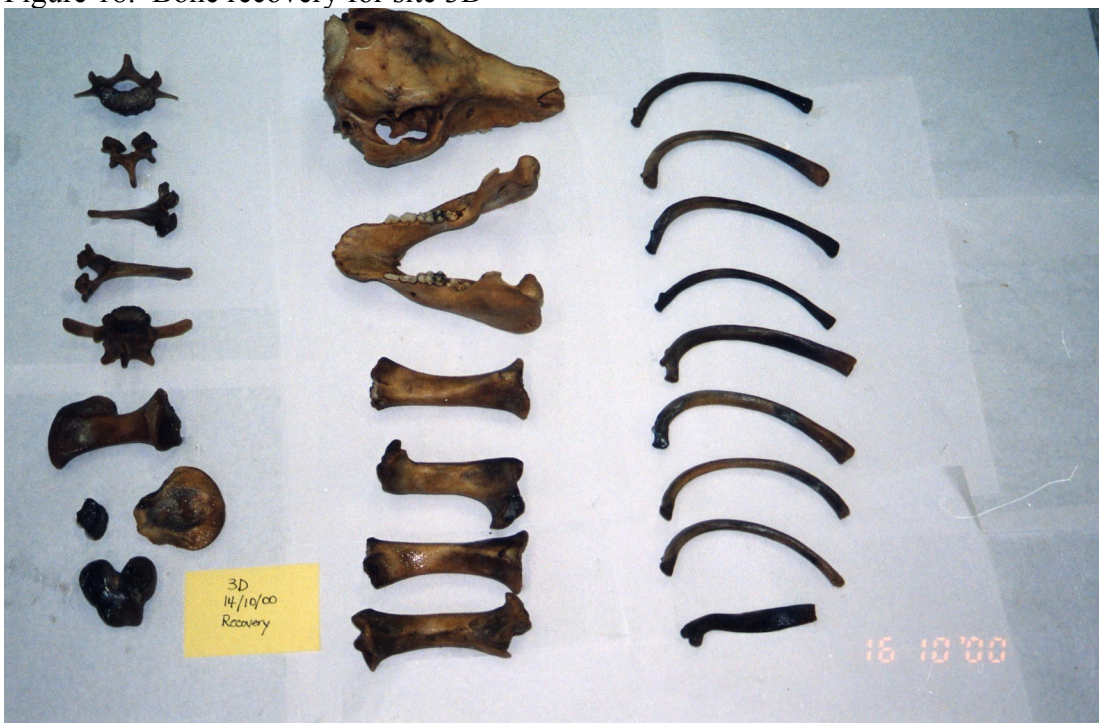

Figure 19. Bone recovery for site 8S

Figure 20. Bone recovery for site 9D

Figure 21. Bone recovery for site 10D

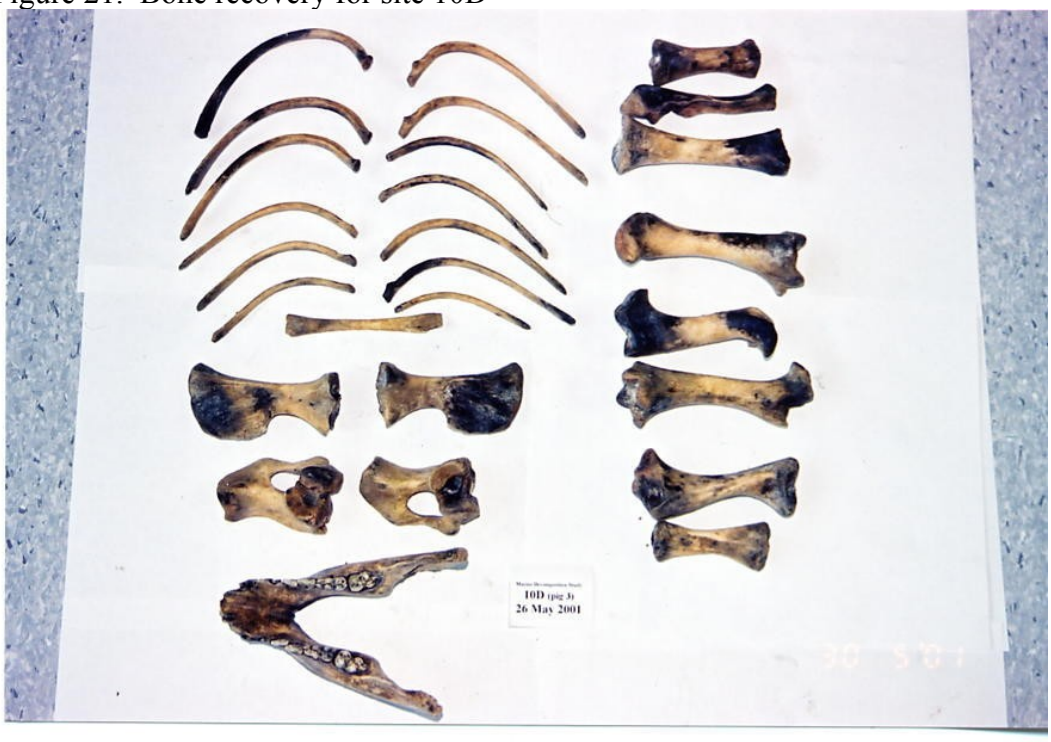

Figure 22. Bone recovery for site 7S

Figure 23. Green sea urchin, *Strongylocentrotus droebachiensis*

Figure 24. Red sea star, *Mediaster aequalis*

Figure 25. Large amphipod (Photo Bruce Ward, RCMP)

Figure 26. Coon striped shrimp, *Pandalus danae* (Photo Bruce Ward, RCMP)

Figure 27. Oregon Triton, *Fusititron oregonensis*

Figure 28. Sunflower sea star, *Pycnopodia helianthoides*

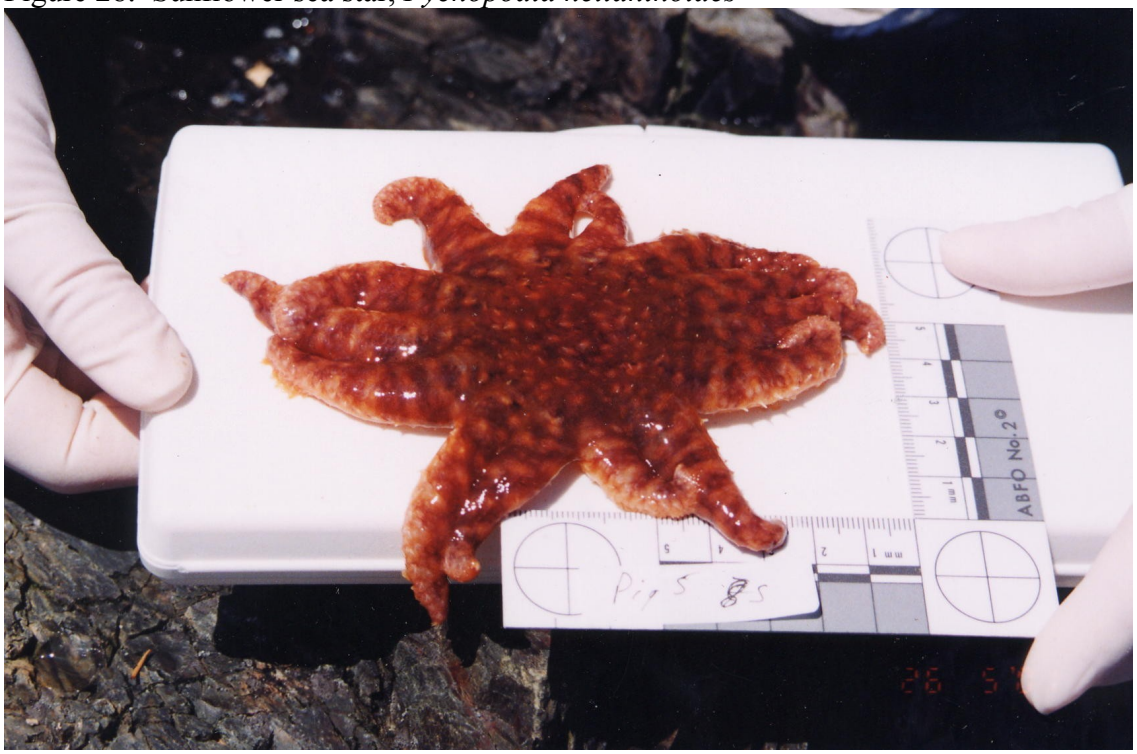

Figure 29. Bloodworms, Euzomus sp., on carcass brought up to surface for examination

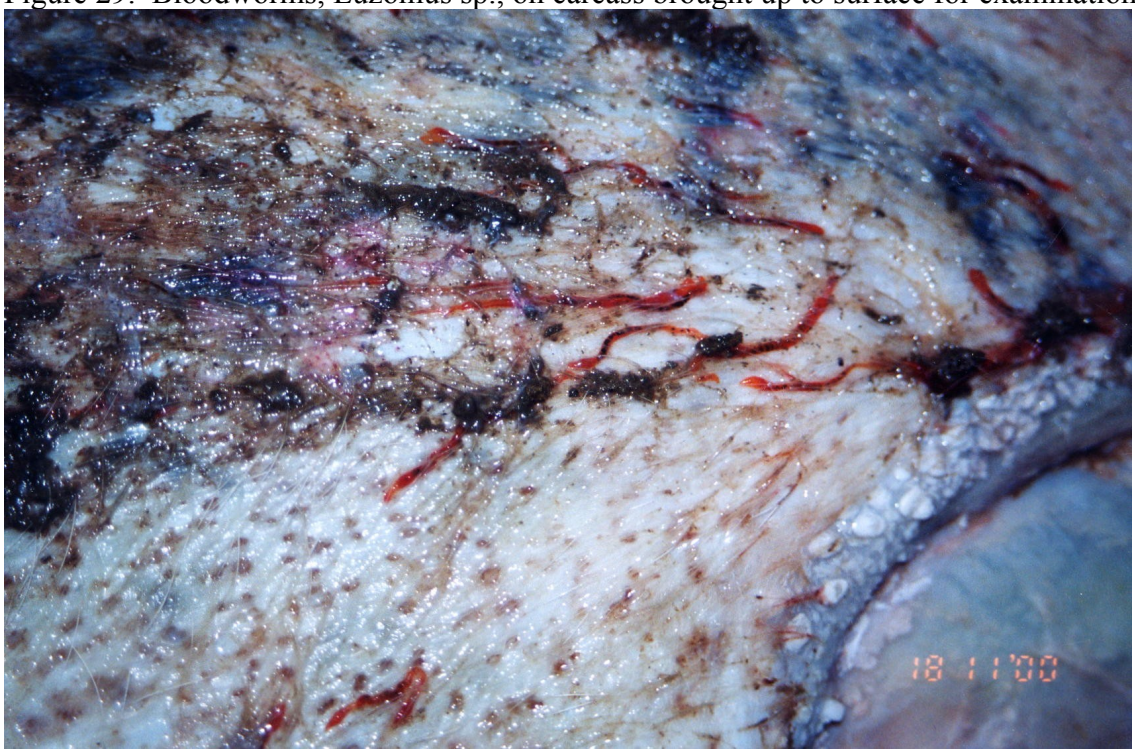

Figure 30. Sea strawberry colonized on bone from 9D, 225 days ETSS

Figure 31. Leafy hornmouth, *Ceratostoma foliata*

Figure 32. "Bore" hole in carcass created by whelk, 12S at 35 days ETSS

Figure 33. Feather star, *Florometra serratissima*, seen numerous times in the vicinity of the carcass (Photo Bruce Ward, RCMP)

Figure 34. Brittle star, Ophiopsilla sp., found on Pig 9D day 225 ETSS

LIST OF TABLES

TABLE 1. Summary of Site Specifics, Summer 2000 Experiment

Site	Depth at anchor placement	Time/ Date of anchor placement	Actual average depth (ft)	Site	Description of Sediment	Time pig set in water	Pig weight (lb/kg)
1S	19 ft 5.79 m	1136-1143 h May 16, 2000	28 8.5 m	Close to end of breakwater	On rocks	1335 h May 27, 2000	46/ 20.9
2S	23 ft 7.0 m	1204-1216 h May 16, 2000	28 8.5 m	Out from breakwater	On rocks	1217 h May 27, 2000	51/ 23.1
3D	44 ft 20.0 m	1326-1330 h May 16, 2000	51 15.5 m	Further out from breakwater, over reef	On rocks	1300 h May 27, 2000	47/ 21.3
4D	46 ft 20.9 m	1417-1431 h May 16, 2000	50 15.2 m	Past reef, back in towards Popham	On sand, closely associated with rocky reef	1305 h May 27, 2000	55/ 25.0
5D	41 ft 18.6 m	1515-1529 h May 16, 2000	42 12.8 m	Past reef, out from entry point at base of breakwater	On sand, pig has two wounds in head	1315 h May 27, 2000	50/ 22.7
6S	23 ft 10.4 m	1338-1343 h May 16, 2000	29 8.8 m	Base of breakwater	On sand, closely associated with rocky reef	1205 May 27, 2000	48/ 21.8

Time of death – 0540 h 27 May 2000
Bagged at Britco at 0540 h
Opened bags and tied ropes to pigs at ~ 1000-1030 h then left pigs on dock, covered with tarpaulin. Very heavy rain so no insect activity
Placed at sites ~ 6.5-8 h after death (say average of 7 hours after death). All pigs floated, buttocks up, snout down, blood seems to have coagulated but is floating from wounds
Weather throughout placement and first examinations very bad, heavy rain, strong winds. Strong storms.

TABLE 2. Summary of Site Specifics, Fall 2000 Experiment

Old Site	New Site	Time and Date of Pig placement	Depth at placement (ft)	Site	Comments	Pig #	Pig Weight (lb/kg)
1S	7S	1640 h Oct 14, 2000	26 7.9 m	Close to end of breakwater	Ear cut, wound to left hind quarter (burn 5”X5”)	34	48/ 21.8
2S	8S	1614 h 14 Oct 00	26 7.9 m	Out from breakwater	Prolapse bowel	41	54/ 24.5
3D	9D	1557 h 14 Oct 00	43 13.1 m	Further out from breakwater, over reef	Small wound left hind quarter/back	26	49/ 22.2
4D	10D	1535 h 14 Oct 00	47 14.3 m	Past reef, back in towards Popham	Clean, no cuts	37	54/ 24.5
5D	11D	1457 h 14 Oct 00	37 11.3 m	Past reef, out from entry point at base of breakwater	More blood from head, ear and mouth	46	44/ 20.0
6S	12S	1440 h 14 Oct 00	26 7.92	Base of breakwater	Some sores on shoulder and side, 2” sore on rear left hock	28	53/ 24.0

TABLE 3. Decomposition Descriptions and Fauna, Summer 2000

27 May 2000 Time – 1850-1929 h
Elapsed Time since Death (ETSD) – 13h 10 minutes – 13 h 50 h – say 13.5 h
Elapsed time since submergence (ETSS) – 6-7 h

SITE	*DESCRIPTION*	*FAUNA*
1S	No change, but had chain looped around it from severe storms. Jeremy unhooked. Body was down to sea floor, but pulled there by chain. No fauna on body, no lividity. Depth when checked, 27 ft	None
2S	Same as pig 1S, no fauna or flora. Very poor visibility. Body still floating. Depth when checked, 26 ft.	None
3D	Whelk in nostril and several more (~5) on skin. Body floating One urchin on rear left hock Also, one sea star moving towards body Depth when checked, 48 ft.	Wrinkled Amphissa, *Strongylocentrotus droebachiensis* green sea urchin, *Mediaster aeqalis* Red Sea Star moving towards body, not on body yet
4D	Body sunk to sea floor, lying on side. Sea stars on body (2) and some coming towards body. Some whelks on body <5, one in wound itself. Depth when checked, 46 ft.	*Mediaster aeqalis* Red Sea Star, *Nassa mendicus* Western Lean Nassa Collection brought to lab contained: marine oligochaetes (Family Enchytraeidae), copepods, proboscis worms (*Glycera* sp.), bloodworms (*Euzonus* sp.), red rock crab (*Cancer productus*), and blue mud shrimp (*Upogebia pugettenis*)
5D	Still floating, snout down. No flora or fauna. Depth when checked, 37 ft.	None
6S	Lividity on back, floating snout down, no lividity at rope sites. Depth when checked, 24 ft.	None

28 May 2000 Time – 0050-0125 h
Elapsed Time since Death (ETSD) – 19h 10 minutes – 19 h 45 h – say 19.5 h
Elapsed time since submergence (ETSS) – 12-13 h

SITE	***DESCRIPTION***	***FAUNA***
1S	Lots of very small amphipods, 1/1", 2-3000 on body, all over body, not concentrated in any one area. (~1-3 mm). Body now lying on sea floor. Face pushed up against a rock. Body looked fresh. Wound looks very clean, all coagulated blood gone/removed. Many larval fish at body, probably feeding on small amphipods	Small amphipods Larval Herring
2S	Small amphipods on body – not as many as on 1S, but still a lot. Also some larger amphipods on body (~6 mm). Larval herring all over, appeared to be feeding on small amphipods. Body resting on ground now. Wound looks very clean, all coagulated blood gone/removed	Larger and small amphipods, and larval herring
3D	Lying on side on ground now, sea stars on body; one huge sea star on hind end and two smaller ones on nose and eyes. Lots of little amphipods, but not as many as on 1S and 2S. Two coon striped shrimp seen on wound, but swam away as soon as lights went on. Also, another shrimp seen but not identified. More of the same whelks as collected in last dive – more now, trying to get into wound. Larval herring all over, appeared to be feeding on small amphipods. 3-4 Larger mollusks, one on ear Wound looks very clean, all coagulated blood gone/removed, body still looked fresh.	Small amphipods, *Mediaster aeqalis* Red Sea Star, *Pandalus danae* Coon Striped Shrimp, Wrinkled Amphissa and Western Lean Nassa, larval Herring, *Fusititron oregonensis* Oregon Triton, *Pycnopodia helianthoides* Sunflower Sea Star
4D	Body lying on side on ground. Small amphipods present, some sea stars. Whelks may have been missed. Coon striped shrimp on and near body, but leave as soon as divers get near. Wound looks very clean, all coagulated blood gone/removed. Pinkish colour to abdomen (lividity). Larval herring all over, appeared to be feeding on small amphipods. Silt starting to accumulate over the entire body.	Small amphipods, *Mediaster aeqalis* Red Sea Star, *Pandalus danae* Coon Striped Shrimp, and larval herring

Elapsed time since submergence (ETSS) – 12-13 h (con't)

SITE	*DESCRIPTION*	*FAUNA*
5D	Body still floating (only one still), nose embedded into the sediment. Coon Striped shrimp on body and also Alaskan Pink Shrimp, very skittish and may have been on others but moved too quickly. A few small amphipods seen. Wound looks very clean, all coagulated blood gone/removed. Larval herring all over, appeared to be feeding on small amphipods.	Small amphipods, *Pandalus danae* Coon Striped Shrimp, *Pandalus eous* Alaskan Pink Shrimp and larval herring
6S	Body on ground, some small amphipods. Gut Larval herring all over, appeared to be feeding on small amphipods. Stomach seems to be a little distended – start of bloat. Wound looks very clean, all coagulated blood gone/removed. Face and throat are pinkish in colour (lividity).	Small amphipods Larval herring

28 May 2000 Time – 0940-1010 h
Elapsed Time since Death (ETSD) – 28 h – 28.5 h
Elapsed time since submergence (ETSS) – 21-21.5 h

SITE	*DESCRIPTION*	*FAUNA*
1S	Strong current, so anything might have been washed off, or might mean that fauna last night was due to night-time conditions. No fauna and no outward signs of decomposition.	None
2S	Strong current, so anything might have been washed off, or might mean that fauna last night was due to night-time conditions. No fauna and no outward signs of decomposition.	None
3D	Much less current, visibility better. Very large starfish on rear end of pig, covering half of pig. Also 2 red sea stars, as before. No amphipods. Small sea star picked off to see if it was feeding – stomach was everted but no sign of feeding damage.	*Pycnopodia helianthoides* Sunflower Sea star *Mediaster aeqalis* Red Sea Star
4D	Body very salty, had two sea stars on it but knocked off by the rope, when divers used it.	*Mediaster aeqalis* Red Sea Star
5D	Some signs of red marks on back of hocks – might be feeding damage. Body still floating. No fauna, but a shrimp seen near carcass.	*Pandalus* sp.
6S	Very silty on top of pig. Lying on ground.	None

30 May 2000 -Elapsed time since submergence (ETSS) – 3 days

SITE	***DESCRIPTION***	***FAUNA***
1S	No apparent fauna, but white, 'frayed' margins on the ears	None
2S	2-3 Oregon Tritons, 1 small Mottled Sea Star (*Pisaster brevispinus*) on body	*Fusititron oregonensis* Oregon Triton (2-3), *Pisaster bervispinus* Mottled Sea Star
3D	3-4 Red Sea Stars on head, 1-2 Oregon Tritons as well, also noticed white 'digested' area on rump area at site of large sea star 2 days ago. sea star gone, but area looks as if it has been partially digested	*Fusititron oregonensis* Oregon Triton (1-2), *Mediaster aeqalis* Red Sea Star (3-4)
4D	4-5 Red sea stars around mouth and neck area, also couple more Oregon Tritons	*Fusititron oregonensis* Oregon Triton (2), *Mediaster aeqalis* Red Sea Star (4-5)
5D	A couple of *Cancer productus* (red rock crab) tearing at flesh of pig, noticed some 'bloating)	*Cancer productus* red rock crab
6S	4-6 amphipods around genital area, noted stomach bloating	Amphipods

7 June 2000 - Elapsed Time since Death (ETSD) –11 days

SITE	***DESCRIPTION***	***FAUNA***
1S	Flesh decay- 'bare patches' and some exposed bone. Skin sloughing, nose on ground having appearance of adipocere. Scavenging on ears, thighs and tail. Silt is accumulating	No fauna visible
2S	Flesh decay- 'bare patches' and some exposed bone. Hind end and legs scavenged, muscles exposed at leg joints. Hair falling off. Scavenging at ears. Silt is accumulating.	No fauna
3D	As pig 4 but with more *Pycnopodia* (body is entirely covered). A small hermit crab (*Pagurus beringanus*) foraging on dorsal side of carcass. Some algae covering entire carcass. Possible bone on the sediment below the carcass.	*Pycnopodia helianthoides* sunflower sea star *Pagurus beringanus* – hermit crab
4D	*Pycnopodia* on pig, actively feeding in the face region. Flesh decay- 'bare patches' and some exposed bone. Hind end scavenged, and is free of algae. Body still seems to be in bloat, rope is constricting body.	*Pycnopodia helianthoides* sunflower sea star
5D	Pig lying on side. More sand dabs picking at pig. Most of skull showing, as well as other exposed bone and gut contents. Not much bloat. Very algae and silt covered. Ears badly scavenged, and scavenging apparent on the abdomen. Exposed bones on the legs. Nose has the appearance of adipocere.	*Citharichthys* sp. Sand dabs
6S	Carcass is lying on its side. 1 leather star (*Dermasterias imbricata*) on butt end. Several small sand dabs around carcass on sand (*Citharichthys* sp.). Noted bloating, flesh decay, and some exposed bone on rear leg. Algae covering entire carcass.	*Dermasterias imbricata* – leather star *Citharichthys* sp. Sand dabs

26 June 2000 -Elapsed Time since Death (ETSD) – 30 days

SITE	***DESCRIPTION***	***FAUNA***
1S	missing, its chain fouled in the construction blocks, where the blocks doubtless frayed the poly line (very neatly. I first thought someone stole it!)	Pig gone
2S	(26', breakwater reef) Floating, with skin and hair remaining in certain areas. Legs without feet; skull (bare) attached. Torso intact	
3D	(46', breakwater reef) 2 sea stars on bone pile, with intact rib structure looking hollow (no guts inside). Posterior, balloon-like entity resembling blown up (uncoiled) part of intestine (belly region). Skull wedged in rocks, attached to torso (protected there?). Did not disturb posture for fear of dismembering. No examination of skull.	*Pycnopodia helianthoides* sunflower sea star
4D	(49' at base of cobble field, breakwater reef) Sunken, with *Pycnopodia* and several *Mediaster* sp. No limbs or skin (or hair). Some ribs show. Skull and spine bare. Belly intact.	*Pycnopodia helianthoides* sunflower sea star, *Mediaster aeqalis* Red Sea Star
5D	38', on sand, peninsula region) Afloat, with no limbs or skin (no hair). Skull, torso and intestine remain. Ribs show. Muscle falling off	
6S	Afloat, with skull, spine & legs bare of flesh. Front right foot remains; other feet gone. Ears intact as skin only (thin flaps). Belly intact, with skin and hair on rump (right side).	

6 July 2000 - Elapsed Time since Death – 40 days

SITE	***DESCRIPTION***	***FAUNA***
1S	Gone	
2S	n/a	
3D	n/a	
4D	n/a	
5D	Snout down, floating, at extend of line, 3.5-4 ft. All chewed around head. Very similar to 6S. Brain like cottage cheese. Internal organs exposed. No sea lice. Bone on face exposed, all ribs exposed. Adipocere tissue formed. Solid organs exposed in stomach wall. No feet. No bones on bottom, no eyes, put hand inside pig. Chewing up to neck areas. No skin on head.	Small crab seen 5 ft away.
6S	No skin; bones, adipocere tissue and spinal column fully exposed. Fish present. Skull exposed. Bone and teeth from top of skull to mandible. Small pile of bones on sea floor, hooves on bottom. No sea lice. Harbour seal nearby. Body floating approx. 7 ft off bottom, at extend of rope. Face chewed, all vertebrae and all ribs exposed. Adipocere tissue around hindquaters, bone underneath. Gut still intact and floating.	Harbour seal Fish nearby, 1 m long, with stripes and large head, very slim body, hovering on rocks. School of small and medium fish

13 July 2000 - Elapsed Time since Death – 47 days

SITE	***DESCRIPTION***	***FAUNA***
1S	Gone	
2S	Curled up. Vertebrae exposed. Adipocere. Right ear – skin fold still present	
3D	All bones. Very little flesh. Floating at end of line	*Pycnopodia helianthoides* sunflower sea star
4D	Lying down on ground. Very skeletonized. Ribs exposed, can see inside. Small sea star in the vicinity of the carcass	
5D	Sunk down on snout, nose touching ground, rest still floating. Similar to last week. Small halibut under body	Small halibut
6S	Floating, but not as high as before, ~2 ft off ground. Appears to be barnacle growth in left eye.	Barnacles

20 July 2000 - Elapsed Time since Death – 54 days

SITE	***DESCRIPTION***	***FAUNA***
1S	Gone. Filmed broken rope	
2S	Body heavily adipocere. Erosion mostly be surge, hitting up against blocks. Vertebrae exposed, face eaten but mandible still articulated. Stomach as a bag hanging out. Mussels around.	Mussels
3D	All bones. Like a bag over bones. Vertebrae in among rocks, intact. Bag of skin left. Big starfish beside it (Figure 20)	*Pycnopodia helianthoides* sunflower sea star
4D	Carcass lying supine. Mandible taken off, and found nearby. Body further gone than previous and further than 6S and 5D. Small fish possibly gobies or sculpins. Vertebrae exposed coiled up in rope. Furthest skeletonized. Star fish present.	Small fish – gobies, sculpins Star fish
5D	All pig on bottom, lying supine, belly has been devoured. Rib cage exposed. Large hole in left chest area, something has eaten it away. Stomach is exposed. Stomach still present and hanging out like a bag. No animal life seen. Jaw bone separate.	
6S	Pig on bottom, face on bottom. Good visibility. Face down, arched at tail end. Still organs present in rectal area. Rear end is bloated. Tissue is adipocere on tail end. Silt around from wave action. No animals in silt – checked. Patted adipocere tissue and bits came loose. Little fish around.	Little fish

20 September 2000 - Elapsed Time since Death 116 days

SITE	***DESCRIPTION***	***FAUNA***
1S	Gone	
2S	Bones present in group, ghostly white moss algae all over bones, and filamented on and around them, “like a soup”. Bones, brown, beige, not bleached. No chewing marks, but no cartilage	
3D	Gone	
4D	Some bones, jaw bone present, some teeth in it, some missing. No animals on it. Lots of kelp – leaf not bull.	
5D	Gone – no bones left	Ling cod in area
6S	Mostly gone, only small bones left “like small pork ribs”	

14 October 2000 - Elapsed Time since Death 140 days

SITE	***DESCRIPTION***	***FAUNA***
1S	No bones recovered	
2S	Bones recovered (59) and many small animals	Marine oligochaetes (Family Enchytraeidae), bloodworms (*Euzonus* sp.), juvenile red rock crab (*Cancer productus*), blue mud shrimp (*Upogebia pugettensis*), pile worms (*Nereis vexillosa*), *Nereis* sp., *Pandora* sp., scaleworm, Aleutian Macoma (*Macoma lama*), Sitka periwinkle (*Littorina sitkana*), *Diastylis rathkei*, *Ammotrypane aulogaster*, copepods, nematodes, ostracoda, wrinkled amphissa (*Amphissa columbiana*), Sitka shrimp (*Heptacarpus sitchensis*)
3D	Bones recovered (24) and small crab	Red rock crab (*Cancer productus*), Pacific lyre crab (*Hyas lyratus*), Pacific red hermit (*Elassochirus gilli*), proboscis worm (*Glycera* sp.), copepods, bloodworms (*Euzonus* sp.), marine oligochaetes (Family Enchrytraeidae)
4D	Many bones (57) at site. Some smaller bones about 15 ft away. 95 % of bones were black.	marine oligochaetes (Family Enchrytraeidae), scaleworm, giant Western Nassa (*Nassarius fossatus*), *Ammotrypane aulogaster*, juvenile red rock crab (*Cancer productus*), nematodes, proboscis worm (*Glycera* sp.), and bloodworms (*Euzonus* sp.)
5D	Nothing	
6S	16 ft out, 1 rib, other bones about 20 ft out, white cloudy algae total number of bones 12	Partial leg from crab, periwinkle (*Littorina scutulata*), unidentifiable limpet, scaleworm, bloodworms (*Euzonus* sp.), and marine oligochaetes (Family Enchrytraeidae)

TABLE 4. Decomposition Descriptions and Fauna Collected, Fall 2000 Experiment

2 November 2000 - Elapsed time since submergence (ETSS)19 days

SITE	*DESCRIPTION*	*FAUNA*
8S	Head of pig wedged between 2 rocks Algae covering entire carcass, not much silt Scavenging on surface including ears, feet and along spine, condition of underneath carcass unknown	
9D	Pig carcass on ground by bricks Heavily scavenged, internal organs exposed and hanging out of body cavity Algae present along with shredded skin Crinoid in the vicinity	Feather star (*Florometra serratissima*)
10D	Pig with head in sediment Half head appears skeletonized Sea star on sediment near head and scavenging on nose and hind end near rope Heavy silt covering entire carcass No evidence of bloat	Sea stars (*Henricia aspersa*)
11D	Floating Scavenging on face, hind limbs scavenged only 2 front legs intact Sea stars in the vicinity of the carcass Algae and silt covering entire carcass	Sea stars (*Henricia aspersa*)
12S	Ear scavenged, less algae than other carcasses Skin sloughing No real silt accumulation Brown snails on and scavenging hind leg, only 1 leg intact	Wrinkled Amphissa (*Amphissa columbiana*)

16 November 2000 - Elapsed time since submergence (ETSS) 33 days

SITE	***DESCRIPTION***	***FAUNA***
7S	Pig carcass lying on ground, curled up, algae covered Heavy scavenging on extremities, bones exposed, only one leg left intact	
8S	Still floating, nose down, hind end up Adipocere on nose, head partially skeletonized Entire carcass covered in algae and silt More surface scavenged including ears, back legs scavenged, spine exposed, and only one leg intact	
9D	Algae and silt covering carcass Floating, nose of carcass in the sediment with hind in upwards, adipocere on nose, head partially skeletonized with ears scavenged Chunk of tissue has fallen from carcass onto the sediment, huge sea star with many little ones scouring the tissue	Sunflower sea star (*Pycnopodia helianthoides*)
10D	Floating at the end of the rope, heavy scavenging, not much stiffness to the carcass, hanging very limp, skull skeletonized, 3 feet intact Adipocere hanging off the carcass mixed with sloughing hair and skin	
11D	Carcass still floating, at the end of the rope Surface scavenging on back, all four feet absent, most algae removed Head partially skeletonized Hair and skin sloughing	
12S	Carcass still floating Ear scavenged, head and hind quarter still intact, scavenging on legs completely removing all four Light covering of algae over entire carcass	

9 November 2000 - Elapsed time since submergence (ETSS) 26 days

SITE	***DESCRIPTION***	***FAUNA***
8S	No change from November 2nd observations	
9D	All remains are on the ground and the rope apparatus is floating at the extent of the rope	
10D	Heavily scavenged carcass Sea star and crinoid	Sea star (*Henricia aspersa*) and feather star (*Florometra serratissima*)
11D	Bits on tissue on the ground beneath the carcass, nothing much left except adipocere	
12S	Heavily scavenged, bits hanging off, no extremities visible, skeletonization Skin sloughing, mostly adipocere with algae, not much tissue left	

18 November 2000 -Elapsed time since submergence (ETSS)- 35 days

Site	***Tag #***	***Description***	***Fauna***	***Removed***	***Replaced***
12S	28	Bloated still, floating at length of chain Hole approx. 1" on left flank, large sore on right flank Skin and hair sloughing 3 legs and feet are gone, front right still intact Face still intact Blood worms visible Adipocere coating most of lower abdomen Silt collecting in shedding hair Surface scavenging on lower abdomen, hind quarter and neck	Fauna collected included marine oligochaetes (Family Enchytraeidae), bloodworms (*Euzonus* sp.), sea lice., copepods, marine worms (*Nereis* sp.), *Ammotryre aulogaster, Diastylis rathkei*	1900 h	2000 h

1 December 2000 - Elapsed time since submergence (ETSS) – 48 days

Site	***Tag #***	***Description***	***Fauna***	***Removed***	***Replaced***
10D	46	Bloated Hair mostly gone Muscle exposed on right side Head partly skeletonized Muscle tissue and spinal column exposed Blood worms visible near rope Skins very bleached, black speckled appearance 3 legs gone, hoof still present on remaining leg	Proboscis worms (*Glycera* sp.) and bloodworms (*Euzonus* sp.)		

26 May 2001 - Elapsed time since submergence (ETSS) 225 days

SITE	***DESCRIPTION***	***FAUNA***
7S	Barnacles were found on the tag that was used to restrain the pig carcass, very little remains, only 4 ribs left 1 large bivalve (5 ft radius) and mussel bed and lots of large kelp in the vicinity of where the carcass was located	Barnacles, and bivalve examined *in situ* 1 leafy hornmouth (*Ceratostoma foliata* (Gmelin)), 1 *Macoma* sp.
8S	Lots of bones (57 in total), spread out on the ground over a large area, 15-20 ft away, most spread out of all the bones Ribs, vertebrae, lower mandible, blackish in colour, few leg bones	Sunflower sea star (*Pycnopodia helianthoides*), lots of fauna; mussel bed, small feather star (*Florometra serratissima*), large univalve (8 ft radius) California sea cucumber (*Parastichopus californicus*), sea lice, nematodes, 2 sea strawberry (*Gersemia rubiformis*), 3 sandworms (*Nephtys* sp.), 7 pile worms (*Nereis vexillosa*), 1 three rib chiton (Lepidozona trifide), 1 smooth margarite (*Margarites helicinus* Phipps), 3 smooth cockle (*Clinocardium blandum*), 4 edible flat oysters (*Ostrea edulis*), 1 Olympia oyster (*Ostrea conchaphila* Carpenter)), 1 variegated chink-shell (*Lacuma variegata* Carpenter), 1 leafy hornmouth (*Ceratostoma foliata* (Gmelin)), 3 pieces of chalky macroma (*Macroma calcerea*), 1 barnacle (*Balanus* sp.)
9D	Pig wedged between two rocks Bones (28 in total) spread out over large area 3 ft X 4 ft, ribs, 1 pelvis, couple of long bones Scapula has growth on bone Bones very spongy Shells found attached to bone	Brittle star (*Ophiopsilla* sp.), sea lice, 9 sea strawberry (*Gersemia rubiformis*), 2 copper's chiton (*Lepidozona cooperi*), immature *Pandalus* sp., 1 smooth cockle (*Clinocardium blandum*), 1 wrinkled slipper-shell (*Crepidula lingulata* Gould), Pacific blue mussel (*Mytilus edulis*), 2 smooth pink scallop (*Chlamys rubida* (Hinds)), 1 thin shell littleneck (*Protothaca tenerrima*), >15 red turban (*Astraea gibberosa* Dillwyn), 1 hooded puncturella (*Cranopsis cucullata*), 1 tucked margarite (*Margarites succinctus* Carpenter)), 1 chalky macoma (*Macoma calcarea*), 1 Macoma sp., 2 Hind's mopalia (*Mopalia hindsii* Sowerby), 2 Sitka littorine (*Littorina sitkana* Philippi), 5 pieces of oyster (*Ostrea*

9D con't		sp.), 1 slender bittium (*Bittium attenuatum* Carpenter), Abolone piddock (*Penitella conradi*), >10 tusk shells (Family Dentaliidae)
10D	Ribs, lower mandible, and long bones scattered over the rocks (total number of bones 27) (~ 5 X 5 ft. area) Bone of mandible spongy in places. Bone with red spot, very clean bones, some have black coloration	Goby Sunflower sea star (*Pycnopodia helianthoides*), marine oligochaetes (Family Enchytraeidae), 1 *Macoma* sp., 1 three rib chiton (*Lepidozona trifida*), 2 sea strawberry (*Gersemia rubiformis*)
11D	The rope apparatus was still intact, bit of unidentified black debris was found on the rope Sea star in the area, few mussels	Sunflower sea star (*Pycnopodia helianthoides*) mussels
12S	Nothing	

TABLE 5. Complete list of fauna collected at each site, Summer 2000

		Site	1S	2S	3D	4D	5D	6S
PHYLUM NEMATODA				X		X		
PHLUM ANNELIDA								
Marine Oligochaetes	Family Enchytraeidae			X	X	X		X
Proboscis Worms	*Glycera* sp.				X	X		
Bloodworms	*Euzonus* sp.			X	X	X		X
Pile Worms	*Nereis vexillosa*			X				
Marine Worms	*Nereis* sp.			X				
Scaleworm	*Arctonoe* sp.			X		X		X
Polychaetes	*Ammotrypane aulogaster*			X		X		
PHYLUM MOLLUSCA								
Oregon Triton	*Fusititron oregonensis*			X	X	X		
Aleutian Macoma	*Macoma lama*			X				
Sitka periwinkle	*Littorina sitkana*			X				X
Wrinkled Amphissa	*Amphissa columbiana*			X	X			
Western Lean Nassa	*Nassarius mendicus*				X	X		
Mussels				X				
PHYLUM ARTHROPODA								
copepods				X	X	X		
Alaskan Pink Shrimp	*Pandalus eous*						X	
Hermit Crab	*Pagurus beringanus*				X			
Pacific red hermit	*Elassochirus gilli*				X			
barnacles								X
Small amphipods			X	X	X	X	X	X
Red Rock Crab	*Cancer productus*			X	X	X	X	
Pacific lyre Crab	*Hyas lyratus*				X			
Blue Mud Shrimp	*Upogebia pugettenis*			X		X		
Large amphipods				X				
Coon Striped Shrimp	*Pandalus danae*			X	X	X	X	
Sitka shrimp	*Heptacarpus sitchensis*			X				
Crustacean	*Diastylis rathkei*			X				
PHYLUM ECHINODERMATA								
Leather Star	*Dermasterias imbricata*							X
Sea Star	*Henricia aspersa*					X		
Mottled Sea Star	*Pisaster brevispinus*			X				
Sunflower Sea Star	*Pycnopodia helianthodes*				X	X		
Red Sea Star	*Mediaster aeqalis*			X	X	X		
Green Sea Urchin	*Strongylocentrotus droebachiensis*				X			

		Site 1S	2S	3D	4D	5D	6S
PHYLUM CHORDATA					X		
Gobies	Family: Gobiidae				X		
Sculpins	Family: Cottidae					X	
Ling Cod	*Ophiodon elongatus*						X
Unidentified Fish						X	
Pacific Halibut	*Hippoglossus stenolepis*					X	
Sand dads	*Citharichthys* sp.					X	X
Larval Herring	Family: Clupeidae	X	X	X	X	X	X

TABLE 6. Complete list of fauna collected at each site, Fall 2000

		Site 7S	8S	9D	10D	11D	12S
PHYLUM CNIDARIA							
Sea Strawberry	*Gersemia rubiformis*		X	X	X		
PHYLUM NEMATODA			X				
PHYLUM ANNELIDA							
Marine Oligochaetes	Family Enchytraeidae				X		X
Bloodworms	*Euzonus* sp.						X
marine worms	*Nereis* sp.						X
Proboscis worm	*Glycera sp.*				X		
Sandworms	*Nephtys* sp.		X				
Pile Worms	*Nereis vexillosa*		X				
Polychaetes	*Ammotryre aulogaster*						X
PHYLUM MOLLUSCA							
Three Rib Chiton	*Lepidozona trifida*		X		X		
Copper's Chiton	*Lepidozona cooperi*			X			
Wrinkled Amphissa	*Amphissa columbiana*						X
Smooth Cockle	*Clinocardium blandum*		X	X			
Wrinkled slipper-shell	*Crepidula lingulata*			X			
Pacific Blue Mussel	*Mytilus edulis*			X			
Smooth Pink Scallop	*Chlamys rubida*			X			
Thin shell littleneck	*Protothaca tenerrima*			X			
Red Turban	*Astraea gibberosa*			X			
Hooded Puncturella	*Cranopsis cucullata*			X			
Tucked Margarite	*Margarites succinctus*			X			
Smooth Margarite	*Margarites helicinus*		X				
Chalky Macoma	*Macoma calcarea*	X	X	X			
Macoma	*Macoma* sp.				X		
Hind's Mopalia	*Mopalia hindsii*			X			
Oyster	*Ostrea* sp.			X			
Edible Flat Oysters	*Ostrea edulis*		X				
Olympia Oyster	*Ostrea conchaphila*		X				
Sitka Periwinkle	*Littorina sitkana*			X			
Slender Bittium	*Bittium attnuatum*			X			
Abolone Piddock	*Penitella conradi*			X			
Variegated Chink-shell	*Lacuma variegata*		X				
Leafy Hornmouth	*Ceratostoma foliata*	X	X				
Tusk Shells	Family Dentaliidae			X			
Mussels		X					
Large Bivalve (5 ft radius)		X					

		Site 7S	8S	9D	10D	11D	12S
PHYLUM ARTHROPODA							
copepods							X
Barnacle		X	X				
Sea Lice			X	X			
small arthropods							X
Shrimp	*Pandalus* sp.			X			
Crustacean	*Diastylis rathkei*						X
PHYLUM ECHINODERMATA							
Sea Star	*Henricia aspersa*				X	X	
Feather Star	*Florometra serratissima*		X	X	X		
Sunflower Sea Star	*Pycnopodia helianthodes*		X	X	X	X	
Brittle Star	*Ophiopsilla* sp.			X			
California Sea Cucumber	*Parastichopus californicus*		X				
PHYLUM CHORDATA							
Goby	Family: Gobiidae				X		

APPENDIX I – Diver's log for summer 2000 experiment

16 May 2000. First day. Setup of pig sites.
Vessel – RCMP – NADON, 66 ft, all welded, aluminum, catamaran, 10 yrs old. Retired and scrapped, then completely rebuilt for St. Roch II voyage.

Personnel	***Affiliation***	***Comments***
Gail Anderson	SFU	
Niki Hobischak	SFU	
Ken Burton, Sgt.	RCMP	Skipper
Dave Smith, Cpl.	RCMP	Diver, dive 3
Bruce Ward, Cpl.	RCMP	Diver, dive 3
Jeff Marliave, Dr.	Vancouver Aquarium Marine Science Centre	Diver
Jeremy Heywood	Vancouver Aquarium…	Diver, Dive 1 and 2
Andrea Park	Vancouver Aquarium…	Diver, Dive 1 and 2
Joyce Kwan	Ident Section, civilian	
Lloyd Smith	Retired RCMP	

Left dock ~ 0930 h returned to dock ~ 1700 h
Set up the 6 research sites off the peninsula on Popham Island (privately owned by Rudy North)
Three sites aimed at 25 ft depth and 3 sites at 50 ft depth. Had to allow for low tide when we went out so actual depths less when we staked them.

First Dive – Divers Andrea Park and Jeremy Heywood
Divers in water 11:15 h, close to base of breakwater, close to Island

Down	***Up***	***Time***	***Comments***
11:15	11:35		Came up during this time, but was not noting, laying rope line and checking depths. Went in close to base of breakwater, where it connects with Island
11:36	11:43	7 minutes	Laying *Blocks 1* at 19 ft at end of breakwater
11:47	11:59	12 minutes	
12:04	12:16	12 minutes	Laying *Blocks 2* at 23 ft out from breakwater

Divers out of water – 12:16 h

Second Dive – Divers Andrea Park and Jeremy Heywood

Divers in water 13:26 h, at site 2

Down	***Up***	***Time***	***Comments***
13:26	13:30	4 minutes	Laying *Blocks 3* at 44 ft further out from breakwater and blocks 2
13:38	13:43	5 minutes	Laying *Blocks 6* at 23 ft close to base of breakwater, where line first laid down

Divers out of water at 13:43

Third Dive – Divers Bruce Ward and Dave Smith

Divers in water 14:17 h, at site 2

Down	***Up***	***Time***	***Comments***
14:17	14:31	14 minutes	Laying *Blocks 4* at 46 ft out but in line roughly with blocks 1. Ran out of rope, had to get some old rope and tie together.
15:07	15:12	5 minutes	
15:15	15:29	14 minutes	Laying *Blocks 5* at 41 ft out but in line roughly with start of line.
15:33	15:43	10 minutes	Connecting rope back to original line

Divers out of water 15:43

27-28 May 2000. Pig placement and first sample dives.

Vessels:-

- RCMP – NADON,
- Nadon's Zodiac,
- Aquarium research boat (23' *Kellehan* aluminum work boat).

Personnel	***Affiliation***	***Comments***
Gail Anderson	SFU	
Ken Burton, Sgt.	RCMP	Skipper
Dave Smith, Cpl.	RCMP	Diver, dive 1
Bruce Ward, Cpl.	RCMP	Diver, dive 1, night dive,
Jeremy Heywood	Vancouver Aquarium Marine Science Centre	Diver, Dive 2, Night Dive, Dive
Nathan Taylor	Vancouver Aquarium Marine Science Centre	Diver
Jennifer Norton	Vancouver Aquarium Marine Science Centre	Diver
David Burton		

Picked up pigs at 0530 h – Britco Packers. 6 pigs killed at 0540 h.
Left Dock on Nadon ~ 0730 h, Aquarium crew met us at Popham Island

First Dive – Divers Cpl's Bruce Ward and Dave Smith, RCMP
Divers in water 1106 h 27 May 2000, off Aquarium vessel, dropped in at site #6S

Down	***Up***	***Time***	***Comments***
1106	1114	8 minutes	Went in at site 6S off base of peninsula, then roped to site 5D. Depth 29ft
1115	1118	3 minutes	Added large buoy to site 5D for visual help locating carcasses from above water. Depth 42 ft
1120	1127	7 minutes	Moving to site 4D, set up buoy - large Depth 50 ft Temperature 53 F
1129	1133	4 minutes	Site 3D, set up large buoy, Depth 51 ft
1134	1136	2 minutes	Site 2S, set up small buoy Depth 28 ft
1142	1146	4 minutes	Site 1S, set up small buoy, but floated away Depth 28 ft Towed back to base of Peninsula at 6S, while boat crew picked up pigs
1203	1210	7 minutes	Down to site 6S to tie on first pig (48 lb) Very high south westerly wind. Towed divers to site 2S. Pig 6S floated to end of length or rope – 3-4 ft off bottom
1216	1218	2 minutes	Down to site 2S to tie on pig 2, (51 lb) Divers out Pig 2S nose heavy, butt up floated to extend of rope – 3-4 ft above sea floor

Second Dive – Divers Jeremy Heywood and Nathan Taylor, Vancouver Aquarium
Divers in water 1254 h 27 May 2000, off Aquarium vessel, dropped in at site #3D

Down	***Up***	***Time***	***Comments***
1254	1255	1 minute	Went in at site 3D
1255	1305	10 minutes	Went down with pig (47 lb), set pig at 1300 h, swam to site 4D
1305	1314	9 minutes	Up for pig (55 lb), down, set pig at 1305 h, then swam to site 5D
1314	1321	7 minutes	Took pig down to site 5D (50 lb)
1326	1330	4 minutes	Retying buoy at 1S
1333	1339	6 minutes	Down with last pig, to site 1S pig set at ~ 1335 h

Divers towed to dock, out 1344 h

Third dive – first sample dive, Divers Jeremy Heywood and Jennifer Norton, Vancouver Aquarium
Elapsed Time since Death (ETSD) – 13 h 10 minutes – 13 h 50 minutes (using 13.5 h)
Elapsed Time since Submergence (ETSS) – 6-7 h
Left dock at 1845 h.
Divers in water 1850 h 27 May 2000, off Aquarium vessel, dropped in at site #1S

Down	***Up***	***Time***	***Comments***
1852	1929	37 minutes	Went in at site 1S, sampled, got turned around and went to 6S next, then 5D, 4D, 3D, 2S and 1S

Fourth dive –second sample dive, Night Dive, Divers Jeremy Heywood and BruceWard
Elapsed Time since Death (ETSD) – 28 h- 28.5 h
Elapsed Time since Submergence (ETSS) – 21-21.5 h
Divers in water 0045 h 28 May 2000, off Zodiak, dropped in at site #1S
Using Video Camera – Sony VX 1000, with Amphibico VH1000 housing and Nikonos V
Weather conditions, wet, raining, very rough, water temperature 43 F.

Down	***Up***	***Time***	***Comments***
1250	0125	35 minutes	Followed rope around 1S, 2S, 3D, 4D, 5D, 6S

Divers out on dock 0135 h

Fifth dive –third sample dive, Divers Jeremy Heywood, Nathan Taylor, Vancouver Aquarium and Bruce Ward, RCMP
Elapsed Time since Death (ETSD) – 19 h 10 minutes – 19 h 45 minutes (using 19.5 h)
Elapsed Time since Submergence (ETSS) – 12-13 h
Left dock 9:30 am, divers in water 0935

Weather a bit calmer, visibility very bad, water temperature 43 F deep sites, 47 F shallow sites

Down	*Up*	*Time*	*Comments*
0940	1010	30 minutes	Followed rope around 1S, 2S, 3D, 4D, 5D, 6S. Visibility was very bad.

30 May 2000 – Elapsed time since submergence – 3 days
Dive by Dr. Jeff Marliave and John Fisher of Vancouver Aquarium Marine Science Centre.

7 June 2000 – Elapsed Time since Death – 11 days
Jeremy Heywood, Nathan Taylor, Aquarium, from Vancouver Marine Science Centre
dive time approx. 1230 h for :35 bottom time
Video'ed using VX1000 in VH1000 housing
Note - my 'finger' notation in front of the camera lens is in the wrong order (we started at pig 6 but I noted that it was pig 1 on film, etc). We actually dove from pig 6 to pig 1 (JH)
Water temp was 8C on deep sites, 10C on shallow sites

Down	*Up*	*Time*	*Comments*
1230	1305	35 minutes	Followed rope around 1S, 2S, 3D, 4D, 5D, and 6S.

26 June 2000 – Elapsed Time since Death – 30 days
Dive by Dr. Jeff Marliave and Vancouver Aquarium staff

Comments: The last pig (shallow, near the offshore tip of the breakwater) was missing, its chain fouled in the construction blocks, where the blocks frayed the poly line. Good observation on methods, though. In future, shallow pigs where wave surge occurs will require a second tether and chain, tied several meters along the guide line, away from the anchor blocks, so that the pig stays safely away from the blocks.

6 July 2000 – Elapsed Time since death – 40 days
Dive by Tim MacFarlane, Luciano Nisi, Canadian Coast Guard
Still camera used by Luciano Nisi
Captain, Sue Pickerell and navigator Jeff Nemrava, Canadian Coast Guard, small hovercraft. Filmed by Marianne Meadahl, SFU News
Left base 1830 h, arrived Popham Island 1910 h

Down	*Up*	*Time*	*Comments*
1942	2012	30 minutes	Followed rope around 6S and 5D. Dive abandoned after 5D, due to complications

13 July 2000 – Elapsed Time since death - 47 days
Dive by Tim MacFarlane, and John Merrett, Canadian Coast Guard.
Still camera used by John Merritt, video by Tim MacFarlane (not set correctly, so only one pig covered)
Captain, Sue Pickerell, Navigator, Craig Rachman, Canadian Coast Guard, small hovercraft
Left base at 1835 h, arrived Popham Island 1912 h.

Down	***Up***	***Time***	***Comments***
1920	1952	32 minutes	Went in at site 2S, then 1S, 6S, 5D, 4D and 3D.

20 July 2000 – Elapsed Time since Death – 54 days
Tim MacFarlane, Luciano Nisi, Captain Brian Wooten and Navigator Bruce Briggs, Canadian Coast Guard, small hovercraft. Also Osprey present, Canadian Coast Guard from Kitsilano.
Dive by Tim MacFarlance, Luciano Nisi, Bruce Briggs and Rick Foreman from the Osprey, and John Merrett, Canadian Coast Guard. Dove off small zodiac piloted by David Gonzalez.
Video by Tim MacFarlane. Left base 1029 h, arrived at Popham Island 1101 h

Down	***Up***	***Time***	***Comments***
1141	1210	29 minutes	Went to 6S first, moved to 5D at 1146 h, moved to 4D at 1150 h, arrived at 1155 h, moved to 3D at 1157 h, arrived at 1200 h, moved to 2S at 1201 h, arrived at 1202 h, moved to 1S and arrived at 1205 h.

20 September 2000 – Elapsed Time since Death – 116 days
Canadian Coast Guard large hovercraft, Siyay, Navigator Jeff Nemrava, pilot Karl Seseleja. Dive by Stu Simms, Julie De Grandpere, Canadian Coast Guard. Julie had problem with mask when going in. Stu did dive by himself with Julie on com lines. Still camera: Stu.
Fish hooks were found all along the rope
Divers in the water at 1244 hours, and returned to base at 1430 hours

Down	***Up***	***Time***	***Comments***
1244 h	1303 h	19 minutes	Went to 6S, 5D Julie had problem with mask, came up immediately. Stu continued observations.
1244 h	1313 h	29 minutes	Went to 4D (depth 55 ft), 3S, and 2S (depth 40 ft)

14 October 2000 – Elapsed Time since Death – 140 days, Pig Recovery
Left Delta Parts approx. 1030 hours, arrived at Popham Island at 1345 hours

Personnel	***Affiliation***	***Comments***
Troy Attfield	CAST	diver
Dan Hilderbrand	CAST	
Brad Falconer	CAST	
Andy Meeher	CAST	diver
Sean Stevenson	CAST	
Greg Ipatowicz	CAST	
Tim MacFarlane	CAST	coordinator
Lynn Hurren	CAST	stayed on shore
Tony Reynolds	CAST	
Mark Miller	Discovery	video
Kevin Mills	Discovery	video
Joss Hallier	Tofino	
John Merrett	Tofino	diver

Teams of 3: video tape, still camera, com lines and recovery
Divers in the water at 1435 hours – did set up for fall experiment then did pig recovery of summer experiment, out at 1651 h. Strong rip tide SW.

APPENDIX II – Taphonomic Modification in Water Environments (copied from Haglund and Sorg (2002).

Modification	Implications
Abrasion	Wearing-down of bone due to sediment action, particularly in high-energy settings.
Encrustation	The overgrowth of hard skeletal elements by other organisms. Indicates exposure above the sediment-water interface, encrustation can specify environment and may be an indicator of time passage.
Bioerosion	Corrosive processes by organisms. The most pervasive causes of degradation are boring or grazing. Bioerosion erases surface features, but leaves traces made by the organism. Patterns and process of bioerosion vary among environments due to the distribution of bioeroders, energy levels, and other habitat differences.
Dissolution	Skeletal remains are often in equilibrium with surrounding waters, but changes in chemical conditions can cause skeletons to dissolve.
Erosion.	Broken edges of skeletons become rounded due to either dissolution or abrasion of the exposed surface. The processes that control edge erosion are not fully known, but are probably a combination of dissolution, abrasion, and bioerosion. Rounding may give a relative estimate of time since breaking.
Decomposition	Decomposition attracts scavengers in phases and increases the probability of soft tissue loss. Its presence generally signifies the presence of oxygen and above-freezing temperatures.
Disarticulation, fragmentation	Separation of body units increases the probability of transport possible. Dispersal resulting from disarticulation may change the accessibility of soft tissue or bone to other taphonomic processes.
Scavenging	Consumption by other organisms decreases the probability of preservation and may increase dispersal and fragmentation. The presence of some scavengers may attract others.