Application of a Bayesian belief network to model black bear intertidal habitat quality

by

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Supervisory Committee

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Abstract

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In this study, I document the steps taken to develop and apply a Bayesian belief network (BBN) model for identifying the probable black bear intertidal habitat quality of Clayoquot Sound, British Columbia. Initial model outputs provide a narrow range of probability values, resulting in three high quality intertidal habitat classes applied to the study area. Day-time, summer observations of bear intertidal utilization improve previous knowledge of bear behaviour and highlight preferred resources and habitat characteristics, along coastal margins. Black bear encounter rates are calculated for the individual and some combinations of the key environmental variables used within the model. Bear encounter rates increase with higher probability class. A revised BBN model is implemented through systematic methods applied to the comparison of the initial model conditional probability tables and black bear encounter rates. This final model improves the discrimination of intertidal habitats resulting in four classes. The range of probability values increases as do the encounter rates with successive higher probability classes. Future recommendations for improvements are presented.

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Chapter 1 Introduction

1.1 Overview

Along the coastline of British Columbia, the intertidal zone has been largely ignored by researchers with respect to its use as a resource for terrestrial mammals. Land use planners, resource managers and emergency response personnel require an understanding of the role and importance of intertidal habitats for terrestrial mammals to ensure effective resource management, conservation and environmental protection decision-making. As a result of this limited research, there is a lack of empirical data on terrestrial mammal intertidal utilization. Hence, there is the need for a cost-effective tool to identify those habitats that are important to various terrestrial species. The Bayesian belief network (BBN) model is one tool that has been successfully applied in ecological modeling and conservation management.

A number of recent studies document the application of the BBN to model ecological scenarios including habitat (e.g., Reckhow 1999, Marcot *et al.* 2001, Hengeveld 2005, Smith *et al.* 2007). BBN models provide a framework that is understandable and adjustable, as well as providing an approach that allows the integration of ecological data and knowledge from experts to produce simulation modeling results (Steventon *et al.* 2006). There are no applications of this model to identify important or significant intertidal habitat for terrestrial mammals.

Here I document the development and application of the BBN model to identify the probable quality of intertidal areas for black bears (*Ursus americanus)* in Clayoquot Sound on Vancouver Island in British Columbia. I attempt to identify the important biophysical variables that influence black bear intertidal habitat quality through literature and bear expert reviews, field surveys of intertidal bear utilization, and development and implementation and testing of a Bayesian belief network (BBN) black bear intertidal habitat model.

Black bear populations are widely dispersed in British Columbia. Bears are found within all British Columbia's biogeoclimatic zones and occupy a wide variety of habitats ranging from coastal estuaries to alpine meadows (Rasheed 2001). Black bear populations in British Columbia are considered to be relatively stable across their range with an estimated population of 120,000 to 160,000 individuals (Hristienko & McDonald 2007). Most terrestrial black bear studies have focused on terrestrial landscapes (e.g., alpine, plateau). Comparatively, little attention has been paid to their interaction with the coastal zone. Knowledge of their behaviour and use of the shoreline is critical to ensure the identification and preservation of those preferred intertidal habitats. This is especially important for those parts of the British Columbia coast where there is increasing expansion and development by humans.

The British Columbia coastline consists of over 27,000 km and is made up of a range of diverse and productive habitats that, in turn, provide abundant resources for the North American (NA) black bear. However, research and associated information concerning their use of the intertidal zone has been poorly documented and is largely anecdotal. Most research of black bear utilization of coastal environments has focused on the return of spawning salmon (*Oncorhynchus spp.*) to estuarine habitats (Frame 1974, O'Clair & O'Clair 1998, Reimchen 1998, Reimchen 2000, Carlton & Hodder 2003, Klinka 2004) in the late summer and autumn seasons. Other black bear intertidal interactions are anecdotal in nature, although intertidal habitats are regarded as a component to their lifecycle providing forage, movement, and scavenging opportunities (MacHutchon 1999).

The black bear was chosen for this project as there is limited knowledge of their utilization of the intertidal zone, a lack of associated empirical data to build a 'traditional' habitat model and the availability of local black bear specialists to provide input into the BBN model development. Clayoquot Sound was selected as the study area as it is a region of known black bear activity within the intertidal zone (MacHutchon 1999), has comprehensive intertidal, marine and terrestrial inventories to assist in the development of the BBN model, and is easily accessible for field surveys. The completion of several Provincial government coastal and adjacent terrestrial physical and biological inventories through the 1990's and the consolidation of this information into a Geographic Information Systems (GIS) makes it increasingly easier to undertake species distribution modeling and develop insights into species interactions. These factors create an ideal situation or opportunity for the application of the BBN modeling approach.

1.2 Purpose and Objectives of this Research Study

The purpose of this study is to identify those intertidal habitats that are important for black bear utilization in Clayoquot Sound on Vancouver Island, British Columbia through the development and implementation of a BBN black bear intertidal habitat quality model. The focus of this study is on black bear utilization of the intertidal area exclusive of black bear activity associated with coastal streams and rivers during the salmon spawning season. Estuaries are included in the study as black bear forage for other resources in these areas during non-spawning times.

It is expected that the BBN model developed for this study will serve as a preliminary model for further enhancement with increased knowledge of black bear use of the intertidal zone that will eventually lead to its application across a broader geographic area. The model is flexible and easily updated and can be refined with the new research results, and potentially may be applied to other terrestrial mammals' intertidal habitat utilization. The results of this project may also help to focus further future research related to improving our understanding of the role of intertidal habitats for black bears.

The following four objectives were developed for this study:

1. Identify the key physical and biophysical shoreline variables that influence which intertidal habitat areas are utilized by black bears through literature and bear expert reviews.
2. Develop a BBN black bear habitat quality model based on the information obtained from the above reviews that predicts the probable quality of different shoreline intertidal zones utilized by black bears for a study area within Clayoquot Sound.
3. Increase knowledge of black bear intertidal utilization by conducting day-time, summer shoreline intertidal field surveys to document black bear behaviour and occurrences, and intertidal habitat bear use within the Clayoquot Sound study area.

4. Improve the BBN black bear intertidal habitat quality model by revising the initial model through the incorporation of knowledge gained from bear field surveys.

Chapter 2: Literature and Information Review

2.1 Introduction

A review of research and in particular spatial studies is an important first step to develop a BBN black bear intertidal habitat model. This review includes west coast NA black bear life history, intertidal habitat ecology, the BBN model with ecological examples, and assessment of the Clayoquot Sound biophysical spatial datasets for their application in model development.

2.2 Black Bear Life History

Black bear (*Ursus americanus*) are the most widely distributed of the three species of North American bears. They occur in a wide range of environments and all Canadian provinces except Prince Edward Island (Guide Outfitters Association of BC 2000). Black bears are yellow-listed (i.e. no subspecies are considered to be at risk) in British Columbia, and they occur in all BC biogeoclimatic zones (MacHutchon 1999, Rasheed 2001), where their populations are stable, numbering 120,000 – 160,000 (Hristienko & McDonald Jr. 2007).

Black bears are omnivorous and rely extensively on their sight and smell for successful foraging (Pelton 1982). They are known to forage frequently throughout the day (Garshelis & Pelton 1980, Lariviere *et al*. 1994) as they have a simple, short digestive tract devoid of complex microbial flora that limits their efficiency of digestion (Rode *et al*. 2001, Garneau *et al*. 2008). Their diet and feeding habits vary by season and location depending upon food availability. Plant material, including grasses, forbs, roots, young shoots, and fruits dominate their diet. A smaller portion of their diet is comprised of animal matter such as insects, beetles, rodents, fish (primarily spawning salmon), and carrion (Pelton 1982, O'Clair & O'Clair 1998).

Black bears are normally solitary and behave in a social order governed by the distribution and abundance of food (Rogers 1987). Food distribution and abundance, as well as population density, age, sex, and season influence the extent of individual bear home range (Pelton 1982, Powell *et al.* 1997, Koehler & Pierce 2003). In general, an adult male home range is three to eight times greater than an adult female. Home range extent of west coast bears is typically smaller than that of interior bears (Lindzey & Meslow 1977, Davis 1996, Davis *et al.* 2006).

Black bear foraging behaviour including seasonal variation is poorly understood due to their complex life-history and secretive behaviour (Koehler & Pierce 2003, Garneau *et al*. 2008). Black bear foraging behaviour has been documented to be selective with the understanding that they are enhancing their energetic and nutritional gains and lowering foraging costs (Breck *et al.* 2009). In variable food resource habitats their foraging behaviour appears to be directed towards maximizing use of the foods with the greatest energetic returns (Rogers 1987, Welch *et al*. 1997). Black bear have a reduced foraging cost when travel is limited due to food resource distribution and availability (Garshelis & Pelton 1981, Rogers 1987).

Black bear activity is primarily diurnal (Lindzey & Meslow 1977, Powell *et al.* 1997, MacHutchon *et al.* 1998). Other studies have demonstrated that crepuscular and nocturnal bear activity patterns do occur in western North America (Frame 1974, Garshelis & Pelton 1980, Reimchen 1998, Klinka 2004). For example, Lee (1985) and Reimchen (1998) recorded the highest bear activity in the evenings during salmon spawning.

Black bears in coastal habitats hibernate for four to six months and enter their dens in late November or early December, emerging in April (Lindzey & Meslow 1976, Davis 1996). Coastal bears may not den in milder climate regimes, however, hibernation is important to stay dry and conserve energy in moist, coastal winters (Davis 1996). Davis (1996) notes that cavities in old-growth trees, mainly yellow cedar (*Chamaecyparis nootkatensis*) and western red cedar (*Thuja plicata*) (e.g., large old trees, stumps, root bolls) are important hibernating sites. Hibernating in second growth forests is limited by suitable den sites.

Black bears emerge from hibernation between March and May with some remaining fat reserves. During the following two months their level of daily activity slowly increases (Garshelis & Pelton 1980, Lariviere *et al.* 1994) and they lose weight as they feed on emergent green vegetation, carrion and insects (Pelton 1982, Rogers 1987). The requirement to locate and consume high-protein foods influences their movement and habitat use at this time (Rode *et al*. 2001, Garneau *et al*. 2008). In early spring, high-protein, digestible food sources are found on warm aspect habitats, south-facing slopes, clear cuts, and slide tracks where they locate early developing grasses, sedges and horsetails *(Equisetum arvense)*. Along the coast, bears move to estuaries, beaches, open riparian areas, wet meadows, swamps, burns, and open valleys where sedges and grasses provide plant forage and they locate marine invertebrates (RIC 1998a, MacHutchon 1999, Rasheed 2001, Burles *et al.* 2004).

Black bears recover from their winter/early spring energy deficits from May to September. Their level of daily activity peaks during this time (Garshelis & Pelton 1980, Lariviere *et al*. 1994) to take advantage of the abundance of food sources primarily berries. Recent clear-cuts provide open areas for early succession berries including: salmonberry (*Rubus spectabilis*), red huckleberry (*Vaccinium parvifolium*), raspberry (*Rubus leucodermis*), blueberry (*Vaccinium* spp.), currants (*Ribes* spp.), black twinberry (*Lonicera involucrata*), elderberry (*Sambucus racemosa*), devil's club (*Oplopanax horridus*), highbush-cranberry (*Vibernum edule*), red-osier dogwood (*Cornus stolonifera*) and salal (*Gaultheria shallon*) (Davis *et al.* 2006). During this time the intertidal areas along the British Columbia coast continue to be utilized for foraging opportunities (Oldershaw 1995, MacHutchon 1999).

September to November is a critical period for bears to increase their fat stores before hibernation (Rogers 1987, Davis 1996). During this time, bears forage extensively and have been known to travel great distances to gain access to food (Rogers 1987, Davis 1996). The most important food source for coastal black bears is spawning salmon in the coastal estuaries, rivers, and streams. Many coastal western North American populations rely on salmon to provide the necessary energy for overwintering (Frame 1974, O'Clair & O'Clair 1998, Reimchen 1998, Reimchen 2000, Carlton & Hodder 2003, Klinka 2004, Smith & Partridge 2004). Spawning salmon alter the foraging behaviour of black bears as the concentration of this food resource provides them with 'inexpensive' weight gain prior to hibernation (Pelton 1982). Black bear fishing observed by Frame (1974), Reimchen (1998) and Klinka (2004) include occurrences of multiple bears fishing within proximity of one another predominantly at dawn and dusk. The alteration in the level and period of daily black bear foraging behaviour to optimize their energetic returns has been observed in terrestrial habitats when food sources are plentiful or there a perceived mortality risk with the presence of humans or grizzly bears (Garshelis & Pelton 1980, MacHutchon *et al*.1998, Lariviere *et al*. 1994, Matthews *et al*. 2006, Rode *et al*. 2007).

2.2.1 Coastal Black Bear Intertidal Foraging Ecology Review

The role of intertidal bear habitat for black bear foraging has not been systematically investigated although black and brown bear use of the coast is widely known in British Columbia (Oldershaw 1985, MacHutchon 1999), Washington (Lindzey & Meslow 1977), and Alaska (Lee 1985, Smith & Partridge 2004). Observations related to black bear intertidal food sources and activities along the west coast of North America are summarized in Tables 1 and 2 (Appendix A). Table 1 provides a list of flora and fauna bear foods observed along coastal areas of North America. Table 2 documents activities and intertidal food sources recorded in the Pacific Northwest. Overall, these observations indicate that intertidal habitats are an integral component of black bear foraging and scavenging. Common intertidal animal food items include barnacles (*Balanus* spp., *Chthamalus* spp.), clams (*Siliqua* spp.), mussels (*Mytilus* spp.), and crabs (*Hemigrapus nudus*); intertidal plant food sources are more limited, but include fucus (*Fucus gardneri*), grasses, and sedges.

Shoreline foods in Clayoquot Sound such as sedges and grasses, horsetail, crabs, and mussels have been found to be common in black bear scat analyses (MacHutchon 1999, Oldershaw 1994). MacHutchon's (1999) interviews with Nuu-Chah-Nulth and local community members indicated that they observed bears eating crabs, barnacles, starfish (*Pisaster* spp.), rockfish (*Sebastes* spp.), blenny eels (*Xiphister* spp.), and gunnels (*Pholis* spp.). Oldershaw (1994) observed black bears primarily feeding on shore crabs under beach cobbles, but they also ate blenny eels, pricklebacks, and starfish at Jenny's Beach in Shelter Inlet.

In British Columbia, black bears are known to forage on intertidal invertebrates (MacHutchon 1999). There is little evidence of bears foraging on intertidal vegetation, although a few bears have been observed foraging on rockweed in Glacier Bay Alaska (Ramsay 1985, O'Clair & O'Clair 1998, Carlton & Hodder 2003). Knowledge related to the location of intertidal black bear foraging and habitat character is limited. However, it is inferred from previous studies (Appendix A – Table 2) that bears commonly forage at low tides in mid and lower intertidal environments characterized by low to moderate wave exposures and cobble-boulder substrates. These conditions provide favourable habitat for larger invertebrates, which are found under larger cobbles and boulders that can be overturned by bears.

Optimal-foraging theory predicts that foragers attempt to maximize their energy intake (Charnov 1976). Other research suggests that the forager includes weighing the cost of predation with the benefits of energetic reward when making foraging decisions (Brown 1988). Applied to bears utilizing the intertidal this means that they would behave in a manner to acquire and consume foods with the highest caloric return while using the least amount of energy and balance any risks of predation before utilization. There are no studies that quantify the risks of predation and mortality to black bears and intertidal utilization. As well, the quality and quantity of resources obtained by black bears from intertidal environments to meet their energetic needs has not been studied. Smith and Partridge's (2004) study of foraging brown bears in the intertidal habitats of Alaska indicates that the high protein content and digestibility of clams allows for a lower rate of digestible energy intake to meet a bear's daily energetic maintenance compared to herbaceous forage such as sedges and grasses. Unlike the increase of herbaceous intake rates correlating with an increase in bear body mass (Rode *et al*. 2001), they found that as a bear's body weight increased the nutritional benefits from clams decreased due to the low intake rates for bears foraging on shellfish (Smith & Partridge 2004). This trait of smaller bears with lower metabolic costs taking advantage of less productive habitats or high energy foods with lower ingestion rates has been found in terrestrial studies (Welch *et al*. 1997, Rode *et al.* 2001).

Research in Clayoquot Sound indicates that shorelines and beaches were commonly used black bear travel routes (MacHutchon 1999). The movements of black bears are influenced by the availability of seasonally important food resources and/or habitat for breeding and hibernation (Powell *et al.* 1997). This suggests that shorelines influence how bears organize their activities around linear habitats, and may alter the size and shape of home ranges. Davis *et al.* (2006) indicate that the probability of site selection by a female black bear decreased by 2% with each 25 m distance from a salmon spawning stream, but only when fish were present. Thus, the juxtaposition and distance of intertidal food sources from known salmon streams may only be a factor during periods of fish spawning.

In summary, there have been no specific systematic black bear surveys examining the role that different intertidal habitats and resources play in the bear life history and energetics. Current knowledge is populated with observations collected in association with other research. The observations of these above studies (refer to Appendix − Table 2) combined with the black bear life cycle studies (Section 2.2) provide a number of potential habitat characteristics related to black bear use of the intertidal shore-zone. They suggest:

- Black bear utilization of the intertidal zone following hibernation tends to begin on south facing sites that are populated with sedges and grasses, such as estuaries and along the backshore of shorelines with wetlands.
- Black bear intertidal use continues throughout spring and early summer to support foraging needs prior to salmon runs.
- Intertidal habitats that consist of cobble and boulder beaches or rock with low to moderate wave exposures and tidal currents that support marine invertebrates are utilized at mid to lower tides.
- Intertidal habitats with moderate to high wave exposures and currents also appeared to provide scavenging opportunities of carrion and beach hoppers (*Traskorchestia traskiana*) found in decaying seaweed at any tidal level.
- By late summer and early fall, black bears move to the estuaries and deltas that have spawning salmon.
- Intertidal foraging by larger bears is limited, partially due to the low intake rates experienced with intertidal food sources even though they appear to have a greater caloric return than plant sources.
- Local terrestrial habitats also appear influential of black bear use of intertidal areas as well. The proximity of high value black bear terrestrial habitats, such as older growth forests for denning, or young open canopied

environments for high berry production, as well as the presence and distance to salmon streams appear to influence intertidal use.

- It can be speculated that black bear use in high valued terrestrial habitats and salmon streams along the coast is closely associated with black bear use of the adjacent intertidal shore.

2.3 Bayesian Belief Network Model: Overview

There is limited knowledge and data with respect to the types of intertidal habitats utilized by black bears in their daily requirements (Section 2.2). Thus, to model black bear intertidal habitat quality, the approach should have the capacity to incorporate expert knowledge where data is limited, and have the ability to integrate field data to calibrate and improve the model. The Bayesian belief network (BBN) is a habitat modeling approach that addresses these requirements.

The BBN has become a popular method of making ecological predictions and is a useful tool for addressing wildlife and resource management issues. A BBN is a probabilistic graphical model that represents the interactions among factors that influence the likelihood states of some parameter of interest. This modeling technique has many advantages including the ability to incorporate empirical data and handle missing data with the combination of expert knowledge, allows for learning about the causal relationships between variables and has proven to provide accurate results with small sample sizes (Uusitalo 2007). Marcot *et al.* (2001) also identified the need to develop models to support wildlife management where the wildlife relationships within ecosystems are poorly understood and there is minimal ecological research data.

BBN models are centered on the application of Bayes' theorem, which is a simple mathematical formula used for calculating conditional probabilities and to estimate the probability that a theory is affected by new evidence (Lee 1997). The BBN model combines available limited scientific data with expert knowledge and experience to develop probable outcomes that can be updated with new information (Marcot *et al.* 2006).

The central component of a biological BBN model is the construction of an influence diagram (Marcot *et al.* 2006). The influence diagram outlines the ecological "causal web" of the key influences or factors (referred to as correlates) that are considered to affect the species of interest. Correlates are identified through a review of related studies, and/or working with experts. The influence diagram consists of boxes (nodes) and arrows (links) that represent functional relationships among and between correlates, variables, and outcomes (Marcot *et al.* 2006). The influence diagram process results in two types of nodes. One node is an input, or parentless, node to which no other nodes are linked. These are comprised of one or more user defined states that are assigned a probability in an associated table. Alternatively, a node may be linked to one or more nodes that feed into it, a child node, whose state is expressed as probabilities conditional on the probability of the state of each of the linked nodes. Probabilities for each state can be based upon and populated by data from research, knowledge supplied by experts, or from a mathematical function.

The BBN approach allows for uncertainty in the modeling process. This feature provides a structure that is understandable and flexible which has made them popular in recent ecological modeling research (Hengeveld 2005, Smith *et al.* 2007). BBN modeling has been used to portray the influence of habitat or environmental predictor variables on ecological response variables (Marcot *et al.* 2006). BBNs have been applied to the assessment of land management choices upon fish and wildlife populations (Marcot *et al.* 2001), determining the effects of limiting quality nesting habitat to Marbled Murrlet (*Brachyramphus marmoratus*) (Steventon *et al.* 2006) population and modeling habitat suitability for the Julia Creek dunnart (*Sminthopis douglasi*) in Australia (Smith *et al.* 2007).

2.4 Physical and Biological Spatial Databases

Most of the spatial land, coastal, and resource information of British Columbia is maintained in the Provincial spatial data warehouse. An analyses of these data sets revealed that there were only a few data sets suitable to support development and implementation of a BBN black bear intertidal habitat quality model for Clayoquot Sound. These are the physical shore-zone and terrestrial ecosystem mapping data sets. Both have been systematically collected to provincial standards. The review also revealed that there are no systematic surveys of intertidal species, such as crab and starfish, for the study area.

2.4.1 Physical Shore-Zone Mapping System

The British Columbia Physical Shore-Zone mapping system was developed in 1979 (Howes *et al.*) to support the systematic inventory of the physical character of the British Columbia coastal zone (Howes 2001). It is a standardized, descriptive method to classify, map, and document the shore-zone physical attributes in the intertidal zone (Howes *et al.* 1995; Howes 2001). The system is hierarchal and provides the framework for the biological shore-zone mapping system (see below). It was developed to assist in coastal oil spill risk assessment and to support conservation, protection, and land use planning initiatives. The primary source of information for the Physical Shore-Zone mapping system is aerial video imagery flown at spring low tides supplemented with limited field surveys (Howes 2001).

The underlying concept of the system is that the shore-zone can be divided into discrete shore units that are systematically described on the basis of its physical character (Howes 2001). As documented in Howes *et al.* (1995), the mapping involves:

- Defining unique linear shore units by changes in either the intertidal sediment, wave exposure, or morphology (e.g., change from gravel beach to rock platform).
- Identifying different across-shore components of each unit on the basis of their morphology and substrate (e.g., beach face, beach flat).
- Recording a number of physical attributes (e.g., texture, slope, width, aspect, morphology) of each across-shore components of the unit.

Unit information is collected including wave exposure and aspect. Each unit is assigned to a coastal class (type). The linear shore unit boundaries are digitized and all information is recorded in associated databases. Table 1 to 6 (Appendix B) provides a partial summary of the physical data collected for each shore unit. For a complete description of the system's attributes and features see Howes *et al.* (1979).

Physical shoreline mapping of Clayoquot Sound was conducted in 1993 and 1994 during some of the lowest daily tide events (Harper, pers. comm.) The data set contains a number of physical features identified in the literature review (Section 2.2) required to support the development of a BBN black bear intertidal habitat quality model. For example, the data set contains information related to shore types (e.g., estuaries, rock platforms), substrate (rock) and clastic sediment (e.g., sand, cobbles, and boulders), morphology (e.g., cliffs, beaches, and platforms), wave exposures, shoreline aspect, and intertidal slope and width.

2.4.2 Terrestrial Ecosystem Mapping

Terrestrial Ecosystem Mapping (TEM) is an inventory and classification system that provides baseline habitat information for interpretation of wildlife values (RIC 1998b). Ecosystem mapping stratifies the landscape into map units, according to a combination of physical features, such as: climate, physiography, surficial material, bedrock geology, soil, and vegetation (RIC 1998b). It provides a biological and ecological framework for land management, a means for integrating abiotic and biotic ecosystem components onto one map, and a basis for rating values of resources or indicating sensitivities in the landscape.

TEM combines aspects of the Biogeoclimatic Ecosystem Classification (BEC) of the Ministry of Forests (MOF) with aspects of the Ecoregion Classification System (ECS) of the Ministry of Environment, Lands and Parks (MELP) (RIC 1998b). It uses a hierarchy of ecological units, including ecoregion units (from ECS) and biogeoclimatic units (BEC) at broad levels, and site units and vegetation development stages, which are combined as ecosystem units, at a more detailed scale. The Ecoregion classification system (ECS) is hierarch with five levels of generalization, from the broadest ecodomain to the most detailed ecosection. TEM is built on the most detailed level of ECS, *the ecosection level*. The Resources Inventory Committee (RIC 1998b) has established and described British Columbia standards for TEM ecosystem mapping at scales from 1:5,000 to 1:50,000.

TEM mapping involves identifying *ecosystem units* based on the underlying bio-terrain features delineated by aerial photograph interpretation (RIC 1998b). The units are a combination of terrain (surficial geology) and landscape (landforms) features with biological features and inferred soil drainage characteristics. The interpreted TEM units (polygons) are digitized and their associated data compiled in a GIS, which facilitates the integration of terrestrial ecosystem mapping with other resource inventories.

TEM has been completed in Clayoquot Sound; however, the black bear Wildlife Habitat Ratings (WHR) have not been applied to the Clayoquot Sound TEM data. Thus, there is no black bear habitat suitability mapping for the terrestrial backshore adjacent to the physical shore units to assist in the development of a BBN black bear habitat quality model. The black bear WHR was applied to the TEM polygons adjacent to the shoreline to make this information suitable to BBN modeling (Refer to Chapter 3).

2.4.3 Biological Shore- Zone Mapping System

The biological shore-zone mapping system was developed to complement the Physical Shore-Zone mapping system (Searing & Firth 1995). It is also a descriptive mapping system and is used to record the distribution of biological features along the shoreline. The physical mapping system framework is used to record the biological character (e.g., species distribution and abundance) of a shore unit. This approach assumes the physical parameters of substrate, intertidal elevation, and wave energy are the determinants of species distribution (Searing & Firth 1995).

Biological information on species assemblages (bio-bands) are identified from the video imagery and recorded in the across-shore unit components. The system involves mapping biological bands of benthic, sessile species in the intertidal zone, their distribution and width. In addition, biological data is usually collected for selected sites during the surveys. For specific details on the mapping system refer to Searing & Firth (1995). The shoreline biological mapping data was not used in the BBN model because:

- The types of intertidal food sources used by black bears are poorly understood. There have been no systematic biological surveys documenting the range and important types of food sources for black bears.
- The biological shore-zone mapping system is restricted to benthic and sessile species (Searing & Firth 1995). The system does not map intertidal distribution of clams, starfish, crabs, and backshore berries, all of which are a shoreline food source for bears (Table 1 and Table 2). The biological mapping does identify fucus and barnacle bands, both a black bear food source, but their role and

importance is unknown. In addition, these bands are common and widely distributed along the west coast of Vancouver Island and are not considered good indicators of favoured intertidal bear habitat.

2.4.4 Data Issues

The availability of the Physical Shore-Zone and TEM/WHR and their compatibility with GIS allowed for their ease of use. Two data issues were identified that had to be addressed prior to their utilization in BBN modeling. These issues were geo-referencing all of the data to a common coastline and developing a terrestrial backshore black bear habitat suitability map (see Chapter 3).

2.5 Summary Comment

Bayesian belief networks are a useful ecological modeling technique whose use is becoming increasing popular. Their increasing application is due to the straight forward graphical representation of model structures and probability distributions, the ability to incorporate expert knowledge when empirical data is lacking, and wide availability of user friendly, advanced software packages. Previous research has cautioned discretion of BBN use due to its inability to incorporate continuous variables or support feedback loops (Uusitalo 2007). However as stated by Marcot *et al.* (2006), rigorous peer review of the model and documentation of the building process as well as model updating and calibration with field data can reduce bias in the model and build validity.

BBN modeling provides a useful tool to model black bear intertidal habitat quality in Clayoquot Sound on the western coast of Vancouver Island, British Columbia. It is an area where there is very limited knowledge and understanding of the role that intertidal habitats play in the black bear activities. In addition, the area has systematic physical shoreline data including several variables cited in the intertidal bear utilization research review, and local bear specialists to assist in the model design.

Chapter 3: Methods

3.1 Methods Overview

The method I used to design the black bear intertidal habitat quality BBN model is outlined in Figure 1. It is a similar process to that employed by Marcot *et al.* 2001 and subsequently refined (Marcot *et al.* 2006). Key steps are to:

- Review the literature supplemented by local bear experts' knowledge to identify the biophysical characteristics of shorelines used by black bears.
- Develop an influence diagram that captures the themes of expected causal links for black bear intertidal habitat quality.
- Assess and assemble the relevant biophysical spatial information based on this knowledge, to enter into the 'initial based' model.
- Develop an initial BBN model with the rational for the nodes and the values populating the conditional probability tables (CPT).
- Conduct field surveys of intertidal bear shoreline habitat use, and the shoreline characteristics.
- Analyze the bear observations and revise the initial BBN model based on the results of this analyses.

Previous research was reviewed to document black bear life history and intertidal foraging and identify shoreline variables that influence black bear intertidal use (see Chapter 2). BBN modeling was also reviewed and a number of biophysical resource inventories assessed to determine their potential use in the BBN model. Provincial black bear experts were interviewed to confirm the results of the literature review and the BBN framework. Field surveys were conducted from May to August, 2005 (Section 3.2). These observations are analyzed to identify the influence that different biophysical variables have on shoreline use (Section 4.1). An initial BBN black bear habitat model was developed to identify intertidal habitat quality based on the literature and expert reviews (Section 3.4.3). A revised BBN model was subsequently developed incorporating the results of the field survey results (Section 5.2).

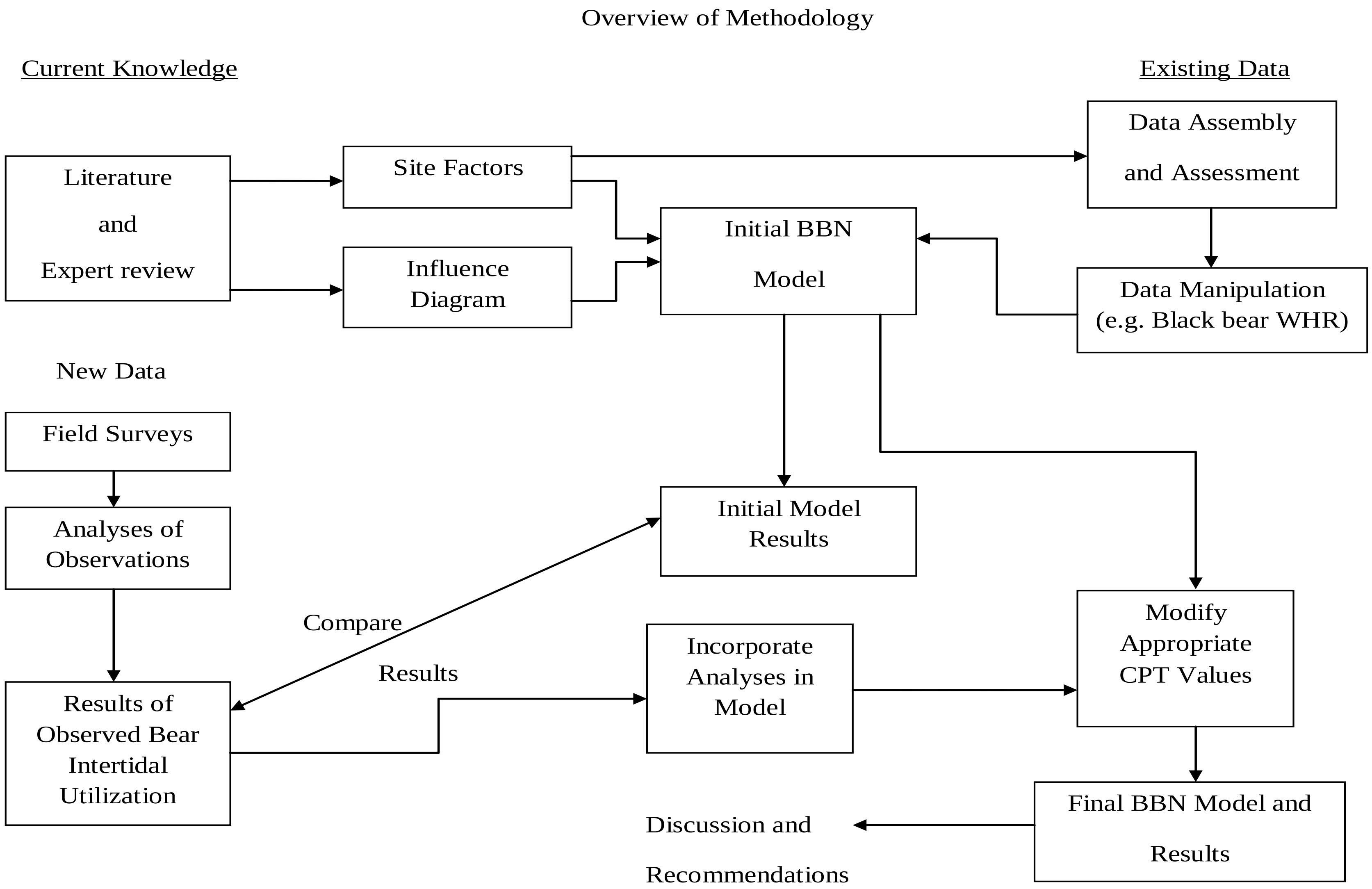

Figure 1. Overview of the methods used to develop a BBN model for black bear intertidal habitat quality.

3.1 Study Area

Clayoquot Sound is located on the west coast of Vancouver Island in the Windward Island Mountains Ecosection (Demarchi 1995) (Figure 2), and consists of approximately 1,300 km of coastline and covers 2,633 km^2 of land. The Sound is characterized by warm, moist summers and cool, wet winters.

The outer coastline of Clayoquot Sound is characterized by swell-dominated, high wave exposures whereas the coastal inlets have low wave exposures with locally wind generated waves. Tides are mixed, mainly semi-diurnal with two complete tidal oscillations per day. Mean tidal range at Tofino is 2.8 metres with a large tidal range of 4.1 metres. The largest tidal range on the coast occurs at Kennedy Cove in Clayoquot Sound (4.8 metres) (Harper, J. in Howes & Wainwright 1999).

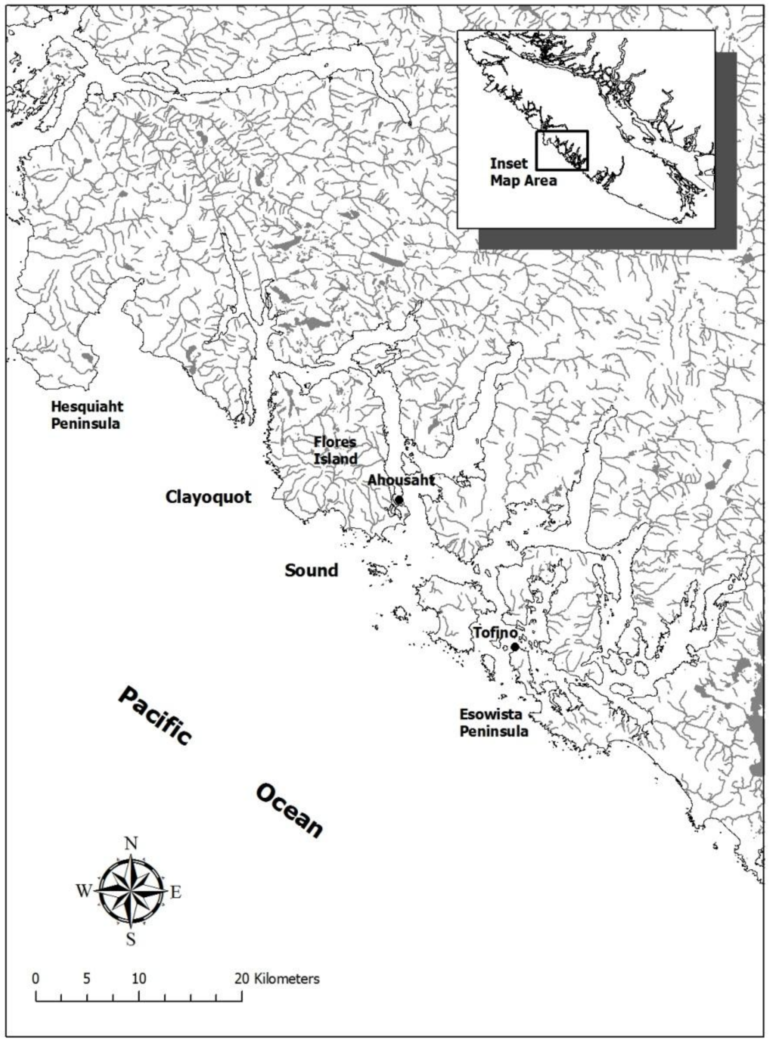

Figure 2. Location of study area, Clayoquot Sound

3.2 Field Survey of Bear Intertidal Habitat Use

Field surveys in the intertidal zone of the study area were conducted from May to August 2005 to collect the locations and activity of black bears. Four survey routes were used (Figure 3). Surveys one through three were located in inner, protected shorelines. In contrast, survey four was on the outer coast with shorelines dominated by semi-exposed and exposed wave coastlines. Clayoquot Sound has 1,321 km of shoreline excluding offshore islands (about 68 km of shoreline). Within the Sound, a total of 1344 physical shore units have been mapped and described. The survey shorelines account for 25% of this area and include 388 classified shore units.

Table 3 compares the distribution of the modified repetitive shore types within the survey routes and Clayoquot Sound. The different shore types are evenly represented within the four surveys. Variations between the sand and rock ramp shore types (lower frequencies in survey areas) and sand/gravel (higher frequency in survey areas) reflect minor differences in the distribution of outer and inner coast shore types. For example, the inner more sheltered coast tends to have slightly more sand and gravel shorelines than the outer coast whereas sand and rock ramp shorelines have a higher frequency of occurrence. In addition, the outer coast was limited to one survey route, due to difficult access and more severe weather and marine conditions impacting survey frequency.

Table 1. Comparison of shore length and unit frequency by shore type within Clayoquot Sound and the survey areas

Modified repetitive shore type	# of units in Clayoquot study area	Shore unit frequency (%)	Shore length frequency (%)	# of units in the survey areas	Shore unit frequency (%)	Shore length frequency (%)
Rock cliff	236	17.6	15.6	67	17.3	19.0
Rock ramp platform	244	18.2	25	52	13.4	19.7
Gravel	253	18.8	14.6	82	21.1	17.0
Sand and gravel	317	23.6	18.7	128	33	25.7
Sand	187	13.9	14.7	26	6.7	6.6
Estuary	96	7.1	11	30	7.7	11.3
Channel	1	.1	0.1	2	.5	0.3
Manmade	10	.7	0.3	1	.3	0.6
Total	1344	100	100	388	100	100

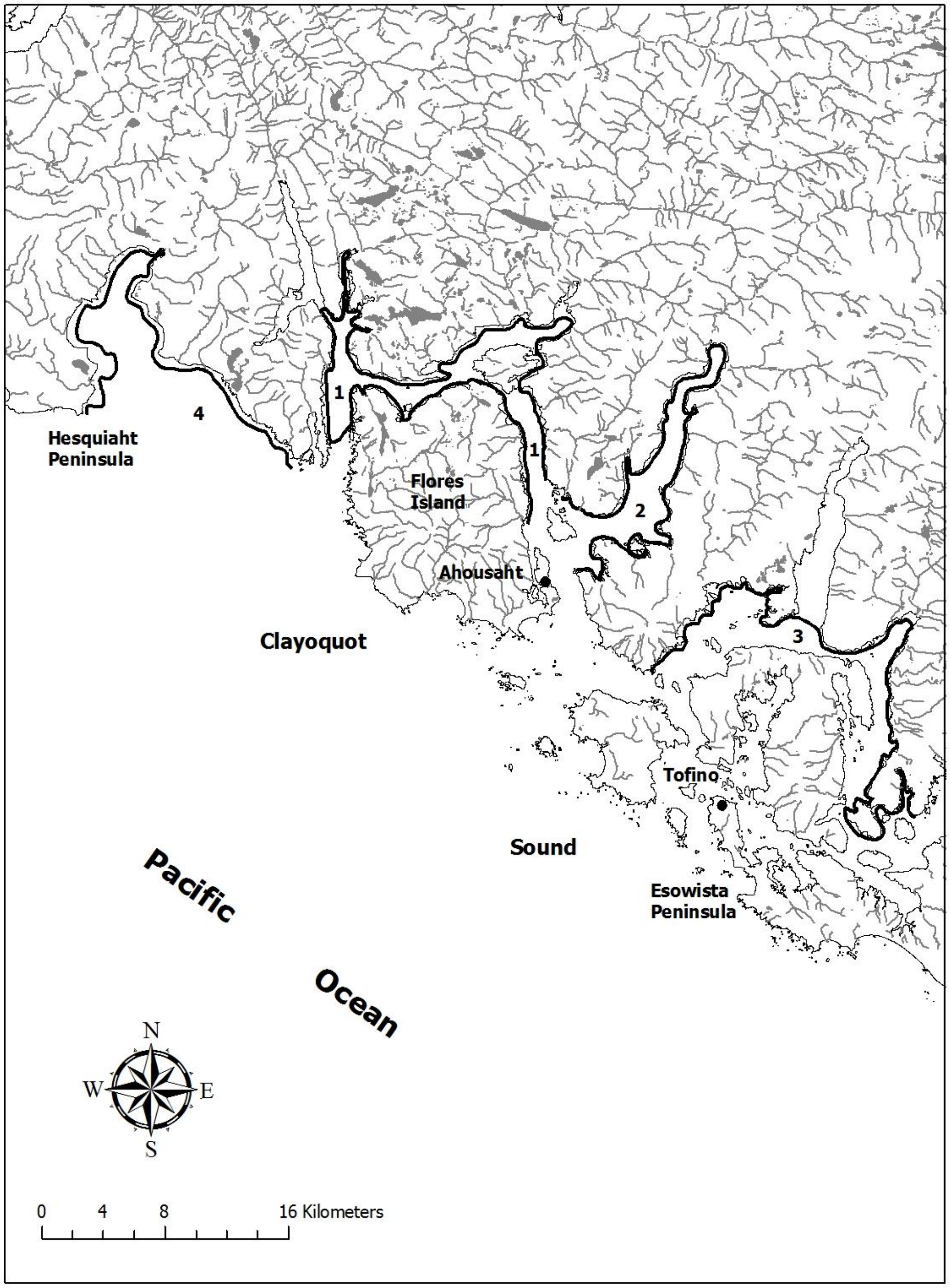

Figure 3. Survey route locations.

An objective of this study is to increase knowledge of black bear intertidal use, exclusive of their use of coastal estuaries during anadromous fish spawning. Estuary shore types, however, were included, as these habitats support black bear foraging during non-spawning periods. To minimize the influence of estuary use due to spawning, the surveys were conducted from May to August.

Surveys were conducted during daylight hours from a 5 metre aluminum boat with a crew of two to three observers traveling at a speed of 5-7 kts, 70-200 m offshore. No nocturnal data was collected. To ensure there was ample intertidal area for bears to use, surveys were only undertaken when the tide height was no greater than 1.4 metres. Only one route was surveyed per day due to the time required to complete the survey, and the tide cycle. Surveys of routes 1, 2 and 3 were initiated from opposite ends on alternative survey days. Survey route four was conducted in a northerly direction due to its distance from Ahousaht, and the higher incidence of unfavourable seas.

Scan and focal-animal observations (Lehner 1998) of bear presence and activity were collected during the surveys. The vessel course would change from the survey line upon sighting a bear to approach the individual. One crew member would maintain visual contact and observe and record behaviour as the vessel approached the shoreline

The reaction of the bear to the approaching vessel was recorded. These behaviours were classified as: avoid (the bear withdrew to the backshore but not in a hurried manner), flee (the bear ran into the backshore), ignore (observers noted, but continued with their activity) and none (the bear made no noticeable recognition of the observers). The approximate distance that a bear noticed the survey boat and their associated response behaviour was also noted.

A range of bear data was recorded and transferred into a database linked to the bear's geographic location, including:

- Number of individuals, each single bear, or female with dependent young, was counted as one bear observation.
- The relative GPS location of the bear(s), transferred to a hardcopy physical shore unit map and incorporated into the GIS.
- Behaviour including the type of foraging activity (e.g., flipping rocks, digging, scavenging, grazing on grasses or unknown).
- Food item being consumed.
- Location in the intertidal zone (upper, middle and lower) based on bears' position relative the waterlines of the shore unit.

- Number of cubs (if present), approximate size of the bear and time of the observation in the tide cycle.
- Photographs and video documenting bear behaviour and shoreline characteristics.

Physical data of the shore unit were recorded with each bear observation to provide insights into the character of the shorelines. Intertidal slope, shoreline aspect, presence of freshwater, slope of the backshore and the approximate age of the backshore forest were noted.

Additional information was obtained by random transects, checks of bear scat (if present) and the review of video and photographs (refer to Appendix C for results). Shoreline transects were conducted to document upper and intertidal biota present, when sufficient time was available during a survey, and no bears were present (refer to Appendix D for results). If a particular beach was strewn with cobbles and boulders previously overturned by a bear, underlying fauna were recorded. Other rocks were randomly turned over and the biota underneath recorded.

3.3 Bayesian Belief Network (BBN) Modeling

The overall design of the BBN black bear intertidal habitat model is based on physical variables and, in particular, those that influence intertidal species. This approach is supported by several authors who identified physical attributes as principal determinants of intertidal species' distributions. Ricketts & Calvin (1968) noted that three interlocking factors determine the distribution of shore invertebrates, the degree of wave shock, the type of bottom, and tidal exposure. Searing & Firth (1995) indicated that substrate type in combination with wave action and currents determine the intertidal flora and fauna distributions, and densities. Shore units defined by physical properties of the BC Physical Shore-Zone mapping system form the framework for mapping and collecting biological data (Searing & Firth 1995).

The use of a physical foundation is warranted by the limited knowledge of intertidal bear food items, the lack of intertidal species mapping (see Section 2.4.3), and the results of the literature/expert reviews. These reviews indicate that the majority of shoreline attributes associated with black bear use are physical parameters such as shore type, substrate, and wave energy. Biological factors do influence intertidal habitat structure through competition, predation, larval recruitment and biological structuring of the substrate (Thorne-Miller & Catena 1991), however, considering the small knowledge base, I use physical determinants for the initial development of the model.

3.3.1 Model Variables and Data Sources

The first step of the BBN modeling process focuses on the identification of environmental variables that influence the quality of intertidal habitats for black bears. The results of literature and expert reviews identified several attributes associated with shorelines and backshore areas used by black bears (Chapter 2 – Appendix A − Table 1 and 2).

Provincial black bear experts (Matt Austin, Tony Hamilton and Bruce McClellan) were enlisted to broaden understanding of black bears, confirm previous observations in the literature, and provide additional information related to black bear interactions with various shoreline habitats. Expert information was collected through a group meeting in Victoria spring 2005. The experts generally confirmed the results of the literature review. They emphasized that cobble boulder beaches and estuaries were the most common habitats used by black bears. Shoreline food sources included shore crabs, barnacles, starfish, carrion and beach hoppers. Adjacent or nearby terrestrial habitats highly suitable for bears were thought to influence coastal bear activities (e.g., higher coastal use nearby to terrestrial areas that favoured by bears). They also noted that the presence of other bears can directly influence the foraging opportunities of another. For example, older larger bears tend to have set territories which include good foraging habitat often displacing younger smaller bears to lesser quality habitat.

The initial BBN model environmental variables were determined from these reviews. In addition, three datasets were identified to populate the model. These are the Physical Shore-Zone mapping data, a principle source of many of the observed environmental variables, and Terrestrial Ecosystem mapping data (TEM), to model black bear terrestrial habitat adjacent to the shoreline.

3.3.2 Physical Environmental Attributes

Physical attributes included in the BBN model from the physical mapping data include: coastal class (shoreline type), shore unit slope, width, shoreline aspect, and wave exposure, each is discussed in turn. The spatial boundaries of the shore units for the survey areas were transferred into a GIS and central database.

Coastal Class - Shoreline Type

Several shoreline types are used more frequently by black bears. Cobble-boulder beaches have been identified as prime black bear forging areas (Oldershaw 1995). Research in Alaska (Smith & Partridge 2004) noted that tidal flats supporting clams were utilized by brown bears. The importance of estuaries to provide early spring forbs and grasses as foraging opportunities as well as late summer and fall when salmon return to spawn has been well documented (Frame 1974, MacHutchon 1999, Rasheed 2001).

The coastal classification attributes are based on the morphology (e.g., cliff, beach, and platform), substrate (e.g., rock, rock and gravel, sand, gravel), across-shore slope, and width of the unit. There are 34 coastal shoreline types in the BC Physical Shore-Zone Mapping System (see Appendix B − Table 1 for a description).

A modified repetitive shore type classification was developed by combining the original shoreline types into 8 shore type classes, because the coastal classification is too comprehensive. It exceeds the limited knowledge of shore types used by bears and the BBN model development guidelines. The 8 aggregated shoreline types are based on substrate and/or sediment characteristics. For example, shore types consisting of gravel (e.g., gravel beach) or with a gravel component (e.g., rock platform with gravel beach) are assigned to the gravel repetitive type. Shore types made up of sand (e.g., sand beach) or with a sand component (e.g., rock cliff with sand beach) are assigned to the sand repetitive type. The modified repetitive shore types are summarized in Appendix B − Table 2.

Shore Unit Slope and Width

Intertidal slope and width influence intertidal habitat use by black bears, despite these factors not being identified in the reviews. Their inclusion is based on the consideration that black bears would more than likely forage and transit on wide and/or gentle sloping shorelines versus narrow and/or steep shorelines. (see Appendix B − Table 3 and Table 4).

Shore Unit Aspect

Shore unit aspect is a variable that influences the intertidal use available by black bears (Pelton 1982, Lee 1985). Lee recorded most of his intertidal bear observations on south facing shores. He reasoned that these contained more beach grasses due to increased solar radiation. Shore aspect is captured as an azimuth number (i.e. 0° to 360°) in the physical data set. Shore unit azimuth values were assigned to one of four classes (north, east, west and south) for use in the BBN model (Appendix B − Table 5).

Shore Unit Wave Exposure

Wave action is a major physical parameter that determines intertidal species distributions (Searing & Firth, 1995). For any particular shore unit, the level of wave exposure influences the type of substrate and habitat conditions. For example, protected shorelines with the appropriate substrate provide the conditions for food sources such as marsh grasses, clams, crabs, starfish, and small barnacles utilized by black bears (Table 2). In contrast, shorelines exposed to very high wave energy levels can provide foraging opportunities through the deposition of carrion or large piles of seaweed that hold beach hoppers, a food source for black bears (Ellis & Wilson 1981 and MacHutchon 1999).

Shore unit wave exposures are derived by a number of measurements and calculations (see Howes *et al.* 1995). Based on these results, a unit's wave exposure is assigned to one of six classes, very protected, protected, semi-protect, semi-exposed to exposed and very exposed (see Appendix B − Table 6). For the BBN model, these six classes were collapsed into four groups by combining the very protected and protected classes, and exposed and very exposed wave exposures classes.

3.3.3 Wildlife Habitat Rating (WHR)

Black bears organize their activities to use the shorelines adjacent to backshore or nearby important terrestrial bear habitat (Powell *et al.* 1997). Thus, the presence of nearby high quality terrestrial habitat will increase the use of the intertidal habitat (e.g., provide additional forage). However, there is no detailed mapping of black bear use of the terrestrial backshores in Clayoquot Sound; nor is there any coastal fringe vegetation mapping. Detailed coastal fringe vegetation information would assist in identifying adjacent shoreline backshore with potential bear food sources (e.g., berries, grasses).

A WHR for black bear suitability was developed to substitute for missing information. A terrestrial black bear suitability map was developed by applying the WHR developed by MacHutchon (1999) to the TEM data (Chapter 2). The WHR ratings classify the relative importance of ecological components for black bears into six life requisite values. The life requisite value of "living" (LI) is a measure of the habitat for general living activities including food, security, hibernation, migration, staging and reproduction (RIC 1999a).

MacHutchon's WHR rating is applied to the TEM site series data of the TEM polygons adjacent to the shoreline following RIC standard procedures (1999a). This process generates a WHR value ranging between 0 - 6 for each TEM polygon during the summer (see Appendix B − Table 8). The WHR values range from high (1), moderate high (2), moderate (3), low (4), very low (5) and nil (6). These values are developed into a three part life request classification to make this variable more manageable in the BBN model (Appendix B − Table 7).

The original WHR polygon values were re-classified by this method:

- Identify the WHR polygon(s) adjacent to an individual shore unit.
- For those shore units with a single adjacent WHR polygon, the shore unit is assigned to one of the three WHR classes based on its original WHR polygon value.
- For those shore units with multiple adjacent WHR polygons, the shore unit WHR was calculated by multiplying the WHR value of each WHR polygon adjacent to the shore unit by the percentage length of the shore unit it

intersects, summing these values, then assigning the derived value to one of the four WHR classes.

3.3.4 Known Important Terrestrial Bear Habitat

Nearby known important terrestrial habitat refers to bear habitat not adjacent to the shoreline that supports a known bear population. MacHutchon (2001) found that the highest density bear populations in Clayoquot Sound are the Bulson Creek watershed which is important bear spring and summer habitat (MacHutchon 1999). Other important areas of spring and summer bear habitat with robust populations include the Sydney River, and Tofino Creek watersheds (MacHutchon 2001). He also highlighted the Ursus Creek watershed and Pacific Rim Park as having moderately dense populations, with lower spring and summer habitat ratings.

To assess the role that known bear habitat plays in the overall rating of the intertidal habitat quality model, there was a need to identify the distance of these watershed areas from the survey routes. Black bears have been recorded to travel from 500 to 850 metres daily to meet their daily life requisites on Vancouver Island (MacHutchon 1999). Based on this knowledge, all surveyed shore units within 1 km from the known bear habitat areas are identified as having nearby terrestrial bear habitat. Two of the watersheds, the Sydney River and Bulson Creek overlapped sections of survey route 1 and 3 (Figure 4). The remaining shore units were classified as having no known nearby important bear habitat, and are incorporated in the central data file.

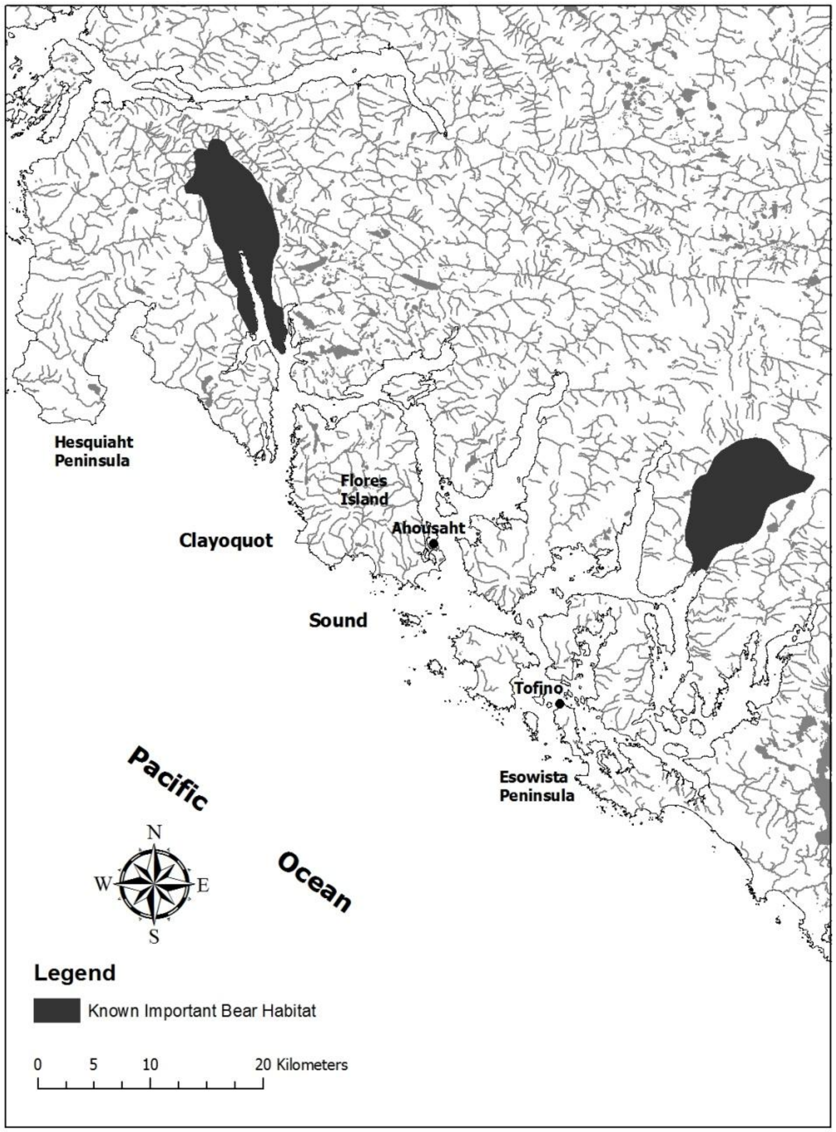

Figure 4. Location of nearby known important bear habitat areas.

3.3.5 GIS and Integration

The physical, coastal, and terrestrial spatial GIS information of Clayoquot Sound has been collected and maintained on either provincial Terrain Resource Inventory Mapping (TRIM) maps (e.g., TEM) or Canadian Hydrographic Service (CHS) charts (e.g., BC Physical Shore-Zone Mapping). For this project, the spatial information is geo-referenced to the CHS chart shoreline. It provides a more accurate portrayal of the coast.

In addition, the shoreline is the focus of this study and the shore unit spatial file is the key component integrating the different data sets required to implement the BBN model.

ArcGIS version 9.2 (ESRI™ Software Corporation 2006) is used to project and integrate the shore unit and TEM spatial data onto the chart coastline. Attribute information from the physical shore unit (above), WHR, and nearby terrestrial bear habitat data is integrated with the shore unit linear spatial file for the BBN model. This associated attribute database contained the environmental variables for the BBN model. Information collected from the bear field surveys is also integrated into the central shore unit BBN database.

3.3.6 BBN Model Structure and Guidelines

An influence diagram of the proposed causal influence of key environmental variables for black bear intertidal habitat quality was developed (Figure 5). It is based on the environmental variables and themes identified or inferred through the literature and expert reviews. The parentless (input) nodes are the key environmental variables with their influence on the child (intermediate) nodes. The states associated with the parentless nodes are attributes that are processed from the shore unit GIS dataset. The child nodes encompass the major themes or habitat variables that influence the black bear intertidal habitat quality. The relationship between the key environmental variables and habitat variables, and between the habitat variables and black bear intertidal habitat quality (i.e. output node) is quantified in conditional probability tables (CPTs). The conditional probability tables for child nodes specify the probability or frequency for the different states of that node. The various child node states are determined by the discrete states of the parent nodes. The values within the CPTs of the initial model were determined from the literature and bear expert reviews. These conditional probability tables were subsequently modified to revise this initial model by the bear surveys (Chapter 5).

Detailed guidelines for developing a BBN model are presented in Marcot *et al.* (2006) (Table 4). My model is structured so that the parentless nodes representing environmental factors (e.g., “repetitive shore type” and “shoreline aspect” nodes) can be empirically evaluated within a GIS. Whereas the child nodes (e.g., “primary influences on intertidal food productivity/availability" and "intertidal forage capability" nodes) summarize the themes that influence intertidal habitat quality. To maintain simplicity, the number of parent nodes for any given child node does not exceed three in this model. The numbers of associated states for all nodes is kept to four or less except for the repetitive shore type node which have eight states (see Section 3.4.2.1). Adherence to these guidelines maintains a model structure that ensures the conditional probability tables (CPT) are not overly complex to difficult to develop and justify. It also facilitates changes to the model as new findings and knowledge becomes available.

Table 2. Summary of the key guidelines for developing an initial BBN (Marcot *et al.* 2006).

Whenever possible keep the number of parent nodes to any given node to three or fewer
Try to maintain the number of states within each node to five or fewer
Parentless (input) nodes should be items that can be empirically evaluated or pre-processed from existing data, such as GIS data
Intermediated nodes should be used to summarize the major themes denoted in the influence diagram
All nodes should be observable and testable entities, to the extent possible
Whenever possible, the number of layers of nodes, or depth, should be kept to four or fewer
The rationale for each node and each linkage should be documented

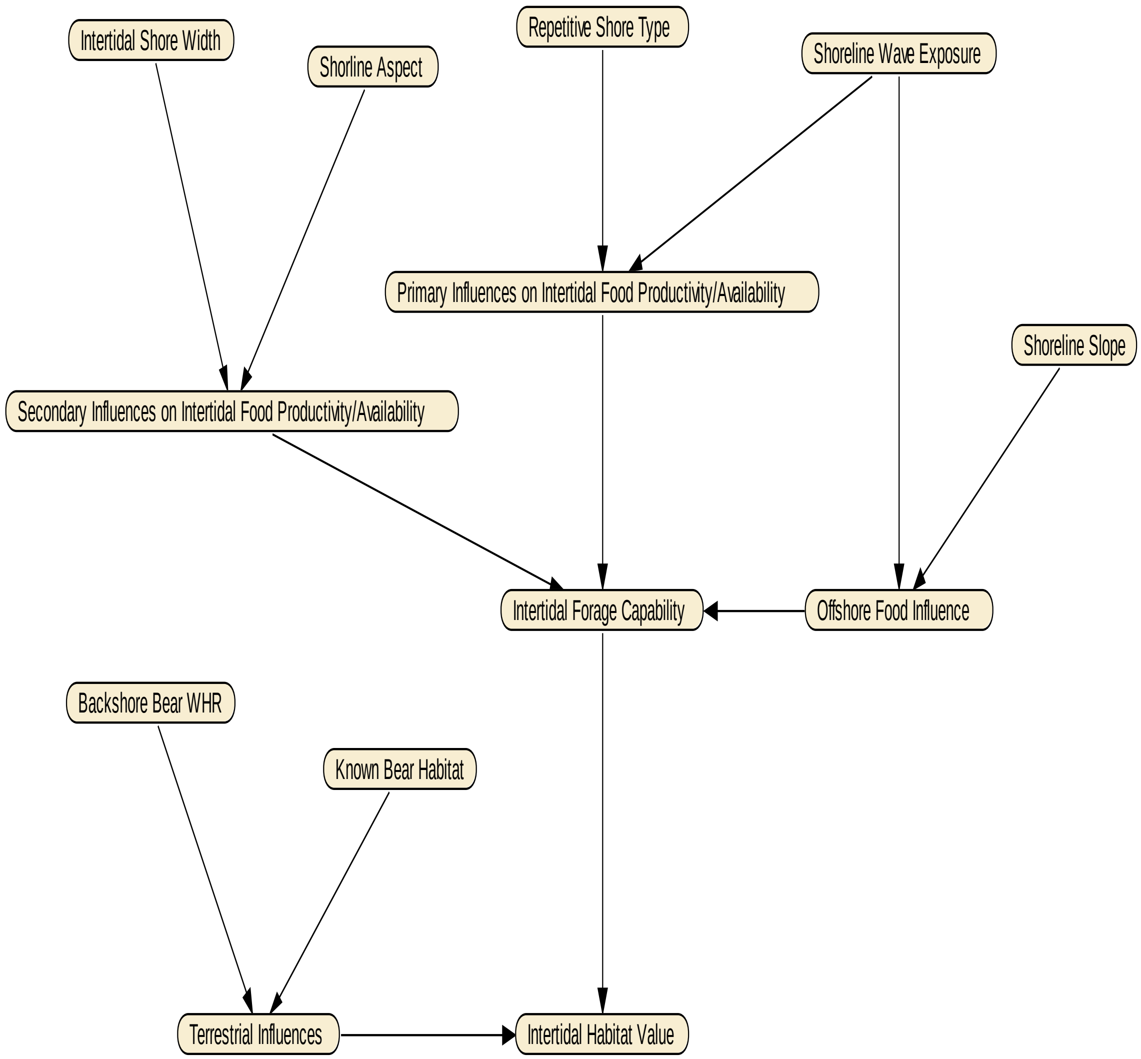

Figure 5. Influence diagram of the black bear intertidal habitat BBN.

3.3.7 Intermediate (Child) Nodes

The child nodes of the model were designed to capture the dominant themes that influence intertidal habitat quality. They contribute to the overall habitat quality classification and are developed from known environmental variables (refer above and Chapter 2).

The '*primary influences on intertidal food productivity/availability*' node assesses the influence of substrate (rock and/or sediment) combined with wave exposure in predicting the probability of potential bear food sources (refer above, also Searing & Firth, 1995). This node differentiates the relative influence that combinations of these two variables have on intertidal food availability. For example, we know that bears forage on purple shore crabs, and that purple shore crabs tend to live under cobbles and boulders on beaches with semi-protected or protected wave exposures. Thus, these shore units will have a higher probability of being classified "better" than similar gravel beaches with high wave exposures. An ideal parent node for this child includes the presence of shoreline biota (e.g., shore crabs, gunnels or clams) that are important to bears. However, there is not sufficient knowledge of a black bear's intertidal food preferences, and the biological dataset does not capture all intertidal species.

The *'secondary influences on intertidal food productivity/availability'* node is included to evaluate sub-dominant factors that affect a particular shore unit. This child node assesses the influence of shore unit aspect and intertidal width. Aspect has some influence on black bears activities (refer above, also Pelton 1982, Lee 1985, Rasheed 2001). The role of intertidal width has not been documented, but it is inferred that a greater amount of area within the intertidal of a shore unit will offer more foraging opportunity. Other potential secondary physical influences, such as fresh water inputs along the shoreline were not included due to a lack of systematic mapping.

Black bears are opportunistic foragers, and utilize intertidal environments to scavenge for carrion (O'Clair & O'Clair 1998, Nordstrom 2002). As well, beach hoppers found in piles of kelp and other seaweeds are a food resource for coastal black bear (Ellis & Wilson 1981). These types of foraging opportunities are captured in the child node '*offshore food influence*'. There is no documentation of the type of shoreline where bears have been observed scavenging carrion. It is postulated that shore units with gentle slopes with high wave exposures are more likely to have carrion and/or seaweed accumulate on their shores than similar shorelines with low wave exposures.

The child node *'intertidal forage capability'* summarizes the three intermediate nodes that influence the potential food resources in each shore unit. The *'terrestrial influences'* node has been included to evaluate the potential impact of adjacent terrestrial bear habitats on shoreline habitat quality. Favourable terrestrial habitats adjacent to the shoreline results in more bear activity by providing additional foraging opportunities.

The influence of the backshore terrestrial habitat node is based on the WHR model which is a substitute for detailed terrestrial fringe vegetation mapping.

The outcome node *'intertidal habitat value'* defines the overall predicted probability of each shore unit to provide quality intertidal black bear habitat. It is based on the input from the forage capability and terrestrial backshore nodes.

3.3.8 Populating Probabilities

Applying Netica™ software (Norsys Software Corporation 1998) the influence diagram was converted into a BBN (Figure 6). The probability tables associated with each node comprise the basis of the BBN method. These tables drive the BBN model, thus, their population with accurate values is a critical step in the modeling process. The probability tables for the parentless nodes' (i.e. environmental attributes) were empirically determined in the GIS using the states of the shore units in the central shore unit data base.

The lack of empirical data to populate the CPTs for the child nodes results in probability estimates based on the knowledge gained from experts and literature reviews. The CPT for each child node was determined by identifying the best-case scenario (combination of states) and the worst-case scenario (combination of states) and assigning an appropriate probability. Using those two scenarios as reference points, I populated the remaining combination states with probabilities ranging between these bench marks. If little or no information was available about a given combination of states a uniform distribution (50/50) was assigned. The CPTs for the six child nodes of the initial BBN are listed in Appendix E − Tables 1-6. The following is a summary of how the child node probabilities were developed.

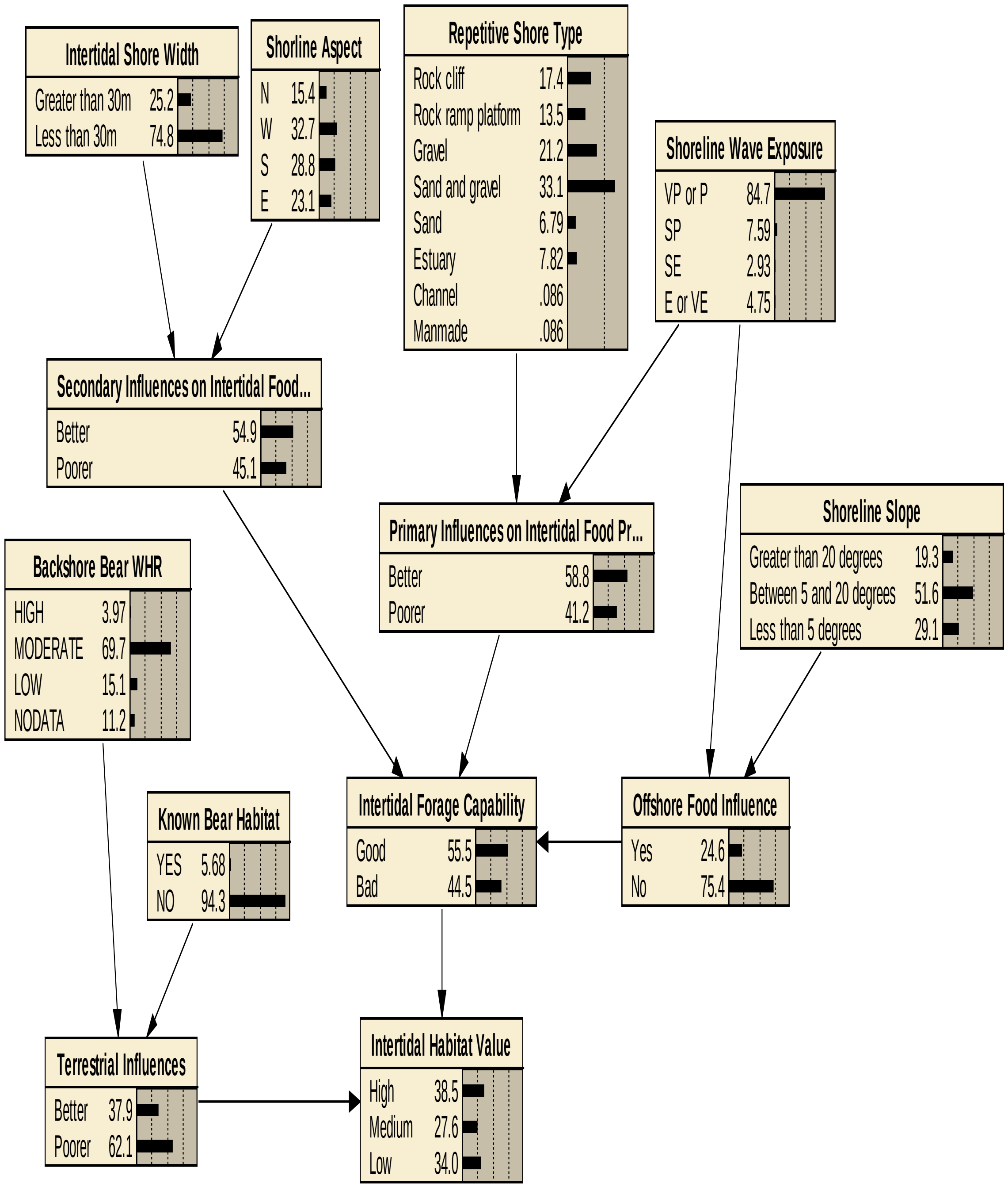

Figure 6. Initial Black bear intertidal habitat quality BBN model.

Primary Influence on Intertidal Food Production Node

- Shore types gravel, sand and gravel or sand with very protected/protected or semi-protected wave exposures and estuaries with all wave exposures were assigned a 75 ‘better’/25 ‘poorer’ probability. These are the most common shore types-exposure combinations identified in the reviews as high quality habitat. They represent the high probability benchmark. All are assigned the same probability as there is no documentation on their relative importance.

- Shore types of rock cliff with all classes of wave exposures, rock ramp platform with exposed/very exposed wave exposures, sand with exposed/very exposed wave exposures, channel with semi-exposed or exposed/very exposed wave exposures and manmade with all wave exposure classes are assigned a 25 ‘better’/75 ‘poorer’ probability. These shore type-exposure combinations represent the low value benchmark. None of these combinations are identified as bear foraging areas in the review process. I infer that these shore types-exposures are the least likely to provide black bear food resources (Appendix A − Table 1 and 2) due in part to their high wave exposures.
- Shore types of gravel, sand and gravel, or sand with semi-exposed wave exposures and channel with very protected/protected, or semi-protected, wave exposures represent the next most favourable habitat conditions. The sediment shore types are known to support black bear food items such as, shore crabs, clams, barnacles, and fucus. Channels areas are dominated by tidal currents provide the water-movement energy rather than waves. Species diversity can be high in channel shore types and can provide bear foraging opportunities although they are rare here (Morris, M. in Howes and Wainwright 1999). A 40 ‘better’/60 ‘poorer’ probability is assigned based on the minimal information provided through the review.
- Shore types of rock ramp platform with very protected/protected or semi-protected wave exposures are assigned a 35 ‘better’/65 ‘poorer’ probability. I infer that these habitat conditions provide some black bear foraging opportunities, but perhaps not as abundant or as frequently used as the above shore types.
- Shore types of gravel, or sand and gravel, with exposed/very exposed wave exposures, or rock ramp platform with semi-exposed wave exposures, are assumed to provide slightly better habitat conditions for black bear intertidal

foods than the lowest benchmark group. Accordingly, they are assigned a slightly higher probability of 30 'better'/70 'poorer'.

Secondary Influences on Intertidal Food Productivity/Availability Node

- Southerly aspect is a contributing factor for favourable black bear habitat. I also infer that wider versus narrower intertidal areas offer greater foraging opportunity. Thus, wide, south aspect shore units are considered the high probability benchmark for this node and assigned 75 'better' /25 'poorer' probabilities. Southern facing, narrow shorelines are assigned a slightly lesser probability value of 65 'better'/25 'poorer' based on their narrow widths.
- Narrow, north aspect shore units represent the low probability bench mark due to their narrow width and the lesser amount of sunshine. They are assigned a probability of 25 'better'/75 'poorer'. Wider, north facing shorelines are assigned a 30 'better'/70 'poorer'.
- There is no documentation of bear foraging on western or eastern facing shorelines. For the model, I infer that the amounts of sunlight available for these shoreline habitats, although less than the southern shores, positively affects intertidal food productivity. Hence, wide shore units with east or west aspect are assigned a probability value of 60 'better'/40 'poorer'; these probabilities are reduced to 55 'better'/45 'poorer' on narrower shorelines.

Offshore Food Influence Node

- No information is available to provide a basis for assigning probability values for the deposition of carrion and seaweed. I infer that that deposition of these food sources is more likely on gentler slopes with higher wave exposures versus steeper slopes with lower wave exposures.
- Steep sloped shorelines (>20°) for all wave exposures are considered to provide the least opportunities for bear foraging on deposited food items. It represents the low probability benchmark with a probability 10 'better'/90 'poorer'.
- The high probability benchmark (90 'better'/10 'poorer') is assigned to shore units with intertidal slopes < 5°, or between 5° to 20°, with very exposed/exposed

wave conditions. These shorelines provide the best forging opportunities for deposited food.

- Semi-exposed shorelines with slopes < 5°, or between 5° to 20°, are assigned a slightly lower probability of 80 'better'/20 'poorer' based on decreased wave exposure.
- As fetch and wave exposure influence the deposition of food items certain shoreline values are reduced. Gentler shorelines, slopes < 5°, or between 5° to 20°, with semi-protected exposures are assigned a lower probability of 60 'better'/40 'poorer' and, 20 'better'/80 'poorer' for those with very protected/protected wave exposures.

<u>Terrestrial Influences Node</u>

- The highest benchmark probability for the terrestrial influence node is assigned to shorelines with high adjacent backshore suitability and the presence of known important bear habitat. These shorelines are enhanced by increased foraging opportunities and improve the adjacent habitat quality.
- I assume that the influence of adjacent backshore foraging opportunities is equal to nearby known important bear habitat on shoreline bear habitat. There was little documentation to populate these probabilities. The high bench mark for the combination of high backshore black bear suitability, and nearby known bear habitat was assigned a probability of 80 'better'/20 'poorer'. The low benchmark of 25 'better'/ 75 'poorer' is assigned to the states of low backshore black bear suitability and no nearby known terrestrial habitat.
- The remaining combinations of states are determined by applying a probability value of 40 to the best state of each variable (i.e. high and yes). If the adjacent habitat suitability is moderate, it received a probability value of 30 while low suitability is assigned a probability of 10. The state of no nearby known bear habitat is assigned a probability value of 10. The probabilities of various combinations of these two states are determined by summing their corresponding probability values. (Refer to Appendix E − Table 4).

Intertidal Forage Capability Node

- Each of the three nodes (Figure 6) going into the intertidal capability forage node generate a 'better' or 'poorer' state. The different combinations of these states are used to develop the probabilities of the intertidal capability forage node CPT (Table 5).
- The dominant influence on intertidal forage capability is the primary influence on intertidal food production. Offshore food and secondary intertidal influences are considered to have lesser influence. These varying influences are considered in development of the intertidal forage capability probabilities. A greater emphasis, or contribution, in determining a probability, is placed on the primary influence on intertidal food production
- The intertidal forage capability high probability bench mark (90 'good'/10 'bad') is assigned when all three parent node conditions are 'better' and represent the most favourable conditions for quality black bear intertidal habitat.
- The low probability benchmark (10 'good'/90 'bad') is assigned when all three parent node conditions were 'poorer'.
- The second highest probability value of 85 'good'/15 'bad' is assigned when the primary and secondary states are 'better', and the offshore influences 'poorer'. This state considers that the combination of primary and secondary better conditions provide ideal conditions for quality habitat.
- The second lowest probability state (15 'good'/85 'bad') is assigned when the primary influences, and the offshore influences parent nodes, are 'poorer' and secondary influence state was 'better'. I assume the foraging capability of the intertidal habitat improved slightly when the offshore influence state is 'better' with 'poorer' primary and secondary influences (30 'good'/70 'bad'), and improved to 35 'good' and 65 'bad' with a 'better' secondary influence.
- The remaining combination of states varies from 85 'good' and 15 'bad' to 75 'good' and 25 'bad'. All of these combinations have 'better' primary influence with different combination of 'better' and 'poorer' of the other two influences.

Table 3. Conditional probabilities assigned for the *"intertidal forage capability"* node.

Primary influence state	Offshore influence state	Secondary influence state	Intertidal forage capability probability
better	better	better	90 good/10 bad
better	poorer	better	85 good/15 bad
better	better	poorer	80 good/20 bad
better	poorer	poorer	75 good/25 bad
poorer	better	better	35 good/65 bad
poorer	better	poorer	30 good/70 bad
poorer	poorer	better	15 good/85 bad
poorer	poorer	poorer	10 bad/90 good

<u>Intertidal Habitat Value Node</u>

- The intertidal forage and terrestrial influence states determine the intertidal habitat probabilities. A greater emphasis is assigned to the state of the intertidal forage capability state, as current knowledge is primarily related to bear utilization of shorelines for foraging opportunities (Table 6). For example, the intertidal forage capability state 'good' in combination with the terrestrial influences state 'poorer' was assigned a 60 'high' probability to reflect the importance of intertidal forage capability.
- The high bench mark value is assigned to the 'good' intertidal forage capability and 'better' terrestrial influence states. Three probability values are assigned. These are 70 'high', / 25 'medium', / 5 'low'.
- The probability values of the low bench mark are assigned a 5 'high', / 25 'medium, / 70 'low', for the 'bad' intertidal forage and 'poorer' terrestrial influence states.

Table 4. Conditional probabilities assigned for the “intertidal habitat value” node.

Intertidal forage state	Terrestrial influence state	Intertidal habitat value probability
good	better	70 high/25 medium/5 low
good	poorer	60 high/ 30 medium/10 low
bad	better	10 high/ 30 medium/60 low
bad	poorer	5 high/25 medium/70 low

Chapter 4: Results

4.0 Introduction

In this chapter I summarize the results and analyses of the black bear field observations that provide further insights into the role that shoreline habitats play in the bears' daily life requisites. Bear occurrence rates for the individual environmental variables (i.e. parentless nodes) and some of their combinations (i.e. child nodes) have been calculated and used to revise the final BBN model (Chapter 5). The output and results of the initial model are also presented.

4.1 Black Bear Field Survey Observations and Results

4.1.1 Distribution of Bear Sightings

I recorded 205 black bear sightings during 40 shoreline surveys on four routes (Figure 7). Table 5 provides a summary of the number of transect surveys conducted per route, total number of bear observations, the average number of sightings per transect and a normalized encounter rate per kilometre of shoreline.

Table 5. Average number of black bear observations and normalized bear encounter rate for each survey transect.

Note: the normalized bear encounter rate was calculated as per the formula documented in 4.2.

Survey Route	Number of Transects	Number of Observations	Average Number Observations/transect	Normalized bear encounter rates per km
1	11	30	2.7	0.113
2	11	30	2.7	0.086
3	10	129	12.9	0.325
4	8	16	2.0	0.170
All Surveys	40	205	5.1	0.174

Single bears comprise 85% of the 205 observations. The remaining observations (15%) are of 31 females with cubs (up to 3). Over 61% of females with cubs occur in survey area 3. Females with cubs in the other survey areas are 23% (survey area 1), 13% (survey area 2) and 3 % (survey area 4).

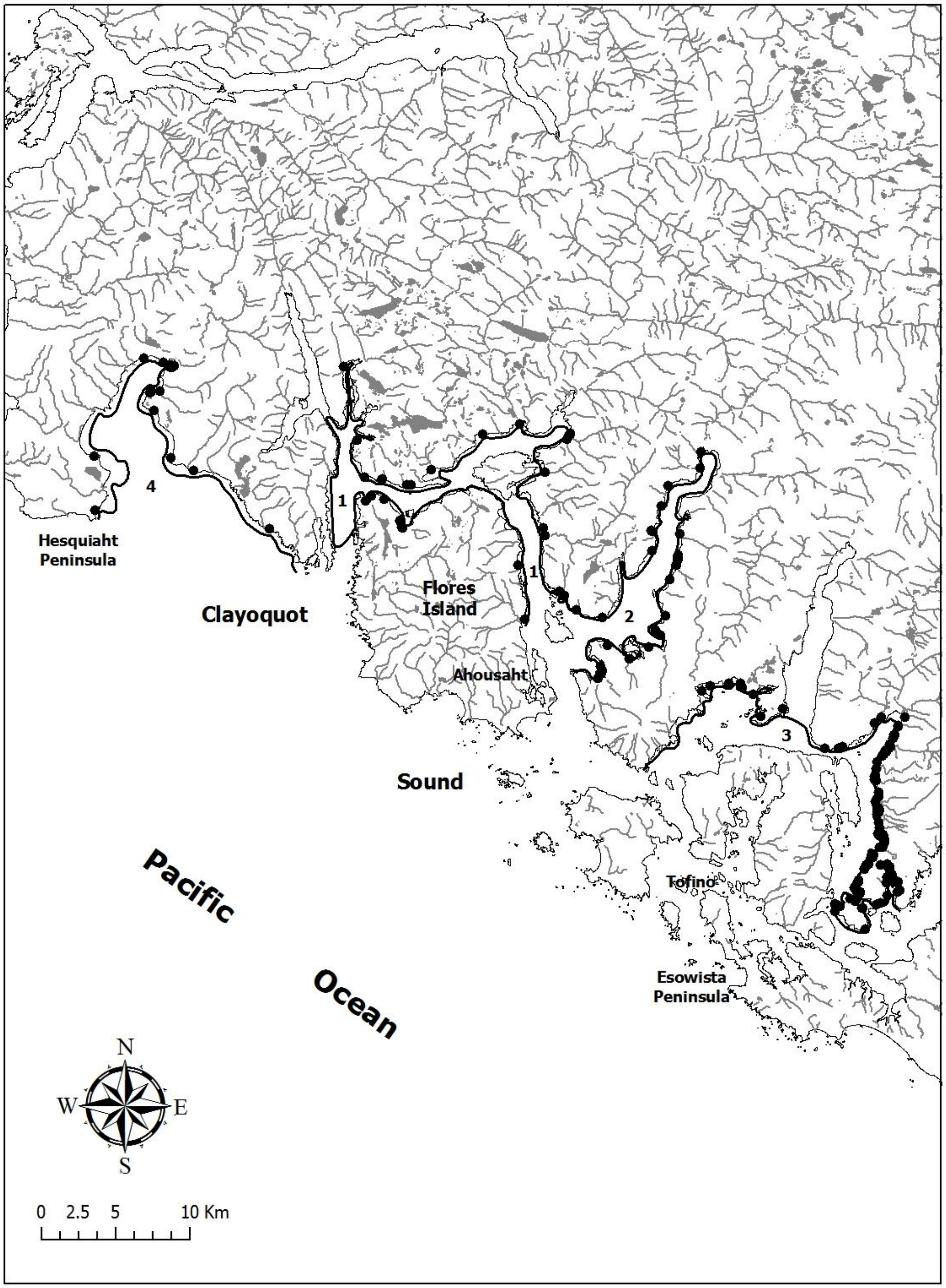

Figure 7. Map of observed black bear locations and survey routes.

4.1.2 Bear Size

I classified bears into one of three size categories, small, medium or large. Size was classified on a preliminary visual estimate based on physical determinants such as general body shape and height. The majority of the bears are in the medium size class (95% of 205 observations). Small and large sized bears account for 4% (8 observations) and 1% (3 observations) respectively.

4.1.3 Black Bear Intertidal Behaviour

I classified bear behaviour into 5 types: foraging, traveling, combined foraging and movement, copulation, and unknown (e.g., researchers unable to determine behaviour). Foraging is the dominate behaviour accounting for 55% of the total observations and 94% of all observations when combined with traversing (39%). Traversing the shore unit (3% - 7 observations), copulating (1% - 2 observations) and unknown (2% - 4 observations) account for the remaining behaviours.

Rock flipping is the dominant foraging activity (70%). Other foraging activities include digging (18%), scavenging (13%) and grazing (13%). These values total more than 100% because all of a bear's activities were recorded during an observation. It was common while observing a foraging female bear for the cubs to mimic her actions particularly flipping rocks.

Bear reactions to the presence of the research vessel varied (Table 6). The most common reaction is to acknowledge the boat presence and ignore the boat and observers (38%) (refer to 3.2). Other reactions include avoiding the researchers (25%), no reaction (21%) and fleeing (16%). There is a difference in bear reaction between the three inner coast survey areas. Ignoring, or no reaction to the approaching vessel accounts for 70% of the observations in survey area 3 versus 34% and 27% for route 1 and 2 (Table 6). Survey route 4 results are similar to route 3. Here, 75% of the bears' response is none or to ignore the research vessel. Bear reaction in survey area 3 is thought to be a result of familiarity due to repetitive human contact, through bear watching tour operations. It is unknown why the bears react in this similar manner in survey route 4. It may be a result of the bears not noticing the research vessel. Observations in route 4 were conducted further offshore due to wide intertidal zones, rough waters and reefs.

Table 6. Comparison of the frequency rates of observed black bear behaviour to the presence of the research vessel by survey route.

Reaction to surveyors	Survey route 1 %	Survey route 2 %	Survey route 3 %	Survey route 4 %
Avoid	40	43	20	6
Flee	33	23	10	19
Ignore	10	7	52	31
None	17	27	18	44

The middle and lower intertidal zones are the more highly used areas (53% and 50%, respectively). Upper intertidal use accounts for 19% and backshore use about 2%. These values total more than 100% because all of the intertidal zones utilized by a subject bear were recorded.

The majority of the bear observations (46%) occur between 1 hour before and 1 hour after the daily low tide. The majority of the remaining observations (44%) occur from 1 hour to 3 hours after the daily low tide. Only 9% occur between 3 hours to 1 hour before the daily low tide; the remainder (1%) more than 3 hours after the daily low tide. Based on these observations, it is speculated that black bears do not have prior knowledge of the daily low tide cycle. Perhaps there is an environmental sign (e.g., smell) that triggers their attraction to the shoreline when the dropping tide reaches a certain level.

4.2 Bear Observation Encounter Rates

Black bear observation encounter rates are used in this study, particularly rates for the combined environmental variables of the model (refer to 4.2.2) to modify and improve the CPTs of the final model. This approach assumes that the bear encounter rates based on a period of continuous survey would be greater on those shore units with habitat conditions (environmental variables) favouring black bear utilization. These results are used judiciously to modify the CPTs (refer to 5.2.1). Bear encounter rates are also calculated to test the validity of the final BBN model (refer to 5.2.3 for details).

Black bear encounter rates for each class of the six environmental BBN variables have been calculated. This calculation involves normalizing the bear occurrence data by the total shore unit length of each class for a given variable to derive encounter rates per kilometre of shoreline.

The following normalization equation was applied to the six key environmental variables to generate the bear encounter frequency rates. The resulting encounter rates have been calculated for each survey routes and all of the study area (all routes) and are presented in Appendix F.

$$P= (B/CL)/L*1/S$$

Where:

- P is the probability of encountering a black bear on a given kilometre of shoreline for a defined class of a key environmental variable(s),
- B equals the total number of observed bears for the defined class of an environmental variable(s),
- CL equals the percentage of shoreline length for the defined class,
- L equals the total length of the surveyed shoreline in kilometres and
- S equals the number of surveys completed for the given transect.

4.2.1 Individual Environmental Variables Encounter Rates (rates/km of shore)

<u>Modified Repetitive Shore Type</u> (sediment/substrate)

The highest bear encounter rate in the study area occurs on sand and gravel shore types (.11). This is twice the rate for a group of types consisting of sand (.05), gravel (.05) or estuary (.04) shores (Appendix F). Rock ramps and platform rates (.03) are slightly less than this group whereas the rock cliff rate (.02) is about half their rate. There were no observations on channel and man-made shoreline types.

Variations of shore type encounter rates do occur when rates within the survey areas are compared. For example, individual shore type rates in survey area 3 are significantly higher than individual shore type rates in all of other survey areas. It is considered that these higher encounter rates are a result of the distribution of bear observations (greater than 60% of the total bear observations occur in this survey area 3). An exception is the sand shore type whose highest encounter frequency rate occurs in survey area 1 (.11).

Sand and gravel shore types have the highest encounter rates in all but survey area 1; its highest rate (.24) occurs in survey area 3. Survey area 1 does not follow this pattern. Here, the highest rate is the sand shore type (.11) followed by estuary shorelines (.06) and sand and gravel (.05). Rock ramp/platform shore type rates vary from a high of .1 to less than .01 by survey area whereas rock cliffs have the lowest rates in all the surveys except for survey area 1.

Wave Exposure

The encounter rates for different wave exposures indicate that the more increasingly protected shorelines have a greater the likelihood of encountering a black bear (Appendix F). The highest encounter rates occur on very protected/protected shorelines (.09). This rate is three times greater than the next class of semi-protected (.03) that in turn, is seven times greater than semi-exposed (.004) and exposed (.003) shorelines. Very protected/protected shorelines (.15) in survey area 4 have the highest encounter rates. This rate is approximately seven times greater than other survey 4 shorelines classified as semi-protected, semi-exposed and exposed/very exposed.

Survey areas 1, 2 and 3 occur within the protected inner coast and do not have high wave exposure shorelines. Very protected/protected shoreline encounter rates are highest in survey areas 1 and 3; however, this is the only wave exposure class in survey area 3. The encounter rates for survey area 2 did not follow this trend as encounter rates on semi-protected shorelines (.06) are twice as great as the very protected/protected shores (.03).

Shoreline Aspect

There are two groups of encounter rates with shoreline aspect. These are a higher rate group consisting of northerly (.105) and westerly (.089) oriented shorelines and a lower rate group comprised of southerly (.043) and easterly (.036) oriented shorelines (Appendix F). The latter two rates are a half to a third less of the higher frequency group.

The higher encounter rates on northerly shorelines and lower encounter rates of southern facing shores were not expected (refer Chapter 2 and 3).

The highest aspect encounter rates occur in survey area 3 on westerly (.232) and northerly (.226) facing shorelines. Survey area 4 has the greatest internal variation of aspect encounter rates. Here, northern facing shorelines encounter rates (.145) are 2.5 to 3 times greater than the rates of western (.051) and southerly (.037) orientated shorelines. There is less internal variation of rates in survey area 1 and survey area 2. Also, their encounter rates are lower in comparison to survey area 3 and 4.

Intertidal Slope

The encounter rates for shorelines with different intertidal slopes indicate that as slope decreases the likelihood of encountering a black encounter increases (Appendix F). Encounter rates on steeply-sloping shorelines (slopes greater than 20°) have the lowest rate (.017). Whereas, encounter rates increase on shorelines with 5°-20° slopes (.061) to a high on gently-sloping shorelines (slopes less than 5°; rate .088).

Survey areas 1, 3 and 4 generally mirror the study area rate trend. The encounter rates for steeply-sloping intertidal zones are considerably lower than other rates in all survey areas. Gently-sloping intertidal shorelines rates are highest for survey areas 1, 3 and 4 with the highest rates in area 3 (refer above). Survey 2 encounter rates do not follow the general trend. Intermediate sloping intertidal shorelines rates (.051) are greater than the gently-sloping shores (.035).

Intertidal Width

Intertidal width encounter rates indicate that shorelines with greater intertidal width result in higher bear encounter rates (Appendix F). Wide intertidal shorelines (greater than 30m) rates are (.088). As a minimum, these rates are 1.5 times greater than narrow (less than 30m) shoreline rates (.049). The 30 metre width criteria is based on the width used to separate narrow and wide shore types in the coastal classification of the BC Physical Shoreline Classification.

With the exception of survey area 2, the remaining survey areas encounter rates display a similar pattern of increasing rates with increasing intertidal width. Encounter rates for wide intertidal shorelines are 3.7 (survey area 1), 1.7 (survey 3) and 1.8 (survey 4) times greater than the narrow intertidal shoreline rates. There is little or no difference in the intertidal width rates for the two width classes in survey area 2 (.037 wide shorelines, .036 narrow shorelines).

Backshore WHR Habitat

The bear encounter rates in the study area do not differ much for shorelines between the different backshore black bear WHR rated habitat suitability, although rates for shore units with moderately suitable backshore bear habitat are highest (.066). In contrast, highly suitable backshore habitat has a slightly lower rate (.047), whereas the low suitability backshore habitat rate (.065) (Appendix F).

The backshore bear habitat suitability encounter rates are highly variable between the surveys. For example, survey area 2 encounter rates increase as backshore bear habitat improves. The highest encounter rate for all of the survey areas occurs in survey 3 for shorelines with moderate suitability backshore habitat (.162). Survey area 1 rates vary from higher rates for low (.130) and high (.114) suitable backshore habitats to a low rate for moderate backshore habitat (.015).

Nearby Known Important Habitat

The rates of bear encounters on shorelines close to nearby known important black bear habitat are less than shoreline without any known nearby black bear habitat (Appendix F). The latter encounter rate is .040 which is over 3 times greater than the rate (.012) of the former. These findings are perplexing. It is unknown why the rates vary considering the expert bear information (Chapter 3). Perhaps it is a result of incomplete knowledge of known nearby terrestrial bear habitat within the study area and/or a small sample size. Only 5% of the study shoreline occurs within 1 kilometre of the known bear habitats.

4.2.2 Combined Environmental Variables Encounter Rates (rates/km of shore)

Modified Repetitive Shore Type and Wave Exposure

The encounter rates for different combinations of shore types/wave exposures suggest that combinations of these variables play an important role for bear intertidal habitat quality. There are a total of 32 possible combinations of shore types and wave exposures; 21 combinations occur in the study area. Only 11 of the 21 combinations had bear encounters (Appendix F). These occur on:

- All sand and gravel shore types/wave exposure combinations except those that are semi-exposed,
- Gravel shore types with very protected/protected and semi-protected wave exposures,
- Estuaries and sand shore types with very protected/protected wave exposures,
- Rock shore types with very protected/protected and semi-protected wave exposures. An exception is rock platform shore types with semi-exposed wave exposures.

The encounter rates of the combined shore types and wave exposures are classified into three groups (high, medium and low). The high encounter rate group consists of sand and gravel types with very protected/protected wave exposures (.171) and gravel shore types with very protected/protect wave exposures (.101). The medium encounter rate group is made up of sand and estuary shore types that have very protected and protected wave exposures (.067 and .046, respectively), sand and gravel shore types with semi-protected wave exposures (.061) and rock ramp/platform shore types with very protected/protected wave exposures (.035). The higher group rates are 1.5 to 2.5 times greater than this group. The low encounter rate group consists of the following shore types: rock cliff/very protected/protected wave exposures (.017), rock cliff/semi-protected wave exposures (.011), rock platform/semi-exposed wave exposures (.008), gravel/semi-protected (.015) and sand and gravel/exposed and very exposed (.007). The latter group encounter rates are lower than the rates of the high and medium group rates.

Shoreline Aspect and Intertidal Width

Encounter rates of these combined variables suggest that north and west wide shorelines (Appendix F) are an important component for favourable intertidal bear habitat. The lower encounter rates on wide southern facing shores, however, were not expected based on the literature review (Chapter 2).

The encounter rates of the combined shoreline aspect and intertidal width are aggregated into three encounter rate groups. There is a high encounter rate group consisting of north aspect/wide intertidal (.137) and west aspect/wide intertidal shorelines (.132). These rates are greater than twice the medium group combinations encounter rates. This middle group consists of east aspect/wide intertidal (.050), south aspect/wide intertidal (.064 respectively), and west aspect/wide intertidal (.067) shorelines. The remaining combinations make up the low rate group. Encounter rates vary between .02 and .04 for north, east and south facing shorelines all with narrow intertidal zones.

4.3 Initial BBN Model Results

The BBN model calculates a high, medium and low probability value of intertidal black bear habitat quality for each shore unit in the study area. The high probability values for each unit were selected to develop a habitat quality map as the focus of this study is the identification of those shoreline habitats utilized by the bears. These values have also been used to compare the model results with the bear survey observations. Each shore unit's characteristics and the initial model probability class are presented in (Appendix G).

The range of high probability class values for the shore units is from .238 to .477. Three high probability classes of 10% increments based on this distribution and range of these values (Table 7) have been identified. Each shore unit has been assigned a probability class and subsequently mapped with the bear observation locations (Figure 8).

The model probability classes are compared to the expected and the observed bear occurrence data and to assess the BBN model results (Table 7). Three bear encounter rates are calculated for each class, an expected bear encounter rate per kilometre, a bear encounter rate per kilometre and a normalized bear encounter rate that was calculated using the formula in section 4.2.

Results of the initial model demonstrate that bear encounter rates increase with increasing probability of high quality habitat. For example, the highest probability class (.4 to .5) has a normalized encounter rate of .084. This rate is 2 times greater than the rate for the .3 to .4 probability class which has a normalized encounter rate of .041. The lowest probability class (.2 to .3) encounter rate is .019 about half the rate of middle probability class. The former class comprises 27% of the study area shore units whereas the high probability class consists of 64% shore units.

The result of a chi-square analysis to test the hypothesis that there is no statistical difference between the distribution of the observed and expected number of bears of the probability classes equals 83.722 with 2 degrees of freedom with a p value of 0.0001. The expected number of bears assumes that they are evenly distributed across the probability classes. It is calculated by dividing the total number of bear observations by length of shoreline in each probably class. The result is statistically significant. It indicates that there is a significant difference in the bear distribution across the probability classes which support the initial model results.

Table 7. Initial BBN model results for the probability class of 'high' quality intertidal habitat

(1) Calculated as per the formula documented in 4.2.

Probability classification of high quality intertidal habitat	Length of shoreline (km)	Number of observed bears	Number of expected bears	Observed encounter rate per km	Length of shore units with bears (km)	% of shoreline units length with bear encounters	Normalized bear encounter rate per km (1)
.2 to .3	95	17	58	.18	12	13	0.019
.3 to .4	51	8	32	.16	8	16	0.041
.4 to .5	188	180	115	.96	88	47	0.084

Attempting to assess the initial model accuracy is difficult given the limited knowledge related to quality intertidal bear habitat. Past studies involved in developing BBN habitat models similar to this study have assessed accuracy by comparing the predicted habitat and associated environmental variables to the actual habitat and environmental variables. Model accuracy was determined by conducting systematic field surveys to verify the environmental GIS input data (Hengeveld 2005, Smith *et al.* 2007, refer to Chapter 2). This approach is not suitable for this study as the GIS input variables were not systematically verified. This review should however be undertaken to assist in improving this model in the future.

Some objectives of this initial BBN model are to test the child node outputs, ensure the results adequately reflect knowledge of the literature and expert reviews, and that the overall approach is appropriate. The current model results and outputs support these objectives. A chi-square analysis reveals that the distribution of bear encounters across the probability classes is not evenly distributed (chi-square=83.722, 2 df, $p < 0.0001$). The normalized bear encounter rates significantly increase with increasing probability of high quality habitat (which was expected). In addition, the narrow range of shore unit probability values in part reflects the limited knowledge used to design the model and populate the CPT tables. The composition of the high quality intertidal classes is consistent with the values applied in the CPT tables (Appendix E). The lack of different habitat separation within the .4 to .5 probability class demonstrates the inability of the current knowledge to discriminate the relative importance between these habitats (refer to Chapter 3).

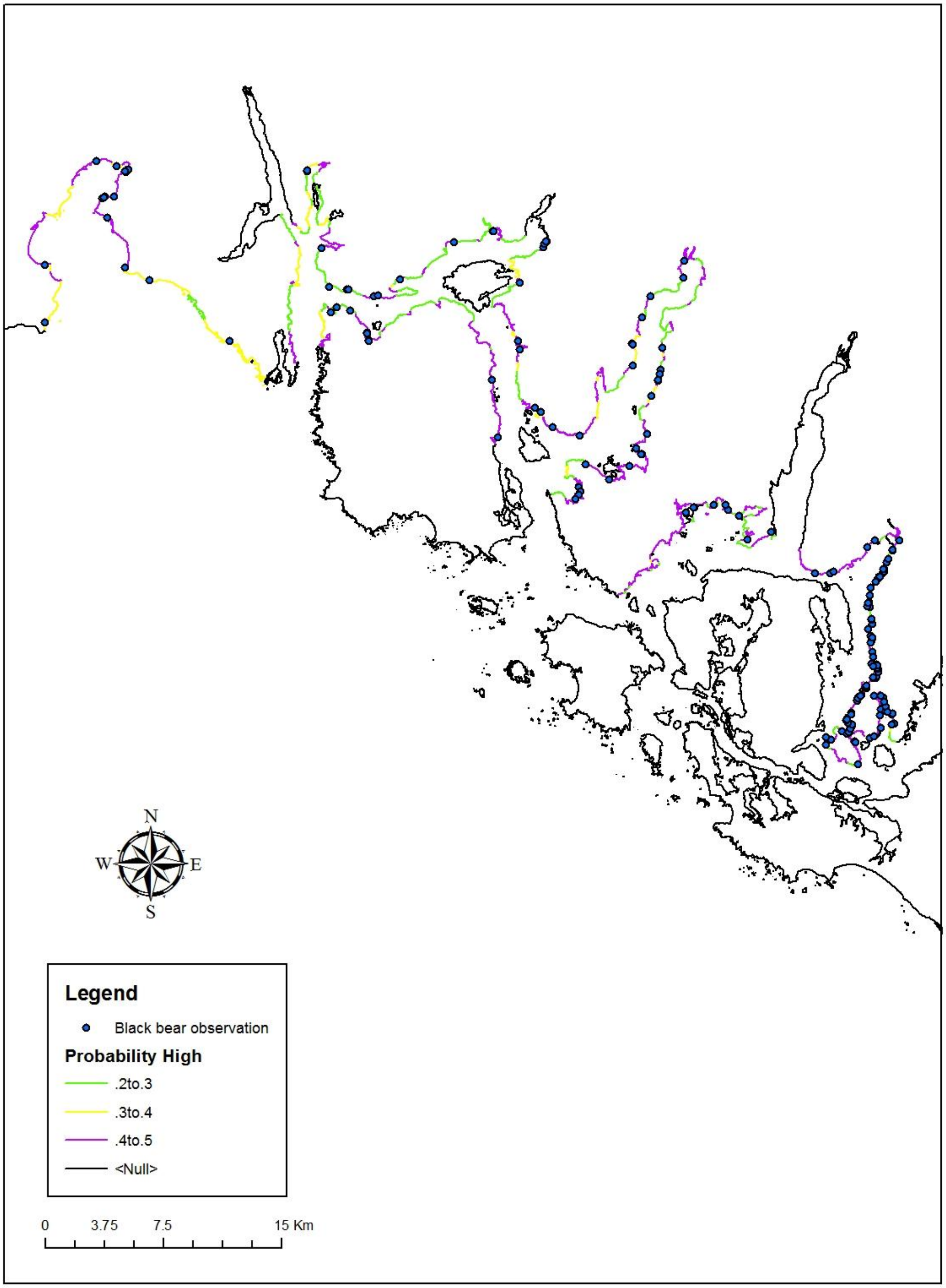

Figure 8. Map of the initial BBN model four "High" quality habitat probability classes with observed black bear locations

Chapter 5: Discussion and Model Revision

5.0 Introduction

Chapter 4 presents an initial BBN black bear intertidal habitat quality model for Clayoquot Sound. In this section I document the revision of the model based on an analysis of the black bear observations.

The observational data is limited by the temporal limits of the survey (e.g., 3.5 months, no nocturnal transects). This data supports the literature and expert reviews and provides additional insights into the environmental variables influencing intertidal bear use. It has been used to revise the BBN model.

5.1 Black Bear Distribution within the Study Area

The higher density of bear observations and encounter rates in survey route 3 (63% of all observations, Figure 7, Table 5) are likely a result of nearby known important terrestrial habitat, the Bulson Creek watershed, with high density populations. A second population of black bears occurs in the Pacific Rim National Park and the nearby landfill approximately 11 km from route 3 (MacHutchon 2001).

Survey route 3's elevated encounter rates may reflect the result of good foraging intertidal habitats and/or the effect of a large bear population. In areas where food is concentrated or bear density is high there is an establishment of a social hierarchy related to bear foraging territories that can result in the dispersal of younger bears (Rogers 1987). This type of behaviour may be occurring in survey area 3 resulting in the displacement of younger bears of the Bulson Creek bear population into the intertidal area to forage or travel to alternative foraging areas. This is supported by the lack of observed large bears in the survey area (reported below).

Sixty-two per cent of mother bear and dependant cubs observations occurred in survey area 3, including observations of a female with 3 cubs (3 observations, 2 of which occurred on the same day). Rogers (1987) indicates that more cubs per female reflects high productivity of its surrounding habitat, which may include good intertidal foraging habitats. The final outputs of the revised BBN model also support this observation (below). The survey area consists of 18 km the highest class of shoreline habitat, 57% of the total for this probability class.

5.1.1 Black Bear Behaviour

The dominant black bear behaviour observed within the intertidal zone is foraging, or foraging in combination with traversing a shore unit (94%). The most frequent foraging activity is flipping rocks. It was not uncommon where boulder flipping was observed that other food resources such as barnacles, fucus and ulva were ignored. This indicates that organisms (e.g., blennies, shore crabs and pricklebacks) found beneath boulders are favoured perhaps due to greater caloric return or ease of handling.

Research on intertidal foraging by brown bears in Alaska indicates that the nutritional benefits decreases as a bear's body size increases (Smith & Partridge 2004). They propose that large male bears with their high basal metabolic rates have high energy requirements that cannot be met by intertidal foods. The intertidal bear size results of this study support this hypothesis. The dominant bear size based on visual estimates within the intertidal is medium and accounted for 95% of all observations. Only 3 bears were considered large. These results are preliminary and require further verification.

Bear reaction to the research vessel supports the idea that bears that routinely come in contact with humans are de-sensitized and do not alter their activities (Table 6, Chapter 4) (Herrero *et al.* 2005). For example, survey area 3 (70%), a region of frequent bear watching tours has the highest rate of ignoring, or not reacting to the vessel (70% of all observations). In contrast, the dominant reactions in survey area 1 and 2 was to avoid or flee the approaching vessel (73% and 66%, respectively). There is less human activity within these areas. Survey area 4 had similar bear reactions to survey area 3. Seventy-five per cent of the bears did not respond to the research vessel. This may be a function of the distance between the research vessel and the shoreline. Observations were conducted further offshore due to the wide intertidal zones, rough waters, and nearby reefs. Alternatively, the bears may have been de-sensitized to humans. The survey area includes a small First Nation settlement at Hesquiat Harbour.

5.1.2 Black Bear Frequency Rates of BBN Single Variables

Single environmental variable black bear encounter rates (Appendix F) confirm and contradict some of the known habitat characteristics that favour use. High encounter rates on coarse sediment shore types (sand and gravel, gravel) supports numerous references to the role of cobble beaches and 'rock flipping' to locate prey items (Chapter 2, Appendix A − Table 2). Observations documenting the non-fish related bear foraging (*i.e.* foraging grasses) within estuary shore types is supported by the moderately high encounter rates. Wave exposure encounter rates indicate that there is a greater likelihood of encountering a black bear as shorelines become more protected. Although not well documented, it can be deduced from past studies that many of the bear observations occurred in more protected environments (e.g., sites in protected inlets).

Higher encounter rates on northerly shorelines and lower encounter rates of southern facing shores contradicts previous observations (refer to 3.3.2). Presently, it is unknown why northerly aspects had higher rates than south aspects. North aspect shorelines account for 17% of the overall shoreline and 15% of the bear observations. The role of aspect in predicting intertidal bear habitat requires further exploration. It may simply be that northerly aspects in this area also include better quality habitat.

Sand shore type encounter rates were slightly higher than expected. Sand shore types provide easy travel routes and foraging opportunities for clams in Alaska (Smith & Partridge 2004). However, there were no observations of bears digging in sand shore types. The higher encounter rate for sand shore types may be the result of shoreline generalization into 8 types for the BBN model. Sand shore types have the highest bear encounter rates in survey route 1 (Chapter 4). However, all of the bear foraging activity observed on these shore types involved cobble flipping. Cobble patches account for a small percentage of these overall shore units' texture and are ignored in the coast class decision procedures. The higher encounter rates are likely a result of these scattered cobble patches. Generalization of shore types based on dominant texture can result in the loss of detail necessary to distinguish important habitat features (see below for model limitations). The WHR backshore habitat types encounter rates are discussed in 5.2.1.

5.2 Revised BBN Black Bear Intertidal Habitat Model

5.2.1 CPTs of the Revised Model

To finalize the BBN model, I updated the CPTs based on bear encounter rates (Figure 9). A systematic approach to modification is implemented to limit the influence of the survey observations and reduce the chance of 'over fitting' the model to the field data. Some child node CPT values are modified to incorporate the bear survey results; others lack new information and are unmodified. An exception is the WHR backshore habitat node. The CPT values for this node are not changed despite the results of their bear encounter rates.

Two child node CPTs are modified based on the bear encounter rates (4.2.2). These are the 'primary influences on intertidal food productivity/availability' and 'secondary influences on intertidal food productivity/availability'. The 'terrestrial influences' CPT node remains unchanged despite the bear encounter rates (see below, also refer to Chapter 4). The remaining child nodes' CPTs of 'intertidal forage capability', 'intertidal habitat value' and 'offshore food influences' are not modified. There is no new information to support changing the latter node. The former nodes are products of the states of other child nodes (Figure 9). Their CPT values represent the current state of knowledge, including the results from the field surveys.

The following procedure was implemented to ensure consistent revision to the CPT probabilities of the 'primary influences on intertidal food productivity/availability' and 'secondary influences on intertidal food productivity/availability' nodes. The first step involves three classes of CPT probability values for the better state (Table 8). The 'better' state probability values in the initial BBN model CPTs are then assigned to one of these classes. The encounter rate class (high, medium, low) of the various combinations of shore type/wave exposure and aspect/intertidal width were as determined in Chapter 4 (refer to 4.2.2, Table 9, Table 10).

Table 8. CPT classification for the CPT values of the state "Better".

CPT value for the state "Better"	CPT Class
67 to 100	High
34 to 66	Medium
0 to 33	Low

The final 'better' probability value for the revised CPTs are developed by comparing the initial CPT class to the encounter rate class for each of the combinations. The 'better' probability value for the combinations is only modified when these two classes differ. If the encounter rate class and the initial CPT class are the same, the final CPT value for 'better' remains the same. If the encounter rate class was initially higher or lower by one level, the corresponding final CPT 'better' probability value is increased or decreased by 10%. A two class difference results in a plus or minus 20% change in the final CPT 'better' value. For example, if an initial CPT value of 'better' for a particular combination was 'high' and the encounter rate 'medium', the 'better' final probability value is deceased by 10% and the corresponding final 'poor' probability value is adjusted accordingly. The final probability values are presented in Tables 9 and 10.

Table 9. Revised CPT values for the node "primary influences on intertidal food productivity/availability".

Repetitive shore type/Wave exposure	Initial CPT class	Encounter rate class	Change in CPT value	Initial CPT value "Better"	Initial CPT value "Poorer"	Final CPT value "Better"	Final CPT value "Poorer"
Rock cliff/VP or P	Low	Low	No change	25	75	25	75
Rock cliff/SP	Low	Low	No change	25	75	25	75
Rock cliff/SE	Low	No shore units	No change	25	75	25	75
Rock cliff/E or VE	Low	No shore units	No change	25	75	25	75
Rock ramp platform/VP or P	Medium	Medium	No change	35	65	35	65
Rock ramp platform/SP	Medium	Low	minus 10%	35	65	25	75
Rock ramp platform/SE	Low	Low	No change	30	70	30	70
Rock ramp platform/E or VE	Low	Low	No change	25	75	25	75
Gravel/VP or P	High	High	No change	75	25	75	25
Gravel/SP	High	Low	minus 20%	75	25	55	45
Gravel/SE	Medium	Low	minus 10%	40	60	30	70
Gravel/E or VE	Low	No shore	No change	30	70	30	70

		units					
Sand and gravel/VP or P	High	High	plus 15%	75	25	90	10
Sand and gravel/SP	High	Medium	minus 10%	75	25	65	35
Sand and gravel/SE	Medium	Low	minus 10%	40	60	30	70
Sand and gravel/E or VE	Low	Low	No change	30	70	30	70
Sand/VP or P	High	Medium	minus 10%	75	25	65	35
Sand/SP	High	Low	minus 10%	75	25	65	35
Sand/SE	Medium	Low	minus 10%	40	60	30	70
Sand/E or VE	Low	Low	No change	25	75	25	75
Estuary/VP or P	High	Medium	minus 10%	75	25	65	35
Estuary/SP	High	Low	minus 10%	75	25	65	35
Estuary/SE	High	No shore units	minus 10%	75	25	65	35
Estuary/E or VE	High	No shore units	minus 10%	75	25	65	35
Channel/VP or P	Medium	Low	minus 10%	40	60	30	70
Channel/SP	Medium	Low	minus 10%	40	60	30	70
Channel/SE	Low	No shore units	No change	25	75	25	75
Channel/E or VE	Low	No shore units	No change	25	75	25	75
Manmade/VP or P	Low	Low	No change	25	75	25	75
Manmade/SP	Low	No shore units	No change	25	75	25	75
Manmade/SE	Low	No shore units	No change	25	75	25	75
Manmade/E or VE	Low	No shore units	No change	25	75	25	75

Table 10. Revised CPT values for the node "secondary influences on intertidal food productivity/availability".

Intertidal width/Shoreline aspect	Initial CPT class	Encounter rate frequency class	Change in CPT value	Initial CPT value "Better"	Initial CPT value "Poorer"	Final CPT value "Better"	Final CPT value "Poorer"
greater than 30m/North	Low	High	plus 20%	30	70	50	50
less than 30m/North	Low	Low	No change	25	75	25	75
greater than 30m/East	Medium	Medium	No change	60	40	60	40
less than 30m/East	Medium	Low	minus 10%	55	45	45	55

greater than 30m/South	High	Medium	minus 10%	75	25	65	35
less than 30m/South	Medium	Low	minus 10%	65	35	55	45
greater than 30m/West	Medium	High	plus 10%	60	40	70	30
less than 30m/West	Medium	Medium	No change	55	45	55	45

Some exceptions to this procedure are:

- The shore type/wave exposure combinations of ‘sand/semi-protected’ and ‘estuary/semi-protected’ have a ‘high’ initial CPT class and a ‘low’ encounter rate class. Only a 10% rather than 20% reduction is applied as I did not want to ‘over fit’ the model due to limited survey data, and disregard the current knowledge related to estuaries. These shore unit/wave exposure combinations have limited distribution accounting for < 1% of the study. There is only 500 metres of the estuary/semi-protected combination.
- The shore type/wave exposure combinations of estuary/semi-exposed and estuary/exposed and very exposed do not occur in my study area. A 10% decrease is applied to the probability ‘better’ for all of these shore type/wave exposure combinations to maintain consistency of the estuary types.
- The combination of sand and gravel/very protected, or protected wave exposures were initially assigned a ‘high’ probability class value. Its encounter class rate is ‘high’. The encounter rates for these combinations are highest for all combinations (4.2.2). A 15% increase is applied to the initial ‘better’ CPT value to reflect this dominant encounter rate.

The ‘terrestrial influences’ CPT node revision is a challenge. The initial CPT for this node (Appendix E − Table 4) has been retained despite the encounter rates for the adjacent WHR backshore habitat and nearby known terrestrial bear habitat (4.2.2). This is based on:

- The reviews suggest that adjacent terrestrial bear habitat to shorelines results in more coastal bear activity by providing additional or increased foraging opportunities (e.g., grasses, berries).

- The reliability of the rates for adjacent backshore bear suitability habitats are low because these habitats were modeled from TEM mapping. TEM mapping lacks the resolution to distinguish coastal fringe vegetation and mappers tend to ignore it.
- The nearby known bear terrestrial habitat encounter rates are based on a small sample size. Only 5% percent of the shoreline is within 1 km of nearby known bear habitats.
- The highest bear observations and encounter rates occur in survey route 3, which suggests that nearby known terrestrial bear habitat does influence shoreline use.

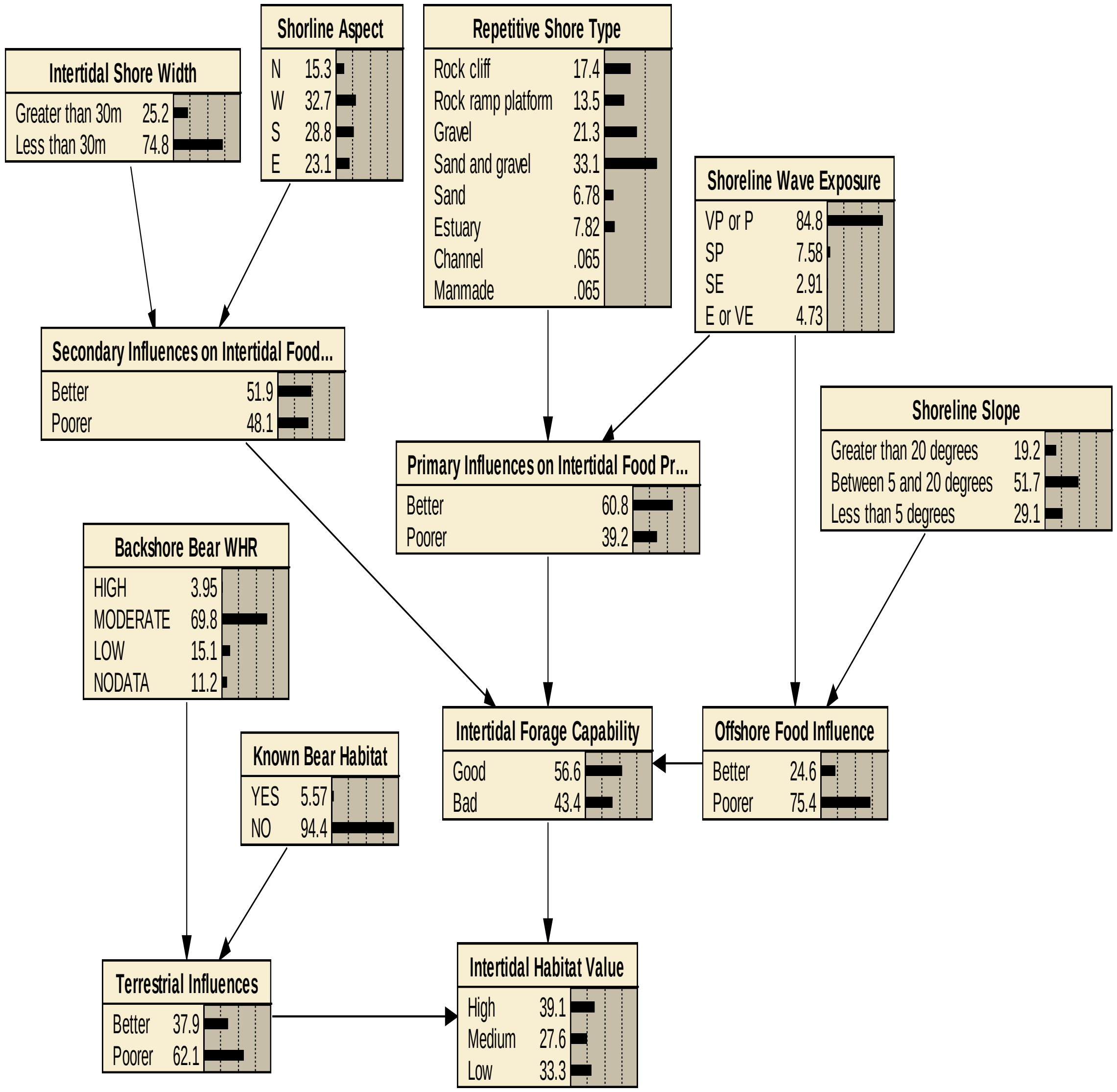

Figure 9. Final black bear intertidal habitat quality BBN model.

5.2.3 Final BBN Model Results and Discussion

The ‘high’ probability class values for the shore units in the final model range from .235 to .529. A four-fold 10% incremental probability classification is defined and based on the distribution and range of shore unit probability values (Table 11). Each shore unit is assigned to a class based on its probability value.

Bear encounter rates are calculated for each class for the overall study area and an area excluding survey area 3 to test the validity of the model (Table 11 and 12). The encounter rates are calculated by normalizing the total shore units bear observations within each class. It is expected that those shore units in the higher valued intertidal probability classes would have higher bear encounter rates (based on a period of continuous survey) as their associated habitat conditions should favour such use.

A map of the final 'high' habitat probability classes with the overlaying location of the bear observations is presented in Figure 10. Individual shore unit initial and final 'high' quality intertidal habitat rating and attributes (e.g., length, aspect, width, and bear observations) are presented in Appendix G.

Table 11. Final BBN model results for the probability of "High" quality habitat.

1. Note: the normalized bear encounter rate was calculated as per the formula in 4.2.

Probability classification of High quality intertidal habitat	Length of shoreline (km)	Number of observed bears	Number of expected bears	Observed encounter rate	Length of shoreline with bears	% of shoreline length with bear encounters	Normalized Bear encounter rate per km (1)
.2 to.3	103	18	63	.17	13	13	0.020
.3 to.4	53	12	33	.23	13	25	0.032
.4 to.5	145	99	89	.68	64	44	0.066
.5 to .6	32	20	20	.63	18	56	0.207

The final model separates the shoreline into more discrete probable bear habitats and improves the capacity to discriminate the most probable shore units with high quality black bear intertidal habitat, due to:

- The normalized 'high' probability bear encounter rate for the .5 to .6 class (.207) is 3 times greater than the next lower probability class whose rate in turn, is more than twice the rate of the two lowest classes (Table 13).
- The per cent of shore unit length with bear encounters progressively increases with successive higher probability classes.

- The range of 'high' probability values (.235 to .530) increase as compared to the initial BBN model (.238 to .477) (Table 14),
- The increase to four probability classes.

Table 12. Final BBN model results for the probability of "High" quality habitat excluding the results of survey area 3.

1. Note: the normalized bear encounter rate was calculated as per the formula in 4.2.

Probability classification of High quality intertidal habitat	Length of shoreline (km)	Number of observed bears	Number of expected bears	Observed encounter rate	Length of shoreline with bears	% of shoreline length with bear encounters	Normalized Bear encounter rate per km without survey 3 (1)
.2 to.3	86	8	27	0.09	10	12	0.006
.3 to.4	50	10	16	0.20	12	24	0.023
.4 to.5	95	48	29	0.51	41	43	0.054
.5 to .6	14	10	4	0.71	6	43	0.156

Positive results such as increasing normalized encounter rates with successive higher probability classes for the study area and improved definition of classes indicates that the general approach and design of the model is sound. Further support is provided by encounter rates for the study area excluding survey 3. This survey area accounts for 63% of all bear observations (refer to 4.1.1) that maybe a reflection of a greater density of bears in this region or other unknown factors that may be influencing bear behaviour such as perceived mortality risk. Although the absolute encounter rates are lower than those of the study area, the pattern of increasing encounter rates with increasing probability of 'high' quality habitat and the difference between classes is similar to those of the overall study area (Table 12). These results indicate that the output of the model is consistent with the combined knowledge of the reviews and the bear encounter rates used to revise the CPTs generated from all the surveys; nor are these results biased due to survey area 3 bear observations.

The model structure was also verified by a sensitivity analysis of the 'intertidal habitat value' output node (Marcot *et al.* 2006). This analysis verified that the 'intertidal forage capability' node is the most influential factor in determining the 'intertidal habitat value' node and that the 'primary influences on intertidal food' is the most influential in determining forage capability. The result of a chi-square analysis is similar to that applied to the initial model. The result indicates that there is a significant difference in the bear distribution across the probability classes (chi-square=203.43, 3 df, $p < 0.0001$).

Table 13. Number of observed bears compared to expected bears for the "high" quality habitat classes for each survey route.

Probability classification of high quality intertidal habitat	Number of observed bears survey 1	Number of expected bears survey 1	Number of observed bears survey 2	Number of expected bears survey 2	Number of observed bears survey 3	Number of expected bears survey 3	Number of observed bears survey 4	Number of expected bears survey 4
.2 to .3	5	15	3	10	10	25	0	1
.3 to .4	4	4	2	2	2	4	4	9
.4 to .5	17	9	20	16	51	74	11	6
.5 to .6	4	2	5	2	66	26	1	0

The final model probability classes of each survey route are compared to the expected and the observed bear occurrence data to assess the distribution of bear encounters across the classes (Table 13). The result of a chi-square analysis for each survey is similar to that applied to the initial and final model. The result of survey 1 indicates that there is a very significant difference in the bear distribution across the probability classes (chi-square=15.778, 3 df, $p < 0.0013$). The result of survey 2 indicates that there is a significant difference in the bear distribution across the probability classes (chi-square=10.400, 3 df, $p < 0.0155$). The result of survey 3 indicates that there is a very significant difference in the bear distribution across the probability classes (chi-square=78.687, 3 df, $p < 0.0001$). The result of survey 4 indicates that there is a significant difference in the bear distribution across the probability classes (chi-square=10.975, 3 df, $p < 0.0118$). These results are circumspect as not all of the values of the expected observations of the four classes in each survey are greater than 5 and therefore not adequately represented to support the results of a chi-square analysis (Jelinski 1990), whereas the four classes are adequately represented for the study area.

The greatest change between the two BBN models occurs in the higher probability classes (Table 14). Approximately 32 kilometres of shoreline (29 shore units) make up the .5 to .6 ‘high’ probability class of the final model. All of these units were previously in class .4 to .5 of the initial model (Appendix G). An additional 10 kilometres of shoreline (13 shore units) is reclassified from the .4 to .5 class to the .3 to .4 class; the remaining shore units in the later class do not change in the final model and have a total length of 145 km (Appendix G). There was only a minor shift of shore units and shoreline length between the two lower classes. Six shore units (8 km of shoreline) in the final .2 to .3 class were previously in the initial model .3 to .4 class. These changes indicate that the identification of ‘high’ probable bear habitats improves in the final model; however, there is less impact in separating the lower probable habitats.

Table 14. Comparison of the initial and final BBN results for the total length of high quality probability classifications and normalized bear encounter rates.

Probability classification of High quality intertidal habitat	Total length (km) of all shoreline Initial model	Total length (km) of all shoreline Final model	Normalized bear encounter rate per km Initial model	Normalized bear encounter rate per km Final model
.2 to.3	95	103	0.019	0.020
.3 to.4	51	53	0.041	0.032
.4 to.5	188	145	0.084	0.066
.5 to .6	-	32	-	0.207

The following are some of the shoreline characteristics associated with the four 'high' quality habitat probability classes (refer to Appendix G):

- All of the shore units in the highest 'high' probability class (.5 - .6) consist of sand and gravel shore types with protected/very protected wave exposures. With the exception of one unit, they occur along the three inner coast survey routes with the majority (57%) located in survey area 3. South and west aspects dominate and the adjacent backshore WHR is dominantly moderate with some high.
- Shore units in the .4 - .5 high probability class, are made up of a mix of sediment shore types: 34% sand, 30% sand and gravel, 22% estuary and 14% gravel shore types. The majority of these shorelines have protected/very protected wave exposures; 12% are associated with semi-protected waters. Shore unit aspects are variable.
- There is greater variation of environmental variables in the high probability class of .3 - .4 than the preceding higher classes. Rock ramp/platform shore types account for 59% of all of the shore types; rock ramp/platform shore types with protected/very protected wave exposures are the most common shore type/wave exposure combination (25%). The remaining shores types consist of gravel (16%), sand and gravel (14), gravel (6%) and estuary shore types (5%). Protected/very protected wave exposures are the most common wave exposures (40%), followed by exposed/very exposed (28%), semi-protected (17%) and semi-exposed (15%).
- The lowest high probability class (.2 - .3) is dominated by shore units with rock substrates (94%). The most frequent shore type is rock cliffs (61%) and rock ramp/platforms (33%). The remainder consist of sand and gravel with exposed/very exposed wave exposures (3%), manmade (2%) and channel (<1%). Protected/very protected wave exposures dominate (81%) and all of the shore units are narrow (<30m).

There is a trend of changing shore type character with increasing probability of high quality bear habitat. The lowest probability class is dominated by narrow rock shores, whereas the highest probability class consists of sand and gravel sediment shorelines. The second highest class is made up of a variety of mixed sediment shore types (i.e. sand, sand and gravel or gravel) whereas the second lowest probability class is a mixture of rock and sediment shore types dominated by rock ramp/platform shore types.

The relatively high bear encounter rate for the sand/very protected/protected wave exposure combinations is, in part, the result of a false positive error. The rate on these combinations is a result of the presence of scattered cobble patches rather than the sand (5.1.2). Generalization of this shore type based on dominant texture resulted in the loss of detail related to an important environmental variable (e.g., cobble/boulder presence). There were no bear observations on shore type/wave exposure combinations of ‘sand/semi-protected’ and ‘estuary/semi protected’. The lack of bear observations is considered to be a consequence of their limited sample size (< 1% of the study) and results in a false negative bear encounter rate error. No bear sighting on these shorelines contradicts the current knowledge of their black bear use and in estuaries.

Finally, the revised BBN model outcomes demonstrate that the procedure to develop, populate and modify the CPTs is consistent with current knowledge. The CPTs values are well documented and can be easily modified with new information. Applying this systematic approach helped address the constraint of collecting and structuring expert knowledge into meaningful probability distributions (Uusitalo 2007).

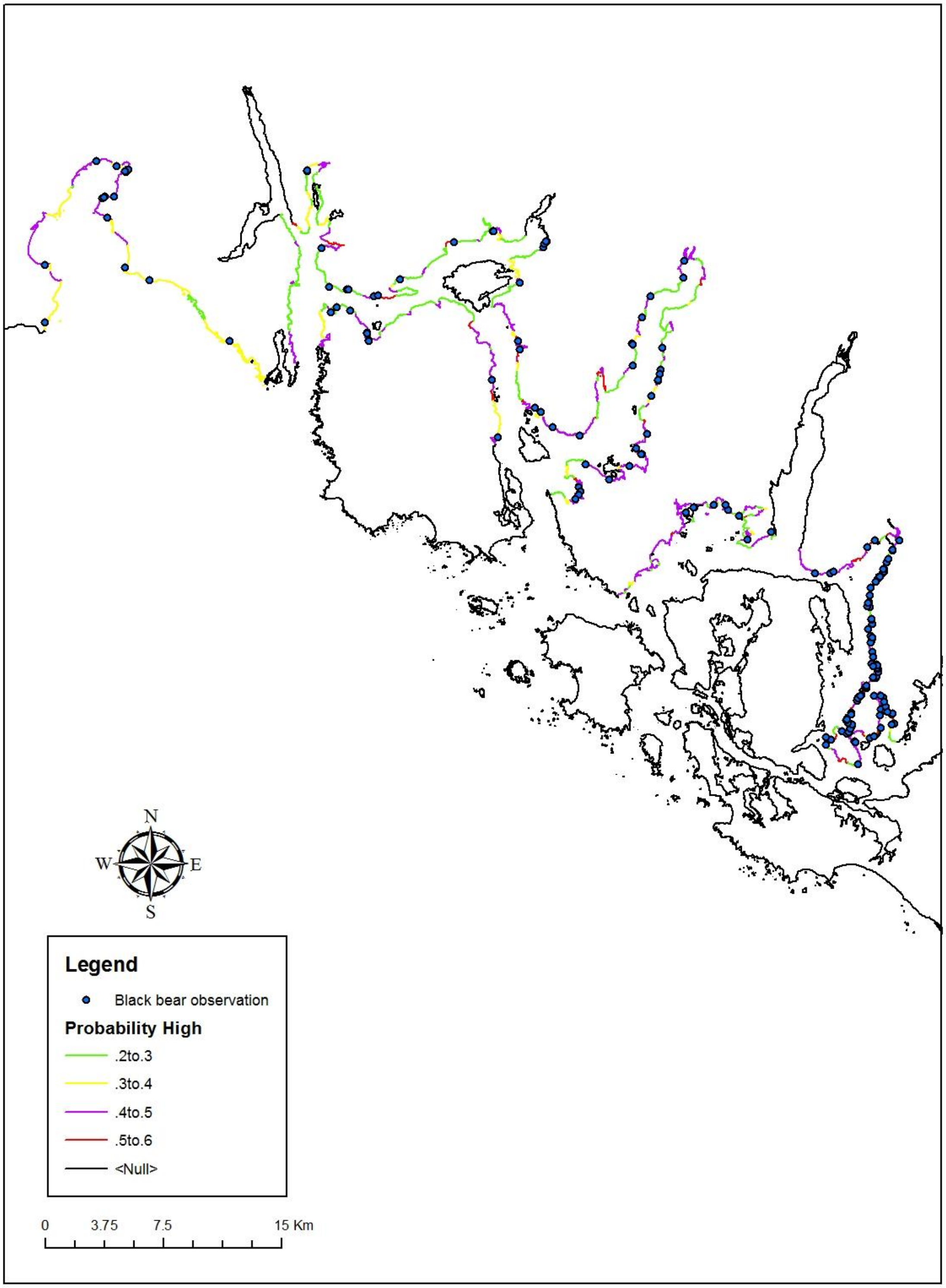

Figure 10. Map of the final BBN model four "High" quality habitat probability classes with observed black bear locations.

5.3 Model Limitations

One of the limitations of the BBN model is that it has been developed and modified on limited information. The literature and bear expert reviews lacked some specific details related to the biophysical characteristics of their intertidal habitat preferences. Information was general, largely related to physical characteristics of the shoreline. As a result, the BBN model structure was constrained and largely focused on physical variables. In addition, revision of the BBN model was based on results generated from a short, three month, daylight field survey. Although this data provides trends related to shoreline variables influencing the identification of quality intertidal bear habitat for updating the CPTs, it is insufficient to quantify the relationships in the child nodes through statistical analyses. For example, the black bear encounter rates were used to develop the CPT for the "primary influence on food productivity/availability" node whereas statistical analyses of information collected from a systematic, repetitive sampling program would provide greater reliability in assigning CPT values. It would also improve the identification of key physical and biological environmental variables.

A second limitation of the data is the availability of systematic biophysical GIS data to support the model. This study benefited from the existence of the BC Physical Shore-Zone mapping system data set to support the BBN model. However, the limited knowledge related to black bear use of intertidal biological resources, and the British Columbia biological shoreline classification focus on benthic, sessile species excluded use of this data set. The model was also restricted by the lack of detailed adjacent terrestrial backshore vegetation/habitat and intertidal species data available along the shorelines of British Columbia.

Assessing the accuracy of the BBN model is also difficult. There has been no systematic field survey to assess and compare the predicted habitat and associated environmental variables to the actual habitat and environmental variables. Shore surveys provided additional anecdotal information regarding the physical and biological characteristics of some shore units utilized by bears. Systematic intertidal sampling provides further information for improving the model design and assignment of CPTs values.

The final BBN model is a high level, preliminary model. It represents an initial understanding of the influence that some environmental variables play in determining probable high quality intertidal bear habitat. It is based on literature and early consultation with bear experts. Bear experts, however, did not participate in the development of the CPTs and model design. CPTs were developed and revised on the basis of the reviews and field survey results.

The limited understanding of black bear intertidal bear utilization is reflected in the simple model structure. Some nodes may have little if any effect on habitat quality, such as intertidal shore width and shoreline aspect. This lack of knowledge and the findings of my study have being incorporated within the probabilities assigned within the CPT's to depict greater or lesser influence over the final output node, intertidal habitat quality. This versatile model structure easily allows for a change in its structure as more data or additional information regarding habitat variables that may influence habitat quality is gained.

There are also limitations with respect to the GIS input data. Some of the GIS data have been generalized to reduce the complexity of the BBN model and analysis, and meet BBN development guidelines. For example, the 8 modified repetitive shore types of the model were generalized from the 34 coastal classification shore types. The application of generalized datasets often results in a loss of detail, which can impact the accuracy of the BBN model (refer above). The modeled TEM/WHR adjacent backshore habitat was used as a substitute for detailed immediate backshore vegetation mapping however it lacks the resolution to distinguish coastal fringe vegetation (5.2.1).

5.4 Recommendations

Recommendations to improve the black bear intertidal habitat quality model:

- The role of intertidal and adjacent terrestrial (backshore) food sources requires further research. Systematic studies focused on coastal bear foraging and diet would provide a better understanding of intertidal and adjacent backshore habitats preference, and improve the model design, identification of key variables, and support direct species/habitat mapping to support the BBN model. As well, intertidal food resources could be systematically collected and tested to provide baseline data on their nutritional content. Forage studies could also address whether or not bears forage along the coast during the night or if there is any intertidal use during higher tides.

- The current model would benefit from formal peer review to reach the standard of a gamma-level model outlined in Marcot *et al.* (2006). The model requires further bear expert review and input related to the model structure, identification of environmental variables and CPT tables.
- Continuing the bear observation studies along the four survey areas would improve the quality of the bear encounter rates. Cross-section surveys of selected shorelines within the survey areas should be undertaken to document the physical and biological properties of key environmental variables and to test the model's accuracy following the methods of previous studies (Hengeveld 2005, Smith *et al*. 2007).
- Studies related to improving information on shoreline bear food sources (above) and mapping the distribution and abundance of these sources are restricted by time and cost constraints (Searing & Firth 1995). As an alternative, it is recommended that a modified Delphic survey be conducted with bear experts to identify what they consider the most important 2-3 intertidal and adjacent backshore food sources.
- The lack of empirical data or knowledge to support the CPTs of the offshore food influence node needs improvement. This component of the model should be discussed with oceanographers to determine alternative methods (i.e. tidal and ocean current patterns) for identifying depositional shorelines.

5.5 Summary

This study accomplished the four objectives outlined in the Chapter 1. It succeeded in identifying the known, although limited physical and biological shoreline variables that influence intertidal habitat areas preferred and utilized by black bears through literature and bear expert reviews. Based on this knowledge, the second objective was met with the development of a Bayesian belief network that predicted and mapped the probable quality of different shoreline intertidal habitats for black bears within Clayoquot Sound. Improved knowledge of summer black bear use of the intertidal habitats, the third objective was accomplished through the day-time, summer shoreline intertidal field surveys. Analyses of these results provided further insights into intertidal bear use, behaviour, encounter rates and the environmental variables (physical and terrestrial habitat) influencing intertidal bear habitats. Incorporation of these results into the BBN model supported completion of the final objective revising the initial black bear BBN through the systematic revision of the model CPTs. The final BBN model is a preliminary high level model for predicting high quality black bear intertidal habitat. Several recommendations including black bear expert input have been suggested to advance the development of the model. The study demonstrates that the BBN process is an effective tool for habitat modeling, particularly where there is limited known knowledge, existence of local expertise and supportive GIS information.

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Appendix A

Documented coastal bear resources and intertidal activity

Table A – 1. List of reported flora and fauna foraged by bears along the west coast of North America.

Genus/species	Common Name	Season	Reference
Actea rubra	Baneberry	unknown	NPS 2004[1]
Angelica genuflexa	Kneeling angelica	Sp, Su, F	NPS 2004
Angelica lucida	Sea-Watch	Sp, Su, F	NPS 2004
Arctostaphylos uva-ursi	Kinnikinnick	Su, F	MacHutchon, 1999; NPS 2004
Aruncus dioicus	Goat's beard	Sp	NPS 2004
Athyrium filix-femina	Lady Fern	Sp	MacHutchon, 1999; NPS 2004
Barbarea orthoceras	American Wintercress	unknown	NPS 2004
Bochnakia rossica	Northern Groundcone	Sp, Su, F	NPS 2004
Calamagrostis canadensis	Bluejoint	Sp	NPS 2004
Carex lyngbyei	Lyngby's Sedge	Sp, Su,	MacHutchon, 1999; NPS 2004; Smith & Partridge, 2004
Carex macrochaeta	Long-awned Sedge	Sp, Su, F	MacHutchon, 1999; NPS 2004; Smith & Partridge, 2004
Carex mertensiana	Merten's Sedge	Sp, Su, F	MacHutchon, 1999; NPS 2004; Smith & Partridge, 2004
Conioselinum	Pacific Hemlock-	Su, F	MacHutchon, 1999; NPS 2004

chinense	Parsley		
Deschampsia caespitosa	Hairgrass	Sp	NPS 2004
Empetrum nigrum	Crowberry	F	MacHutchon, 1999; NPS 2004
Equisetum arvense	Common Horsetail	Sp, Su, F	MacHutchon, 1999; NPS 2004
Elymus spp.	grassess	Sp, Su, F	MacHutchon, 1999; Smith & Partridge, 2004
Fomes, Fomitopsis, Ganoderma, etc.	bracket fungus	Su, F	MacHutchon, 1999
Fucus gardneri	Rock weed	Sp, Su	pers. com. within O'Clair & O'Clair, 1999
Fragaria chiloensis	Coastal Strawberry	Su, F	NPS 2004
Gaultheria shallon	Salal	Su, F	MacHutchon, 1999
Hedysarum alpinum	Alpine Sweet-vetch	Sp, Su, F	NPS 2004
Heracleum lanatum	Cowparsnip	Sp, Su, F	NPS 2004
Hordeum brachyantherum	Meadow Barley	Sp	NPS 2004
Lathyrus maritimus	Beach Pea	Sp	NPS 2004
Ligusticum hultenii	Beach Lovage	Su, F	NPS 2004
Lysichiton americanum	Skunk Cabbage	Sp, F	MacHutchon, 1999; NPS 2004
Lupinus	Nootka Lupine	Sp, Su	NPS 2004

nootkatensis			
Microseris borealis	Apargidium	Sp, Su	MacHutchon, 1999
Opoplanax horridum	Devil's Club	F	MacHutchon, 1999; NPS 2004
Osmorhiza depauperata	Blunt-fruited Sweet Cicely	Sp, Su	MacHutchon, 1999; NPS 2004
Oxytropis campestris	Field Oxytrope	Sp, Su	NPS 2004
Plantago maritime	Goose-tongue	Sp	NPS 2004 Smith & Partridge, 2004
Puccinellia nutkaensis	Pacific Alkaligrass	Sp	NPS 2004
Ribes sp.	Currants	F	MacHutchon, 1999; NPS 2004
Rosa nutkana	Nootka Rose	F	NPS 2004
Rubus arcitcus	Nagoonberry	F	NPS 2004
Rubus parviflorus	Thimbleberry	Sp, Su, F	MacHutchon, 1999; NPS 2004
Rubus spectabilis	Salmonberry	Sp, Su, F	MacHutchon, 1999; NPS 2004
Sambucus racemosa	Red Elderberry	F	MacHutchon, 1999; NPS 2004
Shepherdia canadensis	Soapberry	F	NPS 2004
Stellaria calycantha	Northern Starwort	unknown	NPS 2004
Streptopus amplexifolius	Twisted Stalk	Sp, Su, F	MacHutchon, 1999; NPS 2004
Taraxacum sp.	Dandelion	Sp	NPS 2004
Triglochin	Arrowgrass	Sp	NPS 2004; Smith & Partridge, 2004

maritimum			
Vaccinium sp.	Blue/Huckleberries	F	MacHutchon, 1999; NPS 2004
Viburnum edule	High-bush Cranberry	F	NPS 2004
Fauna			
Ammodytes spp.	Fish	Sp, Su, F	pers. com. within MacHutchon, 1999; Smith & Partridge, 2004
Balanus spp.	Barnacle	Sp, Su unknown	Oldershaw, 1994; MacHutchon, 1999; pers. com. within Carlton & Hodder, 2003 by D. Padilla; pers. com. within Carlton & Hodder, 2003 N. Folsom; Smith & Partridge, 2004; NPS 2004
Chthamalus spp.	Barnacle	Sp, Su unknown	Oldershaw, 1994; MacHutchon, 1999; pers. com. within Carlton & Hodder, 2003 by D. Padilla; pers. com. within Carlton & Hodder, 2003 N. Folsom; NPS 2004
Hemigrapus nudus	Purple shore crab	Sp, Su F	Ellis & Wilson 1981; Ramsay 1985; Oldershaw 1995; MacHutchon, 1999; pers. com. with Bruce Atkey 2004
Mya arenaria	Soft shelled clam	Sp, Su	Smith & Partridge, 2004
Mytilus spp.	Mussel	Sp, Su F	MacHutchon, 1999; pers. com. within Carlton & Hodder, 2003 by C. Hewitt ; pers. com. within Carlton & Hodder, 2003 by T. Klinger ; Smith & Partridge, 2004; NPS 2004
Nereis spp.	Marine worm	Sp, Su unknown	Smith & Partridge, 2004
Oncorhynchus spp.	Salmon	Su, F	Frame, 1974; MacHutchon, 1999; Reimchen, 1998 & 2000; NPS 2004
Pholis spp.	Gunnel	Sp, Su	Oldershaw, 1994; pers. com. within MacHutchon, 1999; NPS 2004
Pisaster spp.	Starfish	Sp, Su	Oldershaw 1995; pers. com. within MacHutchon,

		unknown	1999
Siliqua spp.	Clam	Sp, Su unknown	Smith & Partridge, 2004
Traskorchestia traskiana	Beach hopper	Sp, Su unknown	Ellis & Wilson 1981; MacHutchon, 1999; NPS 2004
Xiphister spp.	Prickleback	Sp,Su unknown	Oldershaw, 1994; pers. com. within MacHutchon, 1999; NPS 2004

1. http://www.nps.gov/glba/naturescience/foods.htm

Table A – 2. Observed black bear interactions and food sources within intertidal environments along the west coast of North America.

Location	**Life Requisite**	**Season**	**Resource**	**Reference**
Glacier Bay, Alaska	Forage	Spring-early summer; summer-fall	Intertidal mussels and barnacles; intertidal and backshore plants; spawning salmon	http://www.nps.gov/glba/naturescience/bears.htm
Glacier Bay, Alaska	Travel	Spring to winter;	Coastal corridor along shore and by way of swimming	http://www.nps.gov/glba/naturescience/bears.htm
Kenai Fjords, Alaska	Forage	Spring-early summer	Intertidal and backshore plants; no mention of other resource uses	http://www.oceanalaska.org/research/blkbear.htm
Katmai Park, Alaska[1];	Forage, Travel	Spring-early summer	Intertidal soft-shelled (*Mya arenaria*) and Pacific razor clams; occasional consumption of Alaska surf clam and peanut worms;	Smith & Partridge, 2004

			consumption of intertidal grasses and sedges; bears utilized shoreline habitat types such as salt marshes (i.e. estuary) and tidal flats	
Moresby Island, BC	Forage	Fall	Spawning salmon in the estuary and stream	Reimchen, 1998 & 2000
Area around Bamfield	Forage	Summer and fall	bears observed foraging within the intertidal zone	Nordstrom, 2002
Glacier Bay, Alaska	Forage	April (spring)	Consumption of *Fucus* (rockweed) within the intertidal	pers. com. within O'Clair & O'Clair, 1998
Area around Bamfield	Forage	Not specified	rolling large cobbles and eating barnacles	pers. com. within Carlton & Hodder, 2003 by D. Padilla
Queen Charlotte Islands and Prince Royal Island, BC	Forage	Not specified	Scrapping barnacles off intertidal rocks	pers. com. within Carlton & Hodder, 2003 by E.A. Mills
Katmai National Park, Alaska	Forage	Not specified	Bivalvia (mussel, *Mytilus californianus*)	pers. com. within Carlton & Hodder, 2003 by T. Klinger
Prince William Sound, Alaska	Forage	Not specified	Foraging in mussel beds	pers. com. within Carlton & Hodder, 2003 by C. Hewitt
Tracy Arm	Forage	Not	Video of bears scraping barnacles	pers. com. within Carlton & Hodder,

and Glacier Bay, Alaska		Specified	off intertidal rocks; scat consists of barnacle remains	2003 N. Folsom
Vancouver Island	Forage	Not specified	Photo of black bear flipping rocks searching for crabs	Ramsay 1985
Clayoquot Sound, BC	Forage		observations of bears consuming *Brachyura* (shore crabs), *Asteroidea*; prickleback, gunnel and starfish; various shorelines used with emphasis on importance of cobble beaches	Oldershaw 1995
Queen Charlotte Islands, BC	Forage		*Amphipoda* (beach hoppers) and *Brachyura*	Ellis & Wilson 1981
Olsen Creek, Alaska	Forage	Fall	Spawning salmon in the estuary and stream	Frame 1974
Hesquiaht Peninsula, Vancouver Island	Forage	Spring (March to early May)	Observations of bears flipping rocks to eat crabs; scat observations show crab remains	pers. com. with Bruce Atkey 2004
Clayoquot Sound	Forage	Spring, Summer, Fall	scat analysis show remains of shore crabs, barnacles, beach hoppers, sea stars, mussels, pricklebacks, gunnels, salmon and graminoids common at coastal margins; various shorelines used with emphasis on importance of cobble beaches	MacHutchon, 1999
Glacier Bay,	Forage, Travel	Spring, Summer	feeding on intertidal sedges, grasses and barnacles; shoreline types of	Lee, 1985

Alaska			rocky strewn beaches with occasional cobble and boulder	

1. Brown (grizzly) bear study, mentions black bears

Appendix B

Variables modified or used in the BBN model

Table B – 1. Coastal classification code definitions for shoreline type

Coastal Classification Code	Shoreline Type	Shore Unit Characteristics
1	Rock ramp, wide (> 30m)	rock shores with a slope range of 5-20°; ramps may be hummocky with a fractured jointed surface and no organized beach features
2	Rock platform, wide	rock shores with a slope range of <5°; thin sediment veneer may be present but typically patchy and no organized beach features
3	Rock cliff, narrow (<30m)	steep sloped (>20°) rock shores
4	Rock ramp, narrow	rock shores with a slope range of 5-20°
5	Rock platform, narrow	rock shores with a slope range of <5°
6	Ramp with gravel beach, wide	rock shores with a rubble, boulder, cobble or pebble beach and a slope range of 5-20°
7	Platform with gravel beach, wide	rock shores with a rubble, boulder, cobble or pebble beach and a slope range of <5°
8	Cliff with gravel beach, narrow	steep sloped (>20°) rock shores with a rubble, boulder, cobble or pebble beach
9	Ramp with gravel beach, narrow	rock shores with a rubble, boulder, cobble or pebble beach and a slope range of 5-20°
10	Platform with gravel beach, narrow	rock shores with a rubble, boulder, cobble or pebble beach and a slope range of <5°
11	Ramp with gravel & sand beach, wide	rock shores with a rubble, boulder, cobble, pebble and sand beach and a slope range of 5-20°
12	Platform with G&S beach, wide	rock shores with a rubble, boulder, cobble, pebble and sand beach and a slope range of <5°
13	Cliff with G&S beach, narrow	steep sloped (>20°) rock shores with a rubble, boulder, cobble, pebble and sand beach
14	Ramp with G&S beach, narrow	rock shores with a rubble, boulder, cobble, pebble and sand beach and a slope range of 5-20°
15	Platform with G&S beach, narrow	rock shores with a rubble, boulder, cobble, pebble and sand beach and a slope range of <5°
16	Ramp with sand beach, wide	rock shores with a sand beach and a slope range of 5-20°
17	Platform with sand beach, wide	rock shores with sand beach and a slope range of <5°
18	Cliff with sand beach, narrow	steep sloped (>20°) rock shores with a sand beach

19	Ramp with sand beach, narrow	rock shores with a sand beach and a slope range of 5-20°
20	Platform with sand beach, narrow	rock shores with sand beach and a slope range of <5°
21	Gravel flat, wide	surface sediments comprised of boulder, cobble, pebble and a slope range of <5°
22	Gravel beach, narrow	surface sediments comprised of boulder, cobble, pebble and a slope range of 5-20°
23	Gravel flat or fan, narrow	surface sediments comprised of boulder, cobble, pebble and a slope range of <5°
24	Sand & gravel flat or fan, wide	sediments comprised of boulders, cobbles, pebbles and sand and a slope range of <5°
25	Sand & gravel beach, narrow	sediments comprised of boulders, cobbles, pebbles and sand and a slope range of 5-20°
26	Sand and gravel flat or fan, narrow	sediments comprised of boulders, cobbles, pebbles and sand and a slope range of <5°
27	Sand beach, wide	sediments >50% sand and <10% gravel and a slope range of 5-20°
28	Sand flat, wide	sediments >50% sand and <10% gravel and a slope range of <5°
29	Mudflat, wide	sediments >50% mud and <10% gravel and a slope range of <5°
30	Sand beach, narrow	sediments >50% sand and <10% gravel and a slope range of 5-20°
31	Estuaries	variable sediments, although mud and organics are common and wetland grasses frequent the high water mark
32	Man-made, permeable	man-made features commonly constructed of concrete, timber, pilings, or rubble and rock
33	Man-made, impermeable	man-made features commonly constructed of concrete, timber, or sheet pile
34	Channel	variable sloped current dominated feature may consist of rock substrates or unconsolidated materials

Table B – 2. Modified repetitive shoreline type classification code definitions.

Modified Repetitive Shore Unit Classification Code	**Coastal Classification Code**	**Shore Unit Characteristics**
Rock cliff	3	steep sloped rock shores
Rock ramp/platform	1, 2, 4, 5	inclined or flat sloped rock shores
Gravel	6, 7, 8, 9, 10, 21, 22, 23	steep, inclined or flat sloped gravel sediments with/out rock present
Sand & gravel	11, 12, 13, 14, 15, 24, 25, 26	steep, inclined or flat sloped sand and gravel sediments with/out bedrock present
Sand	16, 17, 18, 19, 20, 27, 28, 29, 30	steep, inclined or flat sloped sand or mud sediments with/out bedrock present
Estuary	31	commonly low sloped and variable sediments although mud and organics are common as well

		as wetland grasses at high water mark
Channel	34	variable sloped current dominated feature may consist of rock substrates or unconsolidated materials
Man-made	32, 33	man-made permeable and impermeable features commonly constructed of concrete, timber, pilings, rubble and rock

Table B – 3. Shore unit slope code definitions.

Slope Value	**Definition**
<5°	flat or little inclination of shore feature measured from the supratidal to low tide line
5-20°	inclined shore feature measured from the supratidal to low tide line
>20°	steep shore feature measured from the supratidal to low tide line
Not available	no data

Table B – 4. Shore unit intertidal width code definitions.

Intertidal width code	**Definition**
greater than 30m	intertidal widths are greater than 30 metres
less than 30m	intertidal widths are less than 30 metres

Table B – 5. Shore unit aspect code definitions.

Aspect code	**Definition**
N	shore unit faces north with an azimuth value range between 315° - 44°
E	shore unit faces east with an azimuth value range between 45° - 134°
S	shore unit faces west with an azimuth value range between 135° - 224°
W	shore unit faces south with an azimuth value range between 225° - 314°

Table B – 6. Calculated wave exposure code definitions.

Wave Exposure Code	**Definition**
VP (very protected)	maximum wave fetch less than 1km; usually areas of all-weather anchorages, marinas and harbours
P (protected)	maximum wave fetch less than 10km; usually areas of provisional anchorages and low wave exposure
SP (semi-protected)	maximum wave fetch distances in the range of 10 to 50km; waves are low most of the time except during high winds

SE (semi-exposed)	maximum wave fetch distances between 50 to 500 km; swells generated in areas distant from shore unit create relatively high wave conditions; during storms extremely large waves create high wave exposures
E (exposed)	maximum wave fetch distances 500 to 1,000 km; high ambient wave conditions usually prevail within this exposure
VE (very exposed)	maximum wave fetch distances > 1,000 km; Large swell (>1m) almost always present; typical of open-Pacific conditions

Table B – 7. Calculated black bear WHR code definitions.

WHR Rating Code	**Calculated Value**	**Definition**
High	.1 – 1.67	area provides a high potential to support black bear life requisites
Medium	1.68 – 3.34	area provides a moderate potential to support black bear life requisites
Low	3.35 - 5	area provides a low potential to support black bear life requisites
Nil or No Data	0 or no data available	no data or WHR value provided for area

Table B – 8**.** Black bear WHR assigned for "LI" to the site series of Clayoquot Sound, B.C. for the summer period (MacHutchon 1999)**.**

					Site	**Structure**	**Summer**
	Zone	**Sub**	**Var**	**Label**	**Mod.**	**Stage**	**LI**
	CWH	vh	1	HS		3	2
	CWH	vh	1	HS		4	4
	CWH	vh	1	HS		5	4
	CWH	vh	1	HS		6	3
	CWH	vh	1	HS		7	3
	CWH	vh	1	LR		3	3
	CWH	vh	1	LR		4	4
	CWH	vh	1	LR		5	4
	CWH	vh	1	LR		6	3
	CWH	vh	1	LR		7	3
	CWH	vh	1	RS		3	1
	CWH	vh	1	RS		4	4
	CWH	vh	1	RS		5	4
	CWH	vh	1	RS		6	1
	CWH	vh	1	RS		7	1
	CWH	vh	1	RF		3	3
	CWH	vh	1	RF		4	5
	CWH	vh	1	RF		5	5
	CWH	vh	1	RF		6	4

	CWH	vh	1	RF		7	4
	CWH	vh	1	RF	k	3	4
	CWH	vh	1	RF	k	4	5
	CWH	vh	1	RF	k	5	5
	CWH	vh	1	RF	k	6	4
	CWH	vh	1	RF	k	7	4
	CWH	vh	1	RF	w	3	3
	CWH	vh	1	RF	w	4	5
	CWH	vh	1	RF	w	5	4
	CWH	vh	1	RF	w	6	3
	CWH	vh	1	RF	w	7	3
	CWH	vh	1	SF		3	3
	CWH	vh	1	SF		4	5
	CWH	vh	1	SF		5	4
	CWH	vh	1	SF		6	4
	CWH	vh	1	SF		7	4
	CWH	vh	1	SF	k	3	4
	CWH	vh	1	SF	k	4	5
	CWH	vh	1	SF	k	5	4
	CWH	vh	1	SF	k	6	4
	CWH	vh	1	SF	k	7	4
	CWH	vh	1	SF	w	3	2
	CWH	vh	1	SF	w	4	5
	CWH	vh	1	SF	w	5	4
	CWH	vh	1	SF	w	6	3
	CWH	vh	1	SF	w	7	3
	CWH	vh	1	SD		3	2
	CWH	vh	1	SD		4	4
	CWH	vh	1	SD		5	4
	CWH	vh	1	SD		6	2
	CWH	vh	1	SD		7	2
	CWH	vh	1	SL		3	1
	CWH	vh	1	SL		4	3
	CWH	vh	1	SL		5	2
	CWH	vh	1	SL		6	1
	CWH	vh	1	SL		7	1
	CWH	vh	1	ST		3	1
	CWH	vh	1	ST		4	3
	CWH	vh	1	ST		5	2
	CWH	vh	1	ST		6	1
	CWH	vh	1	AL		3	2
	CWH	vh	1	AL		4	3
	CWH	vh	1	AL		5	2
	CWH	vh	1	YG		3	2
	CWH	vh	1	YG		4	4
	CWH	vh	1	YG		5	3
	CWH	vh	1	YG		6	2
	CWH	vh	1	YG		7	2

	CWH	vh	1	LS		3	3
	CWH	vh	1	LS		4	4
	CWH	vh	1	LS		5	4
	CWH	vh	1	LS		6	3
	CWH	vh	1	LS		7	3
	CWH	vh	1	RC		3	1
	CWH	vh	1	RC		4	3
	CWH	vh	1	RC		5	3
	CWH	vh	1	RC		6	1
	CWH	vh	1	RC		7	1
	CWH	vh	1	SS		3	1
	CWH	vh	1	SS		4	4
	CWH	vh	1	SS		5	4
	CWH	vh	1	SS		6	2
	CWH	vh	1	SS		7	2
	CWH	vh	1	SK		3	2
	CWH	vh	1	SK		4	4
	CWH	vh	1	SK		5	4
	CWH	vh	1	SK		6	2
	CWH	vh	1	SK		7	2
	CWH	vh	1	SW		3	1
	CWH	vh	1	SW		4	4
	CWH	vh	1	SW		5	4
	CWH	vh	1	SW		6	1
	CWH	vh	1	SW		7	1
	CWH	vh	1	SE		6	3
	CWH	vh	1	AW		3	1
	CWH	vh	1	AW		4	2
	CWH	vh	1	AW		5	2
	CWH	vh	1	BS		2	4
	CWH	vh	1	CM		2	4
	CWH	vh	1	DS		2	4
	CWH	vh	1	GS		2	4
	CWH	vh	1	PD		3	2
	CWH	vh	1	SB		2	3
	CWH	vh	1	SM		2	3
	CWH	vh	1	SM		3	3
	CWH	vh	1	BE		1	4
	CWH	vh	1	CB			2
	CWH	vh	1	CG		3	3
	CWH	vh	1	ES		1	5
	CWH	vh	1	GB		1	3
	CWH	vh	1	GP		1	5
	CWH	vh	1	LA			5
	CWH	vh	1	MU		1	5
	CWH	vh	1	OW			5
	CWH	vh	1	PO			5
	CWH	vh	1	RI			4

	CWH	vh	1	RO		1	4
	CWH	vh	1	RP			5
	CWH	vh	1	RR			3
	CWH	vh	1	SO			5
	CWH	vh	1	UR			3
	CWH	vh	1	TA		1	5
	CWH	vh	1	WP		1	6
	CWH	vm	1	AB		3	2
	CWH	vm	1	AB		4	4
	CWH	vm	1	AB		5	4
	CWH	vm	1	AB		6	3
	CWH	vm	1	AB		7	3
	CWH	vm	1	LC		3	3
	CWH	vm	1	LC		4	4
	CWH	vm	1	LC		5	4
	CWH	vm		LC		6	3
	CWH	vm	1	LC		7	3
	CWH	vm	1	HS		3	1
	CWH	vm	1	HS		4	4
	CWH	vm	1	HS		5	4
	CWH	vm	1	HS		6	1
	CWH	vm	1	HS		7	1
	CWH	vm	1	RS		3	3
	CWH	vm	1	RS		4	5
	CWH	vm	1	RS		5	5
	CWH	vm	1	RS		6	4
	CWH	vm	1	RS		7	4
	CWH	vm	1	RS	k	3	4
	CWH	vm	1	RS	k	4	5
	CWH	vm	1	RS	k	5	5
	CWH	vm	1	RS	k	6	4
	CWH	vm	1	RS	k	7	4
	CWH	vm	1	RS	w	3	3
	CWH	vm	1	RS	w	4	5
	CWH	vm	1	RS	w	5	5
	CWH	vm	1	RS	w	6	4
	CWH	vm	1	RS	w	7	3
	CWH	vm	1	AF		3	2
	CWH	vm	1	AF		4	4
	CWH	vm	1	AF		5	4
	CWH	vm	1	AF		6	2
	CWH	vm	1	AF		7	2
	CWH	vm	1	AF	k	3	3
	CWH	vm	1	AF	k	4	4
	CWH	vm	1	AF	k	5	4
	CWH	vm	1	AF	k	6	3
	CWH	vm	1	AF	k	7	3
	CWH	vm	1	AF	w	3	1

	CWH	vm	1	AF	w	4	4
	CWH	vm	1	AF	w	5	4
	CWH	vm	1	AF	w	6	1
	CWH	vm	1	AF	w	7	1
	CWH	vm	1	HD		3	2
	CWH	vm	1	HD		4	4
	CWH	vm	1	HD		5	4
	CWH	vm	1	HD		6	2
	CWH	vm	1	HD		7	2
	CWH	vm	1	HD	k	3	3
	CWH	vm	1	HD	k	4	5
	CWH	vm	1	HD	k	5	5
	CWH	vm	1	HD	k	6	3
	CWH	vm	1	HD	k	7	3
	CWH	vm	1	HD	w	3	1
	CWH	vm	1	HD	w	4	3
	CWH	vm	1	HD	w	5	3
	CWH	vm	1	HD	w	6	2
	CWH	vm	1	HD	w	7	2
	CWH	vm	1	AS		3	1
	CWH	vm	1	AS		4	4
	CWH	vm	1	AS		5	3
	CWH	vm	1	AS		6	1
	CWH	vm	1	AS		7	1
	CWH	vm	1	SS		3	1
	CWH	vm	1	SS		4	3
	CWH	vm	1	SS		5	2
	CWH	vm	1	SS		6	1
	CWH	vm	1	SS		7	1
	CWH	vm	1	CD		4	3
	CWH	vm	1	CD		5	2
	CWH	vm	1	CD		6	1
	CWH	vm	1	CW		3	1
	CWH	vm	1	CW		4	3
	CWH	vm	1	CW		5	2
	CWH	vm	1	YG		3	2
	CWH	vm	1	YG		4	4
	CWH	vm	1	YG		5	4
	CWH	vm	1	YG		6	2
	CWH	vm	1	YG		7	2
	CWH	vm	1	LS		3	3
	CWH	vm	1	LS		4	4
	CWH	vm	1	LS		5	4
	CWH	vm	1	LS		6	3
	CWH	vm	1	LS		7	3
	CWH	vm	1	RC		3	1
	CWH	vm	1	RC		4	3
	CWH	vm	1	RC		5	2

	CWH	vm	1	RC		6	1
	CWH	vm	1	RC		7	1
	CWH	vm	1	AW		3	1
	CWH	vm	1	AW		4	2
	CWH	vm	1	AW		5	2
	CWH	vm	1	DS		2	4
	CWH	vm	1	GS		2	4
	CWH	vm	1	SA		3	1
	CWH	vm	1	SC		2	4
	CWH	vm	1	SG		2	3
	CWH	vm	1	SM		2	3
	CWH	vm	1	SM		3	3
	CWH	vm	1	WS		3	2
	CWH	vm	1	BE		1	4
	CWH	vm	1	CB			2
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	CWH	vm	1	ES		1	5
	CWH	vm	1	GB		1	3
	CWH	vm	1	GP		1	5
	CWH	vm	1	LA			5
	CWH	vm	1	MU		1	5
	CWH	vm	1	OW			5
	CWH	vm	1	PO			5
	CWH	vm	1	RI			4
	CWH	vm	1	RO		1	4
	CWH	vm	1	RP			5
	CWH	vm	1	RR			3
	CWH	vm	1	SO			5
	CWH	vm	1	UR			3
	CWH	vm	1	TA		1	5
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	CWH	vm	2	AB		4	4
	CWH	vm	2	AB		5	4
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	CWH	vm	2	AB		7	3
	CWH	vm	2	LC		3	3
	CWH	vm	2	LC		4	4
	CWH	vm	2	LC		5	4
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	CWH	vm	2	HS		5	4
	CWH	vm	2	HS		6	2
	CWH	vm	2	HS		7	2
	CWH	vm	2	RS		3	3
	CWH	vm	2	RS		4	5

	CWH	vm	2	RS		5	5
	CWH	vm	2	RS		6	4
	CWH	vm	2	RS		7	4
	CWH	vm	2	RS	k	3	4
	CWH	vm	2	RS	k	4	5
	CWH	vm	2	RS	k	5	5
	CWH	vm	2	RS	k	6	4
	CWH	vm	2	RS	k	7	4
	CWH	vm	2	RS	w	3	3
	CWH	vm	2	RS	w	4	5
	CWH	vm	2	RS	w	5	5
	CWH	vm	2	RS	w	6	4
	CWH	vm	2	RS	w	7	4
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	CWH	vm	2	AF		4	4
	CWH	vm	2	AF		5	4
	CWH	vm	2	AF		6	2
	CWH	vm	2	AF		7	2
	CWH	vm	2	AF	k	3	3
	CWH	vm	2	AF	k	4	5
	CWH	vm	2	AF	k	5	4
	CWH	vm	2	AF	k	6	3
	CWH	vm	2	AF	k	7	3
	CWH	vm	2	AF	w	3	2
	CWH	vm	2	AF	w	4	4
	CWH	vm	2	AF	w	5	4
	CWH	vm	2	AF	w	6	2
	CWH	vm	2	AF	w	7	2
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	CWH	vm	2	HD		5	4
	CWH	vm	2	HD		6	2
	CWH	vm	2	HD		7	2
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	CWH	vm	2	HD	k	4	5
	CWH	vm	2	HD	k	5	4
	CWH	vm	2	HD	k	6	3
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	CWH	vm	2	HD	w	5	4
	CWH	vm	2	HD	w	6	2
	CWH	vm	2	HD	w	7	2
	CWH	vm	2	AS		3	2
	CWH	vm	2	AS		4	4
	CWH	vm	2	AS		5	3
	CWH	vm	2	AS		6	2
	CWH	vm	2	AS		7	2

	CWH	vm	2	YG		3	2
	CWH	vm	2	YG		4	4
	CWH	vm	2	YG		5	4
	CWH	vm	2	YG		6	2
	CWH	vm	2	YG		7	2
	CWH	vm	2	LS		3	3
	CWH	vm	2	LS		4	4
	CWH	vm	2	LS		5	4
	CWH	vm	2	LS		6	3
	CWH	vm	2	LS		7	3
	CWH	vm	2	RC		3	2
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	CWH	vm	2	RC		5	2
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	CWH	vm	2	SG		2	2
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	CWH	vm	2	ES		1	5
	CWH	vm	2	GB		1	3
	CWH	vm	2	LA			5
	CWH	vm	2	OW			5
	CWH	vm	2	PO			5
	CWH	vm	2	RI			4
	CWH	vm	2	RO		1	4
	CWH	vm	2	TA		1	5
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	MH	mm	1	MB		4	4
	MH	mm	1	MB		5	4
	MH	mm	1	MB		6	3
	MH	mm	1	MB		7	3
	MH	mm	1	MM		3	3
	MH	mm	1	MM		4	4
	MH	mm	1	MM		5	4
	MH	mm	1	MM		6	3
	MH	mm	1	MM		7	3
	MH	mm	1	MO		3	2
	MH	mm	1	MO		4	4
	MH	mm	1	MO		5	3
	MH	mm	1	MO		6	2
	MH	mm	1	MO		7	2
	MH	mm	1	MT		3	2

	MH	mm	1	MT		4	4
	MH	mm	1	MT		5	3
	MH	mm	1	MT		6	2
	MH	mm	1	MT		7	2
	MH	mm	1	SA		3	1
	MH	mm	1	SC		2	3
	MH	mm	1	ES		1	5
	MH	mm	1	LA			5
	MH	mm	1	OW			5
	MH	mm	1	RO		1	5
	MH	mm	1	TA		1	5
	MH	mmp		MM		3	3
	MH	mmp		MM		4	4
	MH	mmp		MM		5	4
	MH	mmp		MM		6	3
	MH	mmp		MH		2	3
	MH	mmp		MH		3	3
	MH	mmp		MK		3	4
	MH	mmp		LA			5
	MH	mmp		OW			5
	MH	mmp		PS			5
	MH	mmp		RO		1	5
	MH	mmp		TA		1	5

Appendix C

Black bear image documentation summary

The results of the video and photo documentation of bear activity provide additional information related to bear resources consumption and behaviour that are similar to those of the literature and the expert reviews. They also provide a data source for future bear researchers. These sources provide the following information:

- a bear flipping rocks and eating something found underneath
- a bear eating ulva and/or barnacles off of rocks
- a bear in the upper intertidal eating sedges/grasses
- a bear foraging through piles of seaweed
- a bear cub mimicking mother flipping rocks on a cobble boulder beach
- bears copulating in mid-intertidal zone
- bears with shore crabs in their mouth collected from under a rock
- a bear eating barnacles and/or fucus off of a log within the intertidal zone
- a bear with a starfish in its mouth
- a partially bear eaten starfish
- partially eaten intertidal sedges/grasses where bears were seen foraging.

Appendix D
Biota associated with bear observation shorelines

Species was recorded on the shore a unit with bear presence during the survey transects. The biota includes shore crabs, starfish, barnacles, salt tolerant grasses and sedges, blenny eels, intertidal snails (*Littorina spp.*), fucus, ulva (*Ulva lactuca*), mussels and beach hoppers. Some of the common combinations include:

- high tide salt tolerant grasses and sedges such as *Carex lyngbyei*, *salicornia*
- fucus, barnacle
- fucus, barnacle, mussel, ulva, crab, oyster
- fucus, barnacle, ulva, enteromorpha (*Enteromorpha spp.*), shore crab, high tide grasses, eel grass (*Zostera marina*)
- fucus, barnacle, enteromorpha, mussel, blenies, crabs, starfish
- fucus, barnacle, ulva, shore crab, clams, blenies, high tide grasses, eel grass

Appendix E
CPT tables

Table E – 1. Initial CPT for child node "primary influences on intertidal food productivity/availability"

Node state combinations of modified repetitive shore type and calculated wave exposure classifications	Probability of "Better"	Probability of "Poorer"
Rock cliff/VP or P	25	75
Rock cliff/SP	25	75
Rock cliff/SE	25	75
Rock cliff/E or VE	25	75
Rock ramp platform/VP or P	35	65
Rock ramp platform/SP	35	65
Rock ramp platform/SE	30	70
Rock ramp platform/E or VE	25	75
Gravel/VP or P	75	25
Gravel/SP	75	25
Gravel/SE	40	60
Gravel/E or VE	30	70
Sand and gravel/VP or P	75	25
Sand and gravel/SP	75	25
Sand and gravel/SE	40	60
Sand and gravel/E or VE	30	70
Sand/VP or P	75	25
Sand/SP	75	25
Sand/SE	40	60
Sand/E or VE	25	75
Estuary/VP or P	75	25
Estuary/SP	75	25
Estuary/SE	75	25
Estuary/E or VE	75	25
Channel/VP or P	40	60
Channel/SP	40	60
Channel/SE	25	75
Channel/E or VE	25	75
Manmade/VP or P	25	75
Manmade/SP	25	75
Manmade/SE	25	75
Manmade/E or VE	25	75

Table E – 2. Initial CPT for child node "secondary influences on intertidal food productivity/availability"

Node state combinations of intertidal width and shoreline aspect classifications	Probability of "Better"	Probability of "Poorer"
greater than 30m/North	30	70
less than 30m/North	25	75
greater than 30m/East	60	40
less than 30m/East	55	45
greater than 30m/South	75	25
less than 30m/South	65	35
greater than 30m/West	60	40
less than 30m/West	55	45

Table E – 3. Initial CPT for child node "offshore food influences"

Node state combinations of calculated wave exposure and shoreline slope classifications	Probability of "Better"	Probability of "Poorer"
VP or P/Greater than 20 degrees	10	90
VP or P/5 to 20 degrees	20	80
VP or P/Less than 5 degrees	20	80
SP/Greater than 20 degrees	10	90
SP/5 to 20 degrees	60	40
SP/Less than 5 degrees	60	40
SE/Greater than 20 degrees	10	90
SE/5 to 20 degrees	80	20
SE/Less than 5 degrees	80	20
E or VE/Greater than 20 degrees	10	90
E or VE/5 to 20 degrees	90	10
E or VE/Less than 5 degrees	90	10

Table E – 4. Initial CPT for child node "terrestrial influences"

Node state combinations of adjacent backshore WHR and nearby known important bear habitat	Probability of "Better"	Probability of "Poorer"
High/Yes	80	20
High/No	50	50
Moderate/Yes	70	30
Moderate/No	40	60
Low/Yes	50	50

Low/No	25	75
No Data/Yes	25	75
No Data/No	25	75

Table E – 5. Initial CPT for child node “intertidal forage capability”

Node state combinations of primary and secondary influences on intertidal food productivity/availability and offshore influences	Probability of “Good”	Probability of “Bad”
Better/Better/Better	90	10
Poorer/Better/Better	35	65
Better/Better/Poorer	85	15
Poorer/Better/Poorer	15	85
Better/Poorer/Better	80	20
Poorer/Poorer/Better	30	70
Better/Poorer/Poorer	75	25
Poorer/Poorer/Poorer	10	90

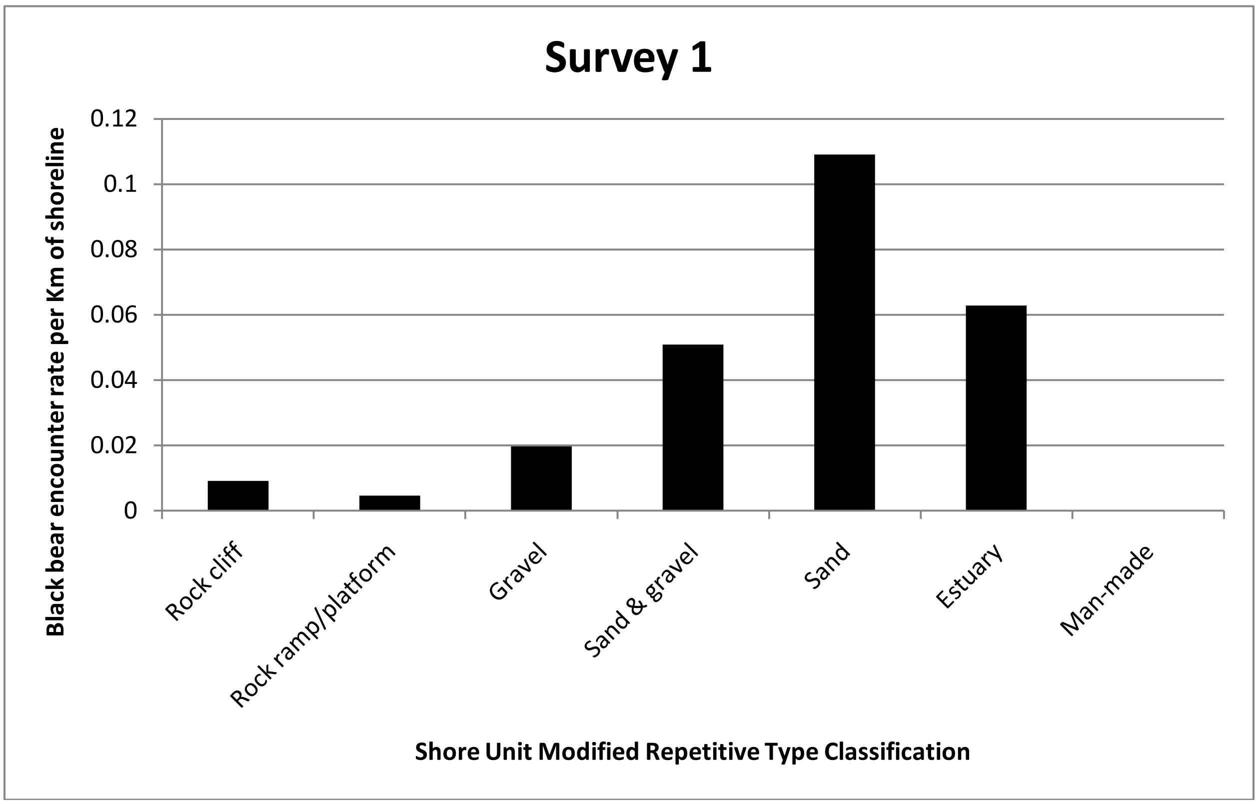
Table E – 6. Initial CPT for child node “intertidal habitat value”

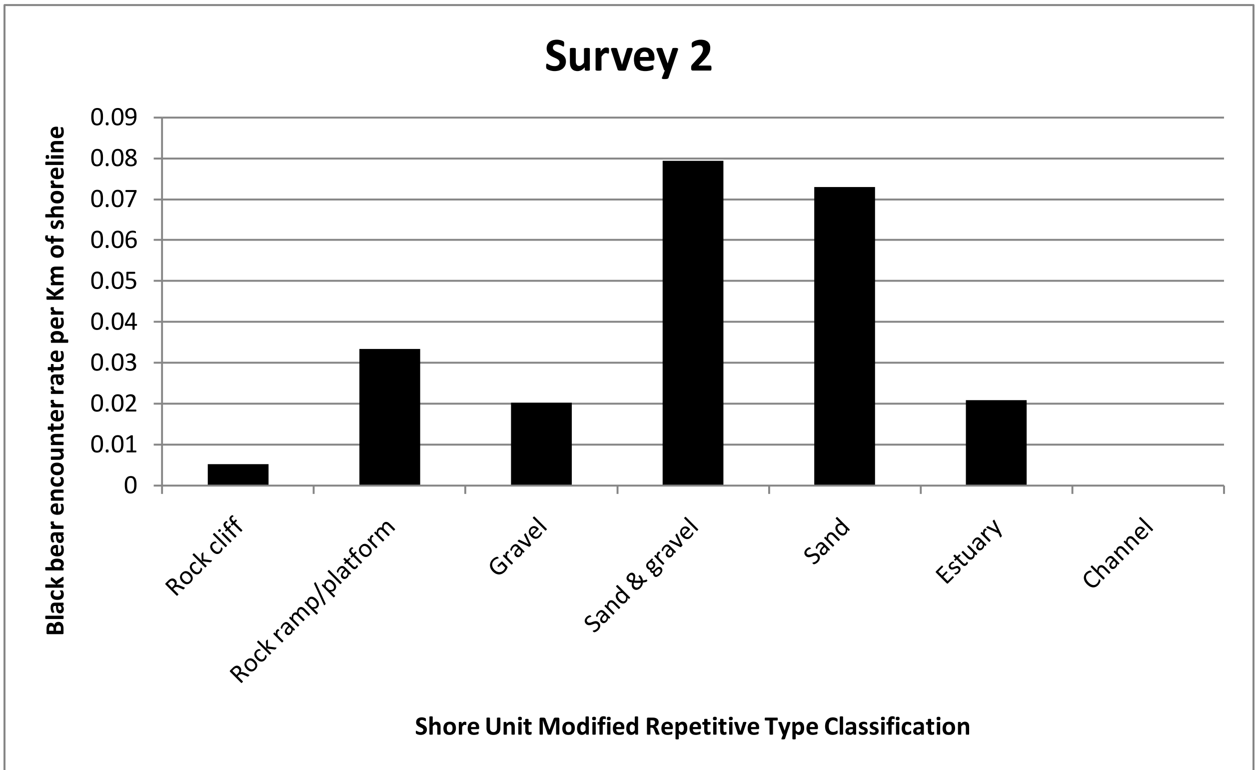
Node state combinations of intertidal forage capability and terrestrial influences	Probability of “High”	Probability of “Medium”	Probability of “Low”
Good/Better	70	25	5
Bad/Poorer	10	30	60
Good/Better	60	30	10
Bad/Poorer	5	25	70

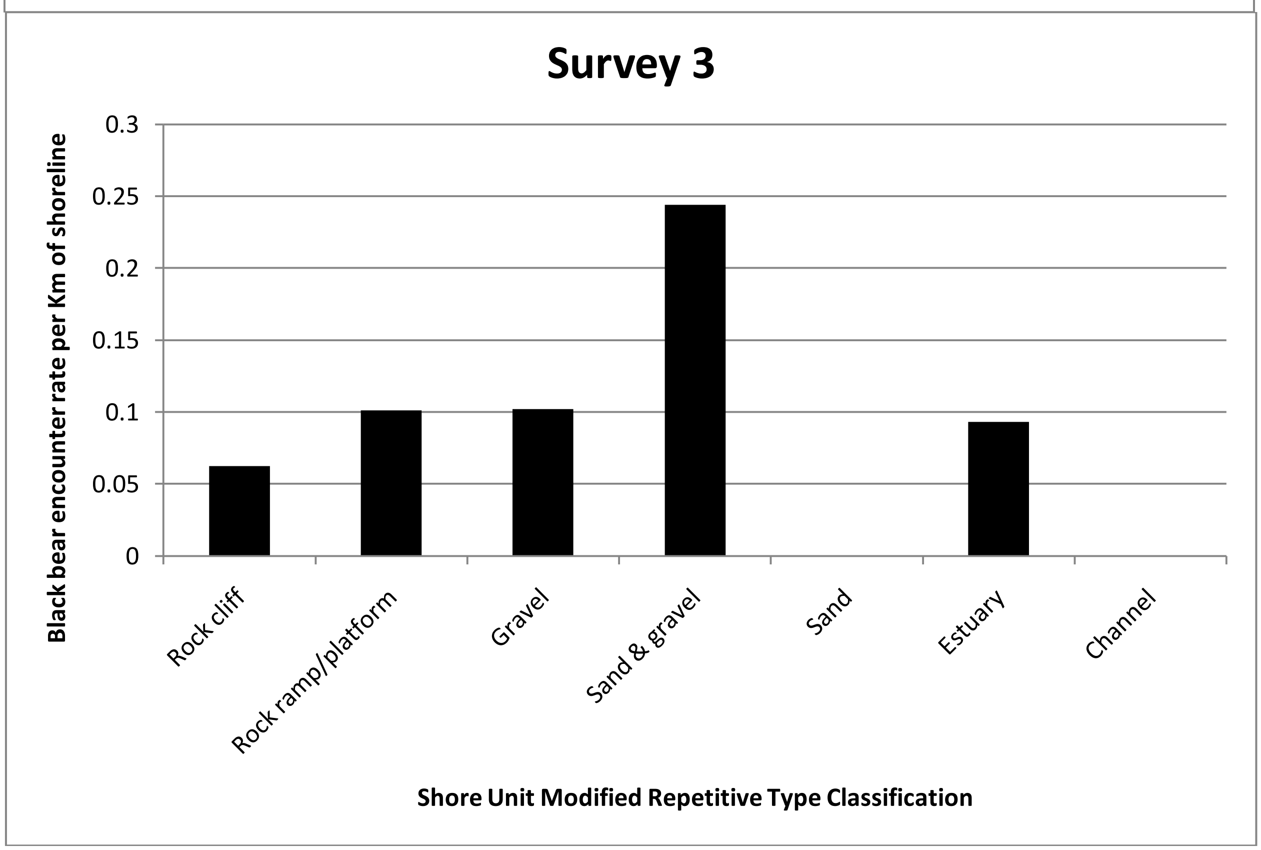
Appendix F

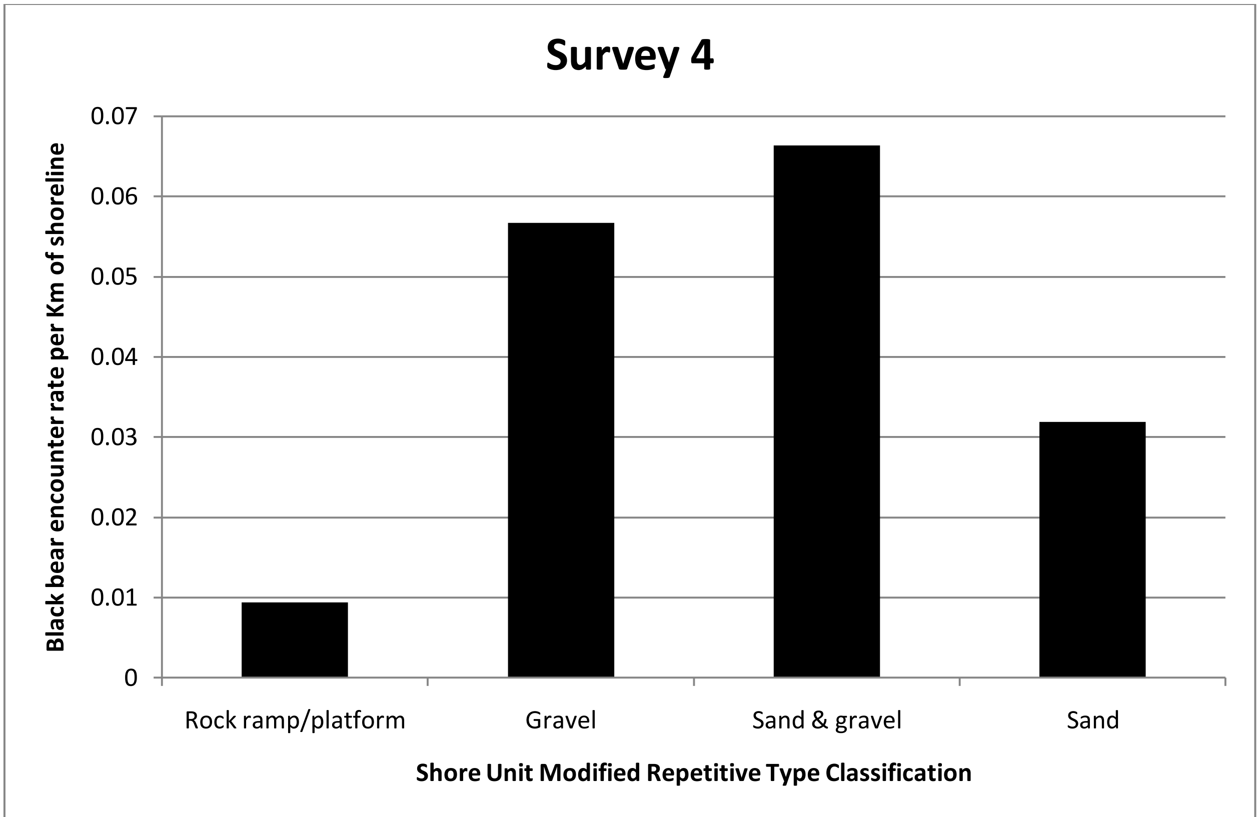
Figures of black bear encounter rate summaries

Figures of Black bear encounter rate charts for the modified repetitive shore type classification

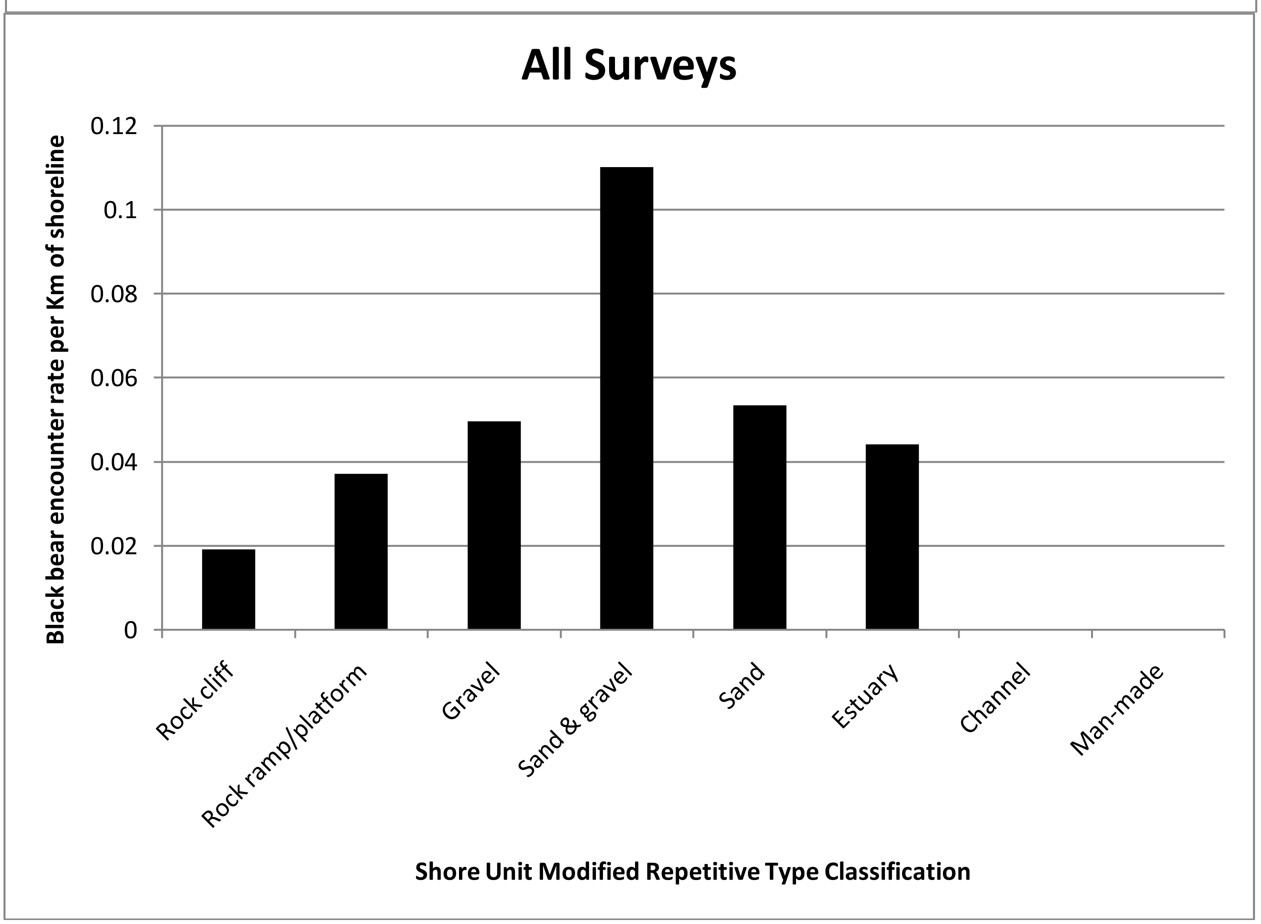



Survey 2
Black bear encounter rate per Km of shoreline
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Rock cliff
Rock ramp/platform
Gravel
Sand & gravel
Sand
Estuary
Channel
Shore Unit Modified Repetitive Type Classification


Survey 3
Black bear encounter rate per Km of shoreline
0.3
0.25
0.2
0.15
0.1
0.05
0
Rock cliff
Rock ramp/platform
Gravel
Sand & gravel
Sand
Estuary
Channel
Shore Unit Modified Repetitive Type Classification

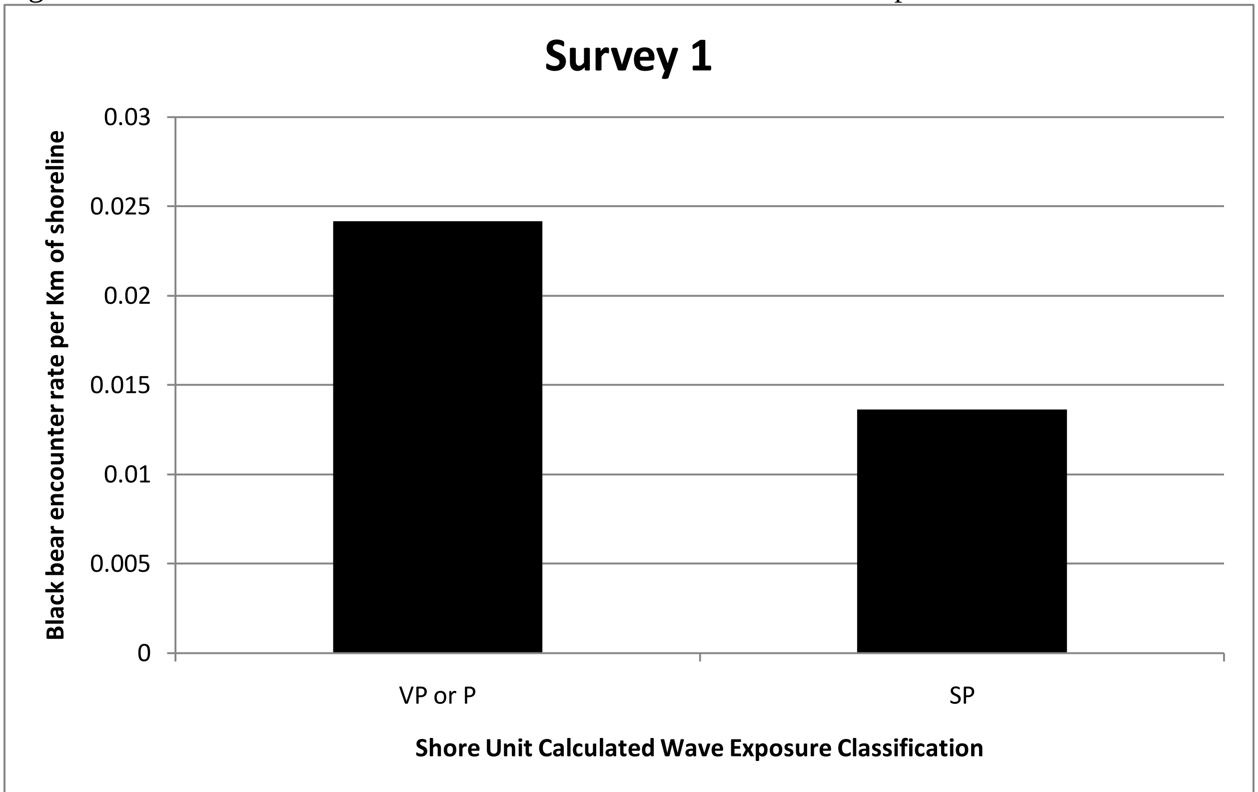


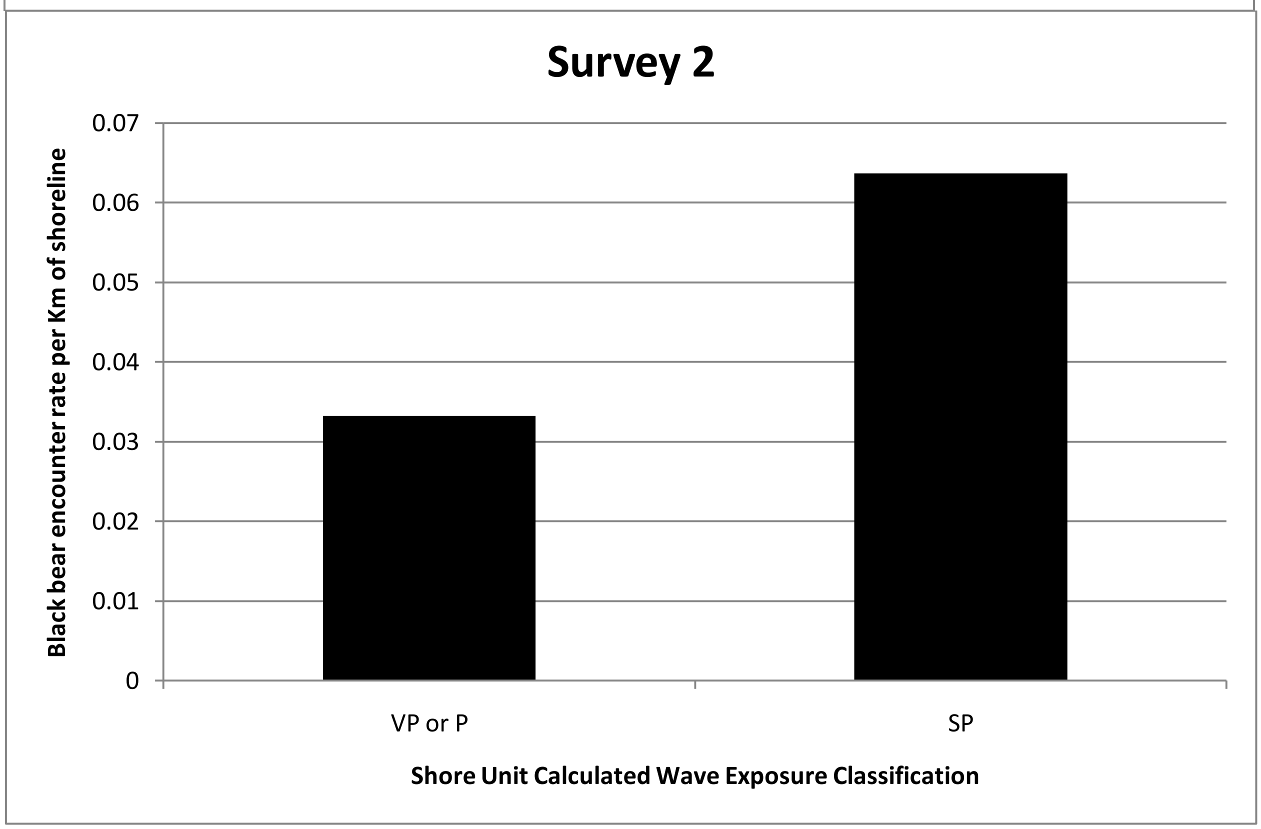
Survey 4
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Black bear encounter rate per Km of shoreline
Rock ramp/platform
Gravel
Sand & gravel
Sand
Shore Unit Modified Repetitive Type Classification

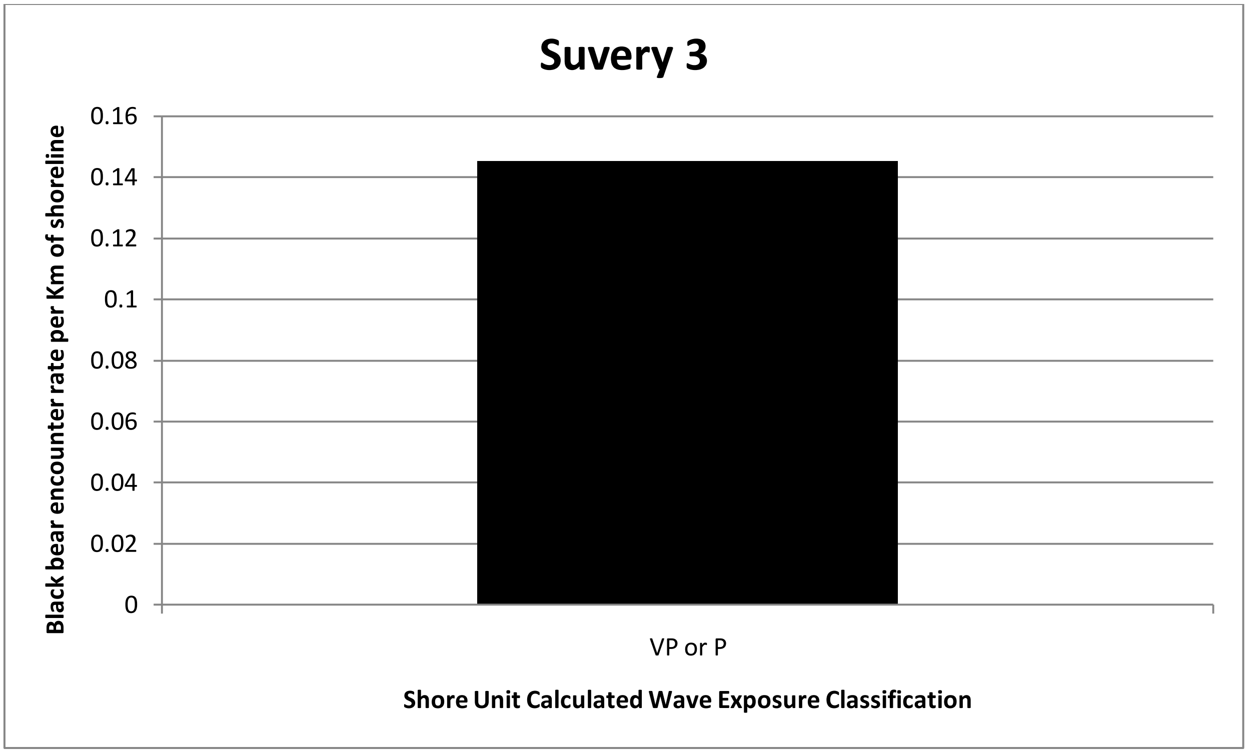


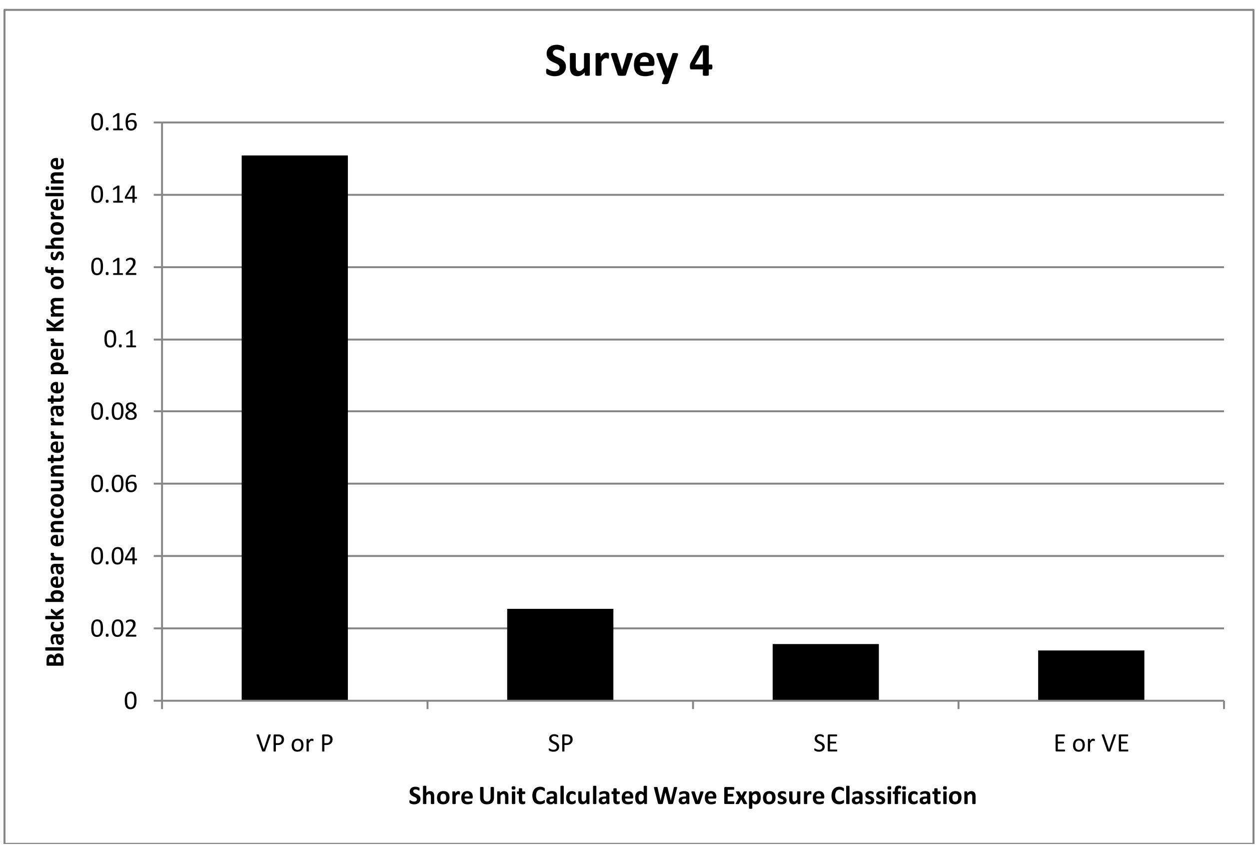
All Surveys
0.12
0.1
0.08
0.06
0.04
0.02
0
Black bear encounter rate per Km of shoreline
Rock cliff
Rock ramp/platform
Gravel
Sand & gravel
Sand
Estuary
Channel
Man-made
Shore Unit Modified Repetitive Type Classification

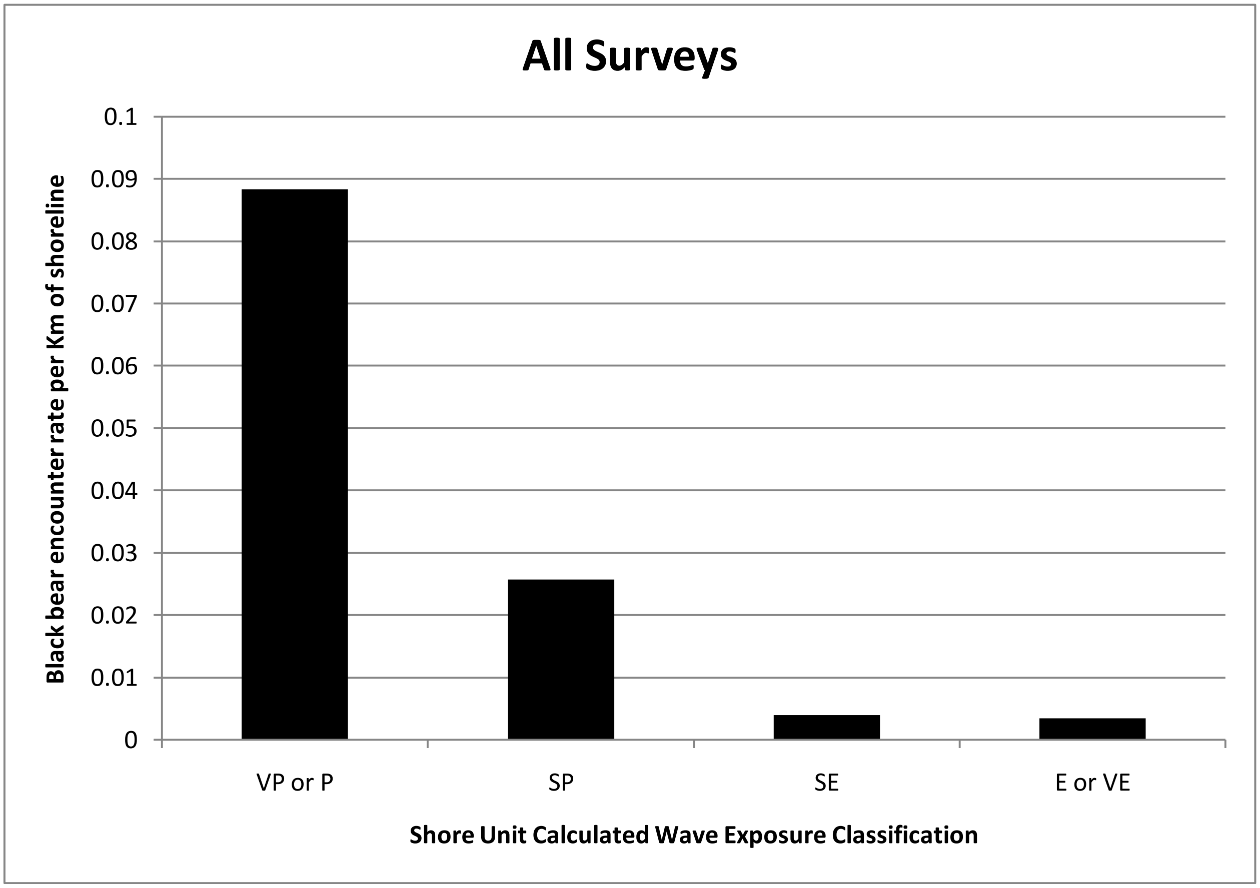
Figures of Black bear encounter rate charts for the calculated wave exposure classification



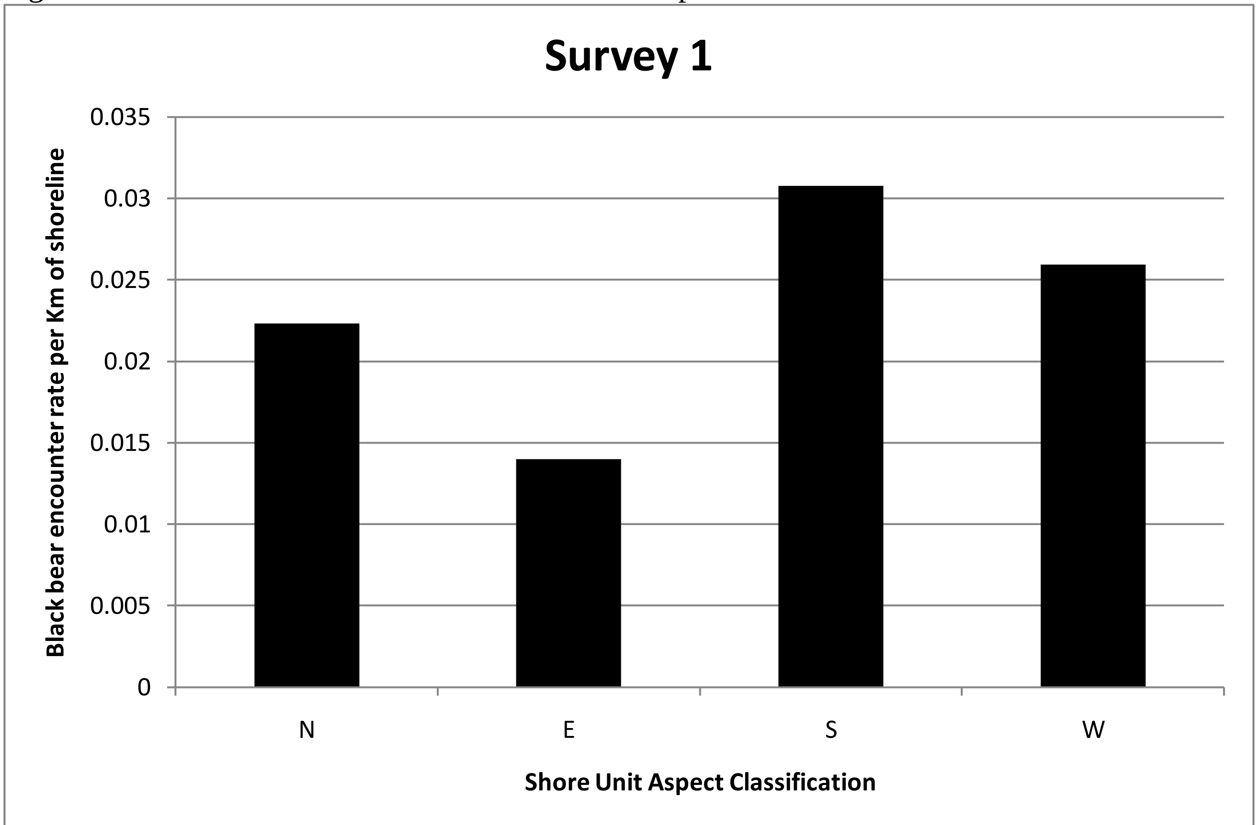


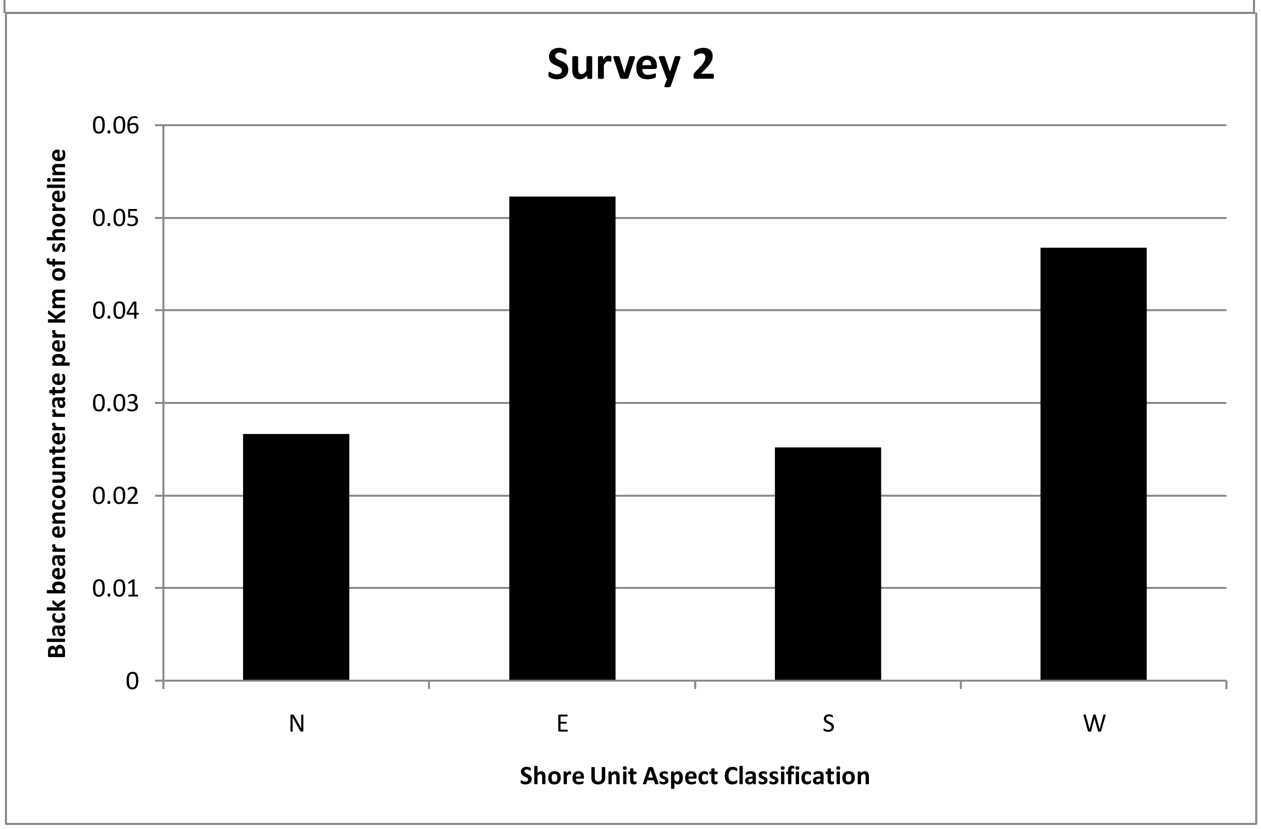

Suvery 3
Black bear encounter rate per Km of shoreline
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
VP or P
Shore Unit Calculated Wave Exposure Classification

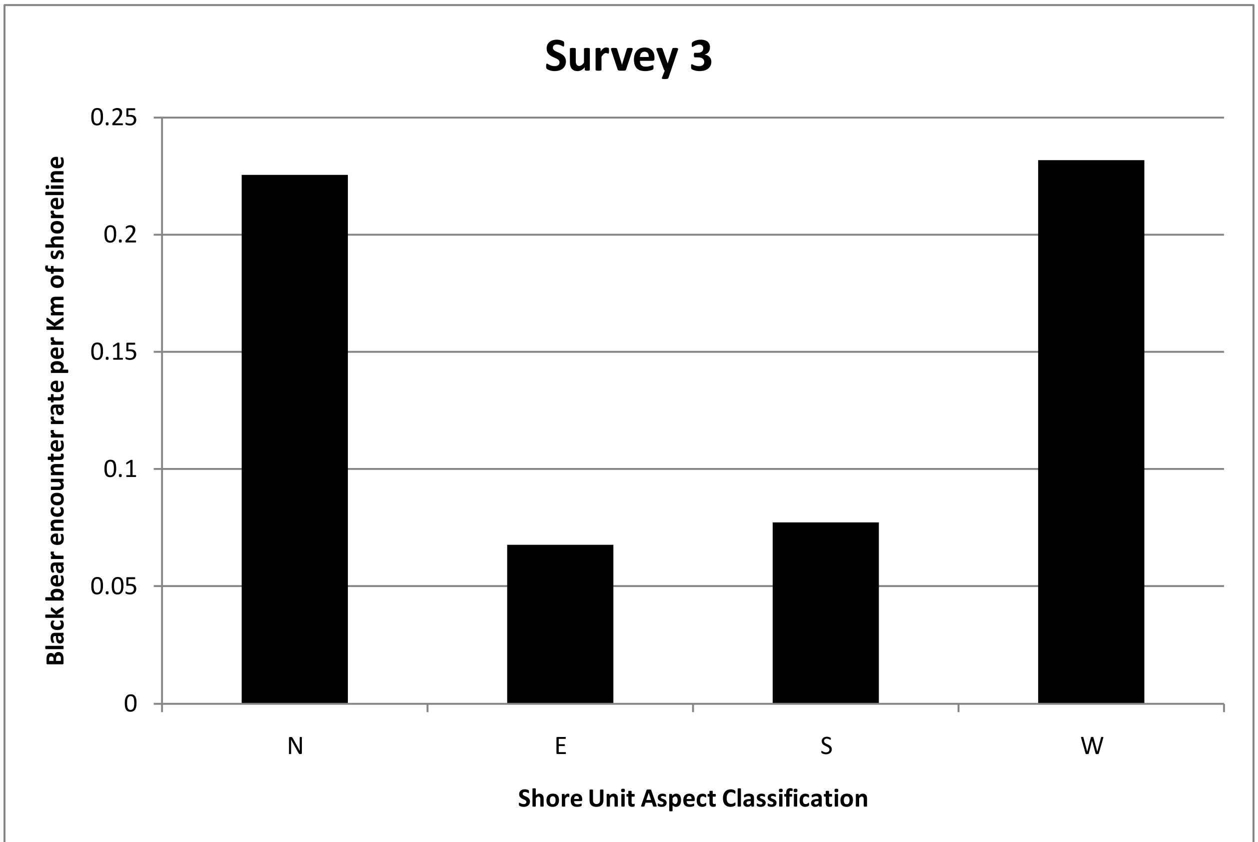

Survey 4
Black bear encounter rate per Km of shoreline
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
VP or P
SP
SE
E or VE
Shore Unit Calculated Wave Exposure Classification

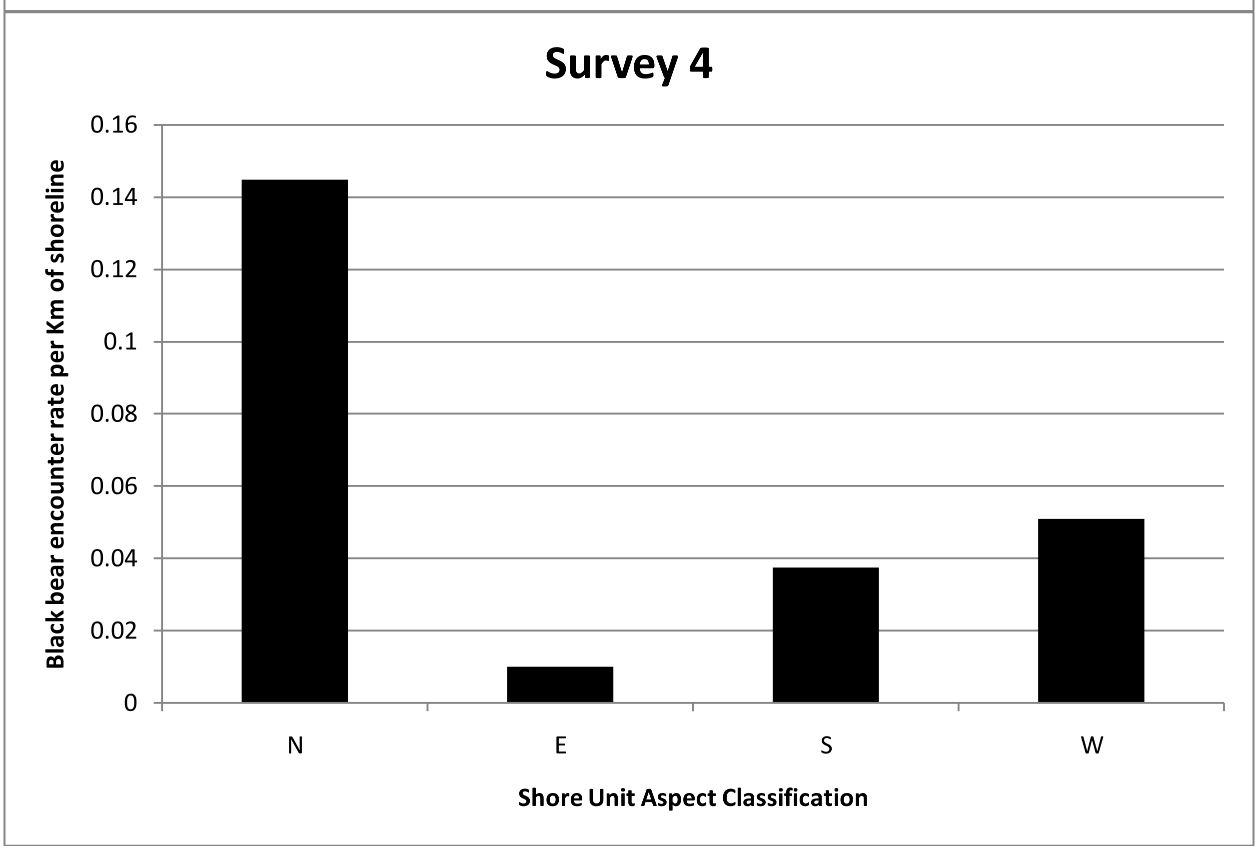

All Surveys
Black bear encounter rate per Km of shoreline
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
VP or P
SP
SE
E or VE
Shore Unit Calculated Wave Exposure Classification

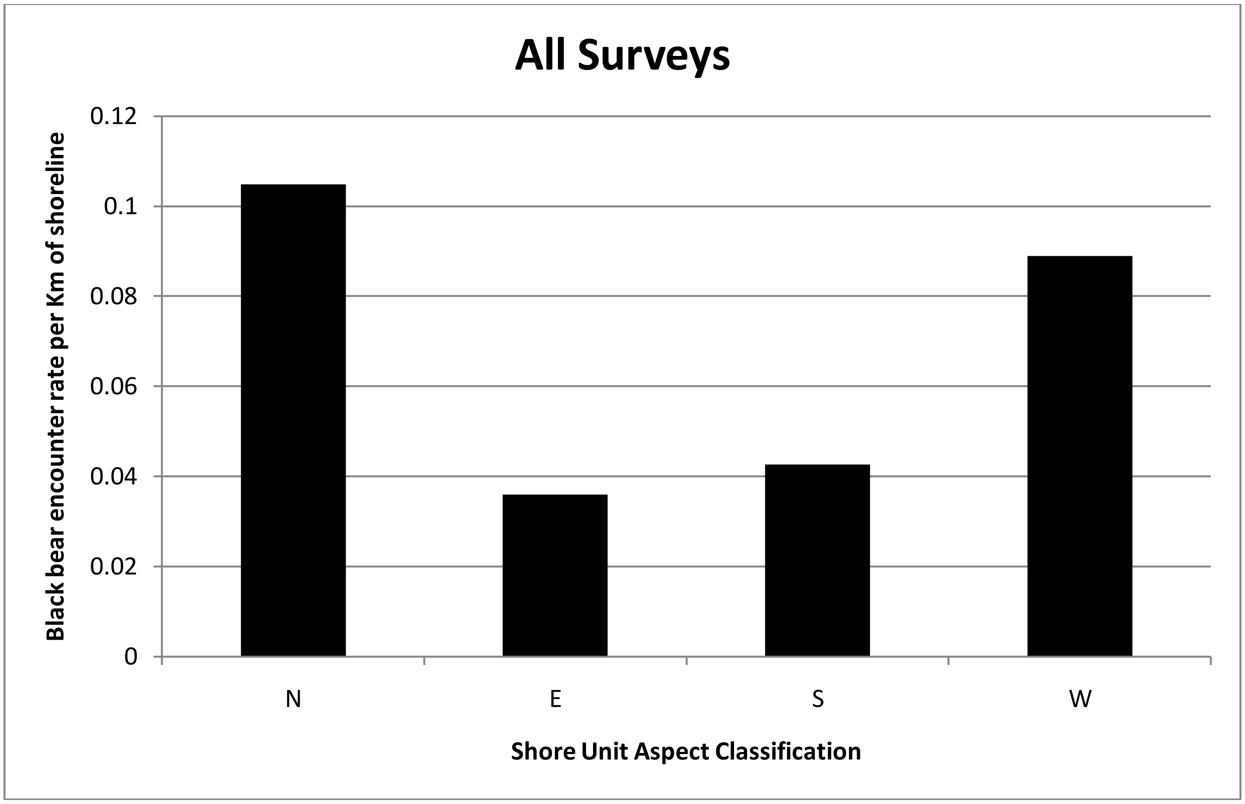
Figures of Black bear encounter rate charts for the aspect classification





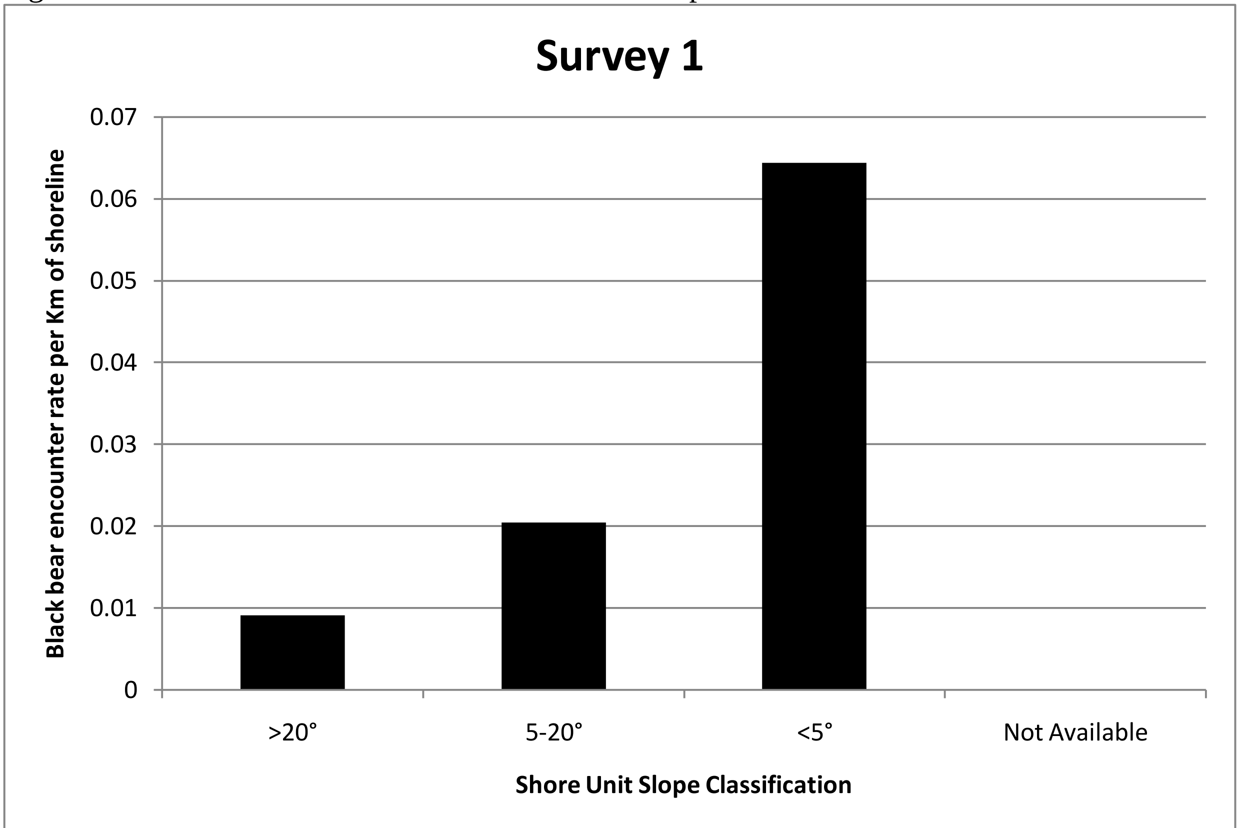

Survey 3
0.25
0.2
0.15
0.1
0.05
0
Black bear encounter rate per Km of shoreline
N
E
S
W
Shore Unit Aspect Classification

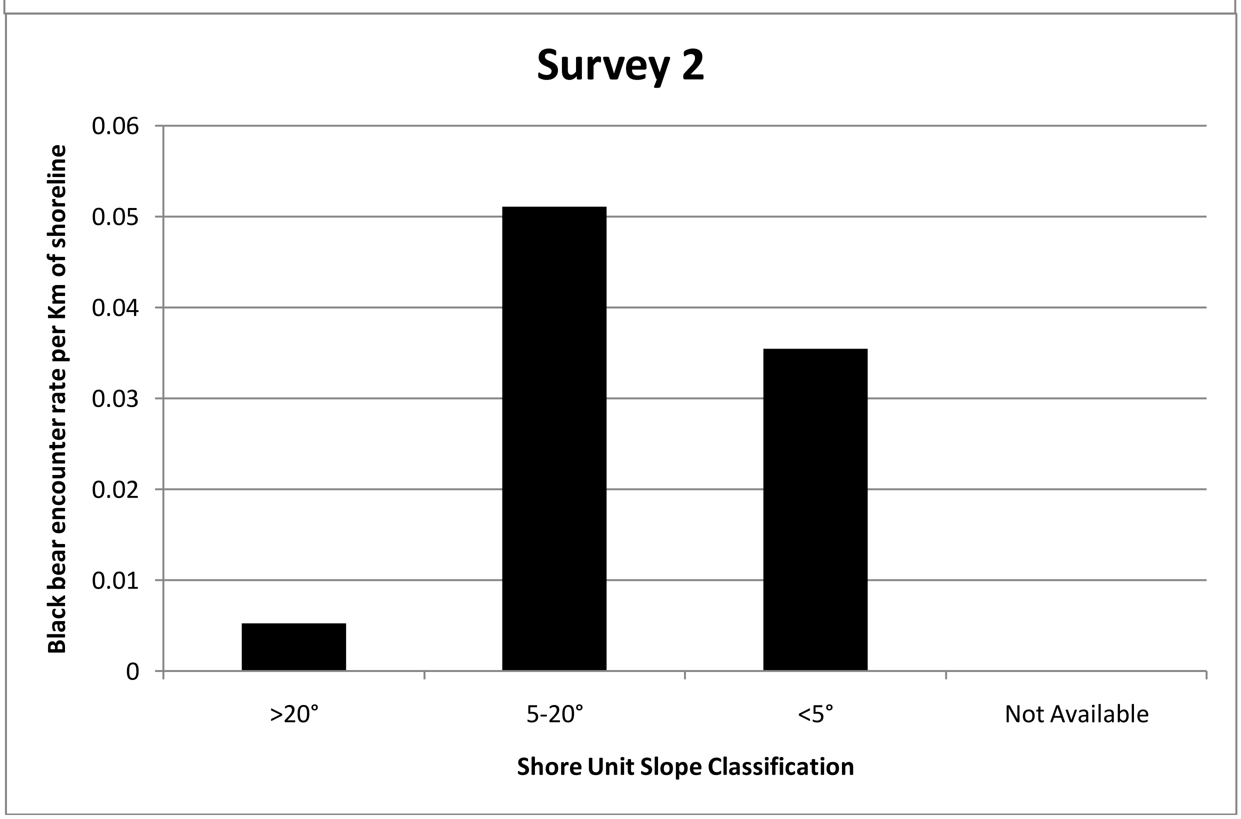

Survey 4
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Black bear encounter rate per Km of shoreline
N
E
S
W
Shore Unit Aspect Classification

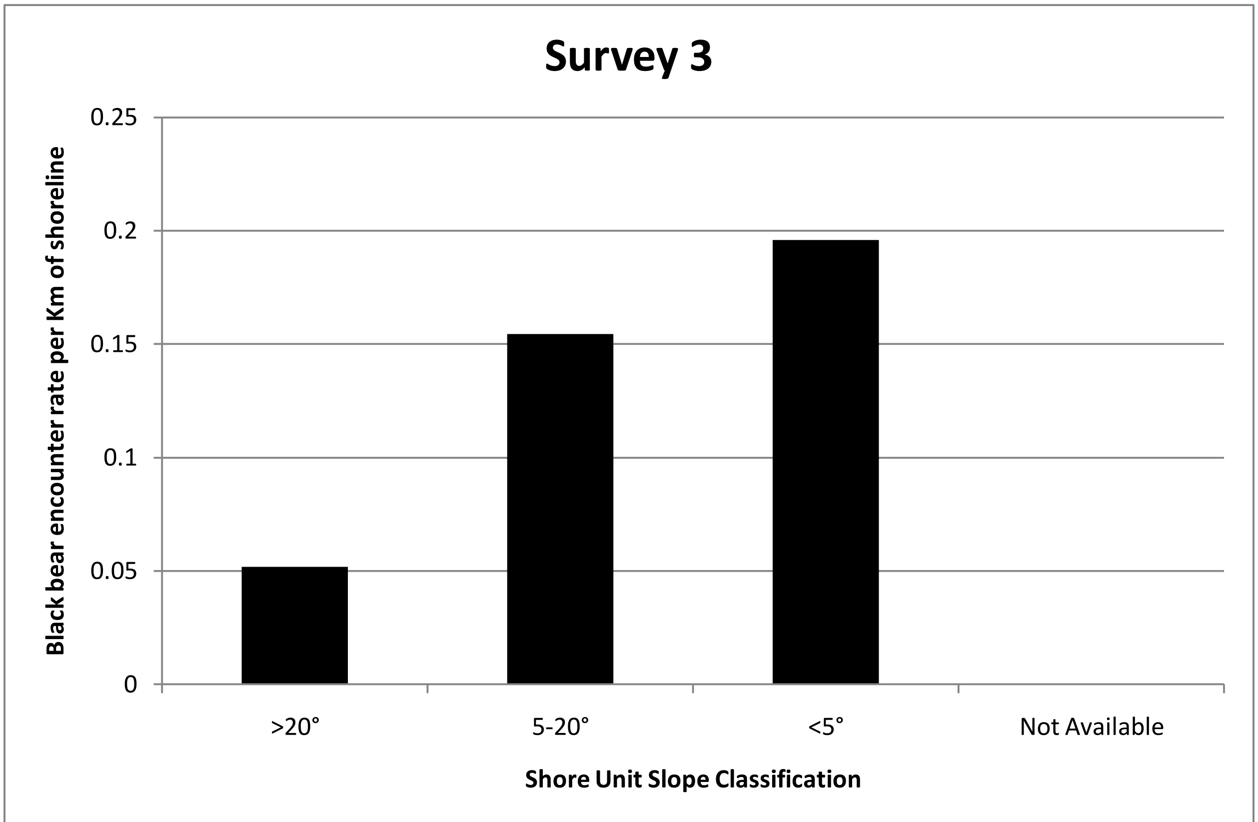


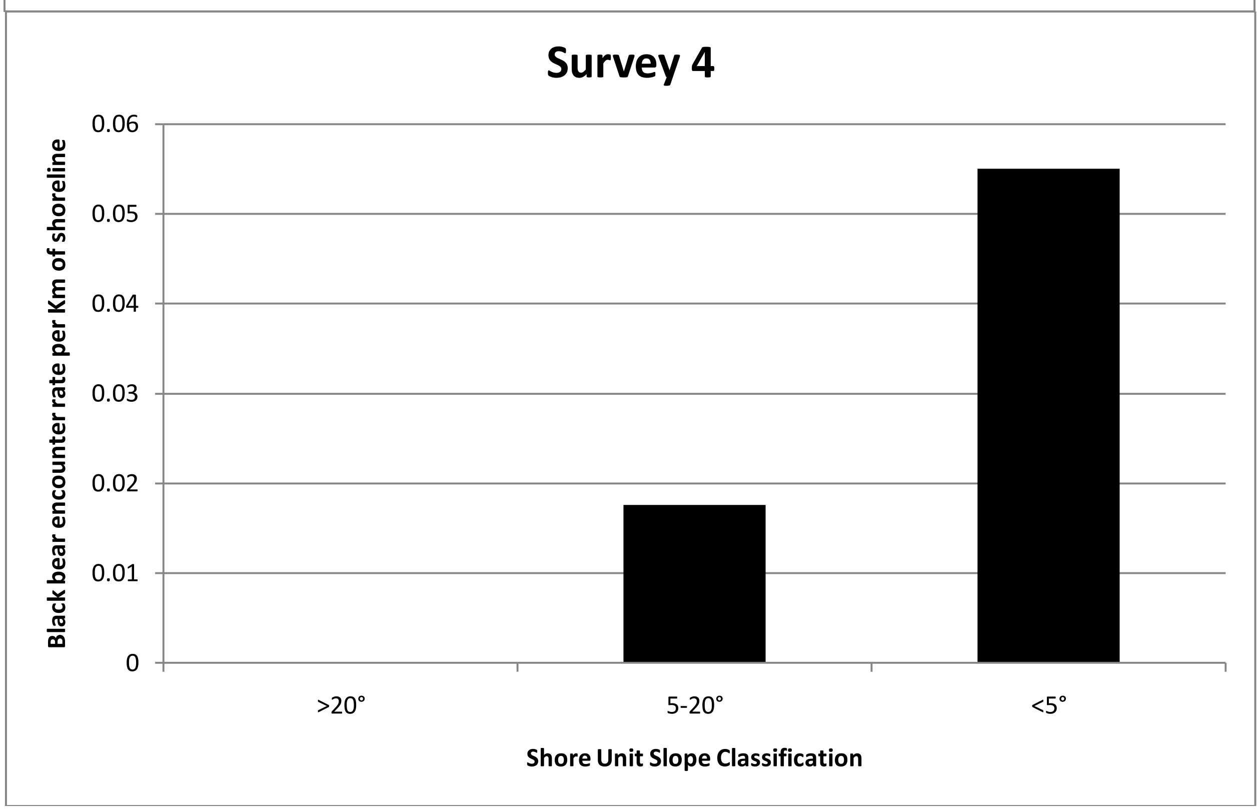
All Surveys
Black bear encounter rate per Km of shoreline
0.12
0.1
0.08
0.06
0.04
0.02
0
N
E
S
W
Shore Unit Aspect Classification

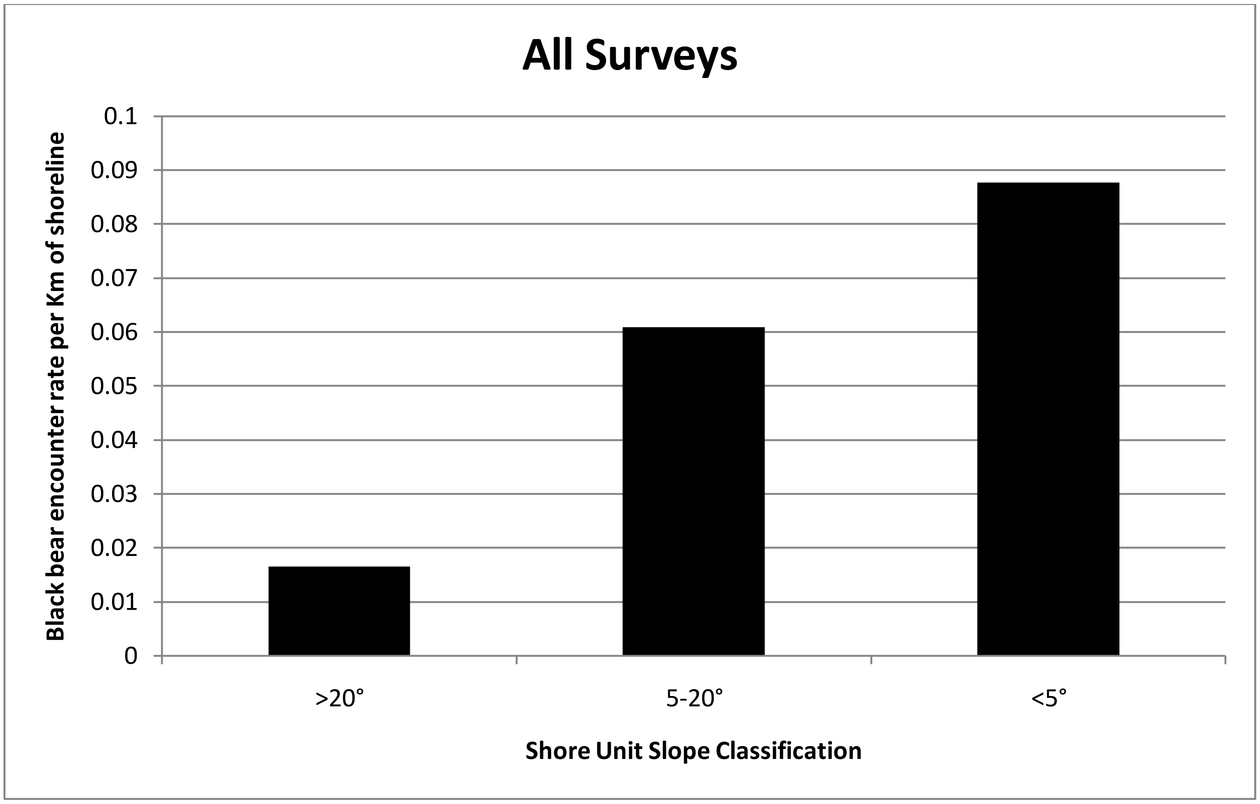
Figures of Black bear encounter rate charts for the slope classification





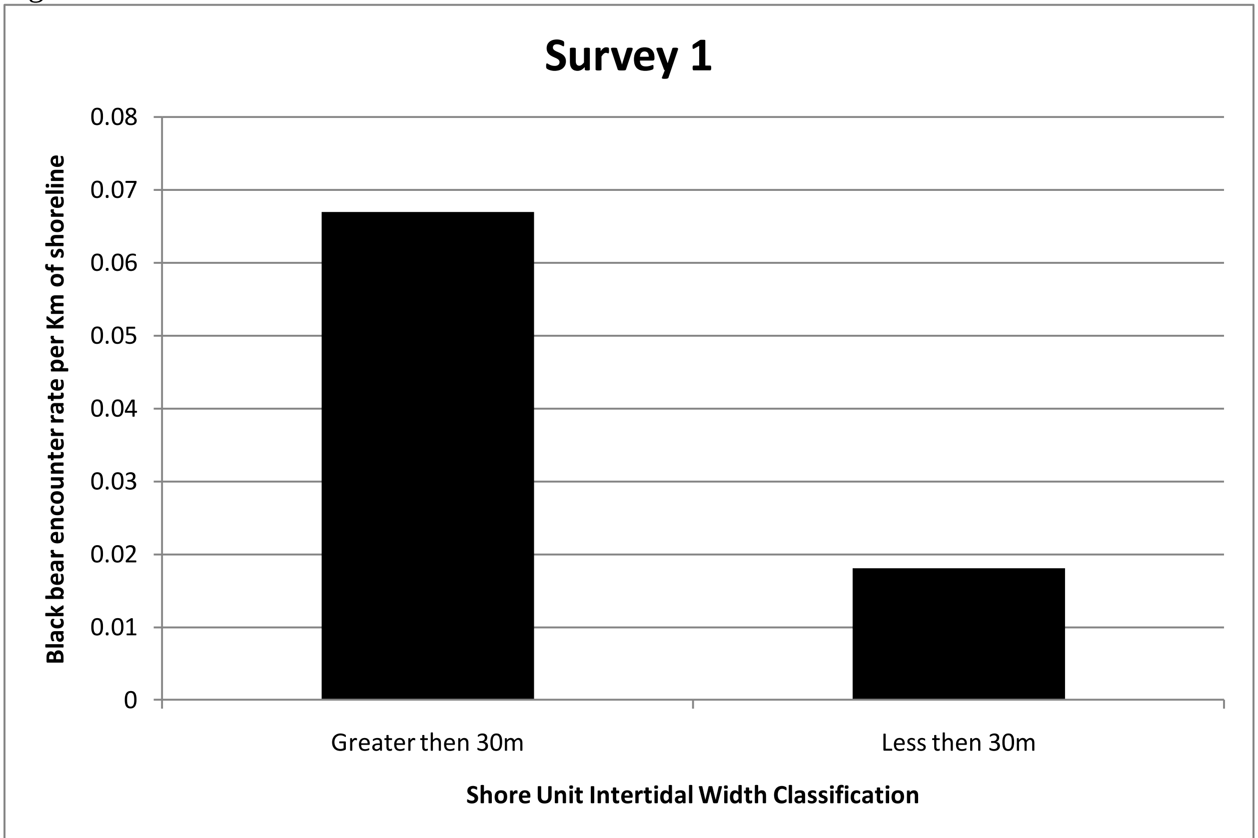

Survey 3
Black bear encounter rate per Km of shoreline
0.25
0.2
0.15
0.1
0.05
0
>20°
5-20°
<5°
Not Available
Shore Unit Slope Classification

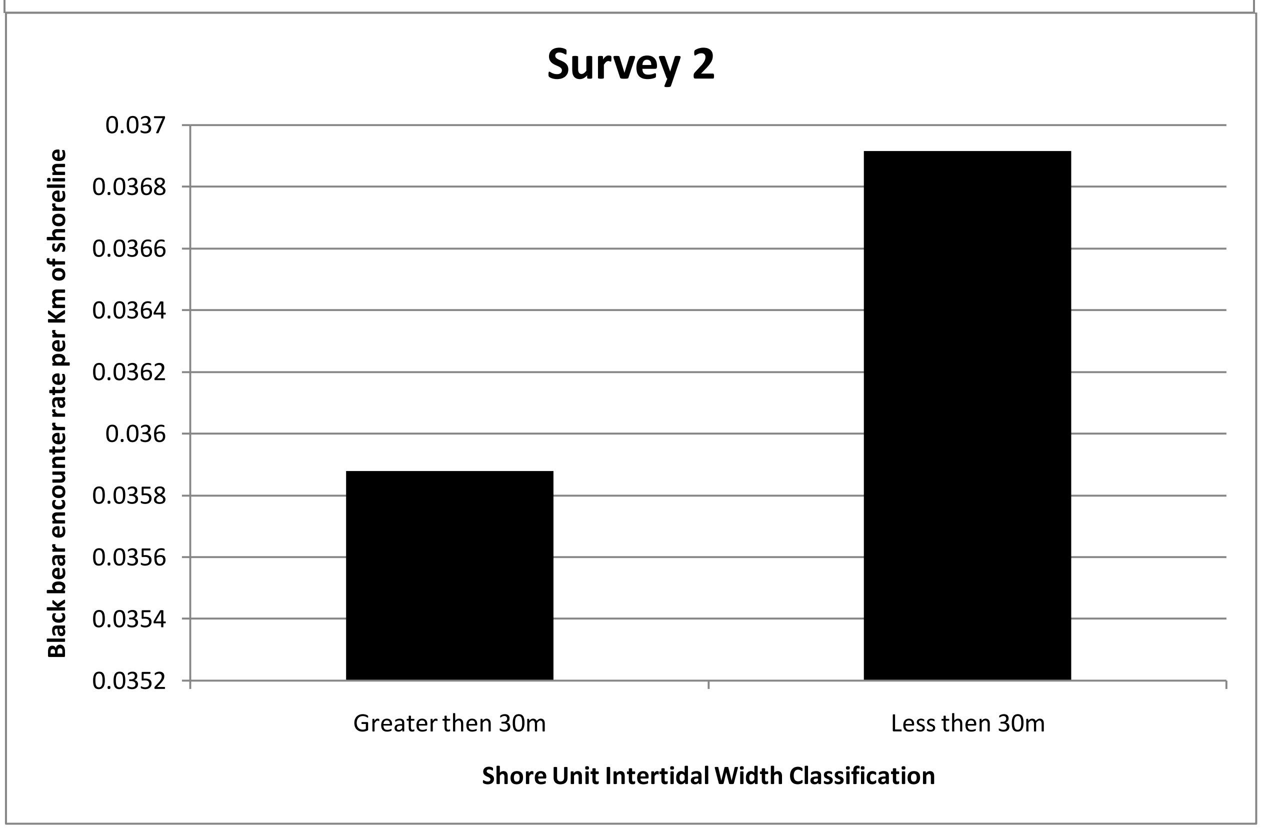

Survey 4
Black bear encounter rate per Km of shoreline
0.06
0.05
0.04
0.03
0.02
0.01
0
>20°
5-20°
<5°
Shore Unit Slope Classification

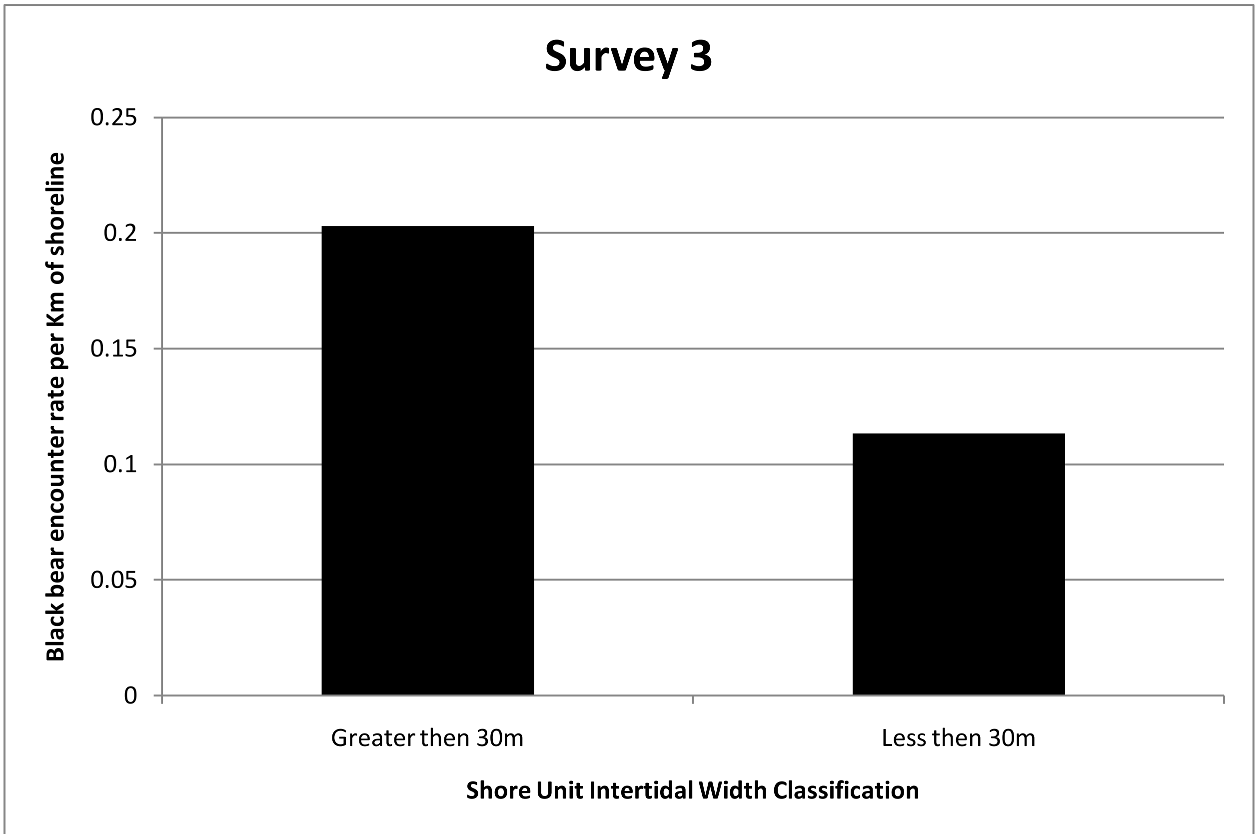


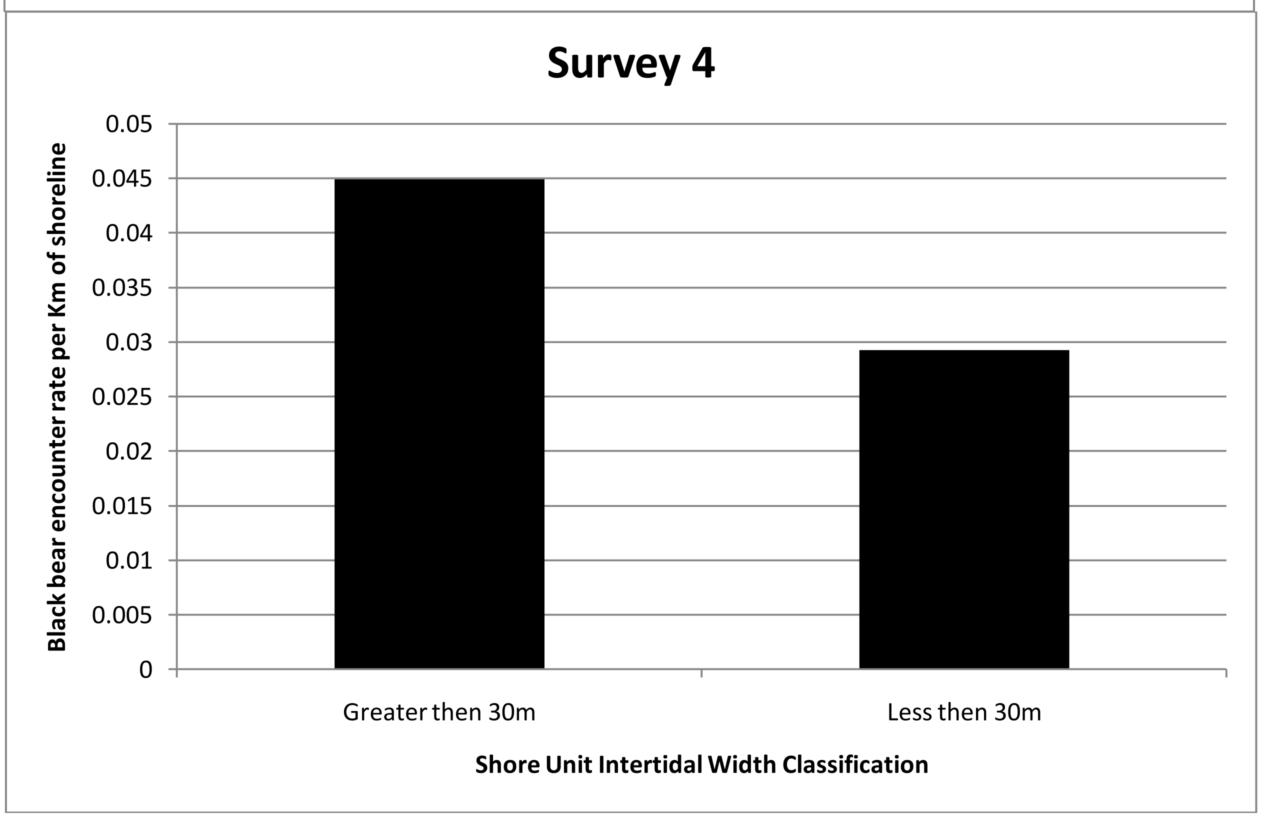
All Surveys
Black bear encounter rate per Km of shoreline
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
>20°
5-20°
<5°
Shore Unit Slope Classification

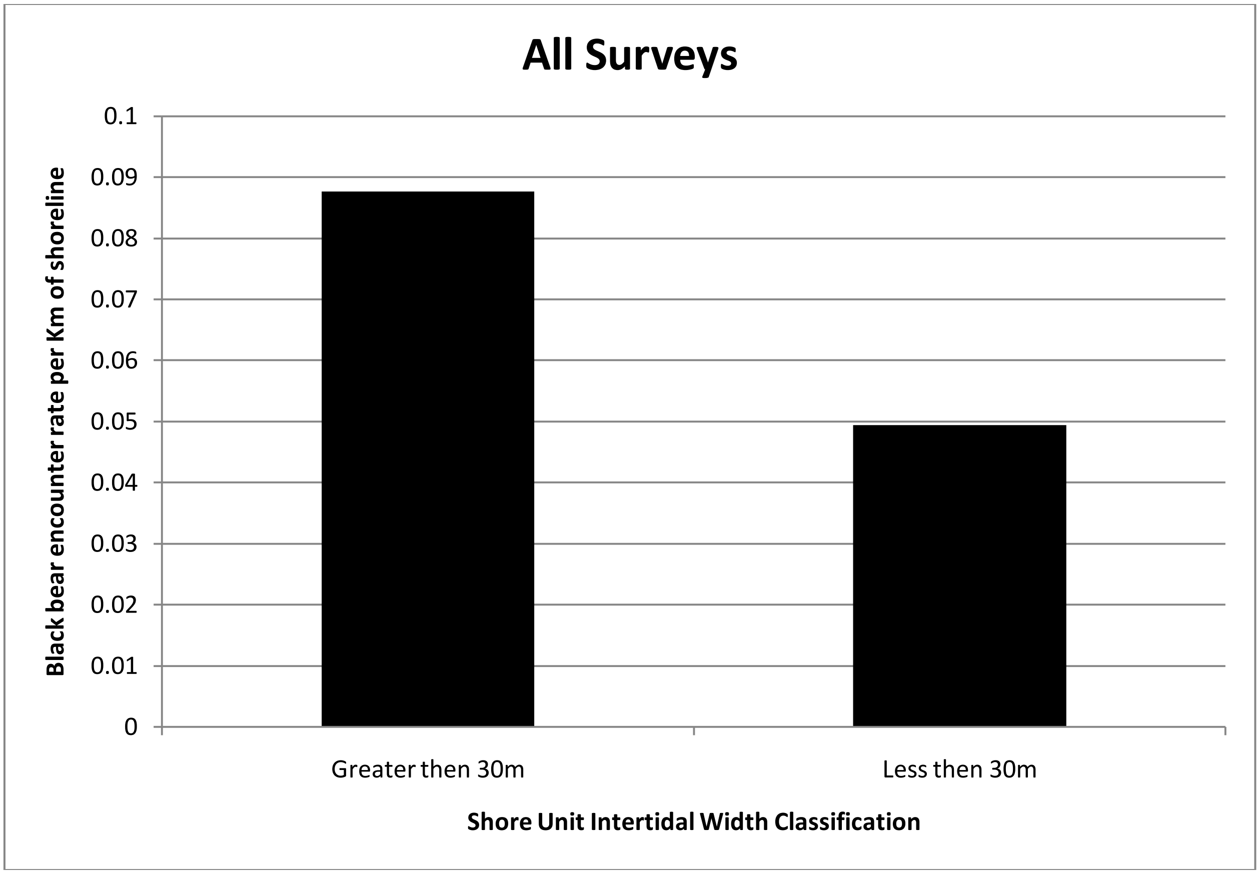
Figures of Black bear encounter rate charts for the intertidal width classification



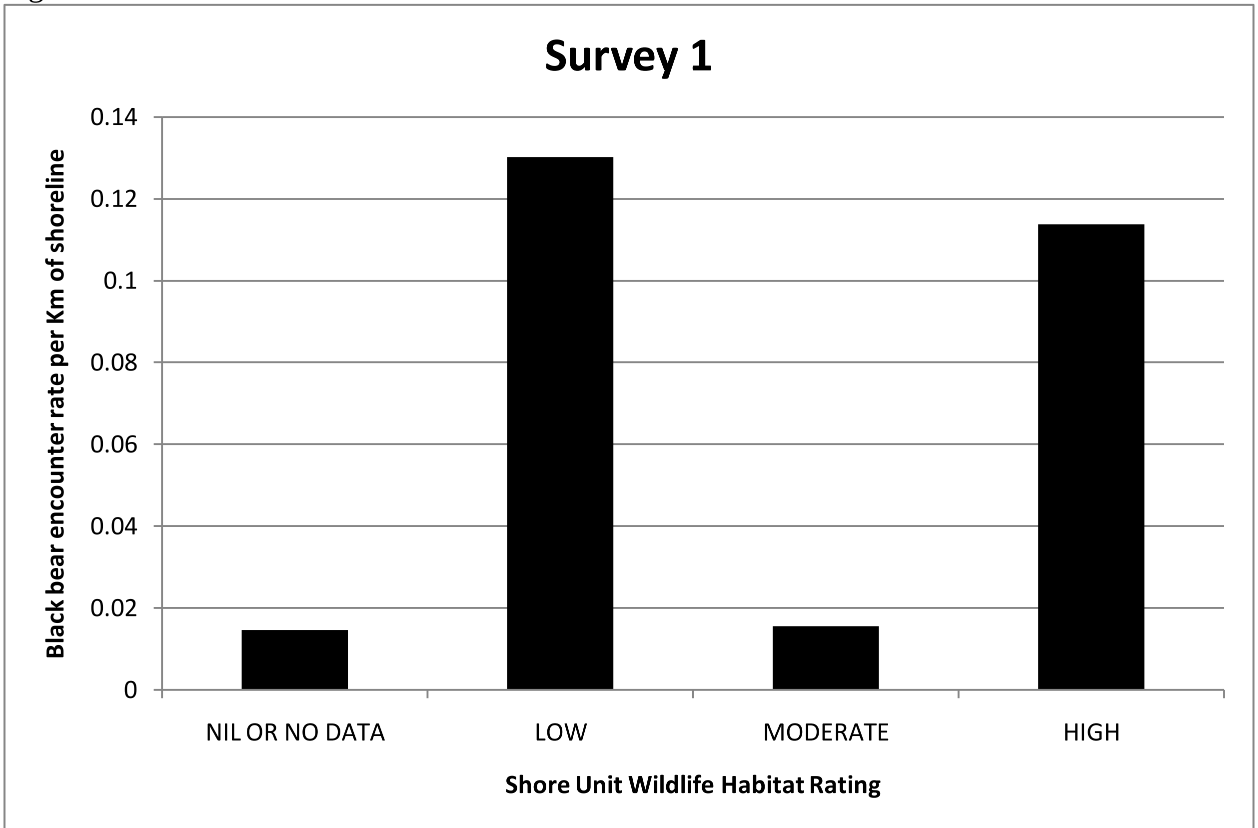


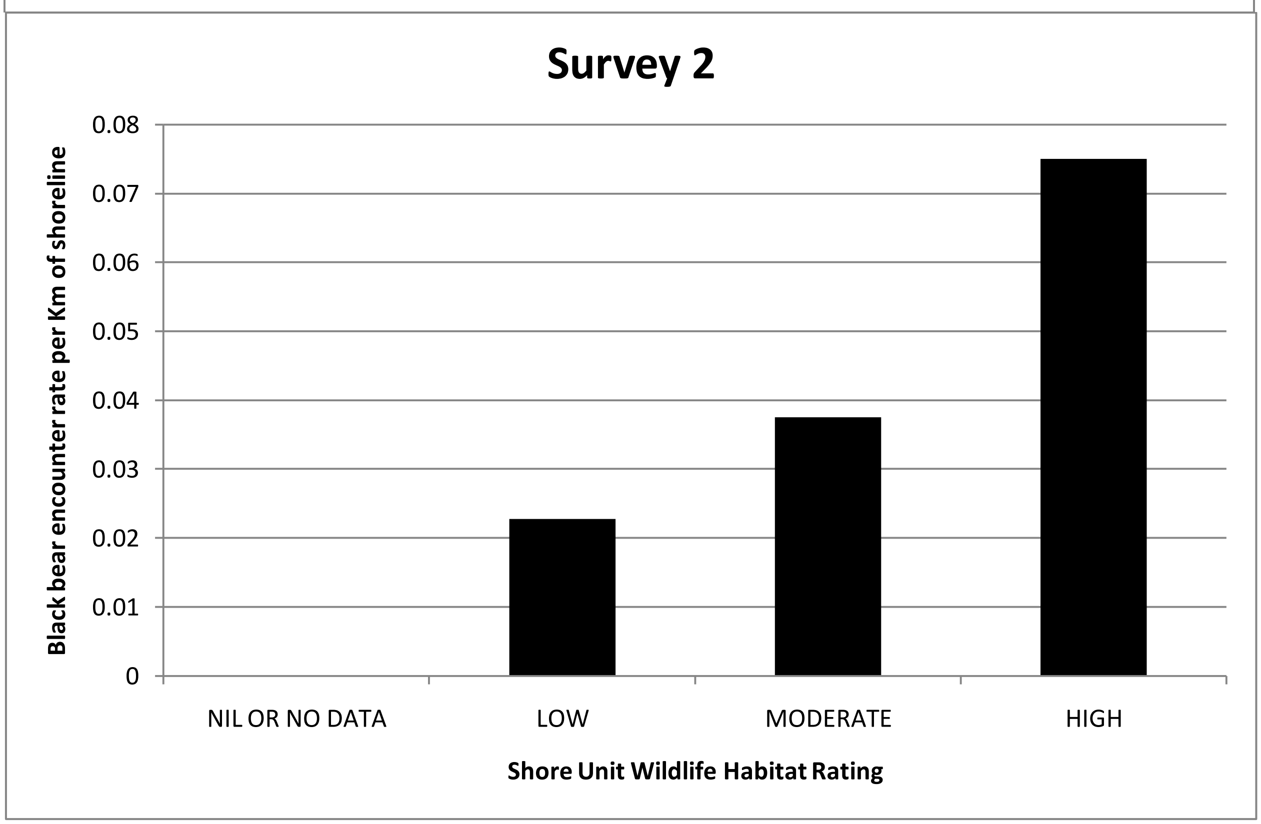

Survey 3
Black bear encounter rate per Km of shoreline
0.25
0.2
0.15
0.1
0.05
0
Greater then 30m
Less then 30m
Shore Unit Intertidal Width Classification

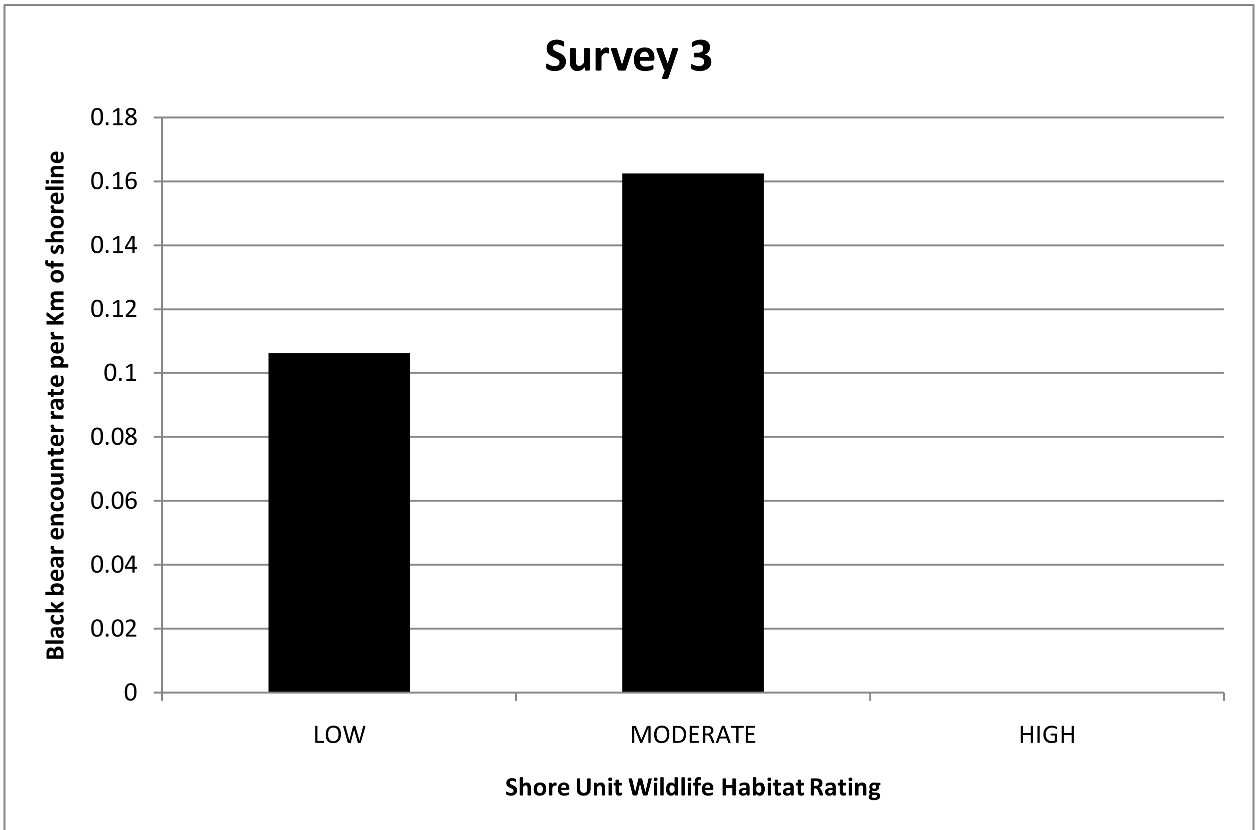

Survey 4
Black bear encounter rate per Km of shoreline
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Greater then 30m
Less then 30m
Shore Unit Intertidal Width Classification

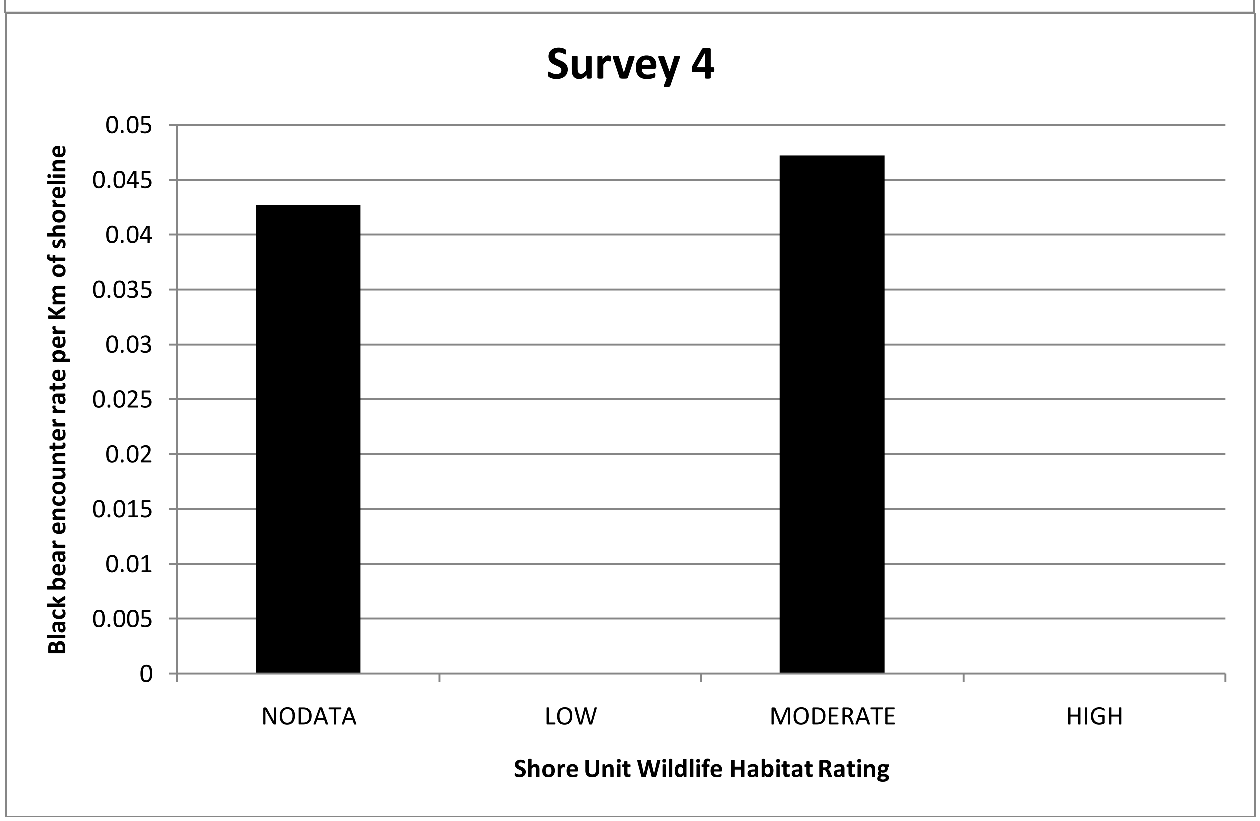

All Surveys
Black bear encounter rate per Km of shoreline
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Greater then 30m
Less then 30m
Shore Unit Intertidal Width Classification

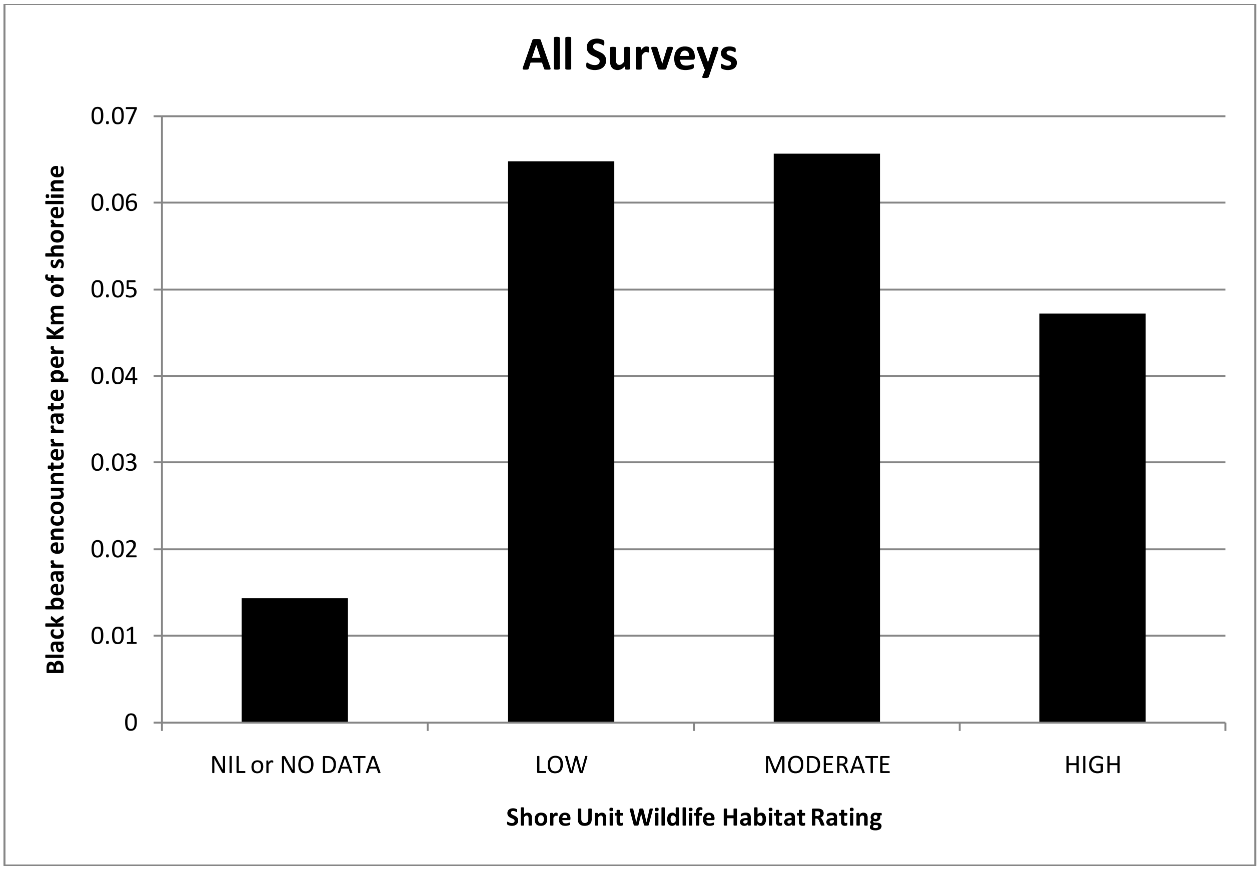
Figures of Black bear encounter rate charts for the backshore WHR classification



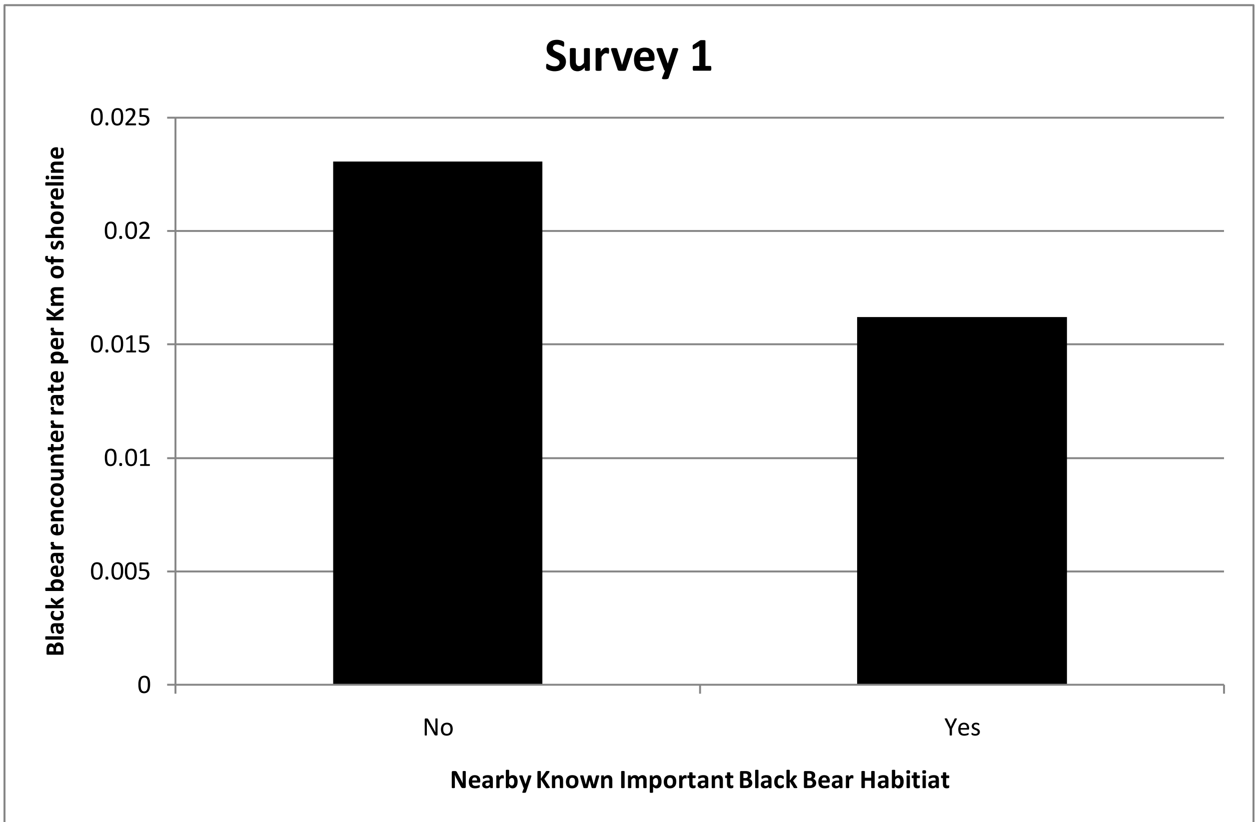


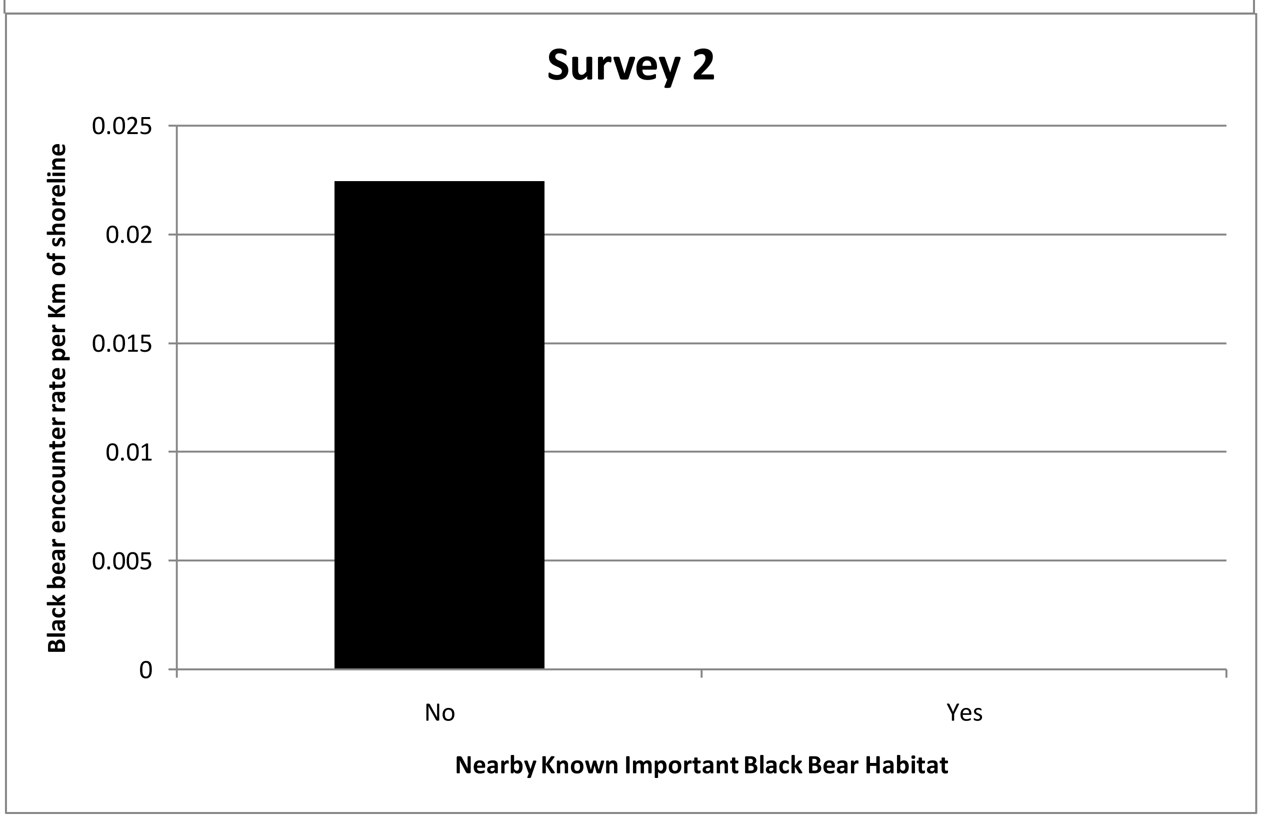

Survey 3
Black bear encounter rate per Km of shoreline
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
LOW
MODERATE
HIGH
Shore Unit Wildlife Habitat Rating

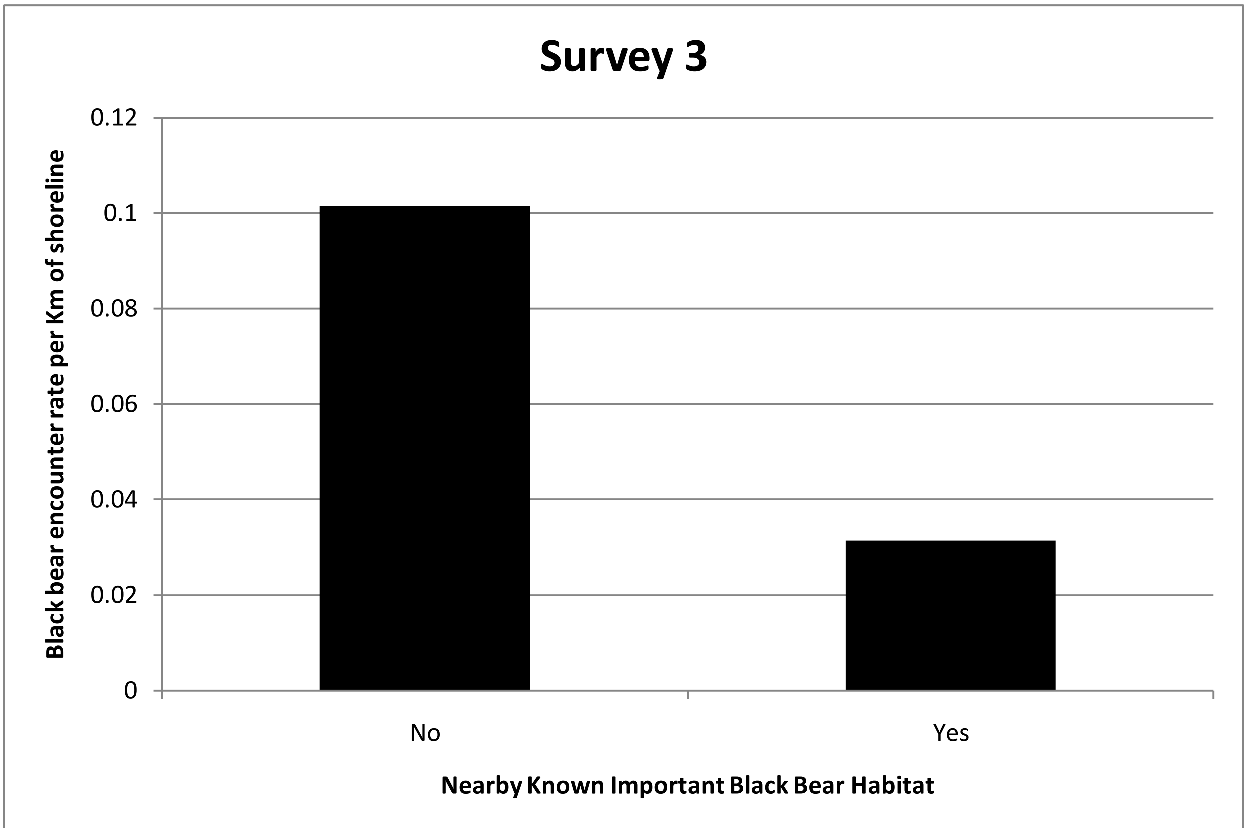

Survey 4
Black bear encounter rate per Km of shoreline
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
NODATA
LOW
MODERATE
HIGH
Shore Unit Wildlife Habitat Rating

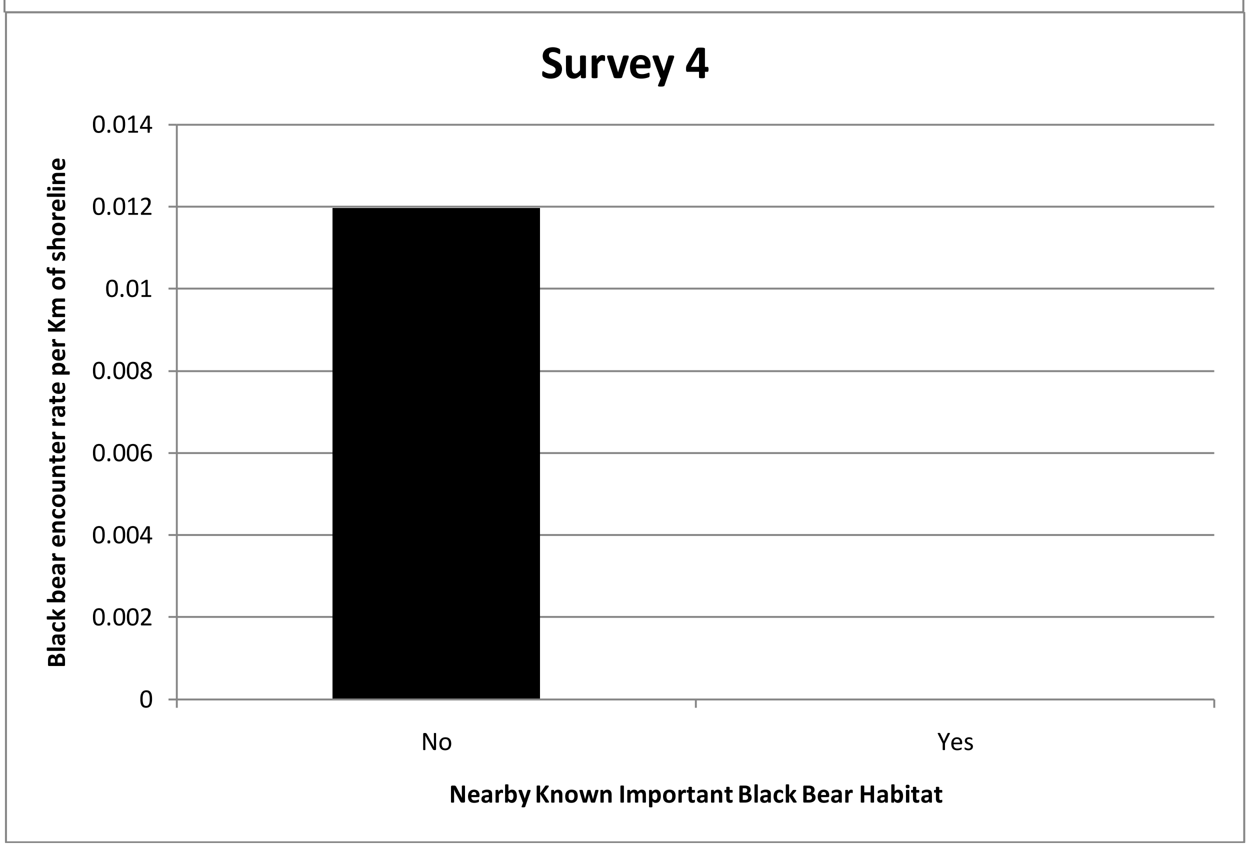

All Surveys
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Black bear encounter rate per Km of shoreline
NIL or NO DATA
LOW
MODERATE
HIGH
Shore Unit Wildlife Habitat Rating

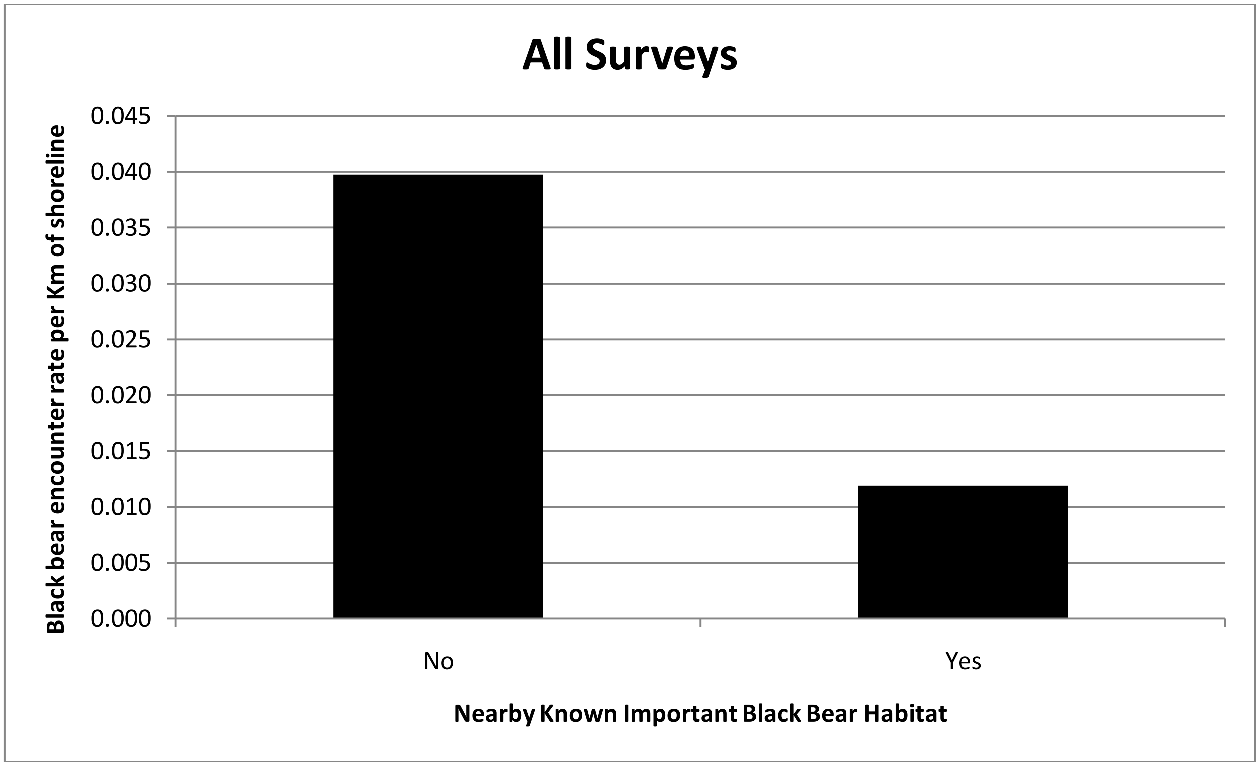
Figures of Black bear encounter rate charts for nearby known important black bear habitat



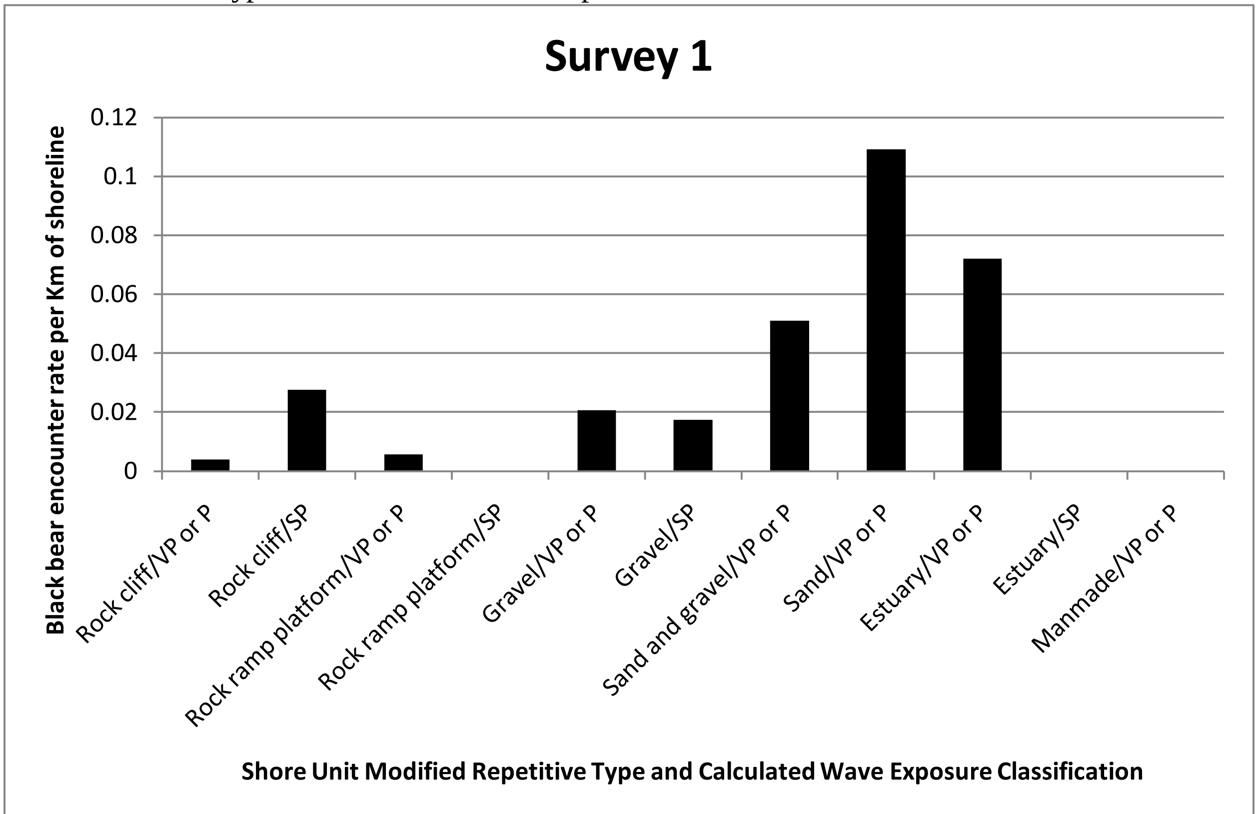


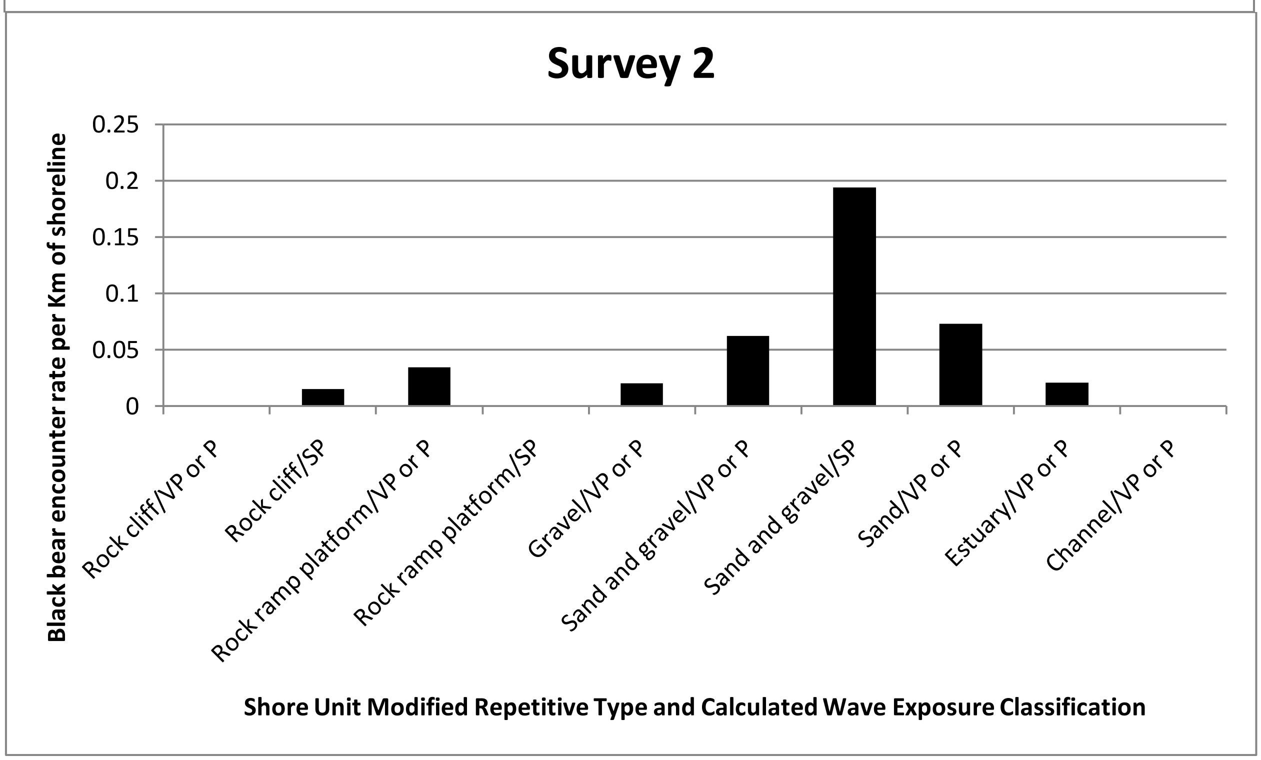

Survey 3
Black bear encounter rate per Km of shoreline
0.12
0.1
0.08
0.06
0.04
0.02
0
No
Yes
Nearby Known Important Black Bear Habitat

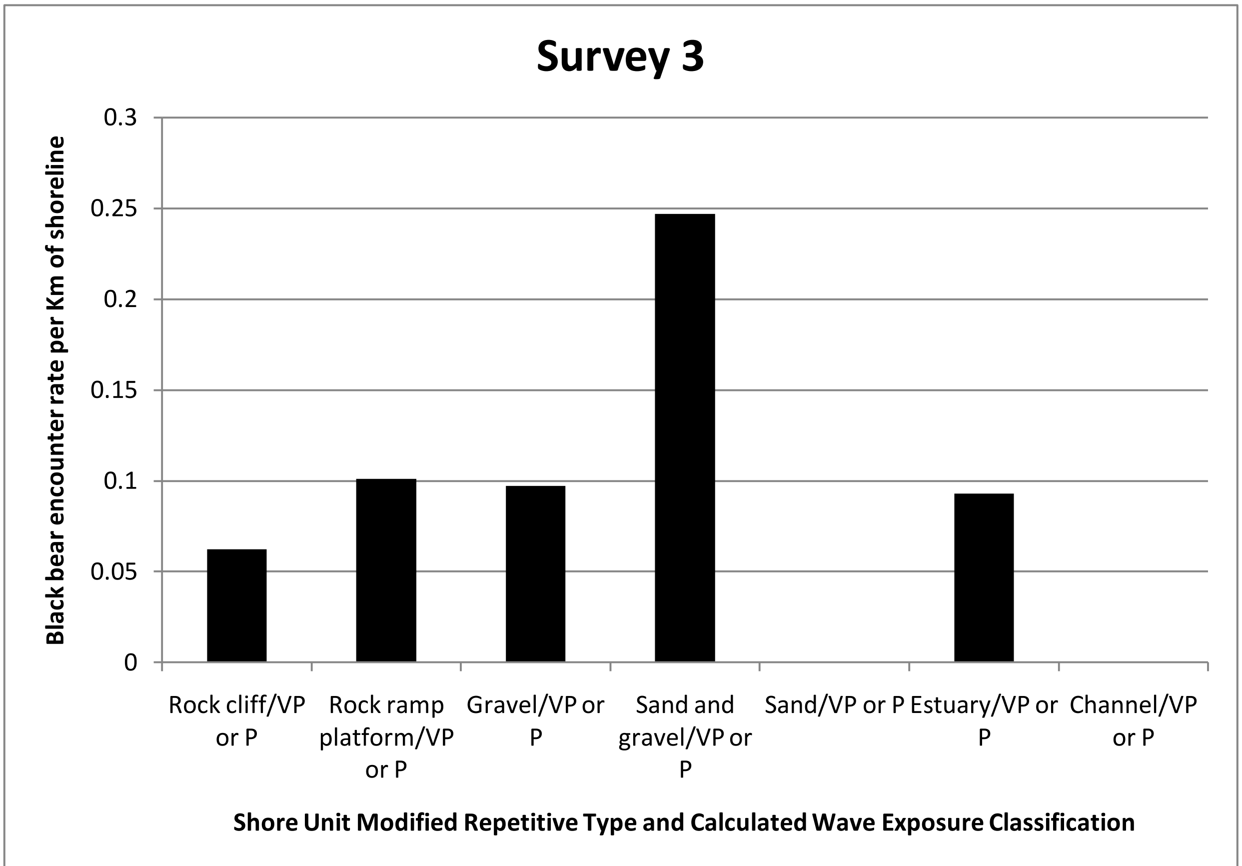

Survey 4
Black bear encounter rate per Km of shoreline
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
No
Yes
Nearby Known Important Black Bear Habitat

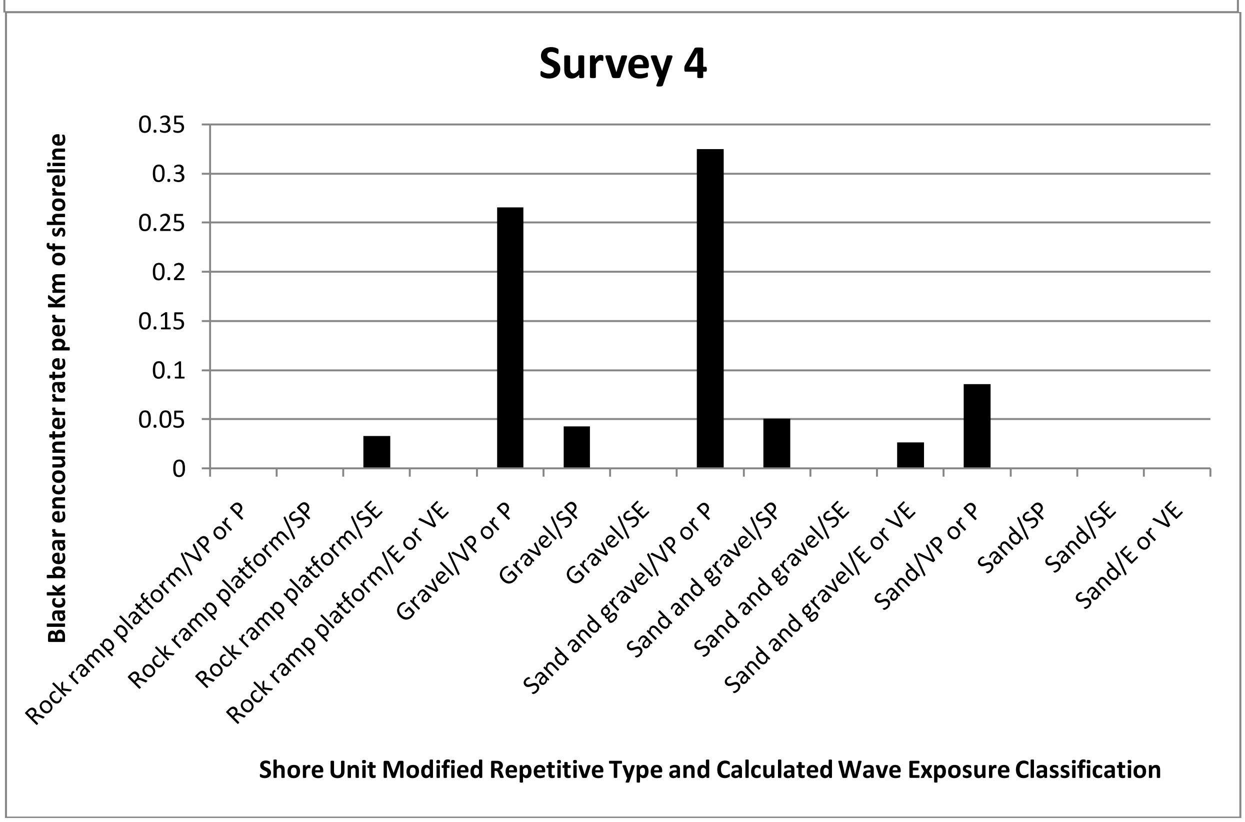

All Surveys
Black bear encounter rate per Km of shoreline
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
No
Yes
Nearby Known Important Black Bear Habitat

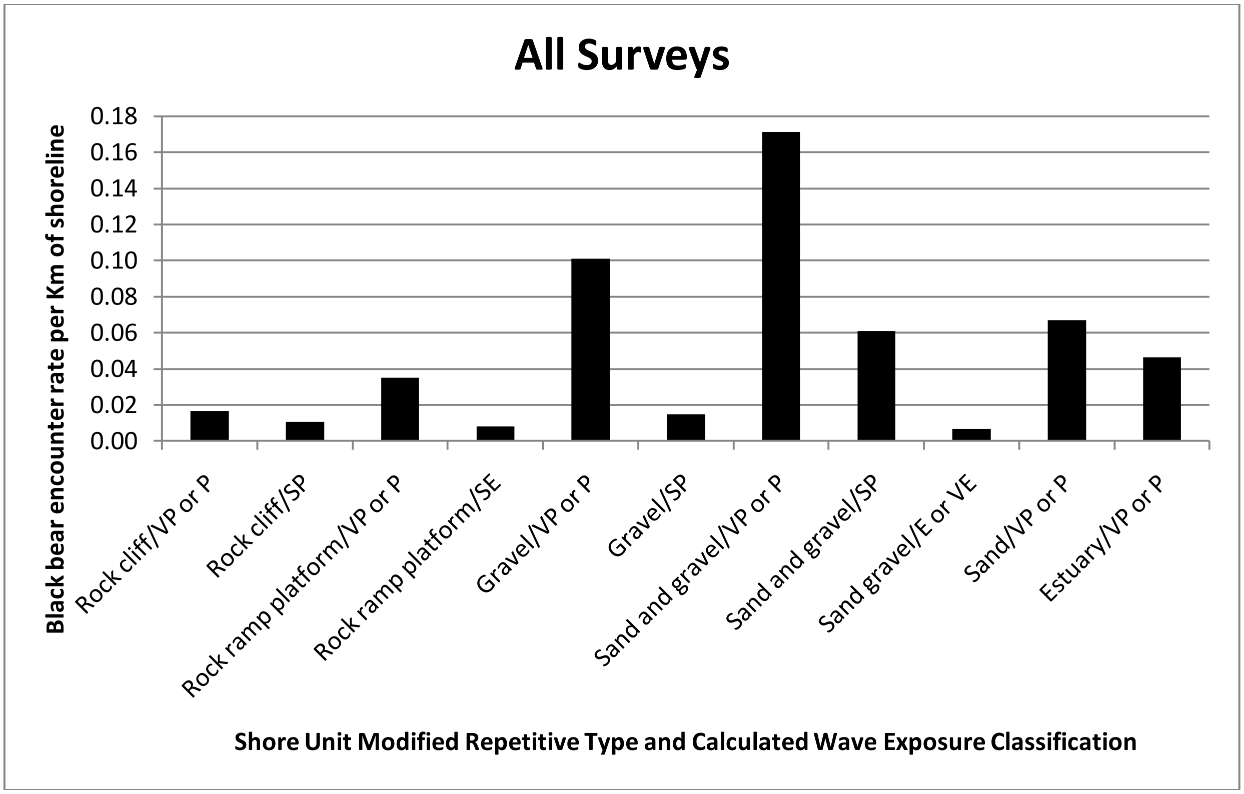
Figures of Black bear encounter rate charts for the combination of the modified repetitve shoreline type and caluclated wave exposure classifications



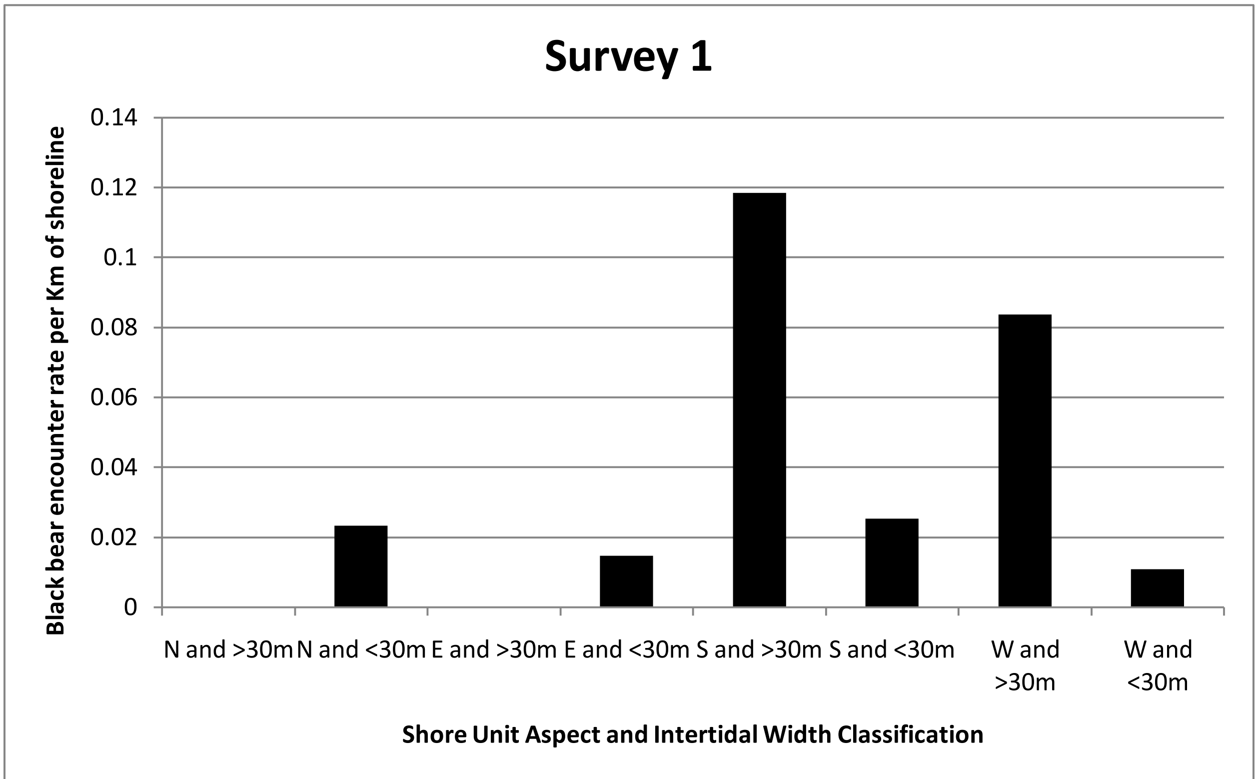


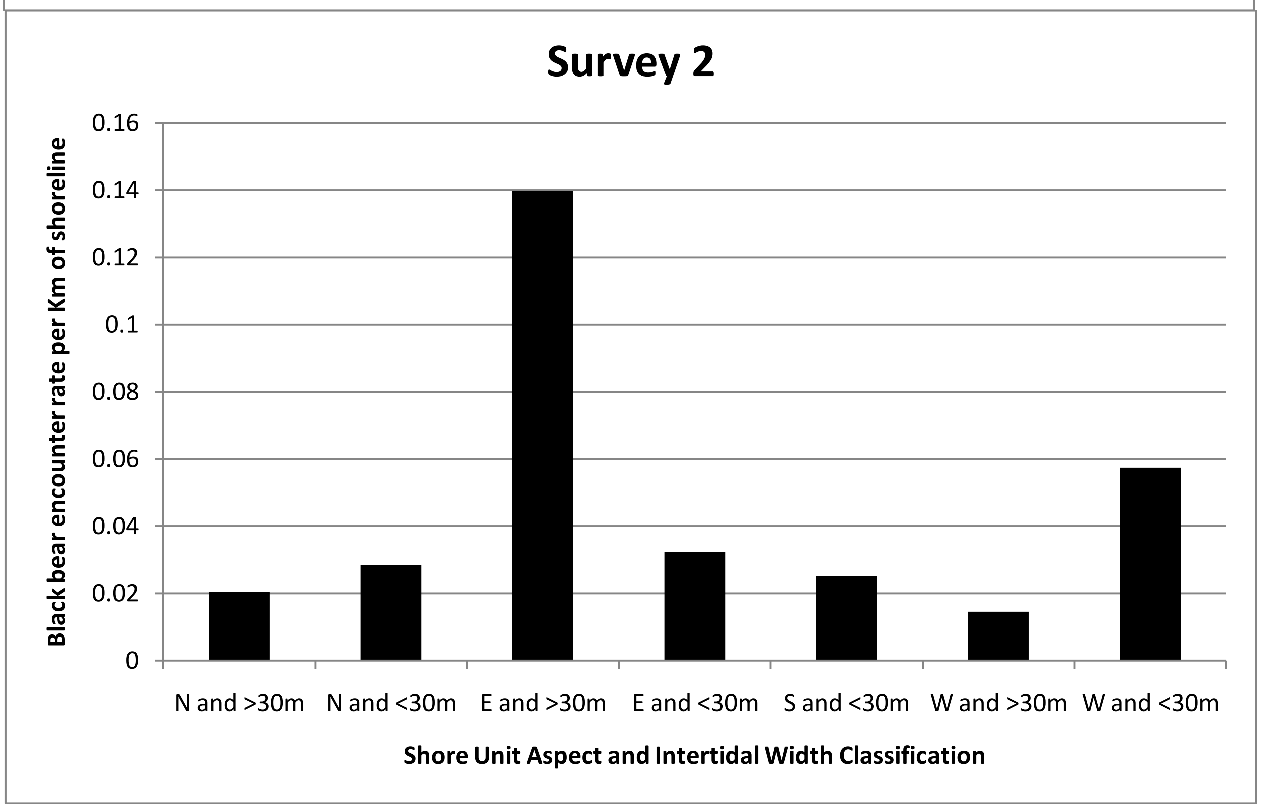

Survey 3
Black bear encounter rate per Km of shoreline
0.3
0.25
0.2
0.15
0.1
0.05
0
Rock cliff/VP or P
Rock ramp platform/VP or P
Gravel/VP or P
Sand and gravel/VP or P
Sand/VP or P
Estuary/VP or P
Channel/VP or P
Shore Unit Modified Repetitive Type and Calculated Wave Exposure Classification

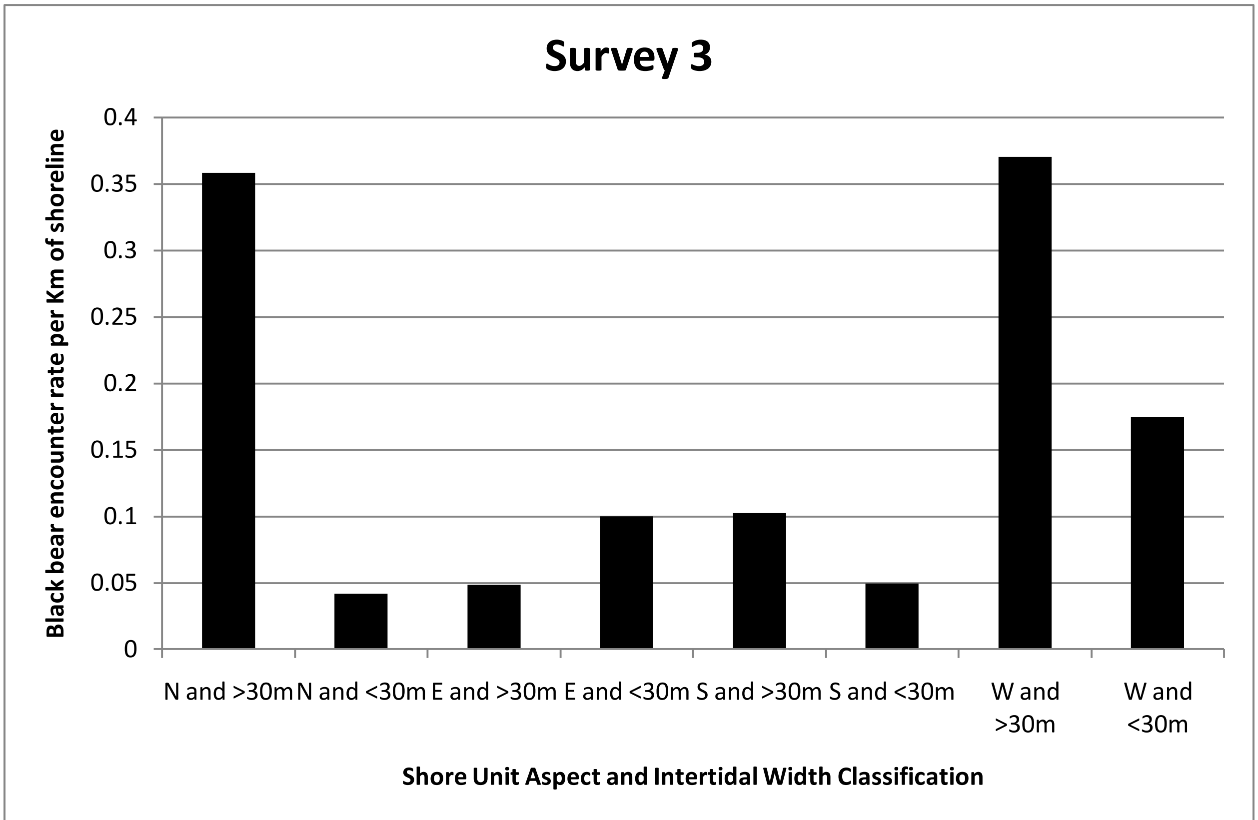

Survey 4
Black bear encounter rate per Km of shoreline
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Rock ramp platform/VP or P
Rock ramp platform/SP
Rock ramp platform/SE
Rock ramp platform/E or VE
Gravel/VP or P
Gravel/SP
Gravel/SE
Sand and gravel/VP or P
Sand and gravel/SP
Sand and gravel/SE
Sand and gravel/E or VE
Sand/VP or P
Sand/SP
Sand/SE
Sand/E or VE
Shore Unit Modified Repetitive Type and Calculated Wave Exposure Classification

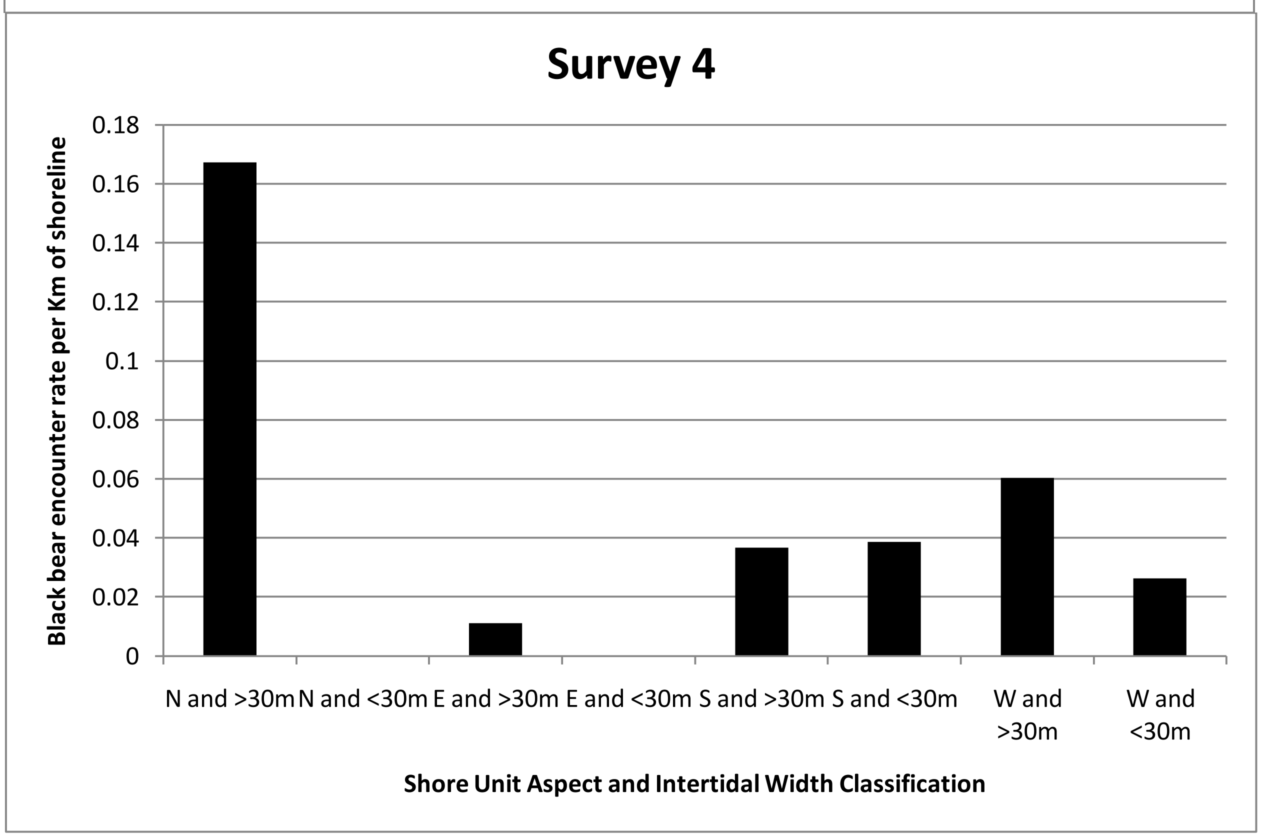

All Surveys
Black bear encounter rate per Km of shoreline
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Rock cliff/VP or P
Rock cliff/SP
Rock ramp platform/VP or P
Rock ramp platform/SE
Gravel/VP or P
Gravel/SP
Sand and gravel/VP or P
Sand and gravel/SP
Sand gravel/E or VE
Sand/VP or P
Estuary/VP or P
Shore Unit Modified Repetitive Type and Calculated Wave Exposure Classification

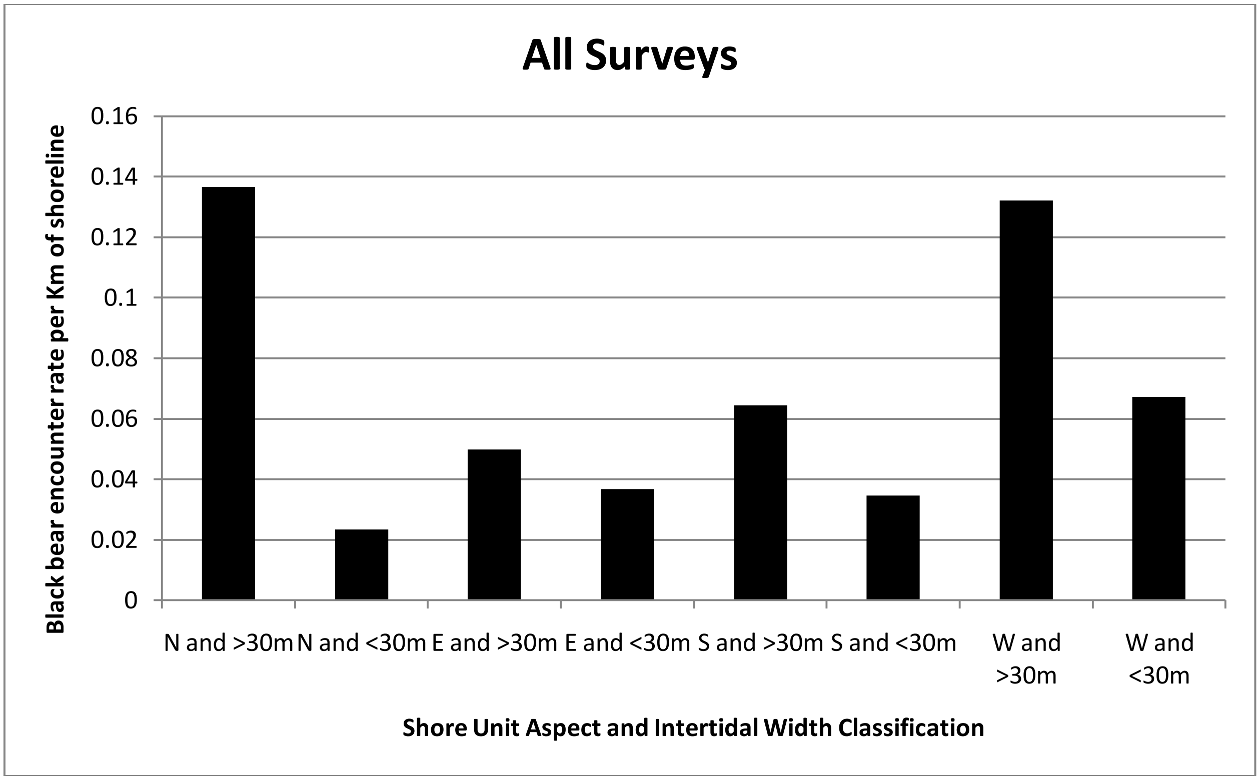
Figures of Black bear encounter rate charts for the combination of shore unit aspect and intertidal width classifications






Survey 3
Black bear encounter rate per Km of shoreline
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
N and >30m
N and <30m
E and >30m
E and <30m
S and >30m
S and <30m
W and >30m
W and <30m
Shore Unit Aspect and Intertidal Width Classification


Survey 4
Black bear encounter rate per Km of shoreline
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
N and >30m
N and <30m
E and >30m
E and <30m
S and >30m
S and <30m
W and >30m
W and <30m
Shore Unit Aspect and Intertidal Width Classification


All Surveys
Black bear encounter rate per Km of shoreline
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
N and >30m
N and <30m
E and >30m
E and <30m
S and >30m
S and <30m
W and >30m
W and <30m
Shore Unit Aspect and Intertidal Width Classification

Appendix G

Individual shore unit variables and model results

Table G – 1. Final and initial BBN model results of the assigned probability class for "High" quality intertidal black bear habitat and the associated key environmental variables for each shore unit within the four study areas.

Number of Observations	Bear Presence	Survey Route	Shore Length	PHYIDENT	WHR Habitat	Known Bear Habitat	Modified Repetitive Shore Type	Shore Slope	Aspect	Wave Exposure	Intertidal Width	Initial 'High' Class	Final 'High' Class
0	NO	3	354.821	03/04/0047/00	MODERATE	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
0	NO	3	436.647	03/04/0059/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	3	250.519	03/04/0078/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	3	477.281	03/04/0150/00	MODERATE	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
0	NO	3	354.064	03/04/0151/00	MODERATE	YES	Sand and gravel	Less than 5°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	3	304.953	03/04/0153/00	MODERATE	YES	Sand and gravel	Less than 5°	East	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
1	YES	3	662.134	03/04/0155/00	MODERATE	YES	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
0	NO	3	173.191	03/04/0157/00	MODERATE	YES	Sand and gravel	Less than 5°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	3	358.988	03/04/0160/00	MODERATE	YES	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
3	YES	3	423.627	03/04/0165/00	MODERATE	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
1	YES	3	594.129	03/04/0171/00	MODERATE	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
3	YES	3	402.600	03/04/0174/00	MODERATE	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
6	YES	3	352.813	03/04/0176/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
5	YES	3	653.714	03/04/0180/00	MODERATE	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.5to.6

1	YES	3	346.644	03/04/0183/00	MODERATE	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
0	NO	3	153.195	03/04/0184/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
2	YES	3	421.953	03/04/0185/00	MODERATE	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
2	YES	3	211.652	03/04/0187/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
9	YES	3	1296.849	03/04/0188/00	MODERATE	NO	Sand and gravel	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
2	YES	3	266.681	03/04/0189/00	MODERATE	NO	Sand and gravel	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
0	NO	3	386.122	03/04/0201/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
2	YES	3	214.975	03/04/0202/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
4	YES	3	386.035	03/04/0205/00	MODERATE	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
1	YES	3	240.415	03/04/0206/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
4	YES	3	362.896	03/04/0207/00	MODERATE	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
5	YES	3	302.928	03/04/0208/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
2	YES	3	323.492	03/04/0209/00	MODERATE	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
2	YES	3	777.218	03/04/0213/00	MODERATE	NO	Sand and gravel	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
1	YES	3	906.127	03/04/0215/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	3	333.472	03/04/0219/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	3	858.695	03/04/0220/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	3	475.122	03/04/0228/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	3	699.558	03/04/0243/00	MODERATE	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
0	NO	3	310.782	03/04/0246/00	MODERATE	NO	Sand and gravel	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
2	YES	3	348.792	03/04/0248/00	MODERATE	NO	Sand and gravel	Less than 5°	East	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
8	YES	3	2967.569	03/04/0251/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6

0	NO	1	687.131	03/05/0036/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	1	624.497	03/05/0045/00	MODERATE	NO	Sand and gravel	Less than 5°	East	Very protected/Protected	Greater than 30m	.4to.5	.5to.6
0	NO	1	347.666	03/05/0061/00	HIGH	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	1	391.936	03/05/0171/00	MODERATE	YES	Sand and gravel	Less than 5°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	1	2007.242	03/05/0195/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
2	YES	1	1624.605	03/05/0205/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
1	YES	1	871.048	03/05/0216/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
1	YES	1	555.850	03/05/0262/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	1	395.539	03/05/0264/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	1	152.731	03/05/0266/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	1	349.984	03/05/0269/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	2	178.095	03/05/0291/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	2	566.238	03/05/0296/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	2	901.352	03/05/0298/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	2	476.744	03/05/0299/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
1	YES	2	575.854	03/05/0308/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	2	309.150	03/05/0311/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
1	YES	2	514.196	03/05/0313/00	HIGH	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
1	YES	2	410.745	03/05/0317/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	2	348.999	03/05/0337/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.5to.6
2	YES	2	505.700	03/05/0340/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	2	560.042	03/05/0381/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6

1	YES	4	369.979	03/05/0426/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.5to.6
0	NO	3	406.386	03/04/0016/00	MODERATE	NO	Sand	5° to 20°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	288.255	03/04/0029/00	MODERATE	NO	Sand	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	201.221	03/04/0032/00	LOW	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	1102.552	03/04/0033/00	LOW	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	383.606	03/04/0034/00	LOW	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	925.277	03/04/0036/00	LOW	NO	Sand	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	417.076	03/04/0037/00	LOW	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	567.952	03/04/0039/00	LOW	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	339.941	03/04/0041/00	LOW	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	316.094	03/04/0042/00	MODERATE	NO	Gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	379.239	03/04/0043/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	572.120	03/04/0044/00	MODERATE	NO	Gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	366.171	03/04/0045/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	999.955	03/04/0046/00	MODERATE	NO	Sand and gravel	Greater than 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	1218.826	03/04/0048/00	MODERATE	NO	Gravel	Greater than 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	948.632	03/04/0051/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	4561.077	03/04/0055/00	MODERATE	NO	Estuary	Less than 5°	East	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
2	YES	3	316.565	03/04/0058/00	MODERATE	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	501.864	03/04/0060/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	428.822	03/04/0061/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	709.723	03/04/0063/00	LOW	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5

0	NO	3	948.536	03/04/0065/00	MODERATE	NO	Estuary	Less than 5°	East	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	3	258.462	03/04/0067/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	625.530	03/04/0068/00	MODERATE	NO	Gravel	Greater than 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	1314.416	03/04/0072/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	1138.000	03/04/0076/00	MODERATE	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	414.300	03/04/0082/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	561.648	03/04/0084/00	LOW	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	605.652	03/04/0092/00	MODERATE	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	165.853	03/04/0095/00	LOW	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	242.018	03/04/0096/00	LOW	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	400.412	03/04/0097/00	LOW	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	736.884	03/04/0098/00	LOW	NO	Gravel	Greater than 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	743.370	03/04/0099/00	MODERATE	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	276.828	03/04/0137/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	1243.740	03/04/0138/00	LOW	NO	Gravel	Greater than 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	211.485	03/04/0139/00	LOW	NO	Gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
2	YES	3	538.904	03/04/0140/00	LOW	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	557.616	03/04/0141/00	LOW	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	457.900	03/04/0142/00	LOW	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	175.175	03/04/0143/00	LOW	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	340.252	03/04/0144/00	LOW	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	329.273	03/04/0145/00	LOW	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5

0	NO	3	677.045	03/04/0146/00	LOW	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	393.078	03/04/0147/00	LOW	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	501.966	03/04/0149/00	LOW	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	426.897	03/04/0152/00	MODERATE	YES	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	272.118	03/04/0154/00	MODERATE	YES	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	2983.411	03/04/0161/00	MODERATE	YES	Estuary	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	409.331	03/04/0163/00	MODERATE	NO	Gravel	Less than 5°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
5	YES	3	895.248	03/04/0166/00	LOW	NO	Estuary	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	3	280.656	03/04/0167/00	LOW	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
3	YES	3	428.651	03/04/0168/00	LOW	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
2	YES	3	843.719	03/04/0177/00	LOW	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	214.726	03/04/0178/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	297.621	03/04/0182/00	MODERATE	NO	Gravel	Greater than 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	162.477	03/04/0186/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	3	349.066	03/04/0190/00	LOW	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
2	YES	3	395.554	03/04/0191/00	LOW	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	299.249	03/04/0193/00	LOW	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
4	YES	3	949.193	03/04/0194/00	LOW	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
4	YES	3	237.164	03/04/0199/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	467.174	03/04/0200/00	MODERATE	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	268.902	03/04/0210/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	715.524	03/04/0211/00	MODERATE	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5

2	YES	3	379.885	03/04/0214/00	LOW	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	999.425	03/04/0218/00	LOW	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	368.382	03/04/0223/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	447.461	03/04/0224/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	923.751	03/04/0225/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
2	YES	3	476.680	03/04/0226/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	1734.241	03/04/0227/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	223.194	03/04/0245/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	3	942.069	03/04/0247/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	3	386.126	03/04/0249/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
5	YES	3	2522.305	03/04/0250/00	MODERATE	NO	Estuary	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	1	1268.857	03/05/0034/00	MODERATE	NO	Estuary	Less than 5°	East	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	1	3173.408	03/05/0038/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	500.528	03/05/0040/00	MODERATE	NO	Estuary	Less than 5°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
refdddddddd0	NO	1	761.256	03/05/0042/00	MODERATE	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	793.289	03/05/0043/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	946.874	03/05/0044/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	931.537	03/05/0049/00	MODERATE	NO	Estuary	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	1	495.367	03/05/0051/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	308.959	03/05/0056/00	MODERATE	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	399.384	03/05/0058/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
2	YES	1	773.508	03/05/0059/00	HIGH	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5

0	NO	1	476.985	03/05/0060/00	MODERATE	NO	Sand	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
2	YES	1	287.960	03/05/0062/00	HIGH	NO	Sand	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	1558.905	03/05/0063/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	1	189.605	03/05/0065/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	261.168	03/05/0068/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	938.245	03/05/0072/00	MODERATE	NO	Sand	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	475.883	03/05/0073/00	MODERATE	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	563.245	03/05/0074/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	299.251	03/05/0130/00	NODATA	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	446.954	03/05/0131/00	NODATA	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	2617.958	03/05/0132/00	NODATA	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	492.736	03/05/0133/00	NODATA	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	496.566	03/05/0135/00	NODATA	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	1	480.540	03/05/0137/00	NODATA	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	2558.343	03/05/0180/00	MODERATE	YES	Estuary	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	1	1487.194	03/05/0194/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	1006.799	03/05/0196/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	664.135	03/05/0197/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
3	YES	1	344.774	03/05/0200/00	MODERATE	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	859.096	03/05/0202/00	MODERATE	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	796.407	03/05/0208/00	NODATA	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	319.763	03/05/0211/00	HIGH	NO	Estuary	Less than 5°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5

0	NO	1	229.446	03/05/0212/00	MODERATE	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	594.421	03/05/0214/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	1	269.580	03/05/0218/00	NODATA	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
2	YES	1	1037.546	03/05/0221/00	NODATA	NO	Sand and gravel	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
4	YES	1	1317.781	03/05/0234/00	LOW	NO	Estuary	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	1	610.853	03/05/0238/00	MODERATE	NO	Estuary	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	1	1870.421	03/05/0258/00	MODERATE	NO	Gravel	5° to 20°	South	Semi-protected	Less than 30m	.4to.5	.4to.5
0	NO	1	1474.596	03/05/0259/00	LOW	NO	Estuary	Less than 5°	West	Semi-protected	Less than 30m	.4to.5	.4to.5
1	YES	1	2023.221	03/05/0263/00	MODERATE	NO	Estuary	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	1	193.662	03/05/0265/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	879.959	03/05/0270/00	MODERATE	NO	Sand	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	2	568.363	03/05/0271/00	MODERATE	NO	Estuary	Less than 5°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
2	YES	2	4940.256	03/05/0289/00	MODERATE	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	306.675	03/05/0290/00	HIGH	NO	Estuary	Less than 5°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	536.580	03/05/0293/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	1047.407	03/05/0294/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	890.925	03/05/0297/00	MODERATE	NO	Estuary	Less than 5°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	920.576	03/05/0301/00	MODERATE	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
2	YES	2	729.006	03/05/0303/00	MODERATE	NO	Sand	Less than 5°	East	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	2	345.566	03/05/0305/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	315.570	03/05/0306/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	482.058	03/05/0307/00	MODERATE	NO	Gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5

0	NO	2	651.452	03/05/0312/00	MODERATE	NO	Gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	390.971	03/05/0314/00	HIGH	NO	Sand	5° to 20°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	2	1278.315	03/05/0315/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	2	852.836	03/05/0318/00	MODERATE	NO	Sand	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	1635.987	03/05/0319/00	MODERATE	NO	Estuary	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	2	1682.180	03/05/0320/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	476.418	03/05/0325/00	LOW	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	604.111	03/05/0326/00	MODERATE	NO	Estuary	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	2	112.553	03/05/0327/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	349.928	03/05/0328/00	MODERATE	NO	Estuary	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	2	303.485	03/05/0329/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	234.657	03/05/0330/00	LOW	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	2	312.933	03/05/0331/00	MODERATE	NO	Estuary	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	2	2009.574	03/05/0332/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	2	1222.585	03/05/0338/00	MODERATE	NO	Sand	Less than 5°	East	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	2	807.877	03/05/0341/00	MODERATE	NO	Estuary	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
2	YES	2	2131.163	03/05/0342/00	MODERATE	NO	Sand and gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	2	931.027	03/05/0374/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	2	5867.202	03/05/0377/00	MODERATE	NO	Estuary	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	2	351.929	03/05/0379/00	NODATA	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	910.318	03/05/0380/00	MODERATE	NO	Sand	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	2	381.099	03/05/0385/00	MODERATE	NO	Estuary	Less than 5°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5

0	NO	2	511.875	03/05/0386/00	LOW	NO	Sand and gravel	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.4to.5
1	YES	2	816.090	03/05/0389/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Semi-protected	Less than 30m	.4to.5	.4to.5
0	NO	2	362.416	03/05/0391/00	LOW	NO	Sand and gravel	5° to 20°	West	Semi-protected	Less than 30m	.4to.5	.4to.5
4	YES	2	1167.114	03/05/0393/00	MODERATE	NO	Sand and gravel	5° to 20°	West	Semi-protected	Less than 30m	.4to.5	.4to.5
0	NO	2	377.615	03/05/0395/00	MODERATE	NO	Gravel	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	4	1002.747	03/05/0403/00	HIGH	NO	Gravel	Less than 5°	North	Semi-protected	Greater than 30m	.4to.5	.4to.5
1	YES	4	767.381	03/05/0406/00	MODERATE	NO	Gravel	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	4	693.913	03/05/0407/00	MODERATE	NO	Sand	Less than 5°	East	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	4	4467.356	03/05/0408/00	MODERATE	NO	Sand	Less than 5°	East	Semi-protected	Greater than 30m	.4to.5	.4to.5
0	NO	4	828.457	03/05/0416/00	MODERATE	NO	Gravel	Less than 5°	East	Semi-protected	Greater than 30m	.4to.5	.4to.5
0	NO	4	494.813	03/05/0417/00	MODERATE	NO	Sand	5° to 20°	East	Semi-protected	Greater than 30m	.4to.5	.4to.5
0	NO	4	266.974	03/05/0418/00	MODERATE	NO	Gravel	Less than 5°	South	Semi-protected	Less than 30m	.4to.5	.4to.5
0	NO	4	519.446	03/05/0419/00	MODERATE	NO	Sand and gravel	Less than 5°	South	Semi-protected	Greater than 30m	.4to.5	.4to.5
1	YES	4	888.822	03/05/0420/00	MODERATE	NO	Gravel	Less than 5°	South	Semi-protected	Greater than 30m	.4to.5	.4to.5
0	NO	4	715.689	03/05/0421/00	MODERATE	NO	Sand and gravel	5° to 20°	South	Semi-protected	Less than 30m	.4to.5	.4to.5
1	YES	4	173.340	03/05/0423/00	MODERATE	NO	Gravel	5° to 20°	South	Very protected/Protected	Less than 30m	.4to.5	.4to.5
0	NO	4	832.427	03/05/0425/00	MODERATE	NO	Sand	Less than 5°	South	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
2	YES	4	321.911	03/05/0427/00	MODERATE	NO	Sand	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
0	NO	4	937.640	03/05/0429/00	MODERATE	NO	Sand	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	4	1591.450	03/05/0430/00	NODATA	NO	Sand	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
4	YES	4	1553.579	03/05/0431/00	NODATA	NO	Sand and gravel	Less than 5°	West	Very protected/Protected	Greater than 30m	.4to.5	.4to.5
1	YES	4	1234.632	03/05/0432/00	NODATA	NO	Sand and gravel	Less than 5°	South	Semi-protected	Greater than 30m	.4to.5	.4to.5

0	NO	4	1167.531	03/05/0434/00	NODATA	NO	Sand	5° to 20°	West	Semi-protected	Greater than 30m	.4to.5	.4to.5
0	NO	3	974.438	03/04/0031/00	LOW	NO	Sand	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.3to.4
0	NO	3	441.417	03/04/0075/00	MODERATE	NO	Estuary	Less than 5°	North	Very protected/Protected	Less than 30m	.4to.5	.3to.4
0	NO	3	556.411	03/04/0083/00	LOW	NO	Estuary	Less than 5°	North	Very protected/Protected	Less than 30m	.4to.5	.3to.4
0	NO	3	289.256	03/04/0203/00	MODERATE	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.3to.4	.3to.4
2	YES	3	701.587	03/04/0229/00	MODERATE	NO	Rock ramp/platform	5° to 20°	South	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	3	464.054	03/04/0252/00	MODERATE	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.3to.4	.3to.4
1	YES	1	3385.309	03/05/0035/00	MODERATE	NO	Gravel	5° to 20°	East	Semi-protected	Less than 30m	.4to.5	.3to.4
1	YES	1	205.851	03/05/0067/00	MODERATE	NO	Sand	5° to 20°	North	Very protected/Protected	Less than 30m	.4to.5	.3to.4
0	NO	1	2822.729	03/05/0071/00	MODERATE	NO	Rock ramp/platform	5° to 20°	West	Semi-protected	Less than 30m	.3to.4	.3to.4
0	NO	1	519.023	03/05/0172/00	MODERATE	YES	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	1	1849.976	03/05/0174/00	MODERATE	YES	Rock ramp/platform	5° to 20°	East	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	1	614.899	03/05/0176/00	MODERATE	YES	Rock ramp/platform	5° to 20°	East	Very protected/Protected	Less than 30m	.3to.4	.3to.4
2	YES	1	556.747	03/05/0178/00	NODATA	YES	Estuary	Less than 5°	East	Very protected/Protected	Less than 30m	.4to.5	.3to.4
0	NO	1	889.008	03/05/0179/00	MODERATE	YES	Rock ramp/platform	5° to 20°	South	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	1	1525.431	03/05/0189/00	MODERATE	NO	Rock ramp/platform	5° to 20°	South	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	1	308.741	03/05/0209/00	MODERATE	NO	Rock ramp/platform	5° to 20°	South	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	1	590.129	03/05/0222/00	NODATA	NO	Sand	5° to 20°	West	Very protected/Protected	Less than 30m	.4to.5	.3to.4
0	NO	1	2475.439	03/05/0236/00	MODERATE	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	1	601.153	03/05/0261/00	MODERATE	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	1	740.877	03/05/0267/00	HIGH	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.3to.4	.3to.4
1	YES	2	1606.639	03/05/0288/00	MODERATE	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.3to.4	.3to.4

0	NO	2	953.902	03/05/0304/00	MODERATE	NO	Rock ramp/platform	5° to 20°	South	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	2	242.140	03/05/0324/00	LOW	NO	Estuary	Less than 5°	West	Very protected/Protected	Less than 30m	.4to.5	.3to.4
0	NO	2	974.800	03/05/0335/00	MODERATE	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	2	748.077	03/05/0343/00	LOW	NO	Estuary	Less than 5°	North	Very protected/Protected	Greater than 30m	.4to.5	.3to.4
0	NO	2	381.959	03/05/0383/00	MODERATE	NO	Estuary	Less than 5°	North	Very protected/Protected	Less than 30m	.4to.5	.3to.4
1	YES	2	1338.941	03/05/0394/00	MODERATE	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.3to.4	.3to.4
1	YES	4	914.061	03/05/0399/00	MODERATE	NO	Rock ramp/platform	Less than 5°	East	Semi-exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	1152.402	03/05/0400/00	LOW	NO	Rock ramp/platform	Less than 5°	East	Semi-exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	1083.158	03/05/0401/00	MODERATE	NO	Gravel	Less than 5°	East	Semi-exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	902.128	03/05/0402/00	HIGH	NO	Gravel	Less than 5°	East	Semi-exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	443.493	03/05/0404/00	HIGH	NO	Sand	Less than 5°	East	Semi-exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	150.215	03/05/0405/00	LOW	NO	Gravel	Less than 5°	North	Semi-protected	Greater than 30m	.4to.5	.3to.4
0	NO	4	451.255	03/05/0409/00	LOW	NO	Sand	5° to 20°	South	Semi-exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	979.403	03/05/0410/00	MODERATE	NO	Rock ramp/platform	Less than 5°	South	Semi-exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	245.544	03/05/0411/00	MODERATE	NO	Rock ramp/platform	Less than 5°	East	Semi-exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	731.358	03/05/0412/00	MODERATE	NO	Sand and gravel	Less than 5°	South	Semi-exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	499.279	03/05/0413/00	MODERATE	NO	Rock ramp/platform	5° to 20°	East	Semi-exposed	Less than 30m	.3to.4	.3to.4
0	NO	4	532.095	03/05/0414/00	MODERATE	NO	Sand and gravel	5° to 20°	East	Semi-exposed	Less than 30m	.3to.4	.3to.4
0	NO	4	398.880	03/05/0422/00	MODERATE	NO	Rock ramp/platform	5° to 20°	South	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	4	303.683	03/05/0424/00	MODERATE	NO	Rock ramp/platform	5° to 20°	South	Very protected/Protected	Less than 30m	.3to.4	.3to.4
0	NO	4	918.352	03/05/0433/00	NODATA	NO	Gravel	Less than 5°	South	Semi-protected	Less than 30m	.4to.5	.3to.4
1	YES	4	1838.956	03/05/0435/00	NODATA	NO	Gravel	Less than 5°	West	Semi-protected	Greater than 30m	.4to.5	.3to.4

0	NO	4	896.902	03/05/0436/00	NODATA	NO	Sand and gravel	Less than 5°	South	Exposed/Very exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	277.693	03/05/0437/00	NODATA	NO	Sand and gravel	5° to 20°	South	Exposed/Very exposed	Less than 30m	.3to.4	.3to.4
1	YES	4	1676.412	03/05/0438/00	NODATA	NO	Sand and gravel	Less than 5°	South	Exposed/Very exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	368.041	03/05/0439/00	NODATA	NO	Sand	Less than 5°	South	Exposed/Very exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	1140.361	03/05/0440/00	NODATA	NO	Sand and gravel	Less than 5°	South	Exposed/Very exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	686.075	03/05/0441/00	NODATA	NO	Sand and gravel	Less than 5°	West	Exposed/Very exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	583.944	03/05/0443/00	NODATA	NO	Rock ramp/platform	Less than 5°	West	Exposed/Very exposed	Less than 30m	.3to.4	.3to.4
0	NO	4	2215.033	03/05/0444/00	NODATA	NO	Rock ramp/platform	5° to 20°	South	Exposed/Very exposed	Less than 30m	.3to.4	.3to.4
1	YES	4	396.941	03/05/0445/00	NODATA	NO	Sand and gravel	Less than 5°	South	Exposed/Very exposed	Less than 30m	.3to.4	.3to.4
0	NO	4	556.478	03/05/0446/00	NODATA	NO	Rock ramp/platform	5° to 20°	South	Exposed/Very exposed	Less than 30m	.3to.4	.3to.4
0	NO	4	335.313	03/05/0447/00	NODATA	NO	Sand and gravel	5° to 20°	West	Exposed/Very exposed	Less than 30m	.3to.4	.3to.4
0	NO	4	2999.920	03/05/0448/00	NODATA	NO	Rock ramp/platform	5° to 20°	West	Exposed/Very exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	528.242	03/05/0449/00	NODATA	NO	Sand and gravel	Less than 5°	South	Exposed/Very exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	502.307	03/05/0451/00	NODATA	NO	Rock ramp/platform	5° to 20°	West	Exposed/Very exposed	Less than 30m	.3to.4	.3to.4
0	NO	4	241.905	03/05/0452/00	NODATA	NO	Sand and gravel	5° to 20°	South	Exposed/Very exposed	Less than 30m	.3to.4	.3to.4
0	NO	4	271.771	03/05/0453/00	NODATA	NO	Sand and gravel	Less than 5°	West	Exposed/Very exposed	Greater than 30m	.3to.4	.3to.4
0	NO	4	1400.426	03/05/0454/00	NODATA	NO	Rock ramp/platform	5° to 20°	West	Exposed/Very exposed	Greater than 30m	.3to.4	.3to.4
0	NO	3	351.554	03/04/0017/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	280.508	03/04/0030/00	MODERATE	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	268.993	03/04/0035/00	LOW	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	269.325	03/04/0038/00	LOW	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	269.767	03/04/0040/00	LOW	NO	Channel	No data	South	Very protected/Protected	Less than 30m	.3to.4	.2to.3

0	NO	3	551.570	03/04/0053/00	MODERATE	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	316.174	03/04/0062/00	LOW	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	654.752	03/04/0064/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	220.007	03/04/0066/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	194.812	03/04/0069/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
1	YES	3	514.562	03/04/0070/00	MODERATE	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	351.061	03/04/0071/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	241.736	03/04/0073/00	MODERATE	NO	Rock cliff	Greater than 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	378.548	03/04/0074/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	518.544	03/04/0077/00	MODERATE	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	1520.546	03/04/0081/00	LOW	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	613.894	03/04/0091/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	254.996	03/04/0093/00	HIGH	NO	Rock cliff	Greater than 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	1006.349	03/04/0094/00	HIGH	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	639.393	03/04/0100/00	LOW	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	212.743	03/04/0156/00	MODERATE	YES	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	591.179	03/04/0159/00	MODERATE	YES	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
2	YES	3	880.550	03/04/0164/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
2	YES	3	821.706	03/04/0170/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	224.569	03/04/0172/00	LOW	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	251.763	03/04/0173/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
2	YES	3	1009.907	03/04/0175/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3

1	YES	3	275.467	03/04/0179/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	224.026	03/04/0181/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	147.725	03/04/0192/00	LOW	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
2	YES	3	136.114	03/04/0198/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	793.805	03/04/0212/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	214.784	03/04/0217/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	412.571	03/04/0221/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	274.688	03/04/0222/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	647.849	03/04/0253/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	3	331.129	03/04/0254/00	LOW	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	224.772	03/05/0041/00	MODERATE	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	596.760	03/05/0046/00	MODERATE	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1869.369	03/05/0047/00	MODERATE	NO	Manmade	No data	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1237.703	03/05/0048/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	2100.026	03/05/0050/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	2082.092	03/05/0052/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	404.939	03/05/0057/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	531.982	03/05/0064/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
2	YES	1	2333.950	03/05/0066/00	HIGH	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	298.649	03/05/0069/00	MODERATE	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	838.288	03/05/0070/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	4752.710	03/05/0134/00	NODATA	NO	Rock ramp/platform	5° to 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3

0	NO	1	3838.521	03/05/0136/00	NODATA	NO	Rock ramp/platform	5° to 20°	East	Semi-protected	Less than 30m	.3to.4	.2to.3
0	NO	1	2406.717	03/05/0138/00	NODATA	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1110.259	03/05/0173/00	MODERATE	YES	Rock cliff	Greater than 20°	South	Semi-protected	Less than 30m	.2to.3	.2to.3
0	NO	1	509.449	03/05/0175/00	MODERATE	YES	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1242.882	03/05/0177/00	MODERATE	YES	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	964.747	03/05/0181/00	MODERATE	YES	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1536.985	03/05/0183/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Semi-protected	Less than 30m	.2to.3	.2to.3
0	NO	1	530.321	03/05/0193/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
2	YES	1	3951.914	03/05/0198/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Semi-protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1483.252	03/05/0199/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	916.351	03/05/0201/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1776.689	03/05/0206/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1476.990	03/05/0207/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
1	YES	1	791.561	03/05/0210/00	HIGH	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1377.059	03/05/0213/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	2521.177	03/05/0215/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1571.051	03/05/0217/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	631.172	03/05/0219/00	NODATA	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	3215.479	03/05/0220/00	NODATA	NO	Rock ramp/platform	5° to 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	1992.520	03/05/0223/00	NODATA	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	2546.055	03/05/0235/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	1	2930.663	03/05/0239/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3

0	NO	1	2244.016	03/05/0268/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	1521.117	03/05/0292/00	MODERATE	NO	Rock ramp/platform	5° to 20°	East	Very protected/Protected	Less than 30m	.3to.4	.2to.3
0	NO	2	601.317	03/05/0295/00	MODERATE	NO	Channel	No data	East	Very protected/Protected	Less than 30m	.3to.4	.2to.3
0	NO	2	2198.586	03/05/0300/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
1	YES	2	1335.603	03/05/0302/00	MODERATE	NO	Rock ramp/platform	5° to 20°	East	Very protected/Protected	Less than 30m	.3to.4	.2to.3
0	NO	2	1285.638	03/05/0310/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	1765.836	03/05/0334/00	MODERATE	NO	Rock cliff	Greater than 20°	North	Semi-protected	Less than 30m	.2to.3	.2to.3
0	NO	2	917.917	03/05/0336/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	1235.214	03/05/0344/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	802.949	03/05/0373/00	MODERATE	NO	Rock cliff	Greater than 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	3324.174	03/05/0375/00	MODERATE	NO	Rock cliff	Greater than 20°	South	Semi-protected	Less than 30m	.2to.3	.2to.3
1	YES	2	253.981	03/05/0376/00	LOW	NO	Rock ramp/platform	5° to 20°	East	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	775.883	03/05/0378/00	NODATA	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	1438.481	03/05/0382/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	3982.549	03/05/0384/00	MODERATE	NO	Rock cliff	Greater than 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	521.064	03/05/0387/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	848.018	03/05/0388/00	LOW	NO	Rock ramp/platform	5° to 20°	West	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	2	320.408	03/05/0390/00	LOW	NO	Rock ramp/platform	Less than 5°	West	Semi-protected	Less than 30m	.3to.4	.2to.3
1	YES	2	813.739	03/05/0392/00	MODERATE	NO	Rock cliff	Greater than 20°	West	Semi-protected	Less than 30m	.2to.3	.2to.3
0	NO	4	219.353	03/05/0415/00	MODERATE	NO	Rock ramp/platform	5° to 20°	East	Semi-protected	Less than 30m	.3to.4	.2to.3
0	NO	4	347.057	03/05/0428/00	MODERATE	NO	Rock ramp/platform	5° to 20°	North	Very protected/Protected	Less than 30m	.2to.3	.2to.3
0	NO	4	2959.450	03/05/0442/00	NODATA	NO	Sand and gravel	Greater than 20°	West	Exposed/Very exposed	Less than 30m	.2to.3	.2to.3