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POTENTIAL PACIFIC COAST OIL PORTS: A COMPARATIVE ENVIRONMENTAL RISK ANALYSIS

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A COMPARATIVE ENVIRONMENTAL RISK ANALYSIS

VOLUME I

A Report By

Fisheries and Environment Canada

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ABSTRACT

Eleven potential British Columbian and Washington State oil ports with accompanying route alternatives were compared on a relative ranking basis in terms of possible environmental risk from marine oil spills. Initially, a rating system of navigational risk, biological, economic and social factors was developed to derive a BIOLOGICAL RISK INDEX, an ECONOMIC RISK INDEX and a SOCIAL RISK INDEX. These indices were compared port/route to port/route by several ranking methods to determine the relatively "least risky" or "most risky" port/route alternatives. Consideration was given also to preventive, cleanup and compensatory measures relevant to oil spills.

RÉSUMÉ

Onze projets d'aménagement de ports pétroliers, en Colombie-Britannique et dans l'état de Washington, ainsi que les diverses options de routes maritimes ont été comparés en fonction des dommages prévisibles à l'environnement résultant d'un déversement de pétrole. On a d'abord élaboré une échelle de classement tenant compte des dangers de navigation et des facteurs biologiques, économiques et sociaux. Le but était d'établir un indice de risques biologiques, un autre de risques économiques et un troisième de risques sociaux. Tous ces indices ont servi à comparer les uns aux autres les diverses combinaisons port-route afin de déterminer, selon certains barèmes de classement, quelles combinaisons présentaient relativement le plus ou le moins de risques. On a également tenu compte des mesures de prévention, de nettoyage et de compensation qu'entraînent les déversements de pétrole.

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PREFACE

The results of this comparative study represent only a contribution towards a relative risk analysis of various routes for delivering oil to eleven port alternatives in British Columbia and Washington State. Emphasis is predominantly on marine aspects of alternative routings; any complete environmental assessment would have to detail such other factors as air pollution potential, terrestrial pipeline impacts, cleanup costs and terminal site characteristics.

This study will doubtless generate some strong "partisan" reactions. However, it is hoped that readers will assess it as a whole, recognizing the conceptual and logistic constraints of such an analysis. The contributors to the study would welcome comment on the general approach used, as well as on specific aspects of the results.

For the sake of concise presentation, this volume is intentionally a summary one. Methodological and technical details can be found in the appendices located in a supplementary volume.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Shipments of crude oil from Alaskan and offshore sources through Canada's Pacific coastal waters have led to concerns about potential oil spill impacts on marine resources and adjacent shoreline environments. This concern has been heightened by specific proposals for new or expanded supertanker terminals in British Columbia and Washington State.

Responding to this issue, the Department of Fisheries and the Environment requested its Estuary Working Group (Pacific) to compare the risks associated with shipments of crude oil to tanker terminals at eleven potential port sites in or near British Columbia.

The study was originally intended to provide a general regional perspective against which to view a specific proposal for a major oil port at Kitimat, British Columbia. The current uncertainty regarding proposals for other terminal sites does not reduce, and perhaps increases, the need for a comparative analysis.

The analysis bears similarities to one applied in 1976 in a study of potential oil ports on the East Coast entitled "An Environmental Risk Index for the Siting of Deep Water Oil Ports" by Fisheries and Environment Canada. However, it is strongly emphasized that the methods applied in this West Coast study differ sufficiently from the East Coast one such that the risk values of each are not numerically comparable. Paramount amongst the differences between the two studies is that the East Coast one evaluates only port sites, while the West Coast study primarily considers various routes to each port site.

This report assesses relative risk. It is not an impact analysis. In fact, all the information necessary to conduct a proper impact study at any one, or several, of the sites described herein is not presently available.

1.2 OBJECTIVES

The principal objective of this analysis is to compare the relative vulnerability of marine resources to oil spills which may occur from crude oil shipments to eleven potential West Coast supertanker terminals. The general method was to evaluate various components of vulnerability, to combine them into indices of risk for each potential port/route, and then to order the ports/routes in groupings from highest risk to lowest.

Although the major objective concerns potential supertanker terminals and routes, a second, more general, objective exists. It is to further develop and test methods in the difficult field of broad-scale environmental assessment of shipping and port development alternatives.

1.3 SCOPE

The region under examination includes all of the British Columbia coast plus portions of the coast of southwest Alaska and northwest Washington State. The time frame is near-future, based on potential crude oil demands for British Columbia, Washington, and other northern U.S. states (the Northern Tier). Data was extracted from the most recent or accurate records and sources available.

There is no attempt to identify specific causes of tanker accidents that would result in oil spills, although it is generally known that collision and grounding, rather than structural failure, ramming, breakdown, fire or explosion, are the dominant probabilities. The focus instead is on comparing the relative impact of marine spills upon various port and route alternatives.

Other pollution sources which are a consequence of oil tanker traffic (air emissions, terminal facilities and pipeline corridors) are given an overview in this study, but they are peripheral to the main objective and no relative ranking of them is attempted.

The most immediately catastrophic environmental event, an explosion, does not play a part in the current analysis. It is emphasized, however, that such an event could obviously cause major damage on land as well as pollution at sea.

There is a broad range of factors which can be taken into account in determining navigational risk. Those dealt with in this report concentrate upon physical environmental parameters such as water depth and visibility. The temporal and spatial variability of these essentially uncontrollable, natural characteristics provides the basis for site/route navigational risk comparison.

However, there are other, controllable undertakings pertinent to marine traffic management and to shipboard and terminal operations, which can lead to significant coastwide improvements in navigational safety and pollution prevention, regardless of the particular choice of site. These include navigational aids, vessel traffic management systems, ship construction standards, crew qualifications, operating requirements, pollution prevention equipment, contingency plans and others. As well, compensation funds provide means to reimburse affected residents when spills do occur. The Canadian Coast Guard has already made significant strides in these directions through the promulgation of regulations (e.g., Navigating Appliance Regulations, Ship's Deck Watch Regulations, Non-Canadian Ships' Compliance Certificates), the establishment of navigational aids and Vessel Traffic Management (VTM) systems, the development of comprehensive national guidelines (e.g., the TERMPOL CODE) and the maintenance of the Maritime Pollution Claims Fund. Although not included in the rankings developed in the report, such items are given a brief overview in Chapter 9.

In the examination of site/route alternatives, it is important to keep in perspective the general goal of reducing, to the maximum extent practicable, all navigational and environmental risks. The results of the present comparative study must not be viewed as an end in itself, but rather as only one of several major parts of a broader context. Only through a combination of optimum site selection, implementation of coastwide risk-reducing measures and port/route specific mitigative design can the objectives for navigational safety and environmental protection be achieved.

1.4 PORTS AND ROUTES STUDIED

The ports selected for analysis include some for which construction or expansion of oil terminals has been proposed or seems likely to be proposed, and others which have received little public attention in the oil port context. Ports in the latter category have been assessed to broaden the range of the analysis and because they are, or could become, active general ports.

The ports are shown in Figure 1.4.1 with potential tanker routes from outer coastal waters. Roughly from north to south the ports are Port Simpson, Ridley Island, Kitimat, Bella Coola, Britannia Beach, Port Moody, Roberts Bank, Esquimalt, Cherry Point, Burrows Bay, and Port Angeles. The study does not attempt to clarify the possible interrelationships between ports, e.g., how development at one port might reduce shipments to existing terminals.

Potential routes include the alternatives of routing Alaskan north-south tanker traffic close to the B.C. Coast (nearshore routes) and 200 nautical miles to seaward (offshore routes). (Mideast tankers would also generally be 200 nautical miles offshore until their final approach.)

All ports are capable of handling very large crude carriers (VLCC) except Port Moody which would be limited to 125,000 DWT tankers because of a 55 foot depth limitation under the First Narrows Bridge; it is therefore not consistent with the assumed maximum vessel size of 325,000 DWT for other ports. However, Port Moody was included as it already has existing oil terminal facilities.

Although Esquimalt would never likely be a pipeline terminal, it could act as a port for transshipments to smaller tankers and therefore was included as a possible location on Vancouver Island.

Terminal design for all ports is hypothesized the same as that originally proposed for Kitimat by Kitimat Pipeline Ltd. (500,000 barrels per day) and detailed in its TERMPOL Submission to the Ministry of Transport. It should be noted that different ports could require different numbers of tanker visits to supply 500,000 bpd, depending on draught and legal constraints. However, for the sake of comparison, the study assumes a uniform number of visits per port.

1.5 DEVELOPMENT OF INDICES

In the analysis which follows, it was necessary to work from both qualitative and quantitative data and to combine a considerable number of sets of dissimilar information.

To do so, considerable judgement was used in the development of indices generally representative of the broad range of values at risk. The index numbers for individual sets of data were combined as described below to produce final indices. (Chapter 7 provides much more specific detail on the various indices.)

Four main indices were calculated for each port and associated routes. These included:

- NAVIGATIONAL RISK INDEX: Nautical, hydrographic, climatic and oceanographic data were combined to produce an index of oil spill relative probability for the various port/route options.
- BIOLOGICAL RESOURCE INDICES: Shoreline biological capability, salmon escapements, other fisheries values, marine-associated birds and marine mammals were used to develop indices of ecological value, as distinct from purely economic resource-use considerations.
- ECONOMIC RESOURCE INDICES: These indices focussed on the commercial value of marine resources, on fishing vessels and on recreational craft.
- SOCIAL RESOURCE INDICES: Social values were related to population distributions in coastal communities. Consideration was given to the distinction between non-native and native cultures.

To obtain the final composite indices, the RESOURCE INDEX values were multiplied by the NAVIGATIONAL RISK INDEX values to obtain BIOLOGICAL, ECONOMIC and SOCIAL RISK INDICES for each port/route combination.

In addition to these risk indices, the study also assessed relative oil spill cleanup costs, reviewed air pollution factors and summarized major impacts along alternative pipeline corridors.

As data were used at a uniform level of generalization for the coast, many detailed sources of information were excluded. It is emphasized that consideration of more detailed information would be mandatory in any site-specific study of impact.

The ranking of risks must be regarded as that to be expected <u>on average for the conditions defined</u>. The indices of navigational risk and of resources appear sound, given available methodology and data. However, the selection of route segments, seasonality of parameters and possible areal extent of contamination required careful, judgemental choices. Owing to the difficulties of predicting such study components accurately, the risk of a particular spill in a particular area could be greater than or less than that implied in the final indices. Therefore, the final ordering presented in this report represents the best reasoned judgement of the experts participating in the study.

It is strongly emphasized that the comparisons are <u>relative.</u> Least risk does not imply no risk. <u>Thus, a port/route identified as</u>

being "least risky" in this analysis could, on comprehensive and detailed study, be found completely unacceptable from a Canadian point of view due to specific liabilities, inadequate benefits or the negative impacts of non-marine factors. The converse might also be true. Endorsement of any of the ports analysed here would require further specific assessment of the likely magnitude of spill impact and of resultant environmental costs, together with a judgement that such costs would be clearly overriden by net benefits to Canada.

CHAPTER 2

SUMMARY CONCLUSIONS

1. This report is an assessment of the relative risk from oil spills to the biological, economic and social marine resources of the West Coast. It does not purport to be a detailed environmental impact analysis of any one port or route alternative. The results of the various ranking systems are based solely on marine considerations; inclusion of such other factors as air pollution potential, terrestrial pipeline impacts, cleanup costs and terminal site characteristics could very possibly alter the ranking derived herein. Such additional factors must be integral to the environmental assessments undertaken prior to the approval of any particular oil port terminal.

2. Major tanker terminals at Port Moody, Britannia Beach, Roberts Bank and Cherry Point pose the highest relative risks, whether served by nearshore or offshore routes from Alaska or the Mideast. Should any one of these sites be contemplated for future development or increased production capability, it must be opposed on the grounds of high relative environmental marine risk.

3. Port Simpson, Ridley Island, Kitimat (Hecate, Caamano) and Port Angeles (Juan de Fuca), if served by offshore routes, are the ports presenting the least marine risk. However, any one of them might still be unacceptable owing to specific liabilities, inadequate benefits, or because of non-marine factors such as air pollution potential or terrestrial pipeline impacts.

4. Results on Port Angeles and Kitimat indicate similar relative marine risk and thus do not permit clear conclusions as to which is more risky. Should firm proposals emerge for major tanker terminals at either of these locations, further site-specific technical evaluations must be undertaken, recognizing not only the relative degree of risk at Port Simpson and Ridley Island, but also the importance of various non-marine factors not dealt with in detail in this report.

CHAPTER 3

THE MARINE BIOLOGICAL EFFECTS OF OIL POLLUTION

This chapter gives a general description of the effects of spilled oil on the living resources of the sea. The subject is discussed in greater detail in the appendices volume.

World experience with the environmental effects of accidental and chronic oil spillage into the ocean unfortunately has been growing rapidly in the past few years. The results of observations and studies of oil spills are reviewed regularly by such organizations as the United Nations, the North Atlantic Treaty Organization, the U.S. National Academy of Sciences, the Paris-based Organization for Cooperation and Economic Development and by various scientific groups and individuals, e.g., the "Oil/Environment-1977" Conference recently sponsored by Fisheries and the Environment Canada and the oil industry.

It is difficult to summarize the ecological impact of spilled oil because crude oils vary in their characteristics and in their effects on living organisms. In spite of this, the following five general effects have been identified:

- lethal toxicity,
- sublethal disruption of physiological or behavioural activities such as respiration, feeding or reproduction,
- mechanical interference,
- incorporation into organisms causing accumulation in food chains or tainting, and
- changes in habitats.

How long contamination might persist depends on the kind of oil, the extent and duration of fouling, and on such physical factors as the nature of the shoreline, wave energy and sea temperature.

3.1 FISHERIES

The impact of oil on fisheries is usually most severe in coastal estuaries and nearshore waters because of the importance of these areas in the spawning, rearing and feeding of fish. By far the most acute effects are on the eggs and larval stages of fish and other marine organisms upon which fish feed. Some petroleum fractions are lethal to adult and juvenile fish at low concentrations, although crude oil itself can be quite toxic to fish eggs and larvae (Kuhnhold, 1972).

On the British Columbia Coast, the worst potential impact of oil spills on the commercially harvested fisheries resources would be on Pacific herring, which spawn on red algae and other intertidal vegetation, and on shore rocks if no vegetation is available. Eggs covered with oil would most likely die. After herring eggs hatch, the larvae drift with the current at or near the surface for two or three weeks when they are still very vulnerable. Apart from the mortality of eggs and larvae, tainting of herring products through uptake of petroleum fractions would be virtually certain. The small but lucrative Indian harvest of herring-roe-on-kelp could be disrupted by an oil spill and closure of the fishery for mature roe-bearing herring would probably be necessary.

Populations of salmonids, i.e., the five species of Pacific salmon, steelhead trout and other sea-going trout, generally would be less vulnerable to a coastal oil spill than herring, because the most sensitive stages, eggs and alevins, occur in freshwater. However, adult salmonids must move through potential spill areas to spawn and young salmon spend considerable time near the water surface in estuaries and other coastal waters on their seaward migrations. Not only could oil kill juvenile fish, but it could also destroy the small aquatic organisms on which they feed. Oil can block sensory perception and affect migration, food searching and avoidance of predation. Chemical dispersants and emulsifiers often advocated for cleanup are also toxic to marine organisms, sometimes considerably more so than oil itself, as found in the TORREY CANYON disaster (Smith, 1968). In the worst case, an estuary ecosystem highly important to salmonid production could be seriously disrupted for years.

Groundfish would probably suffer less than other fisheries, with two qualifications:

- Some species have eggs and/or larvae which float close to the surface. Others sometimes lay eggs near shore. These would risk a similar mortality as for herring,
- The use of sinking agents to remove oil slicks could have an adverse effect on the sea-bottom and its inhabitants. Bottom fish might be tainted by petroleum hydrocarbons directly or through the food chain.

Crustaceans including shrimps, prawns and crabs are vulnerable in their larval stages when they are near the surface. Tainting of the commercial catch could be a severe problem. Clams and oysters could be subject to heavy accumulations of oil in the intertidal zone and, although fairly resistant from the point of view of survival, would be very susceptible to tainting.

Other invertebrates including mussels, abalone, scallops, sea urchins, sea cucumbers, squid and octopi would be affected adversely through direct toxicity, uptake of hydrocarbons and degradation of their habitats. They too would be particularly vulnerable in their larval stages. While these species (some of which are very abundant along the coast) are not yet the basis of a significant fishery, they are sometimes important in the food chains of commercially important fish species.

3.2 MARINE-ASSOCIATED BIRDS

Among the damages caused by oil to marine fauna and flora, the oiling of birds is one of the most striking. Mechanically, oil destroys the waterproof qualities of the plumage by disrupting feather arrangement and allowing chilling by water or air, especially during winter months. The oil may not only saturate the outer contour feathers, but also penetrate the down feathers which insulate the bird. Soaked with oil and water, the bird loses its buoyancy and may drown or make its way to shore eventually to die. Continued exposure to cold and inability to feed render the bird incapable of maintaining its body temperature. Complications, such as internal infections and shock, combined with the depletion of body fat, eventually kill it.

The toxic nature of oil also plays a role in the mortality of oiled birds. It has been shown by means of isotope studies that oiled birds preen about 50% of the oil from their feathers in the first eight days after oiling and ingest most of it in the process. Post-mortem work on several species of seabirds have shown pathological conditions of various internal organs. Finally, oil can present serious hazards to the reproduction of birds through contamination of eggs and ingestion of oil.

Of all aquatic birds, alcids and seaducks appear to be the chief victims of oil pollution on a global basis. That these birds constitute the most frequent and largest casualties is related to their presence in heavily travelled sealanes, their large numbers, their time spent on the water and their behavior towards oil slicks. Both alcids and seaducks dive for their food so that when they break surface in an oil slick, they become coated with oil. Oldsquaws have been observed to land on oil patches where wave action is less (Curry-Lindahl, 1960). During an encounter with an oil slick, common murres have escaped by diving, but risked oil contamination on surfacing (Bourne, 1968).

Although gulls, like alcids and seaducks, are numerous in the North Pacific, they are much less vulnerable to oil pollution because of their more aerial habits. Gulls can fly over surface pollution and usually have little cause to descend onto it. Likewise, waders spend much time on shorelines above deepwater areas and usually are merely stained. Gulls and waders are vulnerable, however, to serious oil pollution under certain conditions. Oil carried onto their roosting areas on night tides may catch gulls at rest on the tideway. Waders may become contaminated by stranded oil when they are feeding at low tide. Short-legged waders such as the dunlin are especially vulnerable. Migrating geese also appear to be susceptible to oil pollution.

In most oil pollution disasters involving birds, it has been impossible to determine how populations as a whole are affected, because population sizes of seabirds prior to disasters are often unknown. In some cases where such baseline information was available, the resulting reductions in populations were dramatic. As a consquence of the recurring heavy mortality from oil pollution in the Baltic, the number of oldsquaws migrating through Finland was reduced by 1960 to 1/10 the number recorded in the late 1930's (Bergman, 1961). The number of puffins on Ile Rouzic in Sept-Iles, Brittany, dropped from 5,000 birds to about 600 as a result of the TORREY CANYON disaster (Milon and Bougerol, 1967). The local population of common murres at Ormes was depleted by

75% in an oil pollution incident there that followed a collision involving the tanker HAMILTON TRADER (Hope-Jones et al, 1970). The breeding populations of common eiders in the oil polluted Kokar and Foglo Archipelago decreased by 25-33% and 20.6%, respectively, after the grounding of the tanker PALVA (Soikkeli and Virtanen, 1972). A tanker accident in 1968 in South African waters resulted in oil pollution which wiped out the entire populations of jackass penguins of Dyer Island, estimated at 8,000 birds in 1963 (Westphal and Rowan, 1970). Along with the estimated 14,000-19,000 penguins killed in the ESSO ESSEN disaster, both incidents may have destroyed ten percent of all the jackass penguins breeding on Cape Island.

3.3 MARINE MAMMALS

In British Columbia, oil pollution can potentially affect the sea otter, five species of pinnipeds (seals and sea lions) and 20 species of cetaceans (whales, dolphins and porpoises). Some studies have been done on the effects of oil on pinnipeds, but none on the sea otter or cetaceans; thus there is a degree of speculation on the exact effects of oil on marine mammals.

The effects are likely to vary considerably between species because of differences in insulation and behaviour. For the sea otter, insulation is provided by a dense fur coat (pelage) rather than blubber. Fouling of the pelage would undoubtedly result in death from chilling and stress. As the species inhabits inshore areas, is slow-moving and nonmigratory, it probably would be unable to avoid oil slicks. The fur seal uses both fur and blubber for insulation and thus fouling could cause death with this species too. However, the fur seal is pelagic and highly mobile and might be able to avoid or quickly swim through oil patches.

Other pinnipeds use primarily blubber for insulation, thus eliminating the stress of chilling from fouled pelage. Studies on sea lions and hair seals suggest that oil fouling and ingestion for short periods may not be particularly harmful for healthy individuals. No adverse effects from fouling could be shown on local populations of California sea lions and elephant seals following the Santa Barbara oil spill (Le Boeuf, 1971; Brownell and Le Boeuf, 1971; both quoted from Davis and Anderson, 1976). Experimental studies involving the immersion of harp and ringed seals in oiled water for 24 hours and the forced ingestion of oil showed transient eye damage and minor kidney and possible liver lesions (Geraci and Smith, 1976). There are indications, however, that individuals in poor condition may die from the additional stress that oil contamination would provide. In nursing grey seals which had become fouled by an oil spill, no differences could be shown in the rate of growth or mortality compared to uncontaminated seals (Davis and Anderson, 1976). Stress from human disturbance in attempting to clean the grey seal was suggested as being a greater cause for pup mortality than oil contamination.

Assuming that cetaceans can swim and breath normally in oil-coated waters, this group probably would be the least affected. Relying upon blubber for insulation, they would not suffer cold stress from oil contact. As well, they are highly mobile and could probably swim through oil slicks in a relatively short time.

3.4 MARINE ECOSYSTEMS

There have been very few thorough studies on the effects of oil on complete local populations of marine plants and animals. The main difficulty is in anticipating a year or more in advance where a spill might occur so that the undisturbed system can be studied and documented to provide baseline information. At best, there have been a number of excellent investigations launched immediately after the occurrence of a spill. A summary of major oil spills and their biological impact is given in the U.S. National Academy of Sciences report "Petroleum in the Marine Environment" (1975).

Crude oil has been shown to be toxic to microscopic plants and animals (the phytoplankton and zooplankton) which are the base of the most important food chains in the sea (Mironov, 1972). (Included in the zooplankton are the larvae of many species of fish and invertebrates.) Benthic organisms can be exposed to residues in sediments from an oil spill for a long time. Both extensive mortality and severe tainting problems of various species can affect marine communities for several years. However, the more important aspects of oil pollution may be the long-term disruption of the complex interrelationships between species and the disturbance of trophic levels in the food web of coastal marine ecosystems.

CHAPTER 4

THE MARINE PHYSICAL ENVIRONMENT

4.1 WATER MASS ORIGINS, MIXING AND MOVEMENT

This section briefly describes the main oceanographic features of the coastal waters of British Columbia and northwest Washington State. A more complete description is provided in the appendices volume.

In the context of this study, the importance of a good understanding of British Columbia and northwest Washington coastal waters is threefold. First, and most obvious, is the fact that spilled oil moves with the water, whose motion is derived from wind and tidal forces which are much modified by topography, stratification and oceanic influences. Second, is the dependence of the living resources on physical processes for oxygen, nutrients and dissemination of eggs, larvae and juveniles, etc. Third, the strong tidal currents in narrow passages, along with the effects of winds and freshwater runoff, play a significant role in the navigational hazard to tankers.

It is clear that the oceanographic regimes on the coast are highly variable, both in time and place and that they are far from being completely described or understood. This complicates the task of categorizing the living resources and their habitats, and makes it virtually impossible to predict beforehand where hypothetically spilled oil might <u>ultimately</u> reach the shore or sea floor.

Oceanic Influences

B.C. coastal waters are strongly influenced by processes offshore in the northeast Pacific Ocean, called in oceanographic language "the subarctic east Pacific", to indicate that it is more arctic than tropical. Northeast Pacific waters characteristically show three distinct layers:

- a surface layer about 100 meters deep whose properties vary with season and location, and which is less saline and less uniform near the coast,
- a stable layer about 60 meters thick in which the salinity increases rapidly with depth while the temperature is nearly constant, and
- a lower layer in which temperature decreases and salinity increases gradually with depth to the ocean floor.

The principal ocean current which influences the B.C. coast is the Alaskan gyre or eddy which in winter flows northward from about 45°North latitude along the coast of Vancouver Island, past the Queen Charlotte Islands and into the Gulf of Alaska. In summer, the Alaskan gyre appears to turn north at about 50°North, so that the west coast of Vancouver Island is more influenced by the weak, variable and south-flowing California current. Both the above currents are easily masked by the effects of storms and strong winds. In general, the surface movement off Vancouver Island is dominated by slow eddies and meanders.

Observations of sea-surface temperature and salinity taken over many years at coastal light stations and from the weatherships travelling to and from Ocean Station P (50°N, 145°W) show relatively cold saline water off Vancouver Island during the summer. As this phenomenon is most evident during periods of northwest winds, it is attributed to upwelling of deep water, perhaps from as deep as 200 to 300 meters. The annual deep inflow into some coastal inlets, which is an important flushing mechanism, has been attributed to this upwelling. Another probable effect of the northwest winds in summer is enhancement of the southeast-setting current along Vancouver Island and inducement of a narrow, weak, variable, southeast current close to the west coast of the Queen Charlotte Islands.

North Coast

For the north coast of British Columbia, oceanographic information is scarce and comes mainly from rather general, exploratory cruises carried out in the 1950's and early 1960's. Long-term current measurements are lacking, so water circulation has to be inferred from broad oceanographic patterns, short-term current measurements and wind and tidal-driving mechanisms.

In winter, the dominant driving force is the southeast wind which produces a northward flow through Hecate Strait. This flow continues seaward through Dixon Entrance, along the north shore of Graham Island and then northward along the Alaskan coast. It introduces relatively warm saline water from the south into Chatham Sound, northern Hecate Strait and eastern Dixon Entrance. Because of strong winds, low river flow, and strong tides in the area, Hecate Strait and Dixon Entrance are quite well mixed and uniform during the winter season.

In the spring, the southeast winds subside and the freshwater discharges of the rivers increase to their principal maxima in June followed by secondary maxima in October. A low-salinity surface layer forms; flushing to seaward of the surface waters of Chatham Sound and Dixon Entrance can occur, causing an intrusion of cool saline water into Dixon Entrance at depth.

In summer, westerly winds can cause an inward flow of surface waters into Dixon Entrance along the north shore of Graham Island.

A feature of the tidal motion in the northern area is a gyre in Dixon Entrance set up by the meeting of the tides. This circular motion - out along the north shore and in along the south shore - is more apparent at times of weak winds and low river run-off. Another feature is the significant tidal current in the region of Chatham Sound and the Skeena estuary caused by a large tidal range and constricted channels.

South Coast

In Juan de Fuca Strait and the Strait of Georgia, the major influence is the Fraser River, which produces a low-salinity surface layer moving predominately seaward and induces a compensating deep inflow of colder, more saline oceanic water. This pattern is clearly evident in Juan de Fuca Strait, but in the Strait of Georgia the surface motion is more complex. There is a general, though intermittent, counter-clockwise surface circulation in the southern Strait and a predominately northward current from the Fraser delta around Point Grey. The surface currents are strongly influenced by winds as well as by the rate of discharge of the Fraser River, which has its maximum in June.

Tidal currents are important to the circulation of the southern region and some of the principal passages have tidal currents up to four knots, although in Juan de Fuca Strait, they seldom exceed two knots. In the northern half of the Strait of Georgia, tidal effects are generally weak, but in the passages leading northward between Vancouver Island and the mainland, currents are strong - up to 15 knots in Seymour Narrows. In the main northern channels connecting the Strait of Georgia with Queen Charlotte Sound, the water is quite well mixed and vertically uniform, although local layering occurs where rivers enter the calmer side channels. In Queen Charlotte Sound, there is an upper layer of lower salinity.

4.2 HYDROGRAPHIC FEATURES

The coastline of British Columbia and northwest Washington is rugged, mountainous and indented with deep fjords, frequently narrow and winding, sometimes constricted by rocks or shoals, and generally lacking in safe anchorages for large ships. When considering the potential for oil ports and supertankers the possibilities have been reduced to a northern area approached through either Dixon Entrance or Queen Charlotte Sound for ports at Port Simpson, Ridley Island, Kitimat and Bella Coola, and a southern area approached through Juan de Fuca Strait for Canadian ports at Britannia Beach, Port Moody, Roberts Bank and Esquimalt and American ports at Cherry Point, Burrows Bay and Port Angeles. Figure 4.2.1 locates coastal place names referred to in this section.

Northern Ports

Any tanker route traversing Dixon Entrance would pass either north or south of Learmonth Bank, which lies in the middle of the entrance, has a charted depth of 120 feet and should be avoided as a possible hazard. Depths on the bank are uneven and the area is subject to tide rips. Sailing Directions for the Entrance include the following caution: "On account of the several dangers and somewhat irregular tidal streams, the navigation of Dixon Entrance from the west is attended with considerable risk in thick weather, when extreme caution is necessary."

On the Queen Charlotte Island shore, Tow Hill is the only good landmark on an otherwise featureless part of the coast. The low-lying land in the vicinity of Rose Spit and that across in the area of Triple Island provide poor radar identification when approaching the Triple Island pilot station. Around the eastern extremity of the shoal areas, east of Rose Spit, are shoals of 49 ft., 36 ft. and 43 ft. and careful attention to soundings is therefore necessary. Again Sailing Directions warn: "Great care should be taken in the vicinity of Rose Spit, especially at night or in thick weather, as tidal streams set strongly across it. Also, when approaching from the west, it should be kept in mind that, as the spit is steep on its northwest side, soundings do not indicate the danger in sufficient time to take avoiding action." It is further noted that, "Heavy overfalls having the appearance of breakers are met with off Rose Spit during the strength of the streams, principally on its north side near the edge of the deep water." It is of interest that a comparison of hydrographic surveys of 1909 and the 1960's indicate no significant changes in the bottom topography.

Approximately 12 miles north of the outer edge of the Rose Spit shoals is Celestial Reef with depths of 13 ft. and 52 ft. which could be of concern to ships taking a more northerly approach to Triple Island. It should be noted that towards the U.S. side of Dixon Entrance extreme magnetic disturbances have been reported.

Northwest of Triple Island are a series of shoal areas, including Stenhouse Shoal with an exposed rock; to the northeast are Hanmer Rocks, which dry to 17 ft., and nine other shoals with depths of less than 85 feet. For large ships inbound the clear channel would be reduced at one point to a width of about 3600 ft. Having due regard for many rocks and shoals bordering the channel, particularly Moore Shoal with a depth of 42 ft. in the middle of Chatham Sound, deeper water then exists to the vicinity of Port Simpson or Ridley Island. Depending on the siting of the port facilities, some dredging might be required in the immediate approaches. There are no recommended safe anchorages along this route suitable for large ships such as supertankers.

The passage north around Dundas Island to Port Simpson and Ridley Island might be navigationally preferable if West Devil Rock, Celestial Reef, McCullock Rock and East Devil Rock were marked. The approach would then be south in clear water through Main Passage.

Proceeding south into Hecate Strait outside Triple Island, the route would be to the westward of Butterworth Rocks, the passage at this point being about three miles wide. It would be necessary to pass well to the eastward of the shoal water that extends over 20 miles from the east shore of Graham Island and at the same time to remain aware of the shoals off the mainland side of Gore-Langton Rock, Grenville Rock, etc. From Browning Entrance the route via Principe Channel, Otter Passage, Lewis Passage, Wright Sound and Douglas Channel is mostly clear and deep to Kitimat. Note must be taken, however, of shoal areas extending into Browning Entrance from the north end of Banks Island and of shoals in Principe Channel within 0.7 miles of centre channel on the west side of McCauley Island and within 0.45 miles of centre channel southwest of Alexander Shoal. The only other underwater hazard on this route is Nanakwa Shoal, depth 49 ft., near mid-channel at the entrance to Kitimat Arm. West of Anger Island, Principe Channel itself narrows to a width of 0.9 miles. In Lewis Passage the width is 1.1 miles. Just north of Anger Island is Anger Anchorage which is the only place in the entire area that appears to offer possibilities as a large vessel anchorage. Several large course alterations would be required on this route, the most critical being that of about 110° when entering Wright Sound and crossing the main north-south traffic flow of the "Inside Passage."

If the route chosen were outside the Queen Charlotte Islands, instead of through Dixon Entrance, no navigational hazards would be encountered. Course should be laid well south of Cape St. James to avoid Gray Rock (depth six feet) about six miles south of the Cape. Five other shoals in the depth range 90 - 120 ft. exist on the west side of the track north into Hecate Strait and are an extension of the shoal water on the east coast of the Queen Charlotte Islands.

Although hazardous shoals exist in Caamano Sound, there is a clear channel of at least two miles in width. The passage to Kitimat is then similar to that already described, including several rather drastic alterations of course in relatively confined areas.

Bella Coola is approached from seaward through Queen Charlotte Sound, Fitz Hugh Sound, Burke Channel and North Bentinck Arm. The route from Queen Charlotte Sound to Fitz Hugh Sound offers alternatives of North and South Passages. Without detailing all the potential hazards, the route is generally very similar in aspect to those approaching Kitimat. The channel width in Fitz Hugh Sound narrows to 1.5 miles. There is a "bar" off Hvidsten Point in Burke Channel, where the deepwater channel is narrowed to about 1800 ft. by an extensive shoal of 96 ft. and tide rips are encountered. Otherwise, the channels here are clear and deep, with fewer and less drastic turns than are encountered when proceeding to Kitimat. Restoration Bay appears to be the only possible anchorage in Burke Channel, but even this could be of doubtful value to very large crude carriers (VLCC's).

In the foregoing, underwater hazards and shoals have been discussed at some length, but these dangers can be marked and may be of less overall significance than the actual problems of maneuvering in relatively confined passages, especially in emergency situations, such as collision approach courses with other vessels or mechanical breakdown coupled with the lack of emergency anchorage areas.

Southern Ports

In the southern area, there are no significant navigational problems involved in approaching and traversing Juan de Fuca Strait as far east as Port Angeles, though Swiftsure Bank with a least depth 112 ft. at the entrance to the Strait should be avoided, and the strong tidal currents demand a careful approach from seaward, especially in thick weather.

If proceeding anywhere near Victoria/Esquimalt, several shoal areas have to be avoided. The first lies off Race Rocks, next is Constance Bank, depth 60 ft., directly south of Victoria, and finally there is another shoal (90 ft) further to the southeast, which would have to be avoided by any large ship en route to Haro Strait. Tidal currents in the vicinity of Race Rocks can be strong, at up to six knots. On the Haro Strait route are several dangerous shoals, which constrict the navigable channel to a width of one mile in places. Currents between Turn Point on Stuart Island and East Point on Saturna Island are powerful, sometimes reaching five knots. From East Point there is clear passage north of Alden Bank across to Cherry Point.

An American route to Cherry Point via Rosario Strait is similar with channel widths of less than a mile in places. There are also shoals and fairly tight turns. From Port Angeles to Burrows Bay, the route is uncomplicated and should present few problems.

There are no navigational problems to be encountered in the Strait of Georgia en route to Roberts Bank, Port Moody or Britannia Beach. At Roberts Bank, the delta area must be approached with caution, being steep on its west side with no advance indication, therefore, of shoaling. Vancouver Harbour itself has a limiting dredged depth of 55 ft. The route to Britannia Beach is clear and deep with the exception of a "bar" between Defence Island and Porteau Cove where, in mid-channel, there is a shoal head of 114 ft. The least channel width is about 0.7 miles, east of Anvil Island. There are no emergency anchorages in Howe Sound, but elsewhere on the southern routes emergency anchoring should not present a problem. Major course changes are required, especially through Rosario and Haro Straits, but these would not be as frequent or as large as on some of the northern routes. The greatest dangers would probably come from manoeuvring in relatively confined passages and encountering numerous other deep-sea vessels.

4.3 CLIMATIC FACTORS

High wind speeds and restricted visibilities relate to navigational risks as do, to a lesser extent, freezing rain, mixed rain and snow and melting snow (the latter affecting radar signals). Wind speeds and directions and the persistence of wind regimes determine, along with ocean currents, the movement of oil spills. Cleanup feasibility and efficiency are related to wind and visibility. Finally, air quality at off-loading sites is determined to a significant degree by the capability of the atmosphere locally to disperse pollutants. Air emissions and pollution potential are further detailed in Section 6.1.

The flow of the weather systems from the west is maximum across the coast of British Columbia in the winter months. During that season, frequent travelling low-pressure systems, i.e., mid-latitude extra-tropical cyclones and their associated weather fronts, cross the coast often accompanied by strong winds and heavy precipitation. Although weather conditions can and do change rapidly with the passage of such disturbances, prevailing winds in winter are from the southeast at most locations. Shorter-lived periods of northwesterly winds usually follow the passage of such storms.

Topography has a marked influence on coastal climate. The prevailing wind directions just described are aligned with the northwest to southeast orientation of the coastline, including its major mountain barriers. On a more local scale, winds are funnelled by valleys and blocked by mountains. Such effects are particularly evident in coastal inlets, which extend deeply into the Coast Mountains and thereby provide passageways for the movement of surface airflows. In many such inlets which extend to the north or northeast, outflow winds prevail during winter months. At times, the build-up of cold Arctic air in the interior of the province leads to strong northeasterly "squamish" winds, as the dense air rushes over passes and down inlets to the sea. A further local effect is evident from precipitation records along the coast. Whereas most winter precipitation along the main coast falls in the form of rain, snow is common at the heads of inlets. Between the head and mouth of inlets, there is often a zone of mixed rain and snow or, on occasion, of freezing rain.

In summer, the frequency and intensity of storms decrease as the north Pacific anticyclone, or high pressure system, strengthens, displacing zonal air currents to the north. The frequency of northwesterly winds along the coast increases markedly, while westerly winds become strongly dominant in Juan de Fuca Strait. In mainland inlets airflow reverses from the winter direction to become predominantly southerly or inflowing during the summer. Although the frequency of restrictions to visibility associated with precipitation generally decreases throughout the area, fog frequencies increase along the outer coast, making average summer frequencies of reduced visibility there as high or higher than those of winter.

For purposes of the relative ranking of routes and port sites as detailed in Chapters 7 and 8, wind speeds and visibilities were utilized directly. A brief review of these factors follows.

The percentage frequency of wind speeds greater than or equal to 25 miles per hour was selected as an indication of adverse wind conditions. Analyses based on observations from land stations and ships for winter and summer seasons are presented in Figures 4.3.1 and 4.3.2. Figure 4.3.1 shows that adverse winds dominate the open waters of the north coast in winter. Although the frequency of strong winds is generally much reduced in summer, persistent west winds in Juan de Fuca Strait are responsible for locally higher frequencies there.

Seasonal analyses of the percentage frequency of visibilities of two miles or less are presented in Figures 4.3.3 and 4.3.4. In the precipitation-dominated winter season, visibility in coastal inlets is considerably lower than in summer, although the entrance to Juan de Fuca Strait is an exception with a high incidence of summer fog.

CHAPTER 5

THE MARINE RESOURCES AT RISK

5.1 FISHERIES RESOURCES

The effects of oil pollution on fisheries resources have been generally discussed in Chapter 3. It is proposed here to focus specifically on the critical fisheries problems on the British Columbia and Washington coasts with respect to oil pollution.

Herring

By far the greatest impact of oil would be on the herring fisheries, with a total catch in 1976 of 80,000 tons in B.C. Herring populations have only recently recovered from an all-time low in 1967 when the fishery collapsed, in part from overfishing and possibly also from environmental factors. Since the fishery moved into the business of herring roe for export to Japan, it has become particularly lucrative, with the carcasses from roe production being used for reduction purposes. A small part of the total herring catch goes for human consumption and bait (6,071 tons in 1976).

The distribution of the herring fishery is shown in Figure 5.1.1. One third of the catch comes from the west coast of Vancouver Island (Barkley Sound-Clayoquot Sound-Nootka Sound areas). The bulk of the remainder is taken from Thompson Bay on the central coast. The Chatham Sound area was highly productive at one time, then it declined; it is now coming back.

It is the egg and early larval stages of the Pacific herring which are the most vulnerable to oil pollution; impact would be greatest during the main spawning period between the last week in February and the third week in April. The eggs are usually deposited within a depth range of two fathoms (four meters), one fathom on either side of low water. The herring spawn largely (60%) on red algae, with some (ten %) on eel grass, mainly in the Strait of Georgia and on the west coast of Vancouver Island; some (ten %) on brown algae (kelps and fucus), mainly on the central coast on the Queen Charlotte Islands; and the remainder (20%) on rock. Herring prefer vegetation to substrate for spawning (less than two percent of spawn is on rock if vegetation is present), but will choose rock if no seaweeds or eel-grass are available. If the kelp *Macrocystis* sp. is present, as much as 90% of the herring spawn will be deposited upon it.

In the Queen Charlotte Islands, the harvesting of kelp encrusted with herring eggs contributes to a small, but culturally important, native Indian industry. The practice apparently consists of coralling ripe herring in an area of about 40 ft by 40 ft (12 m x 12 m) and hanging strips of kelp among the fish. The sticky herring eggs are deposited on the kelp fronds and then harvested for export.

The gillnet fishery takes 30-40% of the herring catch over a period of two to three weeks of fishing, while the seine fishery harvests the remainder in a so-called "instantaneous fishery" lasting for 15 minutes to two hours when the herring are considered to be in their prime for roe, just before spawning. (There is usually a second smaller wave of spawners following the first spawning by about two weeks.) The aim is to have at least ten percent of the body weight of the fish as roe. An oil spill at the time of the seine fishery would affect not only the herring spawn but also the fishing fleet and gear. Furthermore, the substrate used by herring for egg deposition could be affected for more than one spawning in the same year or in subsequent years. The areas of herring spawn deposition on the British Columbia coast during 1976 are given by Webb (1976).

Larval herring are vulnerable to an oil spill, especially in the earliest stages following hatching when they are at the surface. However, they drift with the currents and have a better opportunity of escaping oil than the eggs attached to various nearshore substrates.

Salmon

The salmon fishery of the five species of Pacific salmon, Oncorhynchus spp., is the most valuable B.C. fishery at risk economically in the event of an oil spill. These anadromous species have several life stages that could be affected by an oil spill. However, the most vulnerable stage (aside from the egg and alevin stages which are primarily confined to freshwater), is the juvenile seaward migrant stage when the young salmon are in estuaries and nearshore marine areas. Their migration period and residence in nearshore areas generally occurs between February and October. Depending on the species and the timing of their seaward migration, the juveniles may spend two months or more in the estuarine nursing grounds with some species also spending time in nearshore coastal waters before proceeding offshore. At this time, the salmon themselves could be particularly vulnerable to oil pollution, although another serious effect could arise from the effect of oil on the food organisms of young salmon.

The adult salmon migrating to their spawning grounds, which usually occurs between June and January, could also be affected by an oil spill. Pollutants such as oil can cause avoidance by the fish and disruption of their schooling behaviour, with subsequent disorientation and possible reproductive failure. However, the effect of closure of a salmon fishery by authorities, because of possible oil contamination and tainting, would be the most serious to the industry. The effects of oil on the fish themselves, under the worst circumstances, could eliminate or seriously reduce a spawning cycle for many generations.

Groundfish

The next most important potential impact of oil pollution on the fishery resources would be on groundfish stocks having pelagic eggs and/or larvae. The general distribution of groundfish is shown in Figure 5.1.2. One commercially important groundfish species which has eggs that may float at or near the surface is the English sole (sometimes referred to as lemon sole), Parophrys vetulus. Another species having eggs behaving in the same way is the starry flounder, Platichthys stellatus, but the commercial catch of this species has been comparatively small (106,000 lb. in 1976). With a total catch of 2,882,000 lb. in 1976 (Table 5.1.1), the English sole ranked eighth in poundage of Canadian trawl landings. Because of the demand for this delicately-flavoured species, its landed value ranks it higher in importance than the catch volume would indicate. The largest catches (2,080,000 lb. in 1976) of English sole are from the northern half of Hecate Strait, Dixon Entrance and Chatham Sound. This species spawns from December to March with the eggs floating in the surface layer, which is sometimes in the froth zone. They hatch after about 9 days and then the larvae spend time at or near the surface as part of the zooplankton. Both eggs and larvae of the English sole would be vulnerable to oil pollution during this period.

It should be noted that the rock sole, Lepidopsetta bilineata, is also a valuable commercial species, with a total B.C. catch of 4,749,000 lb. in 1976 (Table 5.1.1). This species has a demersal (sea bottom) egg but a pelagic (open water) larval stage. It spawns from late winter to early spring. Thus oil pollution in Hecate Strait and Dixon Entrance from February to April could seriously affect the larvae of the rock sole.

The Pacific cod, Gadus macrocephalus, is the species of groundfish caught in greatest volume on the B.C. coast (22,193,000 lb. in 1976 - Table 5.1.1). It spawns in winter on banks of clean gravel off the southwest coast of Vancouver Island, in small areas along the southeast coast of Vancouver Island and in Hecate Strait. Eggs are demersal, but they may rise off the bottom depending on the density of the near-bottom water. Eggs hatch in eight or nine days at 11°C, in 17 days at 5°C and in about four weeks at 2°C in northern waters. The larvae are pelagic, but it is unknown at what depth they mainly occur. Some of the banks in Hecate Strait where cod spawn are comparatively shallow (20-25 fm.), and it is conceivable that heavy oil could be mixed down to the bottom and affect cod eggs and larvae during heavy winter storms. Otherwise, the Pacific cod normally would be outside the depth range of oil spill influence.

Pacific halibut, Hippoglossus stenolepis, contributes to the most valuable groundfish resource on the Pacific coast. The fishery is managed by the International Halibut Commission. From a normal annual yield of 15,000 tons, the present catch is down to 5,000 tons from the Commission's Area 2, nearing the all-time low of 1932, partly because of current low recruitment and possibly because of adverse environmental factors. In 1975, the catch was 6,000 tons from Area 2, of which 3,000 tons came from the B.C. coast.

Eggs of the Pacific halibut are deep pelagic, laid at a depth of 200-300 fm. in winter, mostly from November to January. Eggs take about five days to hatch. Then the larvae emerge and begin to rise in the water column for the next four months, but usually do not go shallower than 100 fm. At the end of four months the metamorphosed larvae settle to the bottom as young halibut. Except in shallow water

TABLE 5.1.1 CANADIAN TRAWL LANDINGS (10^3 lb) OF GROUNDFISH, BY SPECIES, AND TOTAL EFFORT BY INTERNATIONAL STATISTICAL AREAS IN 1976

Species	Area									Total
	4B	3C	3D	5A	5B	5C	5D	5E	6	
English sole	289	99	tr.	2	6	406	2,080	-	-	2,882
Rock sole	130	319	53	394	689	606	2,558	-	-	4,749
Petrale sole	9	447	30	104	84	20	48	-	-	742
Dover sole	121	52	tr.	5	112	44	2,207	-	1	2,542
Rex sole	1	8	tr.	-	tr.	7	275	-	-	291
Starry flounder	23	9	-	-	-	4	70	-	-	106
Turbot	5	269	22	89	189	152	2,164	-	-	2,890
Other flatfish	-	20	-	-	-	-	-	-	-	20
Pacific cod	2,045	5,329	194	1,684	1,937	3,275	7,728	tr.	1	22,193
Lingcod	94	1,545	243	388	528	82	135	tr.	tr.	3,015
Sablefish	2	492	tr.	5	239	5	91	1	7	842
Pollock	57	10	4	152	882	427	1,385	tr.	-	2,917
Pacific ocean perch	tr.	3	-	234	3,114	108	81	174	136	3,850
Other rockfish	69	404	396	734	1,636	163	1,044	tr.	4	4,450
Misc. species	24	30	8	23	28	32	296	-	-	441
Dogfish	181	-	-	-	-	-	7	-	-	188
Animal food	22	24	13	47	6	48	60	-	-	220
Reduction	-	22	-	181	410	5	44	-	-	662
Total Landing	3,072	9,082	963	4,042	9,860	5,384	20,273	175	149	53,000
Total hours	5,861	7,469	589	3,255	5,333	2,609	11,118	83	54	36,371

tr. = less than 500 lb.

(less than 25 fm.), it is not anticipated that halibut would be affected by an oil spill. However, any sinking agents used to remove oil on the surface and deposit it on the bottom could be devastating to halibut spawn.

Crustaceans

Because they tend to live on or near the bottom, all crustaceans could be affected by weathered oil or sinking agents either directly or through the benthic food chain. The larvae of some crustacean species come to the surface and therefore also may be adversely affected by floating oil. The general distribution of the Dungeness crab, Cancer magister, along the British Columbia coast is shown in Figure 5.1.3. The most significant populations are off Rose Spit in the Queen Charlotte Islands, off the Fraser River estuary and in Boundary Bay.

The Dungeness crab mates in summer usually in shallow water. Eggs are carried by the female (berried females) until they hatch. The larval, or zoea stage, is near-surface, pelagic and lasts about 120 days from about the beginning of April to the end of August. The zoea are found usually in large quantities among floating detritus where they seek shelter and food. Just before the last stage of the zoea, the larvae moult and settle to the bottom, at which time the crab is considered to be highly vulnerable to oil pollution. Thus an oil spill in the Rose Spit area during August and early September could be particularly destructive to both adults and larval crabs.

There are five species of smaller commercial shrimp in British Columbia: Pink (Pandalus borealis), Smooth Pink or Ocean Pink (Pandalus jordani), Side-stripe or Giant Red (Pandalopsis dispar), Coon-stripe (Pandalus danae), and Hump-back or King (Pandalus hypsinotus). One species of larger shrimp is referred to as a Prawn or Spot, Pandalus platyceros. Distributions of shrimps and prawns along the B.C. coast are shown in Figure 5.1.4. Except for the prawn which is trapped, all species of shrimps are taken by shrimp trawls at a depth of 10-60 fm. on a muddy bottom. However, shrimps can undergo vertical migration and may come right to the surface. The adult prawns sometimes move into shallow water at depths between low tide and five fathoms. They could be affected by an oil spill under these circumstances, especially during intensive mixing in winter storms.

The zoea (larval stages) of shrimps and prawns are pelagic and possibly undergo vertical migration. The eggs hatch in water of 50 fm. depth or less during autumn or early winter. The zoea drift into water 25 to 35 fm. deep. It is not known whether zoea of the smaller shrimps are present at the surface at anytime, although plankton hauls taken during the day have never shown them to be in the surface layer. They may come to the surface at night. Zoea of the prawns have been shown to migrate mainly between the bottom and mid-depth.

There are four species of "tanner crab" along the B.C. coast, none of which is apparently available in commercial quantities. A similar shelf species thought to be present in commercial quantities is Chionoecetes bairdi, taken by the U.S. industry; it ranges from

Washington State to Kodiak, Alaska. The zoea of these species are pelagic, but it is not known whether they frequent the surface waters in the same way as Cancer magister.

The King crab, Paralithodes camtschatica, is found in a few spots along the B.C. coast such as Skidegate Inlet in the Queen Charlotte Islands and Observatory Inlet on the northern B.C. coast, but not in commercial quantities. Probably only the zoeal stage would be significantly affected by oil.

Molluscan Shellfish

The distributions of scallops, Platinopecten caurinus, and other molluscan shellfish are shown in Figure 5.1.5. Scallop beds are generally in quite deep water; adults would be affected by oil only if sinking agents were used to combat it and/or extremely stormy conditions mixed the oil to the bottom. The larval stage is pelagic and it is conceivable that an oil spill would adversely affect scallop larvae.

Abalone, Haliotis kamtschatkana, is taken in shallower waters, and the same conditions as with scallops generally apply.

Other species of commercial shellfish, such as oysters and clams, are intertidal and shallow subtidal. Oil covering beaches where these shellfish are found could be directly toxic to them, taint their flesh, or in severe cases of oil blanketing the intertidal zone, suffocate them. The shellfish industry in British Columbia is small compared to other segments of the fishery, but it contributes to family-type, commercial operations as well as to recreational collecting, and therefore merits preservation.

Other Fisheries

There are other species along the British Columbia coast which could be commercially exploited. These include the sea urchin, Strongylocentrotus franciscanus, squid, Loligo opalescens, and sea cucumbers, Parastichopus californianus. Although all these species are undoubtedly sensitive to oil pollution, especially in the egg and larval stages, they do not represent significant commercial or recreational fisheries at present. Their eggs and larvae, however, may contribute to food of commercially important species.

5.2 MARINE-ASSOCIATED BIRDS

All aquatic birds breeding on land adjacent to, and feeding in, marine waters are included here as seabirds. Species of seabirds breeding along the Canadian West Coast include two storm petrels, three cormorants, seven alcids and one gull. Visiting seabirds such as albatrosses and shearwaters plus freshwater nesters such as loons, ducks, geese and swans spend some time on the B.C. coast, but breed elsewhere. Migrants such as black brant, Branta nigricans, black-legged kittiwakes, Rissa tridactyla, and Northern phalaropes, Lobipes lobatus, travel through the region. Some species are classed as both visitors and migrants, e.g., some Arctic loons, Gavia arctica, remain in B.C. waters during the winter, but most winter further south. Hundreds of thousands of loons migrate north along the coast in May. All three groups of aquatic birds, with the exception of some non-stop travelling migrants, feed in coastal waters; they are most vulnerable to oil pollution as they concentrate in small areas for breeding, resting and feeding.

Distribution of Birds at Sea along the B.C. Coast

Aerial surveys on birds within the first 50 miles of the outer coastline indicate that birds congregate west of Dixon Entrance, along the west coast of Vancouver Island and at the entrance of Juan de Fuca Strait. At Dixon Entrance, common murres dominate in winter and small alcids (auklets) in the fall. Auklets also congregate 30 to 40 miles further westward from there. Along the west coast of Vancouver Island, most birds are found within ten miles of the shore; shearwaters dominate in summer and gulls in fall. At Juan de Fuca Strait, the highest bird densities occur 20 to 30 miles out at sea and consist mostly of California gulls, *Larus californicus*, in the fall and gulls and shearwaters in winter.

Aerial surveys conducted along the west coast of Vancouver Island during August have shown many more birds along the exposed shoreline than in protected inlets. Most numerous in summer are California and glaucous-winged gulls, *Larus glaucescens*. More than half the observed birds are migrants, such as Arctic loons, shearwaters, California gulls, Bonaparte gulls, *Larus philadelphia*, and Heermann's gulls, *Larus heermanni*. A shift from exposed to protected waters occurs in autumn. Marbled murrelets have been the most numerous birds observed in surveys conducted by boat in the protected waters of Vancouver and Queen Charlotte Islands during summer, but they disappear from protected inlets during autumn.

During autumn and winter, waterfowl concentrate in certain coastal inlets and marine deltas. The largest wintering areas along the B.C. coast are at Boundary Bay and the Fraser delta foreshore. Tens of thousands of ducks, geese and Western grebes rest and feed there. These mud flats and estuarine marshes also serve as a roosting place for 35 - 45,000 (1970) glaucous-winged gulls from October to March. One of the most abundant (26,000 - 41,000) shorebirds foraging on the intertidal area is the dunlin. Other B.C. wintering areas contain far fewer birds, but the total number of birds in all the other areas combined may be equal to or greater than those at the Fraser delta.

Arctic loons, sooty shearwaters, *Puffinus griseus*, and Northern phalaropes are the main spring migrants along west Vancouver Island in May and June. Estimates of 660,000 aquatic birds, of which the above three species constituted 85%, migrated northwest along Vancouver Island in May and June of 1973. The peak spring migration of black brant, surf and white-winged scoters along the coast is in March and April. Thousands of black brant and scoters feed on herring spawn in inlets on the west coast of Vancouver Island. Approximately 1,000,000 migrants in all may be vulnerable to oil pollution on the Canadian West Coast in spring, of which Arctic loons, sooty shearwaters, Northern phalaropes, black brant, surf and white-winged scoters, Bonaparte gulls and blacklegged kittiwakes are the most numerous.

Breeding Colonies

Thirteen species of seabirds nest in breeding colonies on the B.C. coast, while a fourteenth (the marbled murrelet) appears to be a tree nester. The three known major concentrations of seabird colonies are in the Langara Island region of northwest Graham Island, the southeast coast of the Queen Charlotte Islands, and the Scott Islands. There are six other known minor concentrations of colonies, while many colonies remain to be discovered.

The ancient murrelet, Synthliboramphus antiquus, is by far the most numerous species in the Langara Island region. Fork-tailed petrels, Oceanodroma furcata, ancient murrelets and Cassin's auklets, Ptychoramphus aleuticus, are the most numerous breeding seabirds on the east and south coast of Moresby Island. A large colony with 5,000 pairs of rhinoceros auklets, Cerorhinca monocerata, is located on Anthony Island at the very southwest end of the Queen Charlotte Islands. Cassin's auklets, rhinoceros auklets and tufted puffins, Lunda cirrhata, are the dominant nesting seabirds on the Scott Islands (extreme northwest coast of Vancouver Island).

Concentrations of 5,000 to 10,000 breeding pairs each are found on Hippa Island on the west coast of Graham Island; on Storm Islands, Tree Islets, and Pine Islands at the north end of Queen Charlotte Strait; on Solander Island near Cape Cook on the northwest coast of Vancouver Island; and in the Barkley and Clayoquot Sound region. It is estimated that there were 10,000 breeding pairs of ancient murrelets at Hippa Island in 1971. There have been reports of three separate large colonies of Leach's petrels, Oceanodroma leucorhoa, and one large colony of rhinoceros auklets on islands at the entrance of Queen Charlotte Strait, as well as an "immense" colony of tufted puffins on Solander Island, comparable in size to that of Triangle Island in the Scott Islands (approximately 10,000 pairs). Seabirds nesting at Barkley and Clayoquot Sound have been reported to be approximately 10,000 pairs, about half of which are Leach's petrels. Another colony, with approximately 3,000 pairs of seabirds and known for its diversified seabird life, is on Mandarte Island in Hecate Strait.

Vulnerability to Oil Spills

Because they are the most numerous breeders and are normally found in the water, alcids in particular would be affected by oil spills. Storm petrels are the second most numerous breeding seabird in the study region and are less threatened by oil spills than alcids, as they spend more time in the air and only dive occasionally. Other tubenoses, Procellariiformes, such as fulmars, shearwaters and petrels constitute a small minority in most marine pollution incidents and their deaths are few compared to their total populations. Alcids and petrels feed mainly on small fish and shrimps in open offshore waters, which are probably less vulnerable to oil spills than the birds themselves.

Although the B.C. rocky intertidal zone is vulnerable to oil spills, few species, such as black oystercatches, Haematopus bachmani, surfbirds, Aphriza melanocephala, and black turnstones, Arenaria interpres, feed extensively in this habitat. Most of these are dispersed along a very lengthy rocky West Coast; only a massive oil spill would threaten their feeding habitat to any large extent. Gulls probably are less threatened than other birds by the destruction of their food supply by oil, as they utilize a variety of habitat and food sources.

The feeding habitats of ducks, geese and shorebirds, which feed in large numbers on tidal sand and mud flats and marshes such as Boundary Bay and the Fraser delta, may suffer heavily from a spill as a result of the dispersion of oil through the water column in shallow waters and its deposition in the intertidal zone, killing the prey organisms on which they feed.

Dunlins and seaducks such as surf scoters, white-winged scoters and greater scaup, Aythya marila, may be very vulnerable, if their food supply consisting of molluscs, crustaceans and marine plants were affected by oil.

5.3 MARINE MAMMALS

A detailed listing of species of marine mammals in British Columbia, with summaries of their distribution, movements and abundance, is shown in Table 5.3.1. Locations of species concentrations are given in Figure 5.3.1.

Sea otters, the marine mammal species most vulnerable to oil spills on this coast, were transplanted here from Alaska from 1969-72. About 70 individuals are now re-established between Nootka and Brooks Peninsulas (northwest Vancouver Island), and a few others are widely scattered along the coast. While some of their time is spent on shore, most of it is spent swimming.

Fur seals occur here during December to May while migrating between the Bering Sea and California. They seldom come closer to shore than about 20 miles, occasionally concentrating off southwestern Vancouver Island. Other pinnipeds spend about half their time ashore at favored locations. Harbour seals are thinly scattered along all parts of the coast throughout the year and haul out on protected reefs and islands in groups of generally less than 50 individuals. About 70% of steller sea lions migrate to breeding islands off Cape St. James and the Scott Islands during June through August. By winter, they disperse widely along the coast going up many inlets and hauling out on exposed islands. California sea lions are found mainly in winter and concentrate on Folger Island in Barkley Sound. They do not breed, as only adult males are present. Elephant seals haul out at irregular times and locations.

Gray whales migrate within a mile of shore off the west coast of Vancouver Island from Barkley Sound northward, off the Queen Charlotte Islands and in Hecate Strait. Migration occurs during November to May between Alaska and Mexico. About 100 remain off western Vancouver Island during the summer along with a few others in Hecate Strait. The largest number of killer whales are found in the region southwards from Bella Bella in the inside waters of Johnstone Strait, the Strait of Georgia and Juan de Fuca Strait. Scattered groups of them are continuously moving;

TABLE 5.3.1 LIST OF MARINE MAMMALS POTENTIALLY AFFECTED BY OIL SPILLS IN BRITISH COLUMBIA, THEIR DISTRIBUTION, MOVEMENTS AND ABUNDANCE

Species	Distribution	Movements	Abundance
Sea Otter	NW Van. Is., coastal	nonmigratory	100
Pinnipeds			
Northern fur seal	B.C.; pelagic	migratory	several hundred thousand
Harbour seal	B.C.; coastal	nonmigratory	35,000
Steller sea lion	B.C.; coastal	migratory	6000
California sea lion	S Van. Is.; coastal	migratory	1000
Elephant seal	B.C.; coastal	migratory	rare
Cetaceans			
Gray whale	B.C.; coastal	migratory	11,000
Killer whale	B.C.; coastal-pelagic	nonmigratory	400
Pac. harbour porpoise	B.C.; coastal	prob. nonmigratory	common
Dall porpoise	B.C.; coastal-pelagic	prob. nonmigratory	common
Pac. striped dolphin	B.C.; coastal-pelagic	movements unknown	common
Sperm whale	B.C.; pelagic	migratory	probably common
Fin whale	B.C.; pelagic	migratory	probably common
Sei whale	B.C.; pelagic	migratory	probably common
Minke whale	B.C.; coastal	movements unknown	probably common
Blue whale	B.C.; pelagic	migratory	rare
Humpback whale	B.C.; coastal	migratory	rare
Black right whale	B.C.; coastal-pelagic	migratory	rare
Baird's beaked whale	B.C.; pelagic	movements unknown	rare
Mesoplodon sp.	B.C.; pelagic	movements unknown	rare
Cuvier's beaked whale	B.C.; pelagic	movements unknown	rare
Stenella sp.	B.C.; pelagic	movements unknown	rare
Pac. common dolphin	B.C.; pelagic	movements unknown	rare
N. right whale dolphin	B.C.; pelagic	movements unknown	rare

about 50 individuals, however, regularly frequent northern Johnstone Strait in summer. The sperm, blue, fin, and sei whales occur in uncertain numbers in all offshore areas and in Hecate Strait. They appear to be most abundant at the western approaches to Dixon Entrance and Queen Charlotte Sound. Recent whaling stations were located at Naden Harbour (northern Queen Charlottes), Rose Harbour (southern Queen Charlottes) and Coal Harbour (northern Vancouver Island). Little is known of the numbers, movements and areas of concentration of the remaining cetaceans. Groups of up to several hundred Pacific striped dolphins and up to about 100 Dall porpoises are periodically observed in a variety of offshore and inshore regions.

5.4 ECONOMIC AND SOCIAL VALUES

Marine resources in the coastal zone of British Columbia and northwest Washington have traditionally been associated with significant economic and social values. The historical development of the coastline was in fact partially prompted by the exploitation of these resources.

The first human settlement on the Northwest Coast began some 5000 years ago with Native Indian populations. Later European exploration and settlement was drawn by the promise of lucrative fur trade. By 1858, the gold rush firmly established coastal communities, thus providing the industrial, service and transportation base necessary to process and distribute coastal resources.

Coastal resources continue to attract human settlement. Today, more than three-quarters of the population of British Columbia and Washington lives within 50 miles of the coast, concentrated around the Strait of Georgia and north Puget Sound. As population has increased, especially in this southern region, uses of shoreline and adjacent waterways have diversified.

Coastal waterways are intensively used as transportation corridors for domestic and international shipping. The ports of Vancouver, Victoria and Bellingham function to link communities to the sea and more remote coastal settlements to the metropolitan areas. Certain industrial uses are dependent upon the coastal zone marine environment and/or a shoreline location. Commercial fishing is carried out coastwide, with processing operations centered in southern urban centres and in Prince Rupert. Coastal logging, which began in the southern region, now occurs in more remote areas owing to marine access with logs being transported south by sea for milling at Nanaimo and Vancouver. Residential and commercial developments, enhanced by proximity to the sea, tend to cluster along the shore. Recreation and tourist activities are among the most popular uses of West Coast resources. The Gulf Islands, San Juan Islands and Long Beach on Vancouver Island are a few of the outstanding natural areas which are enjoyed by both residents and visitors.

These human activities along the coast of British Columbia and northwest Washington depend on accessibility to marine/coastal resources. It is the social and economic values associated with these coastal uses that are most vulnerable to a marine oil transportation accident. The following examples demonstrate more specifically how economic or social values of these resources and/or activities could decrease from oil pollution.

Economic values at risk may be quantified in terms of dollar loss incurred, either privately or publicly, as the result of damage to property or reduction in income. The commercial fishery is one of the industries that would be detrimentally affected by an oil spill. Although the actual long-term effects of oil upon the fishery are uncertain, commercial fishermen noticed a distinct decline in catches after the Santa Barbara spill (Nash, Mann and Olsen, 1972). Fishermen were also denied access for two months to fishing grounds contaminated by the spill, resulting in significant loss of income (Mead and Sorensen, 1970). The recent 25,000 gallon bunker oil spill at the Canadian Fishing Company dock in the Fraser River necessitated a closure of the commercial fishery in the Lower Fraser and southern Strait of Georgia for seven days (Vancouver Sun, August 6, 1977). Cleanup of oil residue on boats and equipment is a costly process even in small localized spills. Insurance adjusters for the Fraser spill estimated the damages to 30 fishing boats contaminated by the spill at $30,000 (Vancouver Sun, August 31, 1977).

Numerous shore-based economic activities may also suffer detrimental impacts from pollution. Businesses relating to boating were the first to feel the effects of the Santa Barbara spill (Nash et al, 1972). Boat brokers, charter and rental boat companies and waterfront restaurants and motels in the vicinity all reported a decrease in business. Additionally, waterfront real estate market values declined over the short term and the volume of land sales dropped. In conclusion, an oil spill may result in loss in income to virtually any business interfacing directly or indirectly with the marine environment.

Social values that may be impacted upon by oil pollution fall into two classes. The first includes those "amenities", including recreation and aesthetic resources, that define a lifestyle for residents and draw tourists to coastal regions. Intensive use areas, usually located in proximity to metropolitan centres, include beaches and marinas plus associated activities such as boating, skin diving, water skiing, beachcombing, strolling and shoreline viewing. Temporary aesthetic degradation is not the only impact of oil pollution that might reduce the social value of a given amenity resource. There might also be a measurable loss in recreation days. For example, it was estimated that the dollar loss of beach-user days after the relatively small Cherry Point spill in 1972 totalled $4,700 (Mos, 1972). An oil spill also has the potential to cause damage to historic and archeological sites and "unique" geological features or landscapes that possess social value both for present and future generations.

The second aspect of social values that could be impacted upon by an oil spill is more difficult to assess, but nevertheless, is significant to the human population concerned. Examples of "social implications" of oil pollution identified in "The West Coast Oil Threat in Perspective" include the psychological effect of knowing that a spill is occurring in the area and the concern that people feel for unique and irreplaceable resource values (Paish and Associates, 1972). It is clear from the publicly expressed response to the threat of oil spills along the West Coast that such implications make a noticeable impact upon the values residents receive from living in coastal areas.

CHAPTER 6

OTHER ENVIRONMENTAL CONSIDERATIONS

6.1 AIR EMISSIONS AND POLLUTION POTENTIAL

Air Emissions

The primary emphasis of this comparative oil port study is the effects of oil pollution on marine-dependent resources. However, associated with oil tanker traffic is another significant pollution factor: air emissions. Evidence from studies undertaken in Washington and California indicates that ambient air quality at terminal facilities can be adversely affected by air emissions from off-loading tankers and tank farms. This section provides a preliminary review of the sources of such air pollutants and the estimated amount of annual air emissions that would be common to the 11 port sites.

Estimates of such air emissions are sensitive to the assumptions made regarding the composition and operation of the tanker fleet. Moreover, the effect of the emissions on ambient air quality would be a function of local meteorology and topography. These factors are discussed in more detail in the following section and in the appendices volume.

There are basically three sources of air emissions from an oil port:

- tanker combustion emissions,
- tanker venting and ballasting emissions,
- crude oil storage tank emissions.

The annual emissions estimated from the above sources at a 500,000 barrel per day design port are summarized in Table 6.1.1. A brief overview of possible mitigation procedures follows.

Sulfur dioxide originates from sulfur in the fuel oil fired in a ship's boilers during in-port operations; it could be controlled by restricting sulfur content in the fuel oil. Other emissions from a ship's power plant are more difficult to mitigate and would generally require major changes in the design and operation of the boilers.

Hydrocarbon emissions emanate mainly from tanker ballasting operations; control of ballasting and ship venting emissions would require a major rebuild of older vessels.

The other major source of hydrocarbons would be from tank farm storage evaporative losses. Control of these would entail use of improved design double-floating roof tanks incorporating double seals.

TABLE 6.1.1 ANNUAL AIR EMISSIONS (METRIC TONS) FOR A 500,000 BARREL PER DAY DESIGN PORT

Source	Sulfur Dioxide	Nitrogen Oxides	Particulates (TSP)	Hydro-carbons	Carbon Monoxide	Others
No Mitigation						
1. Tanker Combustion	800	360	90	30	14	
2. Tanker Venting and Ballasting	-	-	-	930	-	odor?
3. Tank Farm	-	-	-	500	-	odor?
Total Oil Port	800	360	90	1500	14	
With Mitigation						
1. Tanker Combustion (a)	270	130	180	60	28	
2. Tanker Venting and Ballasting (b)	-	-	-	-	-	
3. Tank Farm (c)	-	-	-	75	-	
Total Oil Port	270	130	180	135	28	

NOTES: (a) Sulfur in fuel oil reduced from 1.5% to 0.5% while in port. NO_x emissions reduced 65% through boiler combustion modifications, but with an assumed concurrent increase of 100% in the emission of TSP, HC, and CO.

(b) 20% segregated ballast tanks, inert gas system, pressurized ullage (insignificant venting loss).

(c) Double floating roof tanks incorporating double seals. Losses assumed to be 15% of those calculated for single seals using the API methodology.

To provide an appreciation of the emissions from a 500,000 barrel per day oil port facility, Table 6.1.2 presents the numbers of automobiles which would result in equivalent emissions.

TABLE 6.1.2 COMPARATIVE AIR EMISSIONS: DESIGN PORT VS. AUTOMOBILES

Contaminant	500,000 barrel per day Design Port Emissions (metric tons per year)	Equivalent Automobile Fleet Emissions (a) (number of vehicles)
SO_2	800	(b)
NO_x	360	6,000
CO	14	16
Particulates	90	12,000
Hydrocarbons	1500	15,000

(a) Emission factors from EPS-PR-75-3.
(b) Automobiles are not a significant source of this pollutant.

The sources and amounts of air pollutants identified in this section are not part of the final relative ranking system; rather, they are included to indicate the need for detailed air emissions studies prior to selection of a specific port site. The supplementary volume to this report presents a sample preliminary investigation of the effects of air emissions at a hypothetical oil port located at a specific site.

Atmospheric Dispersion Characteristics

In considering potential air quality deterioration associated with oil port operations, atmospheric dispersive capability is of major importance. Coastal British Columbia experiences relatively low mean ventilation rates, frequent overnight inversions, daytime inversions due to the presence of either marine strata or arctic air and local topography which encourages the establishment of closed circulation patterns in valleys or along coastlines. In view of the complex nature of the interaction of factors affecting atmospheric dispersive capability, categorical statements cannot be made concerning the relative pollution potential of various alternate port sites; rather, one can only recommend that more detailed site-specific studies of the lower atmosphere be made part of the environmental assessment required prior to development of any major new oil port facility. The following is a brief review of the theory of the capability of the atmosphere to disperse airborne pollutants and an overview of climatologic factors specific to the West Coast.

Horizontal transport and vertical mixing together determine the rate at which pollutants are dispersed from a source. Horizontal transport is directly proportional to wind speed; vertical mixing is dependent on the stability of the lower atmosphere as determined by the temperature profile. A temperature decrease with height of just under 10°C/km results in free convective mixing. The product of the mean wind speed in the mixed layer and the depth of that layer (referred to as the mixing height) is defined as the ventilation coefficient. Portelli (1977), in a study of the climatology of these factors for Canada, indicated that for the British Columbia coast, mean afternoon values of the ventilation coefficient peak sharply in spring (April), decline throughout the summer and persist at a low level during fall and winter. On an annual basis, coastal values are relatively low compared to the more continental region just to the east of the Coast Mountains, owing to much higher summertime values in the interior.

Conditions which inhibit vertical mixing and/or horizontal transport include ground-based inversions and persistently light surface winds. Munn, Tomlain and Titus (1970), in a preliminary climatology of ground-based inversions in Canada, indicated that overnight and early morning inversions occur about 40 percent of the time in winter and spring and about 50 percent of the time in summer and fall on the British Columbia coast. Due to daytime heating, afternoon frequencies are much lower, ranging from under five percent in spring to nearly ten percent in the fall. Shaw, Hirt and Tilley (1971) studied the frequency of persistently light winds (under 11 km/h) in Canada. Cases of light winds persisting for a duration of 24 to 47 hours ranged from under one per month on the outer coast in spring to close to three per month on the more sheltered inner South Coast in the fall.

The discussion of ventilation, inversions and wind conditions presented thus far provides a general overview for this coastal region. However, port facilities, whether existing or proposed, occupy specific sites within this region characterized by strong local topographic effects. The degree of complexity introduced by local effects can be revealed by a consideration of two examples: Kitimat on the North Coast and Roberts Bank on the South Coast.

Topographically, Kitimat is confined by the mass of the Coast Mountains with the exception of a narrow channel to the south and a river valley to the north. Roberts Bank, on the other hand, is exposed to the open expanse of the Strait of Georgia with only the flat lowlands of the Fraser delta nearby. One result of a more open exposure at Roberts Bank is a mean annual wind speed of 18 km/h compared to 12 km/h at the Kitimat townsite. However, Kitimat has a more "continental" climate and it can be shown that, on an annual basis for British Columbia, better ventilation is associated with such conditions (Portelli, 1977; Danard, 1973). Greater precipitation at Kitimat should produce greater rainout and washout of pollutants there; more hours of bright sunshine at Roberts Bank would tend to promote greater formation of photochemical pollution products there. Invasions of cold arctic air which can cause deep, persistent inversions are more frequent at Kitimat; Roberts Bank experiences more pronounced marine inversions in summer and fall. At Kitimat, existing industrial sources emit pollutants into an airshed volume limited by surrounding mountains, where stable layers and closed valley-mountain wind regimes may further limit mixing. Roberts Bank is located on the fringe of a heavily populated urban area, where regional pollutant levels are known to build up during stagnation episodes (Lynch and Emslie, 1972), in particular, when land and sea breeze circulations merely slosh pollutants to and fro with limited removal from the airshed.

The complexity of the situation just described leads to the conclusion that detailed studies of the dispersive capability of the local atmosphere be made a part of the environmental assessment required prior to selection of a major oil port facility.

6.2 OIL PIPELINE CORRIDORS AND TERMINAL FACILITIES

This section is a summary of major environmental concerns relative to pipelines and terminal facilities (Figure 6.2.1) selected for this study. (The American ports of Cherry Point, Burrows Bay and Port Angeles have not been included, as they presumably would use existing right-of-ways through Canada or a new line through the northwestern U.S.) More complete documentation is presented in the appendices volume.

It must be noted that no attempt at ranking the corridors has been made in the report. It was felt that the information available was not sufficient to provide an accurate comparison of the suitability of one route over another. Furthermore, in the event that any of the alternative corridors were to become a reality, it is assumed that detailed environmental impact studies would be undertaken.

Pipeline Route Selection

The Port Simpson, Ridley Island, Kitimat and Bella Coola (north) pipeline corridors received consideration from Kitimat Pipe Lines Ltd. The Bella Coola (south) route was once considered by Trans Mountain Pipeline Co. Ltd. The Squamish to Kamloops corridor is based on suitable topography and existing transportation routes. The Roberts Bank/Port Moody to Kamloops route follows an existing pipeline right-of-way, and as current proposals for this route involve mainly existing facilities, it has not been examined in detail.

Knowledge Gaps

Knowledge gaps exist in many of the subject areas studied for the various routes. These include:

- detail on physiographic features amongst corridors,
- information to make up for lack of Canada Land Inventory (or B.C.L.I.) around the Bella Coola Region,
- details on fisheries resources, especially resident stocks in the Rocky Mountain Trench,
- information on bird and wildlife species other than those that are economically important,
- up-to-date landuse information,
- an adequate archaeological sites inventory,
- an historic sites inventory, and
- sufficient knowledge of impacts of crude oil spills on riverine and land ecosystems.

Environmental Concerns

Physical environmental concerns include avalanches, landslides, debris flows and excessive run-off, poor foundation materials, bank instability and river scouring.

Biological environmental considerations include fish migration routes, spawning and rearing areas, bird nesting, staging and resting areas, and wildlife ranges, calving areas, hibernation areas and migration routes.

Socio-economic considerations include effects on land use, changes to recreational, archeological and historical areas, impacts from increased access, effects on local and regional life styles and impacts on special government reserves (ecological, agricultural and Indian).

Comparison of Routes

This section is a summary of site-specific major environmental concerns along selected pipeline corridors based on the general principles outlined in the previous section.

A. Concerns Applicable to All Corridors

Rugged terrain, instability and steep slopes are prevalent throughout all routes. The Kitimat-Prince Rupert area is a high risk seismic zone. All routes have stream crossings which can create problems of bank erosion, river scour and flood potential. All streams and lakes affected by the corridors support significant anadromous and/or resident fish populations.

B. Individual Corridor Concerns

1. Ungulates (moose, deer, caribou, elk, sheep and goats)

   Generally, all the major valleys within the corridors support ranges of high to very high capability. Such ranges are very scarce in British Columbia and are critically important to the animals which use them.

   Squamish-Kamloops - very high capabilities around Cache Creek and Kamloops Lake.
   Bella Coola-Little Fort - very high capabilities around Hotnarko Lake, McClinchy Creek, Towdystan, the Chilanko River, Chilcotin River, Hanceville, Alkali Creek and Roe Lake.
   Bella Coola-Prince George - very high capabilities around Chilako River, Mud River, the confluence of West Road, Euchiniko and Nazko Rivers, Pantage Lake and the West Road-Fraser River to Prince George.
   Port Simpson/Prince Rupert/Kitimat-Prince George - very high capabilities at Tyhee Lake and Walcott.
   Prince George-Alberta Border - very high capability at Moose Lake.

2. Other Wildlife

No information was readily available.

3. Wildfowl - Game (upland/migratory)

Upland Game Birds

No information was readily available.

Migratory Game Birds

Generally all coastal estuaries (Squamish, Bella Coola, Skeena, Kitimat) provide wintering and/or resting areas.

Squamish-Kamloops - in addition to the Squamish River estuary, there is an extremely important area around Kamloops.
Bella Coola-Little Fort - contains the highest diversity of areas which have all-around waterfowl capabilities, mostly along the Chilcotin River.
Bella Coola-Prince George - Anahim Lake and Pelican Lake are of extreme importance.
Port Simpson/Prince Rupert/Kitimat-Terrace-Prince George - contains the largest areas for wintering or resting capabilities of waterfowl.
Prince George-Alberta Border - no known significant waterfowl capabilities.

4. Other Wildfowl

No information was readily available.

5. Recreation

All the corridors have areas of high recreational capability especially along valley bottom lands.

Squamish-Kamloops - important recreational area around Alta Lake-Whistler Mountain.
Bella Coola-Little Fort - very important recreational area around Lac La Hache-Bridge Creek System.
Bella Coola-Prince George - few known significant recreational areas.
Prince Rupert/Port Simpson/Kitimat-Prince George - lake shores along this route are important recreational areas.
Prince George-Alberta Border - Tabor Lake area is an important recreational area.

6. Land Status

a. Indian Reserves

All corridors traverse areas designated as Indian reserves.

Squamish-Kamloops - reserves distributed along whole corridor with concentrations around Lillooet and along the North Thompson River to Kamloops.
Bella Coola-Little Fort - several reserves along the corridor, the largest at Bella Coola, Alexis and Riske Creeks, and Williams Lake.
Bella Coola-Prince George - several small reserves mainly on West Road River.
Port Simpson/Prince Rupert/Kitimat-Prince George - several small reserves, the largest on the Tsimpsean Peninsula and at the mouth of the Kitimat and Kitwanga Rivers.
Prince George-Alberta Border - few Indian reserves.

b. Agricultural Land Reserves

All of the selected corridors traverse agricultural land reserves. The most extensive areas are on the Squamish-Kamloops, Bella Coola-Little Fort, Port Simpson/Prince Rupert/Kitimat-Prince George, and Prince George-Alberta Border routes.

c. Parks

Squamish-Kamloops - several provincial parks along the route.
Bella Coola-Little Fort - Tweedsmuir Provincial Park of high importance.
Bella Coola-Prince George - Tweedsmuir Provincial Park of high importance.
Port Simpson/Prince Rupert/Kitimat-Prince George - several provincial parks along the route.
Prince George-Alberta Border - Mount Robson Provincial Park of high importance.

d. Ecological Reserves

Squamish - Kamloops - Baynes Island on Squamish River; northwest of Trenquille.
Bella Coola - Little Fort - south of Williams Lake.
Bella coola - Prince George - vicinity of Far Mountain; between the Coglistiko and Baezaeko Rivers.
Port Simpson/Prince Rupert/Kitimat - Prince George - Skeena River near the Exchamsiks River; Drywilliam Lake near Fraser Lake; Nechako River.
Prince George - Alberta Border - Sunbeam Creek.

e. Other Restrictions

Squamish-Kamloops - none known.
Bella Coola-Little Fort - Military training area at Riske Creek and archaeological sites distributed along the Fraser River.

Bella Coola-Prince George - tree farm licence reserve at mouth of West Road River.
Port Simpson/Prince Rupert/Kitimat-Prince George - Watershed reserve at Woodworth Lake; government reserve around Prudhomme Lake; tree farm licence reserve around Kitimat River basin; most extensive known archaeological sites distributed along whole corridor; bird sanctuary at Vanderhoof.
Prince George-Alberta Border - tree farm licence reserve on Fraser valley north of Prince George; archaeological sites around Willow River and McBride.

7. Land Use

Forestry, agriculture and to a lesser extent, mining, are the dominant land uses to be found along the corridors. Commercial, residential, manufacturing and other uses are usually found around population centres in valley lowlands.

8. Access (Rail or road)

Squamish-Kamloops - good access except for areas around Lillooet and Hat Creek.
Bella Coola-Little Fort - good access from Riske Creek to 100 Mile House; otherwise little or no access.
Bella Coola-Prince George - good access from mouth of West Road River to Prince George; otherwise very little access.
Port Simpson/Prince Rupert/Kitimat-Prince George - very good access along nearly whole route, but none from Port Simpson to Prince Rupert or the Zymoetz, Telkwa, Kitseguecla Rivers.
Prince George-Alberta Border - good access along whole route.

Upland Considerations at Marine Terminals

Port Simpson - suitable land; low waterfowl, ungulate and agricultural capabilities; some recreation capability; numerous archaeological sites; no land access or services.
Ridley Island - suitable land (Crown-owned); low waterfowl, agriculture and ungulate capabilities; few archaeological sites; no access or services.
Kitimat - population; land access; low ungulate capability; important waterfowl and fisheries area; high potential recreation area; agricultural land and Indian reserves; limited suitable land.
Bella Coola - moderate population; limited suitable land; important fisheries; potential recreation capability; agricultural land and Indian reserves; some archaeological sites; limited access and services.

Britannia Beach - population; good access; low ungulate, waterfowl, agriculture or recreation capabilities; limited suitable land; slump-prone areas.

Roberts Bank - population; suitable land; good access and services; low ungulate capability; critical waterfowl and fisheries area; high recreation capability; agricultural land reserve; bird sanctuary; soil instability potential.

The above review serves only to identify those areas which, at minimum, would require detailed evaluation prior to any pipeline approval. In general, more complete baseline information is needed for all pipeline routes before any ranking of alternative corridors could be derived.

CHAPTER 7

THE RELATIVE ENVIRONMENTAL RISK RATING SYSTEM: METHOD AND RESULTS

The rating system described in this chapter was developed to facilitate the objective comparison of environmental risks associated with West Coast port sites and their alternative marine traffic routes. The system, which primarily addresses the question of a major oil spill, is similar to an earlier technique developed by the Department of Fisheries and the Environment (1976) in its study of East Coast port alternatives. The major difference involves the incorporation of a "route length" concept to take into account the fjords and other coastal waterways that ships must traverse from the open ocean to their terminals.

For the purpose of this study, "environmental risk" was defined as the product of the relative risk or probability of an oil spill and the consequent environmental damages and costs that would result if such a spill occurred. It was virtually impossible to make an absolute determination of the environmental risk, but various numerical indices were developed to provide a relative indication of risk and a comparison of alternatives. These indices included:

- A NAVIGATIONAL RISK INDEX to provide a relative measure of the risk of an accident, i.e., the relative probability of a spill. It was calculated along each route by rating such factors as winds, visibility, currents, water depths, passage widths, course changes and shipping density in relation to a design tanker of 325,000 DWT with a draught of 85 feet and a breadth of 175 feet.
- A BIOLOGICAL RESOURCE INDEX to provide a relative measure of the living resources that could be affected by an oil spill.
- An ECONOMIC RESOURCE INDEX to provide a relative measure of the income-related resources that could be affected by an oil spill.
- A SOCIAL RESOURCE INDEX to provide a relative measure of the human community/cultural resources that could be affected by an oil spill.

By multiplying each of the RESOURCE INDICES by the NAVIGATIONAL RISK INDEX, the BIOLOGICAL RISK INDEX, ECONOMIC RISK INDEX and SOCIAL RISK INDEX were determined. The RESOURCE indices are thus an indication of the relative impacts of a spill and the RISK indices provide a measure of the relative rate at which damage might be expected to occur over time. Because the indices derived in this report are based on hypothetical route alternatives, it is important to note that much more site-specific data collection and analysis would be required for any actual, seriously proposed, port/route.

7.1 NAVIGATIONAL RISK INDEX

The procedure for producing the NAVIGATIONAL RISK INDEX was to identify, rate and combine various navigational factors which contribute to the risk of marine tanker accidents.

The navigation factors identified as "risk indicators" were winds, visibility, currents, water depths, passage widths, course changes and shipping density. Winds and visibility were rated for winter and summer seasons; all others were rated on an annual basis. They were evaluated quantitatively either from available data or from data interpolation where records were lacking.

As previously mentioned, the NAVIGATIONAL RISK INDEX method in this report was basically similar to that used in an East Coast study, with one significant modification. Because of much longer approach routes to Pacific coast terminals, each of the port/route alternatives was first divided into discrete 40-nautical mile segments (Table 7.1.1 and Figure 7.1.1), which were added to derive the NAVIGATIONAL RISK for each route. (It was assumed that spill probability was a linear function of length and therefore directly segment-additive and that tankers would not deviate from their respective routes.)

The rating system used for the seven navigational risk factors identified above was developed to indicate a gradient of risk; it did not show absolute risk. The system was as follows:

Winds

The percentage frequency of hourly wind observations in which the speed was greater than or equal to 25 miles per hour (22 knots) was taken as an indication of risk due to high winds. Data was extracted from records from coastal recording stations, several lighthouse records and summaries of ship weather reports.

Percentage Frequency Wind Speed greater than or equal to 25 mph	Rating
0 - 5 percent	1
6 - 10 percent	2
11 - 15 percent	3
16 - 25 percent	4
Over 25 percent	5

Recognizing that strong winds pose a greater hazard near shoals or shorelines, a modification to the rating for wind speed was incorporated based upon the distance from the 16-fathom line. This depth meets the minimum TERMPOL standard, as set forth by the Ministry of Transport for underkeel clearance for the design ship.

Distance	Rating
More than 4.0 nautical miles	1
2.6 - 4.0 nautical miles	2
1.6 - 2.5 nautical miles	3
0.76 - 1.5 nautical miles	4
0 - 0.75 nautical mile	5

TABLE 7.1.1 SEGMENT AND ROUTE NUMBERS AND NAMES

Route Number	Route Name	Number of Segments	Segment Number																
1	Port Simpson (Dixon)	3	1	2	3														
2	Ridley Island (Dixon)	3	1	2	4														
3	Kitimat (Dixon, Principe)	6	1	2	5	8	12	9											
4	Kitimat (Outer Coast, Hecate, Principe)	11	6	10	13	15	17	18	14	7	8	12	9						
5	Kitimat (Outer Coast, Hecate, Caamano)	9	6	10	13	15	17	16	11	12	9								
6	Bella Coola (Outer Coast, North Passage)	10	6	10	13	15	17	19	20	23	24	25							
7	Bella Coola (Outer Coast, South Passage)	11	6	10	13	15	17	19	21	22	23	24	25						
8	Kitimat (Hecate, Principe)	8	15	17	18	14	7	8	12	9									
9	Kitimat (Hecate, Caamano)	6	15	17	16	11	12	9											
10	Bella Coola (North Passage)	7	15	17	19	20	23	24	25										
11	Bella Coola (South Passage)	8	15	17	19	21	22	23	24	25									
12	Port Angeles (Outer Coasts, Juan De Fuca)	14	6	10	13	15	17	26	27	28	29	30	31	32	33	34			
13	Esquimalt (Outer Coasts, Juan De Fuca)	14	6	10	13	15	17	26	27	28	29	30	31	32	33	35			
14	Burrows Bay (Outer Coasts, Juan De Fuca)	15	6	10	13	15	17	26	27	28	29	30	31	32	33	36	37		
15	Cherry Point (Outer Coasts, Juan De Fuca, Rosario)	15	6	10	13	15	17	26	27	28	29	30	31	32	33	36	38		
16	Cherry Point (Outer Coasts, Juan De Fuca, Haro)	16	6	10	13	15	17	26	27	28	29	30	31	32	33	36	39	40	
17	Roberts Bank (Outer Coasts, Juan De Fuca, Haro)	16	6	10	13	15	17	26	27	28	29	30	31	32	33	36	39	41	
18	Port Moody (Outer Coasts, Juan De Fuca, Haro)	17	6	10	13	15	17	26	27	28	29	30	31	32	33	36	39	41	42
19	Britannia Beach (Outer Coasts, Juan De Fuca, Haro)	17	6	10	13	15	17	26	27	28	29	30	31	32	33	36	39	41	43
20	Port Angeles (Juan De Fuca)	5	30	31	32	33	34												
21	Esquimalt (Juan De Fuca)	5	30	31	32	33	35												
22	Burrows Bay (Juan De Fuca)	6	30	31	32	33	36	37											
23	Cherry Point (Juan De Fuca, Rosario)	6	30	31	32	33	36	38											
24	Cherry Point (Juan De Fuca, Haro)	7	30	31	32	33	36	39	40										
25	Roberts Bank (Juan De Fuca, Haro)	7	30	31	32	33	36	39	41										
26	Port Moody (Juan De Fuca, Haro)	8	30	31	32	33	36	39	41	42									
27	Britannia Beach (Juan De Fuca, Haro)	8	30	31	32	33	36	39	41	43									

The foregoing two factors were then combined according to the following composite matrix:

		Distance Rating 1	2	3	4	5
Physical Parameter Rating	1	0	0	0	1	1
	2	0	1	1	2	2
	3	1	2	2	3	3
	4	2	3	3	4	4
	5	3	4	4	5	5

An example would be a final wind rating of four for a physical parameter (wind) rating of five and a distance rating of three.

Visibility

Risk due to restricted visibility was developed on the basis of the percentage frequency of occurrence of recorded visibilities of two miles or less. Data was extracted from records from coastal recording stations, several lighthouse weather reporting stations, including the use of foghorn records, and summaries of ship weather reports.

Percentage Frequency Visibility less than or equal to 2 miles	Rating
0 - 3 percent	1
4 - 6 percent	2
7 - 9 percent	3
10 - 12 percent	4
Over 12 percent	5

A distance/physical parameter composite matrix, as used for winds, was used to produce the final visibility values.

Currents

Maximum tidal currents, as recorded for each locality, were used as the basis for this factor. Data were extracted from current observation records and from published information.

Current Speed	Rating
less than 1 knot	1
1 - 2 knots	2
2.1 - 3 knots	3
3.1 - 4 knots	4
greater than 4 knots	5

As with winds and visibility, a same distance/physical parameter composite matrix was used.

Water Depths

Water depths were rated from the information extracted from large scale nautical charts, using 16 fathoms as the minimum underkeel clearance within a 1600-foot wide channel for a vessel of 325,000 DWT, according to TERMPOL standards. The minimum water depth on each route segment was rated on the following basis.

Water Depth	Rating
greater than 33 fathoms	0
26.1 - 33 fathoms	1
21.1 - 26 fathoms	2
18.1 - 21 fathoms	3
16 - 18 fathoms	4
less than 16 fathoms (Unacceptable as per TERMPOL guidelines)	5

Channel Widths

Channel width ratings were derived using nautical charts, taking 1600 feet as the minimum channel width for a vessel of 325,000 DWT, according to TERMPOL guidelines. The minimum channel width on each route segment was rated on the following basis.

Channel Width	Rating
greater than 20 miles	0
5.1 miles - 20 miles	1
1.1 mile - 5 miles	2
2501 feet - 1 mile	3
1601 feet - 2500 feet	4
0 feet - 1600 feet (Unacceptable as per TERMPOL guidelines)	5

Course Changes

Course changes were measured from large-scale nautical charts on the basis of turn angle groupings according to TERMPOL guidelines.

Turn Angle Groupings	Rating
0 - 25°	1
26° - 35°	2
36° - 55°	3
56° - 65°	4
65°+	5

Because many route segments included several turn angles, the initial ratings, as determined above, were added together for each segment to produce a summed range between 1 and 21. New rating values from 0 to 4 were then applied to this range to produce a final rating for course changes.

Segment Sum	Final Rating
1 - 4	0
5 - 8	1
9 - 12	2
13 - 16	3
16+	4

Shipping Density

From a detailed analysis and summary of various Canadian and U.S. shipping records, values for the density of deep-sea vessel traffic, including tugs and barges but excluding commercial fishing boats and recreational craft, were developed and rated. (Deep-sea vessels were those considered large enough to constitute a potential hazard to a supertanker.)

Number of Annual Vessel Movements	Rating
0 - 1000	0
1001 - 3000	1
3001 - 7000	2
7001 - 15,000	3
15,001 - 20,000+	4

Compilation of the NAVIGATIONAL RISK INDEX

The NAVIGATIONAL RISK INDEX was compiled as follows (Tables 7.1.2, 7.1.3 and 7.1.4):

- Each route segment was rated for each of the seven parameters.
- The ratings estimated for two seasons (October to April representing winter, and May to September representing summer), were weighted in each route segment. Weights were decided on by a group of Department of Fisheries and the Environment staff as an indication of the relative importance of each of the navigational risk factors. By testing various extreme weights, they determined that the standing of each route segment in relation to the others was not greatly changed by different weightings, i.e., relative risk was insensitive to the weighting scheme chosen. The weight agreed on for each parameter was the maximum possible for that parameter, except in those cases not in conformance with TERMPOL standards, e.g., water depth and passage width for segment 42 (Vancouver harbour). These weighted values were totalled by segment for each season.
- Seasonal segment totals were scaled down to 100 from 114, where 114 represented the total of the maximum weightings.

TABLE 7.1.2 WINTER NAVIGATIONAL RISK VALUES BY ROUTE SEGMENT

Segment Number	Winds	Visibility	Currents	Water Depths	Passage Widths	Course Changes	Shipping Density	TOTAL	Seasonal Navigational Risk (Scaled against 114 and Adjusted for Odd Lengths)
	(12.0)*	(18.0)	(14.0)	(20.0)	(17.0)	(15.0)	(18.0)	(114.0)	(100)
1	7.2	.0	.0	.0	4.2	.0	.0	11.4	10.0
2	7.2	.0	.0	.0	8.5	.0	4.5	20.2	17.7
3	7.2	10.8	2.8	15.0	12.7	7.5	.0	56.0	36.9
4	7.2	7.2	2.8	15.0	17.0	7.5	4.5	61.2	40.3
5	7.2	3.6	.0	10.0	8.5	3.8	9.0	42.0	36.9
6	7.2	.0	.0	.0	.0	.0	.0	7.2	6.3
7	7.2	3.6	.0	15.0	8.5	7.5	.0	41.8	36.7
8	7.2	14.4	5.6	10.0	12.7	3.8	9.0	62.7	55.0
9	4.8	18.0	2.8	5.0	12.7	3.8	.0	47.1	41.3
10	7.2	3.6	.0	.0	4.2	.0	.0	15.0	13.2
11	7.2	7.2	2.8	10.0	8.5	3.8	.0	39.4	34.6
12	4.8	14.4	2.8	.0	12.7	15.0	.0	49.7	43.6
13	7.2	7.2	.0	.0	4.2	.0	.0	18.6	16.4
14	7.2	.0	.0	.0	4.2	.0	.0	11.4	10.0
15	7.2	7.2	.0	.0	4.2	.0	.0	18.6	16.4
16	7.2	.0	.0	.0	.0	.0	.0	7.2	6.3
17	7.2	.0	.0	.0	.0	.0	.0	7.2	6.3
18	7.2	.0	.0	.0	4.2	3.8	.0	15.2	13.3
19	7.2	.0	.0	.0	.0	.0	.0	7.2	6.3
20	4.8	.0	.0	15.0	8.5	.0	.0	28.3	24.8
21	4.8	.0	2.8	15.0	12.7	.0	.0	35.3	31.0
22	4.8	7.2	5.6	15.0	8.5	3.8	.0	44.8	9.8
23	4.8	10.8	5.6	10.0	12.7	3.8	.0	47.7	41.8
24	4.8	10.8	5.6	20.0	12.7	11.2	.0	65.2	57.2
25	4.8	14.4	2.8	.0	12.7	3.8	.0	38.5	8.4
26	4.8	.0	.0	.0	4.2	.0	.0	9.0	7.9
27	4.8	.0	.0	.0	4.2	.0	.0	9.0	7.9
28	4.8	.0	.0	.0	4.2	.0	.0	9.0	7.9
29	4.8	3.6	.0	.0	.0	.0	.0	8.4	7.4
30	4.8	3.6	.0	.0	4.2	.0	.0	12.6	11.1
31	4.8	3.6	.0	15.0	4.2	.0	.0	27.6	24.3
32	2.4	3.6	.0	5.0	4.2	.0	4.5	19.7	17.3
33	2.4	.0	2.8	.0	4.2	.0	18.0	27.4	24.1
34	2.4	.0	2.8	.0	8.5	3.8	4.5	21.9	4.8
35	4.8	3.6	2.8	15.0	8.5	7.5	.0	42.2	14.1
36	2.4	.0	.0	15.0	8.5	.0	4.5	30.4	13.3
37	4.8	7.2	5.6	15.0	8.5	3.8	.0	44.8	19.7
38	7.2	10.8	11.2	25.0	12.7	11.2	9.0	87.2	76.5
39	4.8	7.2	11.2	20.0	12.7	7.5	13.5	76.9	67.5
40	4.8	7.2	5.6	5.0	8.5	.0	.0	31.1	6.8
41	2.4	.0	2.8	.0	4.2	7.5	9.0	25.9	22.8
42	2.4	7.2	11.2	25.0	21.2	3.8	18.0	88.8	38.9
43	4.8	7.2	2.8	.0	12.7	.0	4.5	32.0	14.1

*() Weightings

TABLE 7.1.3 SUMMER NAVIGATIONAL RISK VALUES BY ROUTE SEGMENT

Segment Number	Winds	Visibility	Currents	Water Depths	Passage Widths	Course Changes	Shipping Density	TOTAL	Seasonal Navigational Risk (Scaled against 114 and Adjusted for Odd Lengths)
	(12.0)*	(18.0)	(14.0)	(20.0)	(17.0)	(15.0)	(18.0)	(114)	(100)
1	.0	3.6	.0	.0	4.2	.0	.0	7.8	6.9
2	.0	3.6	.0	.0	8.5	.0	4.5	16.6	14.6
3	2.4	10.8	2.8	15.0	12.7	7.5	.0	51.2	33.7
4	2.4	7.2	2.8	15.0	17.0	7.5	4.5	56.4	37.1
5	.0	3.6	.0	10.0	8.5	3.8	9.0	34.8	30.6
6	.0	3.6	.0	.0	.0	.0	.0	3.6	3.2
7	2.4	3.6	.0	15.0	8.5	7.5	.0	37.0	32.5
8	4.8	10.8	5.6	10.0	12.7	3.8	9.0	56.7	49.7
9	2.4	7.2	2.8	5.0	12.7	3.8	.0	33.9	29.7
10	.0	7.2	.0	.0	4.2	.0	.0	11.4	10.0
11	2.4	7.2	2.8	10.0	8.5	3.8	.0	34.6	30.4
12	2.4	10.8	2.8	.0	12.7	15.0	.0	43.7	38.4
13	.0	7.2	.0	.0	4.2	.0	.0	11.4	10.0
14	2.4	3.6	.0	.0	4.2	.0	.0	10.2	9.0
15	2.4	7.2	.0	.0	4.2	.0	.0	13.8	12.1
16	2.4	3.6	.0	.0	.0	.0	.0	6.0	5.3
17	2.4	3.6	.0	.0	.0	.0	.0	6.0	5.3
18	2.4	3.6	.0	.0	4.2	3.8	.0	14.0	12.3
19	2.4	3.6	.0	.0	.0	.0	.0	6.0	5.3
20	.0	3.6	.0	15.0	8.5	.0	.0	27.1	23.8
21	.0	3.6	2.8	15.0	12.7	.0	.0	34.1	30.0
22	.0	7.2	5.6	15.0	8.5	3.8	.0	40.0	8.8
23	2.4	10.8	5.6	10.0	12.7	3.8	.0	45.3	39.7
24	2.4	7.2	5.6	20.0	12.7	11.2	.0	59.2	51.9
25	2.4	7.2	2.8	.0	12.7	3.8	.0	28.9	6.3
26	2.4	3.6	.0	.0	4.2	.0	.0	10.2	9.0
27	.0	3.6	.0	.0	4.2	.0	.0	7.8	6.9
28	.0	3.6	.0	.0	4.2	.0	.0	7.8	6.9
29	.0	3.6	.0	.0	.0	.0	.0	3.6	3.2
30	.0	7.2	.0	.0	4.2	.0	.0	11.4	10.0
31	.0	7.2	.0	15.0	4.2	.0	.0	26.4	23.2
32	.0	10.8	.0	5.0	4.2	.0	4.5	24.5	21.5
33	2.4	7.2	2.8	.0	4.2	.0	18.0	34.6	30.4
34	.0	.0	2.8	.0	8.5	3.8	4.5	19.5	4.3
35	2.4	3.6	2.8	15.0	8.5	7.5	.0	39.8	13.3
36	.0	.0	.0	15.0	8.5	.0	4.5	28.0	12.3
37	2.4	3.6	5.6	15.0	8.5	3.8	.0	38.8	17.0
38	2.4	3.6	11.2	25.0	12.7	11.2	9.0	75.2	66.0
39	2.4	3.6	11.2	20.0	12.7	7.5	13.5	70.9	62.2
40	2.4	3.6	5.6	5.0	8.5	.0	.0	25.1	5.5
41	.0	.0	2.8	.0	4.2	7.5	9.0	23.5	20.7
42	2.4	3.6	11.2	25.0	21.2	3.8	18.0	85.2	37.4
43	2.4	3.6	2.8	.0	12.7	.0	4.5	26.0	11.4

* () Weightings

TABLE 7.1.4 NAVIGATIONAL RISK INDEX

Route No.	Route Name	Navigational Risk (Annually Adjusted Route Totals)	NAVIGATIONAL RISK INDEX (Scaled to 100)
1	Port Simpson (Dixon)	60.78	20
2	Ridley Island (Dixon)	64.18	21
3	Kitimat (Dixon, Principe)	190.43	64
4	Kitimat (Outer Coast, Hecate, Principe)	239.63	80
5	Kitimat (Outer Coast, Hecate, Caamano)	168.03	56
6	Bella Coola (Outer Coast, North Passage)	185.18	62
7	Bella Coola (Outer Coast, South Passage)	200.78	67
8	Kitimat (Hecate, Principe)	208.97	70
9	Kitimat (Hecate, Caamano)	137.36	46
10	Bella Coola (North Passage)	154.51	52
11	Bella Coola (South Passage)	170.12	57
12	Port Angeles (Outer Coasts, Juan De Fuca)	165.20	55
13	Esquimalt (Outer Coasts, Juan De Fuca)	174.35	58
14	Burrows Bay (Outer Coasts, Juan De Fuca)	192.12	64
15	Cherry Point (Outer Coasts, Juan De Fuca, Rosario)	245.72	82
16	Cherry Point (Outer Coasts, Juan De Fuca, Haro)	245.20	82
17	Roberts Bank (Outer Coasts, Juan De Fuca, Haro)	260.84	87
18	Port Moody (Outer Coasts, Juan De Fuca, Haro)	299.19	100
19	Britannia Beach (Outer Coasts, Juan De Fuca, Haro)	273.81	92
20	Port Angeles (Juan De Fuca)	84.98	28
21	Esquimalt (Juan De Fuca)	94.13	31
22	Burrows Bay (Juan De Fuca)	111.90	37
23	Cherry Point (Juan De Fuca, Rosario)	165.51	55
24	Cherry Point (Juan De Fuca, Haro)	164.98	55
25	Roberts Bank (Juan De Fuca, Haro)	180.62	60
26	Port Moody (Juan De Fuca, Haro)	218.97	73
27	Britannia Beach (Juan De Fuca, Haro)	193.60	65

- Several of the segments which were not the full 40 nautical miles in length, e.g., some final approach segments, were decreased in value in proportion to their shorter lengths.
- Segment values were added by season for each route as in Table 7.1.1.
- Seasonality was removed by averaging winter and summer values proportionately.
- These annual route values were scaled to 100, with 100 representing the highest route risk. This was the NAVIGATIONAL RISK INDEX.

7.2 THE RESOURCE INDICES

The BIOLOGICAL, ECONOMIC and SOCIAL RESOURCE INDICES were developed on a regional basis using modified Fisheries Statistical Areas along each route (Table 7.2.1 and Figure 7.2.1).

An alternative method based on specific oil slick areas was also used in preparation of this study and is described in the appendices volume. As the results of that method correlated very highly with the results presented herein, only the one method was detailed in this first volume, as follows:

1. BIOLOGICAL RESOURCE INDEX

The BIOLOGICAL RESOURCE INDEX was compiled to permit comparison of factors that could not be readily evaluated in monetary or other commonly accepted quantitative terms. Included in the index were nearshore biological capability, salmon escapements, other fisheries stocks, marine-associated birds and marine mammals.

These five biological factors were first rated by geographic location through a method specific to each, as detailed in the following sub-sections. The resulting ratings were then regionally apportioned on a modified Fisheries Statistical Area basis (Table 7.2.2). Final steps in the calculation of the BIOLOGICAL RESOURCE INDEX are detailed at the end of this section.

Nearshore Biological Capability

Intertidal and associated areas can support rich and highly variable biological communities which may possess value in their own right, and whose productivity may be important in sustaining commercial and recreational species, including young salmon. However, data on nearshore biological communities and their productivity are sparse for much of the coast. Therefore, a biological capability rating was developed from certain shoreline physical factors derived from one mile samplings at five mile intervals from photogrammetric and aerial surveys. The coded physical factors and methods of assessment are presented in the appendices volume.

Exposure, bottom-type and slope were postulated as the important determinants of productivity. Exposure and bottom-types were first arrayed in a table and assigned qualitative productivity values

TABLE 7.2.1 ROUTES COMPRISED OF MODIFIED FISHERIES STATISTICAL AREAS

Route No.	Route Name	Modified Fisheries Statistical Areas
1	Port Simpson (Dixon)	1-W, 1-E, 2-E-N, 3-X, 3-Y, 3-Z-S, 4, ALAS-1
2	Ridley Island (Dixon)	1-W, 1-E, 2-E-N, 3-X, 3-Y, 3-Z-S, 4, ALAS-1
3	Kitimat (Dixon, Principe)	1-W, 1-E, 2-E-N, 3-X, 3-Y, 4, 5, 6-N, 6-S, ALAS-1
4	Kitimat (Outer Coast, Hecate, Principe)	1-W, 2-E-N, 2-E-S, 2-W, 4, 5, 6-N, 6-S, 30
5	Kitimat (Outer Coast, Hecate, Caamano)	1-W, 2-E-S, 2-W, 5, 6-N, 6-S, 30
6	Bella Coola (Outer Coast, North Passage)	1-W, 2-E-S, 2-W, 6-S, 7, 8, 9, 10, 11, 12-W, 30
7	Bella Coola (Outer Coast, South Passage)	1-W, 2-E-S, 2-W, 6-S, 7, 8, 9, 10, 11, 12-W, 30
8	Kitimat (Hecate, Principe)	2-E-N, 2-E-S, 2-W, 4, 5, 6-N, 6-S, 30
9	Kitimat (Hecate, Caamano)	2-E-S, 2-W, 5, 6-N, 6-S, 30
10	Bella Coola (North Passage)	2-E-S, 2-W, 6-S, 7, 8, 9, 10, 11, 12-W, 30
11	Bella Coola (South Passage)	2-E-S, 2-W, 6-S, 7, 8, 9, 10, 11, 12-W, 30
12	Port Angeles (Outer Coasts, Juan De Fuca)	1-W, 2-W, 10, 11, 19, 20, 21, 22, 23, 24, 25, 26, 27, 30, US-1
13	Esquimalt (Outer Coasts, Juan De Fuca)	1-W, 2-W, 10, 11, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 30, US-1, US-2
14	Burrows Bay (Outer Coasts, Juan De Fuca)	1-W, 2-W, 10, 11, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 30, US-1, US-2
15	Cherry Point (Outer Coasts, Juan De Fuca, Rosario)	1-W, 2-W, 10, 11, 17-S, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, US-1, US-2
16	Cherry Point (Outer Coasts, Juan De Fuca, Haro)	1-W, 2-W, 10, 11, 17-S, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, US-1, US-2
17	Roberts Bank (Outer Coasts, Juan De Fuca, Haro)	1-W, 2-W, 10, 11, 14-S, 16, 17-N, 17-S, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, US-1, US-2
18	Port Moody (Outer Coasts, Juan De Fuca, Haro)	1-W, 2-W, 10, 11, 14-S, 16, 17-N, 17-S, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, US-1, US-2
19	Britannia Beach (Outer Coasts, Juan De Fuca, Haro)	1-W, 2-W, 10, 11, 14-S, 16, 17-N, 17-S, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, US-1, US-2
20	Port Angeles (Juan De Fuca)	19, 20, 21, 22, 23, 24, 25, US-1
21	Esquimalt (Juan De Fuca)	18, 19, 20, 21, 22, 23, 24, 25, US-1, US-2
22	Burrows Bay (Juan De Fuca)	18, 19, 20, 21, 22, 23, 24, 25, US-1, US-2
23	Cherry Point (Juan De Fuca, Rosario)	17-S, 18, 19, 20, 21, 22, 23, 24, 25, 29, US-1, US-2
24	Cherry Point (Juan De Fuca, Haro)	17-S, 18, 19, 20, 21, 22, 23, 24, 25, 29, US-1, US-2
25	Roberts Bank (Juan De Fuca, Haro)	14-S, 16, 17-N, 17-S, 18, 19, 20, 21, 22, 23, 24, 25, 28, 29, US-1, US-2
26	Port Moody (Juan De Fuca, Haro)	14-S, 16, 17-N, 17-S, 18, 19, 20, 21, 22, 23, 24, 25, 28, 29, US-1, US-2
27	Britannia Beach (Juan De Fuca, Haro)	14-S, 16, 17-N, 17-S, 18, 19, 20, 21, 22, 23, 24, 25, 28, 29, US-1, US-2

TABLE 7.2.2 BIOLOGICAL RATINGS BY MODIFIED FISHERIES STATISTICAL AREAS

Modified Fisheries Area	Biological Capability	Salmon Escapements	Other Fisheries Stocks	Marine-Associated Birds	Marine Mammals
ALAS-1	80	3,678,400	30	1	1
1-W	119	-	-	16	3
1-E	139	3,042,175	29	41	3
2-W	704	1,810,830	99	19	3
2-E-N	64	838,850	24	21	2
2-E-S	382	2,130,885	89	71	3
3-X	80	-	-	6	2
3-Y	74	163,400	27	4	1
3-Z-S	438	3,652,247	-	1	1
4	1062	6,844,277	107	15	3
5	752	1,119,000	60	7	3
6-N	427	3,967,930	23	2	1
6-S	550	1,323,925	28	15	2
7	424	1,910,187	51	17	2
8	328	3,440,875	429	2	3
9	94	1,683,060	52	2	2
10	98	204,450	19	1	2
11	45	208,025	28	1	5
12-W	180	705,932	4	13	2
14-S	194	756,918	101	13	2
16	119	721,845	16	16	2
17-N	94	155,320	90	8	2
17-S	126	189,440	34	7	2
18	87	400,100	36	8	2
19	127		-	7	2
19 & 20		244,550			
20	126		-	6	2
21	87	-	-	1	2
22	37		-	1	2
22 & 23		2,024,657			
23	68		-	20	3
24	278	436,000	169	32	3
25	311	813,552	167	9	8
26	197	453,370	39	18	8
27	289	515,845	4	20	3
28	200	1,828,852	10	6	2
29	104	8,999,954	-	37	2
30	-	-	-	9	2
US-1	1070	4,739,156	23	30	2
US-2	99	-	45	7	4

(high, medium, low) with arbitrarily assigned numerical ratings, to which was added a reef factor, if present. The resulting number was multiplied by an arbitrary slope value. Other numerical ratings, varying with exposure, were added where estuaries were present to give final nearshore biological capability ratings. Rating components and sample calculations are shown in Table 7.2.3. Regional apportioning on a modified Fisheries Statistical Area basis is shown in Table 7.2.2.

Salmon Escapements

British Columbia's most commercially and recreationally valued fisheries resource is the Pacific salmon: sockeye, *Oncorhynchus nerka*, pink, *O. gorbuscha*, coho, *O. kisutch*, chum, *O. keta*, and chinook, *O. tshawytscha*. While there are considerable differences of size, habits and commercial and recreational values among the five species, it is assumed they are equally vulnerable to oil pollution.

The most vulnerable marine stage of the life cycle is the juvenile. It is during this stage of development that the salmon utilize estuarine and nearshore areas of the coast as rearing and feeding grounds. Considering the vulnerability of these nursery areas to oil spills, the Canada Department of Fisheries and the Environment and the Alaska and Washington state records of salmon escapement data (i.e., estimates of the numbers of adult fish reaching spawning grounds) were reviewed for all areas of the coast. These escapement figures were used as indicators of the number of juvenile salmonids likely to be reliant on the estuarine and nearshore areas of the coast for feeding and rearing.

Interpretation of escapement data requires a basic knowledge of its inherent limitations. Figures for salmon escapements are derived mainly from visual surveys and their accuracy varies considerably from stream to stream because of prevailing stream conditions, changes in recording personnel and different techniques of estimation. In many cases, both over-and under-estimates exist in the data. On the other hand, relatively accurate records are available for streams in some areas where salmon are enumerated at fishways and counting weirs or by tag and recapture programs. Consequently, the escapement data should be viewed only as a rating of relative abundance. This is particularly true with chinook and coho populations because their behavior patterns, spawning times and smaller numbers make them especially difficult to enumerate.

The maximum ever-recorded escapements by stream location were considered to most closely represent the maximum potential natural production and were used as the basis for determining the salmon escapement component of the BIOLOGICAL RESOURCE INDEX. These figures might be surpassed if salmon enhancement technology were applied to increase stream productivity.

The maximum recorded escapements for all species in all streams were summed by modified Fisheries Statistical Areas as per Table 7.2.2. (The appendices volume details salmon escapement values by stream location.)

TABLE 7.2.3 NEARSHORE BIOLOGICAL CAPABILITY RATINGS

EXPOSURE AND BOTTOM-TYPE RATINGS

	Protected	Channel	Open	Reefs
Estuary	high (12)	medium (8)	low (2)	-
Cobble	high (8)	high (8)	low (2)	medium (2)
Rock	medium (3)	low (2)	high (7)	high (3)
Sand	medium (3)	medium (3)	low (1)	low (1)

SLOPE RATINGS

Low (3)	Moderate (2)	Steep (1)

Sample Calculations:

1. Protected, rock, with reefs : 3 + 3 = 6
   Moderate slope : x2
   = 12
   Estuary : +12
   Nearshore Biological Capability Rating 24

2. Channel, cobble, with reefs : 8 + 2 = 10
   Low slope : x3
   = 30
   Estuary : +8
   Nearshore Biological Capability Rating 38

3. Open, Sand : 1
   Low slope : x3
   Nearshore Biological Capability Rating 3

Other Fisheries Stocks

Through comparison of the relative importance of fisheries stocks other than salmon, in terms of vulnerability to oil spills, herring were determined to be the most significant by a factor of at least ten to one over groundfish and other non-salmonids. Herring spawn, a good indication of herring values, was therefore used as the basis for rating "other fisheries stocks".

Herring spawn abundance is surveyed every year. In 1976, an unusually large spawn was recorded, with 508.2 miles of spawn deposited in British Columbia waters, far surpassing the 25-year average (1940 to 1964) of 199 miles and the previous record of 490.4 of spawn in 1975 (Webb, 1976). Based on the extent of herring spawn locations and their respective intensities of spawn for 1976, Webb developed rating values called "miles of spawn at a standard intensity of medium." These values were the ones used to rate "other fisheries stocks" from data acquired from available Canadian, Alaskan and Washington fisheries records. Herring ratings were then apportioned on a modified Fisheries Statistical Area basis (Table 7.2.2).

Marine-Associated Birds

The information used to calculate marine-associated bird ratings along the coast was derived from aerial and boat survey data, specific site study data, maps of breeding colonies and seabird concentrations and personal communications with seabird and survey biologists. Because of the sparsity of reliable data and the frequent shifting of bird populations, calculations necessarily were undertaken on a relatively broad, regional basis. Three categories were defined for the marine-associated bird data reviewed: abundance, species sensitivity and the importance of individual concentrations. A rating system was developed for each of these categories.

A. Abundance

The abundance of birds along the coast was rated according to the number of birds per linear mile of coastline or, in the case of breeding colonies, by the number of breeding individuals.

Birds/Mile	Breeding Individuals	Rating
less than 31	Less than 10,000	1
31 - 70	10,000 to 49,999	2
71 - 125	50,000 to 99,999	3
126 - 200	100,000 to 500,000	4
greater than 200	>500,000	5

B. Species Sensitivity

The species of birds were rated according to their sensitivity to oil spills.

Species	Rating
gulls, dabbling ducks, snow geese, Canada geese	1
bald eagles, swans, diving ducks, shearwaters	2
loons, grebes, cormorants, kittiwakes	3
storm petrels, phalaropes, brant	4
alcids, sea ducks	5

C. Importance of Individual Concentrations

This category served to weight the importance of particular concentrations of species in relation to the total coastal population for that species.

Importance of Concentration	Rating
low	1
medium	3
high	5

Key areas of known marine-associated bird significance were first mapped by season and then rated by adding the values from the three rating systems above for each key area (Figures 7.2.2 and 7.2.3). Seasonality was removed after regional apportioning on a modified Fisheries Statistical Area basis (Table 7.2.2).

Marine Mammals

The marine mammal rating system from 0 to 5 was based on the estimated degree to which an oil spill would deplete a species. Sea otters received the highest rating of 5, steller sea lions - 2, pelagic whales - 0 and all others - 1.

Key areas of known marine mammal significance were first mapped (Figure 5.3.1) and then assigned the forementioned ratings. Important areas are described below.

A. Nootka Peninsula-Brooks Peninsula

At least 90% of the B.C. population of sea otters is resident here all year and the species is highly sensitive to oil.

B. Cape St. James and the Scott Islands

Steller sea lions would be threatened during June-August when about 70% of the B.C. population is here to breed. As the species may well tolerate some oil contamination, the threat would be less than for sea otters.

C. La Pérouse Bank

Fur seal vulnerability to oil probably would be at a relatively low level here. While the species may have some sensitivity to oil, individuals tend to be scattered over a wide area and are quite mobile.

D. Fraser River-Boundary Bay; Rose Spit; Skeena River Mouth

The largest concentrations of harbour seals in B.C. occur in these localities, each of which numbers 500-800 seals (1-2% of the B.C. population). Owing to lack of experimental evidence, it is not known for certain how well harbour seals can tolerate oil, but it is likely they are not particularly vulnerable. This, in conjunction with their wide distribution suggests that the oil threat to harbour seals in B.C. is relatively low.

E. Folger Island, Barkley Sound

California sea lions are vulnerable here during winter, but to a lesser degree than the steller sea lion, as no breeding occurs.

The marine mammal ratings for various coastal regions were then apportioned on a modified Fisheries Statistical Area basis (Table 7.2.2).

Compilation of the BIOLOGICAL RESOURCE INDEX

The five components of the BIOLOGICAL RESOURCE INDEX (nearshore biological capability, salmon escapements, other fisheries stocks, marine-associated birds and marine mammals), having been apportioned on a modified Fisheries Statistical Area basis (Table 7.2.2), were next added by route (Table 7.2.1). The resulting route values were modified as follows (Table 7.2.4):

- Scaled to 100 to give common basis for weighting, with 100 representing the highest route rating for each component.
- Weighted (biological capability - 1.000, salmon escapements - .875, other fisheries stocks - .875, marine-associated birds - .750, marine mammals - .375) through a consensus of the research biologists who were involved in developing the individual rating factors.
- The five components were added.
- The totals were scaled to 100, with 100 representing the maximum BIOLOGICAL RESOURCE INDEX value. These scaled numbers composed the BIOLOGICAL RESOURCE INDEX (Table 7.2.4).

2. ECONOMIC RESOURCE INDEX

The economic exploitation of coastal resources in British Columbia has largely determined the historical development of the province; today the provincial economy remains significantly dependant on these resources. During the five-year period from 1971 to 1976, for example, the average wholesale value of salmon was $158 million with some 12,000 licensed commercial fishermen working on 7,400 vessels. Fishing activity additionally supported processing and retailing activities employing 5,000 people.

TABLE 7.2.4 BIOLOGICAL RESOURCE INDEX

Route No.	Annually Adjusted, Scaled to 100 and Weighted Values: Biological Capability	Salmon Escapements	Other Fisheries Values	Marine-Associated Birds	Marine Mammals	TOTAL	BIOLOGICAL RESOURCE INDEX (Scaled to 100)
1	42	55	18	23	8	146	38
2	42	55	18	23	8	146	38
3	71	65	27	29	10	202	52
4	89	65	34	41	11	240	62
5	64	37	23	32	9	165	42
6	60	48	63	40	14	225	58
7	60	48	63	40	14	225	58
8	89	65	34	36	9	233	60
9	64	37	23	28	7	159	41
10	60	48	63	35	13	219	56
11	60	48	63	35	13	219	56
12	77	41	50	56	25	249	64
13	82	42	67	58	28	277	71
14	82	42	67	58	28	277	71
15	87	75	71	68	34	335	86
16	87	75	71	68	34	335	86
17	100	88	88	75	38	389	100
18	100	88	88	75	38	389	100
19	100	88	88	75	38	389	100
20	47	30	37	29	12	155	40
21	52	31	55	31	15	184	47
22	52	31	55	31	15	184	47
23	54	64	59	41	21	239	61
24	54	64	59	41	21	239	61
25	70	76	75	48	25	294	76
26	70	76	75	48	25	294	76
27	70	76	75	48	25	294	76

To construct the economic ratings of coastal resources at risk from tanker traffic, five indicator data series were chosen. These were the average wholesale values of salmon, shellfish and other fish measured over the last five years, the value of commercial fishing vessels at home port and the value of recreational craft resident in coastal communities. Given the opportunity to perform more detailed analyses, it would have been possible to include other factors related to the value of marine resources such as forest products transported by sea, tourism or waterfront property values. However, for the purpose of determining relative risk, the parameters chosen were considered reasonable indicators of the "relativity" of economic concerns in coastal British Columbia and northwest Washington.

It should be noted that economic data for the U.S. were limited and were not available in a form similar to Canadian data. However, it was considered possible to render U.S. data series generally comparable to Canadian data for the purposes of this report.

Some consideration was given to the appropriateness of mixing concepts of "stock" and "flow", i.e., examining boat values in the same light as fish values. It was concluded that in ratings aimed at measurement of probable relative risk "at any point in time", the value of assets or activities simultaneously exposed to oil threat would be most appropriate.

Development of the ECONOMIC RESOURCE INDEX

A. Sections of Coastline

All data included in the economic ratings were grouped by coastal Regional District boundaries (including ocean areas) shown in Figure 7.2.4. For districts on the outside coasts, the boundaries of the ocean areas extended approximately 40 nautical miles from land.

B. Rating Components

1. Seaward Values

This first section of the ratings was composed of two values which were considered to relate directly to marine area; i.e., catch values of salmon and other fish (Table 7.2.5). For B.C. sections of the coast, wholesale values in thousands of dollars obtained from Fisheries Management statistics were averaged for the past five years. For the U.S. sections of coast, comparative data were obtained from a 1975 study (Stokes, 1975).

2. Landward Values

The three parameters included in the landward value component of the economic ratings were commercial fishing vessel values, recreational boat values and shellfish values (Table 7.2.5). Data for 1976 on the value of commercial vessels listed by home ports for B.C. were obtained from the Small Craft Harbours Branch, Department of Fisheries and the Environment. No such figures were available for the

TABLE 7.2.5 ECONOMIC RATINGS BY COASTAL SECTION

Coastal Section	Seaward Values: Water Area (NM^2)	Salmon ($000 5 y. av.)	Other Fish ($000 5 y. av.)	Total ($000)	Average Value per Square N.Mi.	Resulting Ratings	Landward Values: Nautical Miles of Shoreline	Commercial Vessel ($000)	Recreational Vessel ($000)	Shellfish ($000)	Total ($000)	Average Value per N.Mi.	Resulting Ratings
Skeena-Queen Charlotte													
Islands	16,807	8,926	12,364	21,290	1.27	3	957	3,368	1,337	812	5,517	5.76	1
Mainland	1,548	10,719	2,681	13,400	8.66	20	252	31,979	5,008	115	37,102	147.23	4
Kitimat - Stikine	3,332	14,233	4,420	18,653	5.60	13	892	2,142	6,071	246	8,459	9.48	1
Central Coast	4,782	28,543	9,042	37,585	7.86	18	357	3,840	784	99	4,723	13.23	1
Mt. Waddington													
Mainland (& Islands)	417	8,579	913	9,492	22.76	52	305	540	218	183	941	3.09	1
East Island	554	8,579	913	9,492	17.13	39	109	10,728	4,150	183	15,061	138.17	4
West Island	1,485	3,586	587	4,173	2.81	6	78	1,815	592	12	2,419	31.01	1
Comox-Strathcona													
Mainland (& Islands)	309	3,386	888	4,274	13.83	32	401	1,637	497	358	2,492	6.21	1
East Island	397	4,101	283	4,384	11.04	25	104	17,696	9,453	51	27,200	261.54	8
West Island	1,426	4,612	4,588	9,200	6.45	15	113	1,042	2,130	40	3,212	28.42	1
Powell River	524	683	355	1,038	1.98	5	187	4,447	7,605	81	12,133	64.88	2
Sunshine Coast	250	399	205	604	2.42	6	96	5,949	3,514	11	9,474	98.69	3
Nanaimo	343	1,527	2,096	3,623	10.56	24	70	15,044	13,651	525	29,220	417.43	13
Cowichan Valley													
East Island	142	203	380	583	4.11	9	39	5,764	4,044	56	9,864	252.92	8
West Island	108	4,086	281	4,367	40.44	92	17	16	-	68	84	4.94	1
Capital	671	11,575	1,763	13,338	19.88	45	174	25,447	27,869	507	53,823	309.33	9
Alberni - Clayoquot	3,048	18,355	14,130	32,485	10.66	24	96	17,357	8,657	1,565	27,579	287.28	9
Greater Vancouver	358	7,335	620	7,955	22.22	51	113	143,456	237,580	24	381,060	3,372.21	100
Squamish Lillooet	34	-	-	-	-	0	26	165	646	-	811	31.19	1
Juan De Fuca	2,124	2,210	1,700	3,910	1.84	4	150	4,860	6,966	186	12,012	80.08	2
North Puget Sound	605	25,370	1,110	26,480	43.77	100	375	55,760	60,115	123	115,998	309.33	9

U.S. sections. A rough estimate of U.S. values was obtained by multiplying values for adjacent Canadian waters by the ratio of U.S. to Canadian commercial catches made there.

Recreational vessel values were based on studies done by the Fisheries Management Service in 1974 and 1972 and updated in 1976. Boat ownership figures per household were projected to 1977 on the basis of population growth rates in coastal Regional Districts in B.C. Figures for northern B.C. and U.S. sections were extrapolated from boat ownership rates established for the north and west coast of Vancouver Island, and for Duncan - Gulf Islands, respectively.

Shellfish values for B.C. were derived from data compiled by the Fisheries Management Service of the Department of Fisheries and the Environment and averaged over the last five years. Values for the U.S. were obtained from a 1975 comparative study (Stokes, 1975).

C. Varying Size of Geographic Units

For the seaward values, the average dollar value per square nautical mile of marine area in each section was calculated. For the landward values, average dollar value per linear nautical mile of shoreline in each section was calculated. Rating numbers were assigned to each of the 21 sections on the basis of this dollar figure adjusted to reflect size and length of coastal sections. Although it was necessary to calculate values to compare sections of coastline, it should be noted that unit values showed significant variation owing to different configurations of geographic boundaries.

D. Special Localized Modification

A special modification was performed to the landward component in the Strait of Georgia region. It was considered that the recreational pressure exerted on areas adjacent to the dense population in the Greater Vancouver Regional District should be reflected in increased landward values in these areas. Therefore, an increment based on the dollar value associated with recreational vessel value for Greater Vancouver was added to adjacent areas through application of a modified transportation gravity model. (The original model suggests that the number of trips made from one centre to another is directly related to the population of the two centres and inversely related to the distance and/or travel cost between them.)

Modifying the basic gravity model relationship to consider a single population source (Greater Vancouver), the following formula was developed:

$$IRp_B = Rp_A \cdot \frac{DA}{DB}$$

where IRp_B = the incremental recreational pressure in zone B (the zone adjacent to Greater Vancouver)

Rp_A = the recreational pressure in zone A (Greater Vancouver)

DA = the radius of zone A (=10 miles)

DB = the distance from the centre of zone A to the outer limit of zone B (=30 miles)

The zonal relationship is displayed in Figure 7.2.4. Analyzing distance parameters as indicated, it was observed that the incremental recreational pressure to be associated with zone B would be one-third the pressure in zone A. Applying this incremental pressure assessment to the relative coastal recreational boat analysis, a value equal to one-third the value of recreational vessels moored in Greater Vancouver was assigned to each of the Regional Districts within zone B. Value per lineal foot of shoreline was then accordingly increased.

E. Final ECONOMIC RESOURCE INDEX

From the resulting economic ratings by section (Table 7.2.5), economic resource values were apportioned on a modified Fisheries Statistical Area route basis (Table 7.2.1), then scaled to 100 to derive the ECONOMIC RESOURCE INDEX as summarized in Table 7.2.6. (100 represented the highest ECONOMIC RESOURCE INDEX value.)

3. SOCIAL RESOURCE INDEX

Relative accessibility, a mild climate and the presence of marine resources are elements that have maintained the historic settlement pattern of urbanization of coastal B.C. and northwestern Washington. Today some 88 percent of the population of B.C. lives within 50 miles of the sea. Potentially then, any coastal developments have impacts upon the lifestyle of most residents of the province.

The ratings for the coastal region with respect to social resources were based on coastal residents' utilization of amenity opportunities. As it has been demonstrated (Krueckeberg and Silvers, 1974) that utilization of recreational/aesthetic opportunities is fundamentally a function of distance between residence and such opportunities, the number of people resident in a given area was taken as the basic measure of social value of each coastal section. (It was assumed that residents of Prince Rupert, Campbell River or Victoria associate similar values with living on the coast and have "equal" desires to have access to recreation opportunities.)

There are unquestionably a number of specific coastal features which could have been incorporated into an assessment of social resources. Certain historical or archeological sites and special, unique recreation areas (such as Long Beach on Vancouver Island) should receive consideration. However, it was concluded that if a choice had to be made by coastal residents between protecting "special" features from impacts and protecting areas "at home", people would choose the latter. On this basis, it was decided:

- to depend on distribution of population to provide the basis for the social ratings,
- to identify the need to provide additional, site-specific protection for historic, archeologic, cultural and other special features as detailed in the appendices volume. (It should be recognized that that listing is incomplete and that a more

TABLE 7.2.6 ECONOMIC RESOURCE INDEX

Route No.	Route Name	ECONOMIC RESOURCE INDEX (Scaled to 100)
1	Port Simpson (Dixon)	6
2	Ridley Island (Dixon)	6
3	Kitimat (Dixon, Principe)	11
4	Kitimat (Outer Coast, Hecate, Principe)	14
5	Kitimat (Outer Coast, Hecate, Caamano)	15
6	Bella Coola (Outer Coast, North Passage)	15
7	Bella Coola (Outer Coast, South Passage)	15
8	Kitimat (Hecate, Principe)	12
9	Kitimat (Hecate, Caamano)	9
10	Bella Coola (North Passage)	11
11	Bella Coola (South Passage)	11
12	Port Angeles (Outer Coasts, Juan De Fuca)	38
13	Esquimalt (Outer Coasts, Juan De Fuca)	43
14	Burrows Bay (Outer Coasts, Juan De Fuca)	43
15	Cherry Point (Outer Coasts, Juan De Fuca, Rosario)	72
16	Cherry Point (Outer Coasts, Juan De Fuca, Haro)	72
17	Roberts Bank (Outer Coasts, Juan De Fuca, Haro)	100
18	Port Moody (Outer Coasts, Juan De Fuca, Haro)	100
19	Britannia Beach (Outer Coasts, Juan De Fuca, Haro)	100
20	Port Angeles (Juan De Fuca)	30
21	Esquimalt (Juan De Fuca)	36
22	Burrows Bay (Juan De Fuca)	36
23	Cherry Point (Juan De Fuca, Rosario)	64
24	Cherry Point (Juan De Fuca, Haro)	64
25	Roberts Bank (Juan De Fuca, Haro)	93
26	Port Moody (Juan De Fuca, Haro)	93
27	Britannia Beach (Juan De Fuca, Haro)	93

thorough identification of such features, together with appropriate provision for their protection, must be an integral part of any properly conducted impact assessment.)

With population as the basis for calculating the social ratings, it was decided to rate both native and non-native populations. The two ratings were then combined, in an equal cultural weighting basis, to produce aggregate social ratings for both societies.

Development of the SOCIAL RESOURCE INDEX

A. Sections of Coastline

The geographic limits decided on for calculation purposes were the boundaries of the coastal Regional Districts of British Columbia (Table 7.2.7 and Figure 7.2.4). These areas were selected as they are the basis of population figures for the province. Wherever a Regional District included more than one shoreline (e.g., Mount Waddington includes three shorelines), it was subdivided. For the United States, the areas of the Strait of Juan de Fuca and North Puget Sound were utilized (Stokes, 1975).

B. Index Components

1. Affected Non-Native Population

The 1976 preliminary census results provided population figures for non-native residents in B.C. United States figures for county populations were obtained from the U.S. Department of Commerce, Bureau of Census.

2. Affected Native Population

Population figures for 1976 were obtained from the Department of Indian and Northern Affairs and from the U.S. Bureau of Indian Affairs.

C. Varying Size of Geographic Shoreline Units

The coastal sections selected demonstrated considerable variation in miles of shoreline within their boundaries. To compensate for this variation, the social ratings were recalculated to show numbers of native and non-native residents per nautical mile of shoreline for each section.

D. Aggregate Social Ratings

The non-native and native nautical shoreline mile ratings were each scaled to 100 to provide equal weighting to each, added together and the resulting sum was scaled to 100 against the highest section's value for final determination of aggregate social ratings (Table 7.2.7).

TABLE 7.2.7 SOCIAL RATINGS BY COASTAL SECTION

Coastal Section	Non-Native Coastal Population	Native Coastal Population	Nautical Miles of Shoreline	Non-Native People Per N.Mi. Shoreline	Native People Per N.Mi. Shoreline	Aggregate Social Ratings (Scaled to 100)
Skeena-Queen Charlotte						
Islands	3,365	1494	957	4	1	2
Mainland	17,129	1580	252	68	8	9
Kitimat - Stikine	28,266	5417	892	32	6	7
Central Coast	2,681	2369	357	8	6	7
Mt. Waddington						
Mainland (& Islands)	977	895	305	3	3	4
East Island	7,050	1459	109	65	13	16
West Island	3,100	143	78	40	2	2
Comox-Strathcona						
Mainland (& Islands)	2,180	229	401	5	1	2
East Island	40,564	638	104	390	6	11
West Island	12,285	564	113	109	5	7
Powell River	19,421	560	187	104	3	5
Sunshine Coast	12,016	560	96	125	6	7
Nanaimo	52,150	738	70	745	11	20
Cowichan Valley						
East Island	42,180	3181	39	1081	82	100
West Island	800	248	17	47	15	18
Capital	224,566	964	174	1291	5	18
Alberni - Clayoquot	30,625	3094	96	319	32	38
Greater Vancouver	1,055,245	1073	113	9338	10	100
Squamish Lillooet	9,000 (approx.)	1226	26	346	47	55
Juan De Fuca	14,504	1528	150	97	10	12
North Puget Sound	154,986	4207	375	413	11	15

E. Final SOCIAL RESOURCE INDEX

From these final aggregate social ratings by section (Table 7.2.7), social resource values were apportioned to modified Fisheries Statistical Areas by route (Table 7.2.1), then scaled to 100 to derive the SOCIAL RESOURCE INDEX as summarized in Table 7.2.8. (100 represented the highest SOCIAL RESOURCE INDEX value.) It should be noted that the range of values within the native ratings described above was relatively narrow compared to that in the non-native ratings, owing to a more even distribution of native peoples along the coast. However, combining the two sets of ratings, instead of presenting them independently, caused no significant reordering of coastal sections within the final SOCIAL RESOURCE INDEX.

7.3 FINAL RISK INDICES

The final BIOLOGICAL, ECONOMIC and SOCIAL RISK INDICES were derived by multiplying the NAVIGATIONAL RISK INDEX by each of the RESOURCE INDICES and scaling the results to 100, with 100 representing the highest resource risk values. Table 7.3.1 summarizes the three RISK INDICES which are used in Chapter 8 for ranking the various port/route alternatives.

TABLE 7.2.8 SOCIAL RESOURCE INDEX

Route No.	Route Name	SOCIAL RESOURCE INDEX (Scaled to 100)
1	Port Simpson (Dixon)	3
2	Ridley Island (Dixon)	3
3	Kitimat (Dixon, Principe)	4
4	Kitimat (Outer Coast, Hecate, Principe)	4
5	Kitimat (Outer Coast, Hecate, Caamano)	2
6	Bella Coola (Outer Coast, North Passage)	6
7	Bella Coola (Outer Coast, South Passage)	6
8	Kitimat (Hecate, Principe)	4
9	Kitimat (Hecate, Caamano)	2
10	Bella Coola (North Passage)	6
11	Bella Coola (South Passage)	6
12	Port Angeles (Outer Coasts, Juan De Fuca)	26
13	Esquimalt (Outer Coasts, Juan De Fuca)	41
14	Burrows Bay (Outer Coasts, Juan De Fuca)	41
15	Cherry Point (Outer Coasts, Juan De Fuca, Rosario)	69
16	Cherry Point (Outer Coasts, Juan De Fuca, Haro)	69
17	Roberts Bank (Outer Coasts, Juan De Fuca, Haro)	100
18	Port Moody (Outer Coasts, Juan De Fuca, Haro	100
19	Britannia Beach (Outer Coasts, Juan De Fuca, Haro)	100
20	Port Angeles (Juan De Fuca)	23
21	Esquimalt (Juan De Fuca)	39
22	Burrows Bay (Juan De Fuca)	39
23	Cherry Point (Juan De Fuca, Rosario)	67
24	Cherry Point (Juan De Fuca, Haro)	67
25	Roberts Bank (Juan De Fuca, Haro)	97
26	Port Moody (Juan De Fuca, Haro)	97
27	Britannia Beach (Juan De Fuca, Haro)	97

TABLE 7.3.1 FINAL RISK INDICES (Scaled to 100)

Route No.	Route Name	BIOLOGICAL RISK INDEX	ECONOMIC RISK INDEX	SOCIAL RISK INDEX
1	Port Simpson (Dixon)	8	1	1
2	Ridley Island (Dixon)	8	1	1
3	Kitimat (Dixon, Principe)	33	7	3
4	Kitimat (Outer Coast, Hecate, Principe)	50	11	3
5	Kitimat (Outer Coast, Hecate, Caamano)	24	8	1
6	Bella Coola (Outer Coast, North Passage)	36	9	4
7	Bella Coola (Outer Coast, South Passage)	39	10	4
8	Kitimat (Hecate, Principe)	42	8	3
9	Kitimat (Hecate, Caamano)	19	4	1
10	Bella Coola (North Passage)	29	6	3
11	Bella Coola (South Passage)	32	6	3
12	Port Angeles (Outer Coasts, Juan De Fuca)	35	21	14
13	Esquimalt (Outer Coasts, Juan De Fuca)	41	25	24
14	Burrows Bay (Outer Coasts, Juan De Fuca)	45	28	26
15	Cherry Point (Outer Coasts, Juan De Fuca, Rosario)	71	59	57
16	Cherry Point (Outer Coasts, Juan De Fuca, Haro)	71	59	57
17	Roberts Bank (Outer Coasts, Juan De Fuca, Haro)	87	87	87
18	Port Moody (Outer Coasts, Juan De Fuca, Haro)	100	100	100
19	Britannia Beach (Outer Coasts, Juan De Fuca, Haro)	92	92	92
20	Port Angeles (Juan De Fuca)	11	8	6
21	Esquimalt (Juan De Fuca)	15	11	12
22	Burrows Bay (Juan De Fuca)	17	13	14
23	Cherry Point (Juan De Fuca, Rosario)	34	35	37
24	Cherry Point (Juan De Fuca, Haro)	34	35	37
25	Roberts Bank (Juan De Fuca, Haro)	46	56	58
26	Port Moody (Juan De Fuca, Haro)	55	68	71
27	Britannia Beach (Juan De Fuca, Haro)	49	60	63

CHAPTER 8

COMPARATIVE RANKINGS OF PORT/ROUTE ALTERNATIVES

Previous chapters of this report have dealt descriptively and numerically with biological, economic and social resources of marine origin relative to oil spills off the West Coast. Chapter 7 summarized a system of resource risk ratings. This chapter outlines several methods of relative ranking of the Chapter 7 RISK INDICES and provides an interpretation of the final rankings.

It must be noted that the present analysis is not a substitute for detailed assessment of the impacts of oil terminal construction at selected ports. Thus, results of this report, while suggestive, are not adequate for deciding between ports which are closely ranked. However, some of the data gathered was in considerable detail and could be used to assist in a more thorough examination of specific ports.

It is also emphasized that the risks examined herein are primarily of marine origin. Further details on such other factors as air quality and terrestrial pipelines would have to be taken into account should development of an oil terminal be seriously considered.

This, and similar analyses, represent a departure from traditional methods of port site selection. All too often, it has been the case that a site has been chosen first and then presented individually for evaluation. This and similar studies, on the other hand, attempt to provide a regional overview of several alternative sites and a broad range of marine factors important in their selection. This is to determine, at least on a comparative basis, those port alternatives which present the "least marine risk". However, it is emphasized that even "least risky" ports could prove unacceptable owing to non-marine risk factors.

8.1 METHODS OF COMPARATIVE RANKING

Examination of Table 7.3.1 indicates that the three marine RISK INDICES clearly agree on the two port/route alternatives which are relatively "least risky" and the three that are relatively "most risky". It is further evident that a strong relationship exists overall between the rankings of the three RISK INDICES. (The Kendall Coefficient of Concordance for the three rankings suggests that they are strongly related at the .001% confidence level.) On this basis, the three rankings of the RISK INDICES were summed and averaged to obtain an overview of study results. The ranks so obtained are presented in Table 8.1.1, with port/route alternatives rearranged from "least risky" to "most risky". Resulting averages were then ranked as shown in Column 1 of Table 8.1.2.

In addition to considering this "average ranking" system, three other methods were used. These are described below and their resulting values appear in Table 8.1.2.

TABLE 8.1.1 AVERAGE OF RISK INDICES RANKINGS

Route Name	(Route No.)	BIOLOGICAL RISK INDEX Ranking	ECONOMIC RISK INDEX Ranking	SOCIAL RISK INDEX Ranking	Average of Rankings
Port Simpson (Dixon)	(1)	1.5	1.5	2.5	1.8
Ridley Island (Dixon)	(2)	1.5	1.5	2.5	1.8
Kitimat (Hecate, Caamano)	(9)	6	3	2.5	3.8
Kitimat (Outer Coast, Hecate, Caamano)	(5)	7	8	2.5	5.8
Bella Coola (North Passage)	(10)	8	4.5	7	6.5
Bella Coola (South Passage)	(11)	9	4.5	7	6.8
Port Angeles (Juan De Fuca)	(20)	3	8	12	7.7
Kitimat (Dixon, Principe)	(3)	10	6	7	7.7
Esquimalt (Juan De Fuca)	(21)	4	12.5	13	9.8
Kitimat (Hecate, Principe)	(8)	17	8	7	10.7
Burrows Bay (Juan De Fuca)	(22)	5	14	14.5	11.2
Bella Coola (Outer Coast, North Passage)	(6)	14	10	10.5	11.5
Bella Coola (Outer Coast, South Passage)	(7)	15	11	10.5	12.2
Kitimat (Outer Coast, Hecate, Principe)	(4)	21	12.5	7	13.5
Port Angeles (Outer Coasts, Juan De Fuca)	(12)	13	15	14.5	14.2
Esquimalt (Outer Coasts, Juan De Fuca)	(13)	16	16	16	16
Cherry Point (Juan De Fuca, Rosario)	(23)	11.5	18.5	18.5	16.2
Cherry Point (Juan De Fuca, Haro)	(24)	11.5	18.5	18.5	16.2
Burrows Bay (Outer Coasts, Juan De Fuca)	(14)	18	17	17	17.3
Roberts Bank (Juan De Fuca, Haro)	(25)	19	20	22	20.3
Cherry Point (Outer Coasts, Juan De Fuca, Rosario)	(15)	23.5	21.5	20.5	21.8
Cherry Point (Outer Coasts, Juan De Fuca, Haro)	(16)	23.5	21.5	20.5	21.8
Britannia Beach (Juan De Fuca, Haro)	(27)	20	23	23	22
Port Moody (Juan De Fuca, Haro)	(26)	22	24	24	23.3
Roberts Bank (Outer Coasts, Juan De Fuca, Haro)	(17)	25	25	25	25
Britannia Beach (Outer Coasts, Juan De Fuca, Haro)	(19)	26	26	26	26
Port Moody (Outer Coasts, Juan De Fuca, Haro)	(18)	27	27	27	27

TABLE 8.1.2 RESULTS OF FOUR METHODS OF RANKING PORT/ROUTE ALTERNATIVES

Route Name	(Route No.)	Ranking of Average of RISK INDICES Rankings (Col.1)	Ranking of Sum of RISK INDICES (Col.2)	Ranking of Worst RISK INDEX Ranking (Col.3)	Ranking of Worst RISK INDEX (Col.4)
Port Simpson (Dixon)	(1)	1-2	1-2	1-2	1-2
Ridley Island (Dixon)	(2)	1-2	1-2	1-2	1-2
Kitimat (Hecate, Caamano)	(9)	3	3	3	6
Kitimat (Outer Coast, Hecate, Caamano)	(5)	4	5	4-5	7
Port Angeles (Juan De Fuca)	(20)	7-8	4	8	3
Bella Coola (North Passage)	(10)	5	6-7	4-5	8
Esquimalt (Juan De Fuca)	(21)	9	6-7	9	4
Bella Coola (South Passage)	(11)	6	8	6	9
Kitimat (Dixon, Principe)	(3)	7-8	9	7	10
Burrows Bay (Juan De Fuca)	(22)	11	10	11	5
Bella Coola (Outer Coast, North Passage)	(6)	12	11	10	12
Bella Coola (Outer Coast, South Passage)	(7)	13	12-13	12-13	15
Kitimat (Hecate, Principe)	(8)	10	12-13	15	17
Port Angeles (Outer Coasts, Juan De Fuca)	(12)	15	15	12-13	11
Kitimat (Outer Coast, Hecate, Principe)	(4)	14	14	19	19
Esquimalt (Outer Coasts, Juan De Fuca)	(13)	16	16	14	16
Cherry Point (Juan De Fuca, Rosario)	(23)	17-18	18-19	17-18	13-14
Cherry Point (Juan De Fuca, Haro)	(24)	17-18	18-19	17-18	13-14
Burrows Bay (Outer Coasts, Juan De Fuca)	(14)	19	17	16	18
Roberts Bank (Juan De Fuca, Haro)	(25)	20	20	20	20
Britannia Beach (Juan De Fuca, Haro)	(27)	23	21	21	21
Cherry Point (Outer Coasts, Juan De Fuca, Rosario)	(15)	21-22	22-23	22-23	22-24
Cherry Point (Outer Coasts, Juan De Fuca, Haro)	(16)	21-22	22-23	22-23	22-24
Port Moody (Juan De Fuca, Haro)	(26)	24	24	24	22-24
Roberts Bank (Outer Coasts, Juan De Fuca, Haro)	(17)	25	25	25	25
Britannia Beach (Outer Coasts, Juan De Fuca, Haro)	(19)	26	26	26	26
Port Moody (Outer Coasts, Juan De Fuca, Haro)	(18)	27	27	27	27

- Because the three RISK INDICES showed a strong consistency in their relationship to one another, a decisional judgement was made to treat the BIOLOGICAL, ECONOMIC and SOCIAL RISK INDICES as equally important. On this basis, the sums of the RISK INDICES were ranked and are shown in Column 2 of Table 8.1.2.
- A "most conservative" approach of avoiding worst events, regardless of the RISK INDEX, was assumed. In this procedure, only the highest risk ranking of the three indices rankings listed for each port/route alternative was considered. The resulting rankings of worst RISK INDEX rankings are shown in Column 3 of Table 8.1.2.
- The "most conservative" approach of avoiding worst events was also taken for ranking worst RISK INDEX values, as shown in Column 4 of Table 8.1.2.

8.2 RESULTS OF THE RANKING METHODS

In surveying the various RESOURCE INDICES developed in Chapter 7, it is apparent that no port/route alternative is free of negative impact. Therefore, any port site and corresponding tanker route that might eventually be seriously proposed threatens valuable environmental resources and thus must undergo detailed pre-construction impact assessment.

In the present analysis, it should be noted that port/route alternatives which rank close to one another are dependent upon the decisional criteria assumed. For example, from Table 8.1.2, Kitimat (Hecate, Caamano) ranks quite close to Port Angeles (Juan De Fuca). However, if one were to consider the final RISK INDICES shown for these two port/route alternatives in Table 7.3.1, it is apparent that the BIOLOGICAL RISK is higher at Kitimat and the ECONOMIC and SOCIAL RISKS are higher at Port Angeles. Any final choice between the two ports would depend on the relative weightings that might be assigned to each of the three RISK INDICES.

Notwithstanding the above observations, it is evident that two alternatives, Port Simpson (Dixon) and Ridley Island (Dixon) are "least risky" under all the various methods used (Table 8.1.2). Beyond these ports, Kitimat (Hecate, Caamano) appears next "least risky", but this judgement could be .altered in favour of Port Angeles (Juan de Fuca), Bella Coola (North Passage) or Esquimalt (Juan de Fuca), under alternative decisional criteria. Clearly, further detailed analyses would have to be undertaken if a final choice were to be made between the latter alternatives.

The results of the various ranking methods thus far delineated can be further clarified by selection of only the "least risky" approach to each port (Table 8.2.1). This in affect results in the elimination of all nearshore routes in close proximity to the outer coast(s), as well as several routing alternatives in internal waterways.

TABLE 8.2.1 RANKINGS OF LEAST RISKY ROUTE ALTERNATIVES FOR EACH PORT

Route Name	(Route No.)	Ranking of Average of RISK INDICES Rankings	Ranking of Sum of RISK INDICES	Ranking of Worst RISK INDEX Ranking	Ranking of Worst RISK INDEX
Port Simpson (Dixon)	(1)	1-2	1-2	1-2	1-2
Ridley Island (Dixon)	(2)	1-2	1-2	1-2	1-2
Kitimat (Hecate, Caamano)	(9)	3	3	3	6
Port Angeles (Juan De Fuca)	(20)	5	4	5	3
Bella Coola (North Passage)	(10)	4	5-6	4	7
Esquimalt (Juan De Fuca)	(21)	6	5-6	6	4
Burrows Bay (Juan De Fuca)	(22)	7	7	7	5
Cherry Point (Juan De Fuca, Rosario)	(23)	8	8	8	8
Roberts Bank (Juan De Fuca, Haro)	(25)	9	9	9	9
Britannia Beach (Juan De Fuca, Haro)	(27)	10	10	10	10
Port Moody (Juan De Fuca, Haro)	(26)	11	11	11	11

8.3 DISCUSSION OF DECISIONAL POLICY FOR APPROPRIATE RISK DISTRIBUTION

Having appraised the relative rankings of various port/route alternatives, a final comment on decisional policy strategy seems appropriate. In theoretical terms, a choice exists (in the event a West Coast oil port were considered desirable) between concentrating risk along a single port/route and distributing the risk across several ports/routes. In the former case, impact would fall upon a single subregion; in the latter, across several subregions. In decisional terms, a distribution of risk across several port/route alternatives might hold better hope for continued viability over time of all subregional ecosystems. Alternatively, the costs of vessel traffic management, navigation aids and standby cleanup equipment could mitigate strongly for the selection of one centralized port location.

Either alternative must be re-evaluated when present and potential U.S. oil ports are considered. For example, protection of Canadian coastlines could be preempted by unilateral American decisions regarding port location(s), vessel traffic management systems and cleanup readiness. What international methods might be open to secure understanding and assurance are beyond the scope of the present report. However, the potential of West Coast Canada facing environmental risk from not one, but two major ports, and the consequent reordering of economic benefits and economic and environmental costs obviously would require extensive detailed analysis and negotiation. Similarly, the existence of a major Alaskan oil route to Washington State will continue to pose a degree of threat, irrespective of whether or not Canada decides to build a West Coast superport.

At best, this report is only one contribution towards any specific environmental port/route assessment. A complete analysis would necessarily include not only more detailed marine information, but also evaluation of pipeline impacts, air pollution potential and terminal site characteristics.

CHAPTER 9

PREVENTIVE, CLEANUP AND COMPENSATORY CONSIDERATIONS

While preceeding chapters concentrated on the relative risks of oil spills and potential damages to resources of the B.C. and Washington coasts, this chapter deals briefly with the international/national nature of the oil spill problem, means of spill prevention, cleanup costs and compensatory measures.

9.1 INTERNATIONAL TANKER SAFETY - A NATIONAL PROBLEM

The principal international body attempting to control and upgrade tanker safety is the Inter-Governmental Maritime Consultive Organization (IMCO), an agency of the United Nations. It convenes conferences to develop conventions, protocols and regulations which must then be ratified by the member states - an often time-consuming process. Governments not in agreement are not bound by the conventions. Further, IMCO sometimes has proved susceptible to pressure from shipping nations and oil transport interests, and cannot be assumed, a priori, to clearly align itself with the interests of coastal states threatened by oil transport routings.

It is significant that major recent improvements in safety and pollution control have more often than not involved unilateral action by such coastal states as Canada, the United States and the United Kingdom, in response to immediate threats where the national costs of inaction were perceived as high. This appears to be the case on the Canadian West Coast for the near to medium term.

Not only may international interest be dicotimised between oil exporters/importers on the one hand, and coastal areas under threat on the other, but also economic returns from oil transportation activities can provide further complications. While incident data are still limited, it has been clearly established from testimony by tanker owners that tankers are run under flags of convenience for one broad purpose - to bypass the construction and operation costs required by nations with more stringent laws. Although it is plausible that such nations might be willing to "follow along behind" in matters of safety, it is unlikely that they will unilaterally adopt a uniform and stringent safety code, thereby eliminating to a considerable degree their comparative economic advantage.

Finally, the degree to which international oil companies and their related tanker fleets can be expected to enforce strict standards will likely be affected by the relative supply of and demand for tankers. Oil companies characteristically use their own tankers which are for the most part well-controlled and manned, and are acquired to fulfill some predetermined portion of oil transportation requirements. Consequently, when transportation requirements are stabilized at or near the level that can be met by their own fleets, oil companies may not find it difficult to meet high shipping standards. However, requirements in excess of that level are met by charter and can vary widely. At such times, it is unlikely that companies voluntarily defer additional shipments in order to meet strict safety standards.

9.2 PREVENTION - THE PREFERRED STRATEGY

Because there is no guarantee that oil spills will not occur on this coast and because spill cleanups rarely prove totally effective, the major thrust of a sound coastal oil strategy must be directed towards prevention. Preventive measures generally can be enacted with nominal cost to the international tanker fleet and at an extremely small cost to Canada. This conclusion is further reinforced should Canada and the United States act in concert. Conversely, the full and considerable costs of not implementing such a policy has to be borne by Canadians.

Examples of preventive measures are discussed below.

Design and Construction Standards

Currently, there are several safety design features being considered for implementation on tankers, particularly by the U.S. and IMCO. These include segregated ballast, load-on-top, double bottoms, defensive location of segregated ballast, crude oil washing techniques, inert gas systems, backup and collision avoidance radars, emergency steering gear, backup power systems and bow thrusters. While there is controversy over some of these engineering features, the U.S. and several major oil companies are strongly supporting several of them. Canada's interest would best be served by the taking of a similarly strong position. This is particularly significant in light of the fact that the costs associated with design improvements and modifications largely affect foreign tanker fleets and owners, while the costs of inaction fall on Canadians.

Another oft-discussed factor in tanker design safety is that of vessel age, but because standards of construction vary greatly, vessel age provides only a general indicator of safety. Consequently, application of standards must be vessel-by vessel.

Equipment and Operating Procedures

The Canadian Coast Guard has substantial regulations on vessel equipment and safe operating procedures. It must also be given the authority and incentive to verify that regulated equipment is in working order and that specified operating procedures are followed.

Manning of Vessels

It is estimated that 80 to 85 percent of tanker incidents involve human error. Therefore, it is critically important that Canadian Coast Guard regulations involving certification of competence be closely adhered to. A periodically updated medical certificate also should be required and crews of vessels approaching the coast must be sufficiently fluent in English. Finally, it is recommended that each vessel be adequately manned so that no single officer bears an undue share of responsibility at the time of vessel entry into Canadian waters.

Vessel Control - Inspection and Penalties

If the safety standards required to protect Canadian interests are to be guaranteed, Canadian officials must be able to meet each inbound tanker at its point of departure or entry into Canadian waters to ascertain whether safety requirements are in effect. In the case of oil from Alaska, the placing of an inspector on each tanker at Valdez should receive careful consideration. Certification at other points of origin of vessels that must meet Canadian standards might also be considered.

Large financial penalties, when coupled with the often low probability of getting caught, are not absolute guarantees that safety standards will be observed. As large oil tankers have been known to make a profit of several million dollars on a single trip - making delay extremely costly - it is strongly recommended that:

- Tankers failing to meet Canadian standards be denied entry to Canadian waters, except when denial might constitute a greater risk to the Canadian shoreline.
- Tankers and their masters convicted of violating Canadian safety standards be denied subsequent entry into Canadian waters.

These two measures would likely be highly effective in reducing the oil spill risks associated with coastal tanker traffic.

Other Vessels

As a significant number of tanker accidents involves collision with other types of vessels, safety standards applied to oil tankers alone can not be fully successful. It is therefore recommended that the standards enacted for tanker traffic, particularly in terms of crew qualifications, operating procedures and equipment, be applied to other commercial traffic over a three to five year period.

Tanker Support Facilities

Should an oil terminal be established on the Canadian West Coast, other complementary facilities might subsequently be proposed - especially supertanker drydocking facilities which are in short supply internationally. Such a facility would have to be subjected to its own rigorous impact assessment, as it might serve as a beacon for every battered or disabled supertanker in this part of the North Pacific, considerably intensifying the pollution risk to the British Columbia coast.

Offshore Tanker Traffic

If Canada decides it is not in her best interests to accommodate a major supertanker port on her West Coast, the threat of oil pollution still would not be entirely removed, as tanker traffic will continue to move off the B.C. coast from Valdez and the Mideast. Experience along other similarly situated shores (South Africa is a particularly striking example), suggests that oil slicks could become frequent as a result of tanker accidents.

It is therefore fundamental that Canada collaborate with the United States to establish routing procedures for ensuring that assistance and cleanup crews reach stricken ships and for monitoring offshore vessels (particularly by means of a more extensive Vessel Traffic Management system). It is further necessary to develop explicit procedures concerning rescue, provision of refuge for disabled vessels, or alternatively, disposal at sea of wrecks which pose too great a risk to shoreline values.

9.3 CLEANUP COSTS

Route Cleanup

Because each of the potential routes presents different impediments to oil spill cleanup operations, sample individual cleanup ratings were calculated using methodologies similar to those developed for the evaluation of alternative oil port sites on the East Coast of Canada (Canada, Department of Fisheries and the Environment, 1976). Modifications to that methodology reflect conditions specific to West Coast tanker traffic, i.e., several longer routes running parallel and close to the coastline and extended transits through relatively narrow passages. Therefore, a larger representative oil spill volume and a greater number of sample slick areas were selected for the purposes of the present study.

Based on a hypothetical 50,000 ton crude oil continuous spill lasting seven days, slick areas or "envelopes" were plotted for summer and winter from each of the route segment mid-points (Figures 9.3.1 and 9.3.2). Details on the underlying assumptions and techniques of this slick area method are provided in the appendices volume. Quantification of total cleanup costs on a route basis was carried out as follows (Tables 9.3.1 and 9.3.2):

- Offshore cleanup costs were determined for winter and summer slick areas.
- Shoreline cleanup costs were determined for winter and summer slick areas.
- The offshore and shoreline seasonal values thus derived were added together by slick area and divided by seasonal effectiveness factors.
- These modified seasonal slick area values were then adjusted to annual cleanup ratings and scaled to 100, with 100 representing the highest slick area cleanup rating.
- Slick area ratings were added by route and scaled to 100, with 100 representing the highest route cleanup rating (Table 9.3.2).

TABLE 9.3.1 SLICK AREA ANNUAL CLEANUP RATINGS

Slick No.	Offshore and Shoreline Totalled Costs		Effectiveness Values		Seasonal Cleanup Ratings		Final Annual Cleanup Ratings Scaled to 100
	Winter	Summer	Winter	Summer	Winter	Summer	
1	17.2	8.8	.32	.47	53.8	18.7	41
2	10.7	12.5	.29	.43	36.9	29.1	35
3	40.4	39.5	.58	.70	69.7	56.4	67
4	23.8	18.7	.61	.72	39.0	26.0	35
5	23.3	12.5	.33	.50	70.6	25.0	54
6	15.7	8.1	.25	.39	62.8	20.8	47
7	29.5	8.8	.31	.43	95.2	20.5	67
8	42.1	31.6	.43	.51	97.9	62.0	86
9	45.1	37.4	.51	.64	88.4	58.4	79
10	31.1	13.8	.23	.38	135.2	36.3	98
11	38.8	15.1	.36	.47	107.8	32.1	79
12	55.7	45.8	.51	.59	109.2	77.6	100
13	28.2	13.3	.25	.42	112.8	31.7	82
14	21.3	8.9	.31	.41	68.7	21.7	51
15	22.4	14.0	.25	.36	89.6	38.9	72
16	19.5	10.9	.31	.41	62.9	26.6	50
17	34.3	10.5	.25	.34	137.2	35.9	99
18	17.5	11.5	.31	.46	56.5	25.0	45
19	17.2	10.4	.25	.34	68.8	30.6	55
20	43.8	8.4	.31	.41	141.3	20.5	95
21	42.9	8.2	.33	.42	130.0	19.5	88
22	22.6	13.5	.36	.47	62.8	28.7	51
23	40.9	37.9	.55	.61	74.4	62.1	72
24	34.4	21.0	.60	.68	57.3	30.9	48
25	30.1	29.4	.61	.71	49.3	41.4	48
26	18.0	8.4	.30	.34	68.0	24.7	52
27	17.8	7.6	.30	.39	59.3	19.5	45
28	17.7	6.7	.31	.41	57.1	16.3	42
29	24.0	6.6	.32	.43	75.0	15.3	52
30	23.2	5.6	.34	.43	68.2	13.0	47
31	27.9	5.2	.47	.56	59.4	9.3	41
32	33.2	7.0	.57	.58	58.2	12.1	41
33	11.8	5.9	.61	.57	19.3	10.4	17
34	9.2	6.5	.65	.71	14.2	9.2	13
35	9.6	5.1	.69	.75	13.9	6.8	11
36	9.4	5.4	.67	.73	14.0	7.4	11
37	15.3	14.0	.77	.85	19.9	16.5	20
38	17.5	12.0	.72	.80	24.3	15.0	21
39	14.6	6.0	.74	.82	19.7	7.3	16
40	24.4	20.0	.77	.85	31.7	23.5	29
41	22.2	25.3	.73	.86	30.4	29.4	31
42	11.6	22.7	.78	.80	14.9	28.4	22
43	13.8	22.4	.86	.94	16.0	23.8	20

TABLE 9.3.2 ROUTE CLEANUP RATINGS

Route No.	Route Name	Cleanup Ratings
1	Port Simpson (Dixon)	19
2	Ridley Island (Dixon)	12
3	Kitimat (Dixon, Principe)	77
4	Kitimat (Outer Coast, Hecate, Principe)	100
5	Kitimat (Outer Coast, Hecate, Caamano)	73
6	Bella Coola (Outer Coast, North Passage)	69
7	Bella Coola (Outer Coast, South Passage)	73
8	Kitimat (Hecate, Principe)	88
9	Kitimat (Hecate, Caamano)	62
10	Bella Coola (North Passage)	54
11	Bella Coola (South Passage)	58
12	Port Angeles (Outer Coasts, Juan De Fuca)	42
13	Esquimalt (Outer Coasts, Juan De Fuca)	46
14	Burrows Bay (Outer Coasts, Juan De Fuca)	46
15	Cherry Point (Outer Coasts, Juan De Fuca, Rosario)	54
16	Cherry Point (Outer Coasts, Juan De Fuca, Haro)	50
17	Roberts Bank (Outer Coasts, Juan De Fuca, Haro)	54
18	Port Moody (Outer Coasts, Juan De Fuca, Haro)	58
19	Britannia Beach (Outer Coasts, Juan De Fuca, Haro)	54
20	Port Angeles (Juan De Fuca)	15
21	Esquimalt (Juan De Fuca)	15
22	Burrows Bay (Juan De Fuca)	15
23	Cherry Point (Juan De Fuca, Rosario)	23
24	Cherry Point (Juan De Fuca, Haro)	23
25	Roberts Bank (Juan De Fuca, Haro)	23
26	Port Moody (Juan De Fuca, Haro)	31
27	Britannia Beach (Juan De Fuca, Haro)	27

Further details on some of these calculations follow:

A. Offshore Cleanup Costs

The formula developed for this component of the cleanup ratings for each of the seasonal slick areas was as follows:

Offshore Costs =

$$[\text{Disposal} + (\text{Operating Costs} \times \text{Distance Factor})] \times \frac{y}{y\ max} \quad \text{where:}$$

y = square nautical mile area of sample slick

y max = square nautical mile area of maximum slick

Disposal referred to the costs of disposing of recovered materials and used treating agents such as absorbents.

Operating Costs represented vessel rental and operation, materials, labour, meals and lodging.

Distance Factor indicated, on a scale from one to two, the effects of accessibility on costs of road, air and marine transport of equipment, supplies and manpower.

Capital costs of equipment such as booms, slick-lickers, skimmers, ancillary devices and treating agents were not included in the formula. They were assumed to be constant for each route alternative because of their presumed availability at any marine oil terminal.

B. Shoreline Cleanup Costs

The shorelines contaminated by each of the seasonal slick areas were measured in nautical miles on the basis of four categories: mud flats, sand beaches, cobble and rocky shorelines and cliffs. (Mud flats were important in this study as a reflection of the ecological sensitivity of estuary areas and the proportionately higher costs of estuary cleanup operations.)

Dollar values ascribed to these four categories in terms of cleanup costs were:

mud flats - $9.60 / lineal foot
sand beaches - $4.80 / lineal foot
cobbles and rocks - $8.40 / lineal foot
cliffs - $6.00 / lineal foot

These costs were higher than those used in the East Coast study. Present values were based on more recent cost estimates, higher operating costs on the Pacific Coast and cost figures from spills that have occurred since the writing of the East Coast report.

Finally, the same distance factors as derived for offshore cleanup costs were used to modify shoreline cleanup values for each slick area.

C. Effectiveness Criteria

Effectiveness criteria represented the basic physical limitations to successful oil cleanup operations. To rate effectiveness for each slick area, values for several factors were determined from meteorological, oceanographic and demographic data. The factors identified and weighted included wind (50 points), nearby human settlements (50), currents (30), wave heights (25) and visibility (20) - with low scores indicating low effectiveness.

Terminal Cleanup

Cleanup ratings for slick areas at each terminal (Figure 9.3.3) were calculated by a method similar to the one used for route cleanup ratings, except for three modifications. First, no distance factor was required, as the spill was assumed to occur at each terminal. Second, effectiveness of cleanup at the various ports was estimated to be very nearly the same, as it was implicit that a certain minimum level of contingency response capability would be established by any terminal operator, wherever the site; thus, no effectiveness index was developed. Third, the formula for offshore cleanup near terminals differed in the calculation of operating costs, because it was possible to make more precise predictions as to what equipment would be used. The formula adopted in this case was:

Offshore Cleanup Cost = Operating Costs x $\frac{y}{y_{max}}$ where:
Operating Costs for offshore cleanup included tugs, smaller craft, equipment, labour, meals and lodging. It was calculated at $195,000 for the largest terminal spill and then proportionally rated for the other slicks.

Total offshore and shoreline cleanup costs were added together for each port site. Table 9.3.3 shows the final terminal cleanup ratings.

TABLE 9.3.3 TERMINAL CLEANUP RATINGS

Terminal No.	Terminal Name	Cleanup Ratings
1	Port Simpson	30
2	Ridley Island	100
3	Kitimat	26
4	Bella Coola	42
5	Britannia Beach	45
6	Port Moody	44
7	Roberts Bank	19
8	Esquimalt	40
9	Cherry Point	38
10	Burrows Bay	28
11	Port Angeles	26

Cleanup Considerations

In view of the wide range of cleanup values in both the route and terminal ratings, it is evident that effective contingency plans must be highly route and site-specific. Careful pre-planning for cleanup operations is essential prior to port approval. It must include practical details on equipment and supplies, manpower training and practice, living accommodations and emergency tug and barge support relative to the spill potential in each case.

9.4 COMPENSATION

Although a West Coast oil port may conceivably be advantageous to Canada as a nation, it can not be beneficial to the B.C. coastline. Despite possible conscientious efforts towards preventing oil spills, West Coast tanker traffic is unlikely to provide any direct benefits to the present users of B.C.'s marine resources and will inevitably bring about adverse impacts, some of which could be substantial. It is in this framework that the issue of compensation must be considered.

Presently there are several international and U.S. funds available to parties suffering loss or damage because of an oil spill. These include TOVALOP (Tanker Owners Voluntary Agreement Concerning Liability), CRISTAL (Contract Regarding an Interim Supplement to Tanker Liability for Oil Pollution) and the $100,000,000 TAPS fund. Canada has instituted a Maritime Pollution Claims Fund which currently totals about $45,000,000. The major limitation with such sources of compensation is the difficulty of access to them; litigation is frequently protracted and complicated, particularly for the individual who suffers damage. The authors of this report suggest that consideration be given both to increasing the Canadian compensation monies available and to revising the terms on which the Maritime Pollution Claims Fund is accessible.

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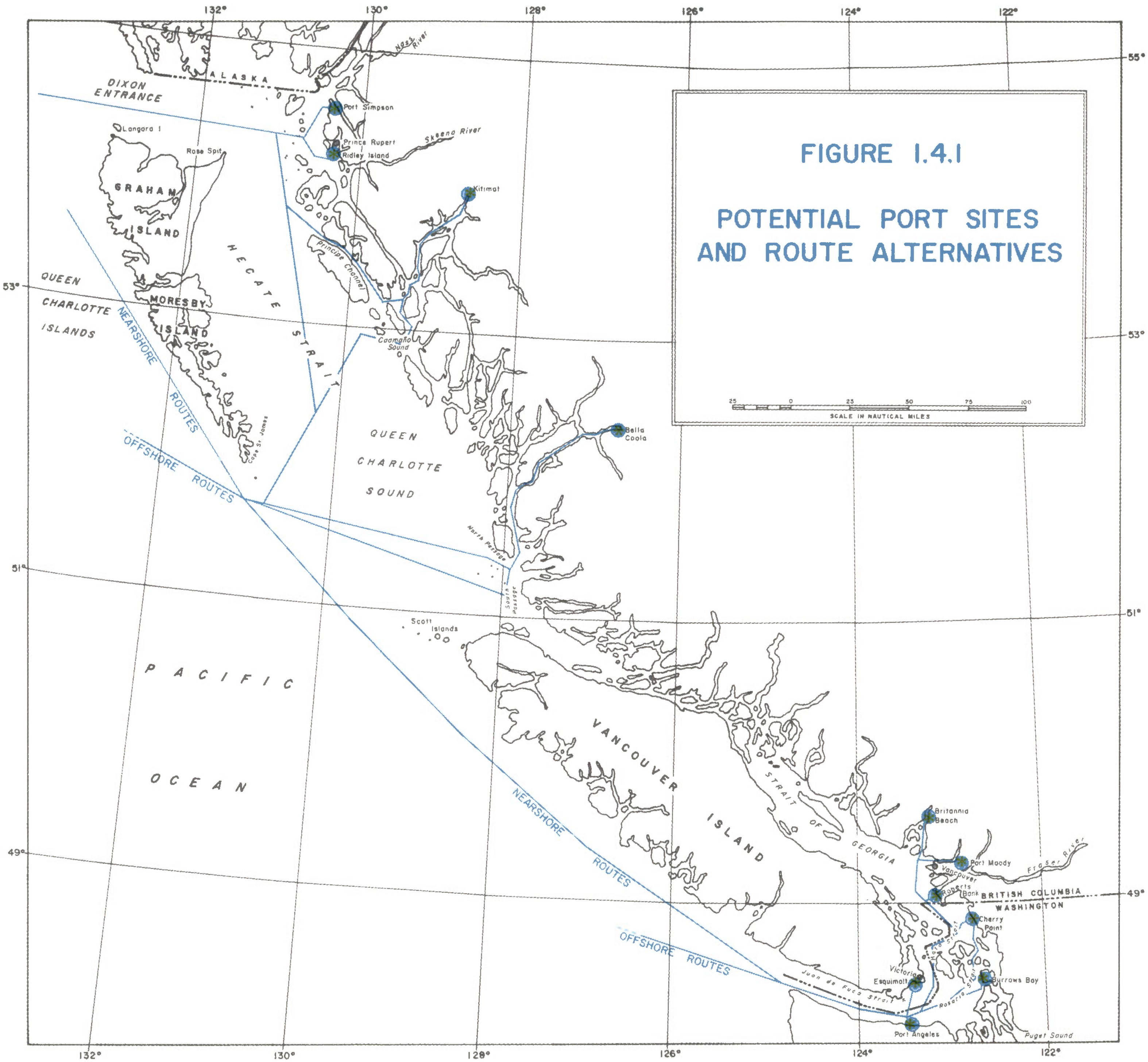

FIGURE 1.4.1
POTENTIAL PORT SITES
AND ROUTE ALTERNATIVES
SCALE IN NAUTICAL MILES
ALASKA
DIXON ENTRANCE
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Kitimat
Langara I
Rose Spit
GRAHAM ISLAND
HECATE STRAIT
Principe Channel
QUEEN CHARLOTTE ISLANDS
MORESBY ISLAND
Caamaño Sound
NEARSHORE ROUTES
OFFSHORE ROUTES
Cape St James
QUEEN CHARLOTTE SOUND
Bella Coola
North Passage
South Passage
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Fraser River
Roberts Bank
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Juan de Fuca Strait
Burrows Bay
Port Angeles
Puget Sound

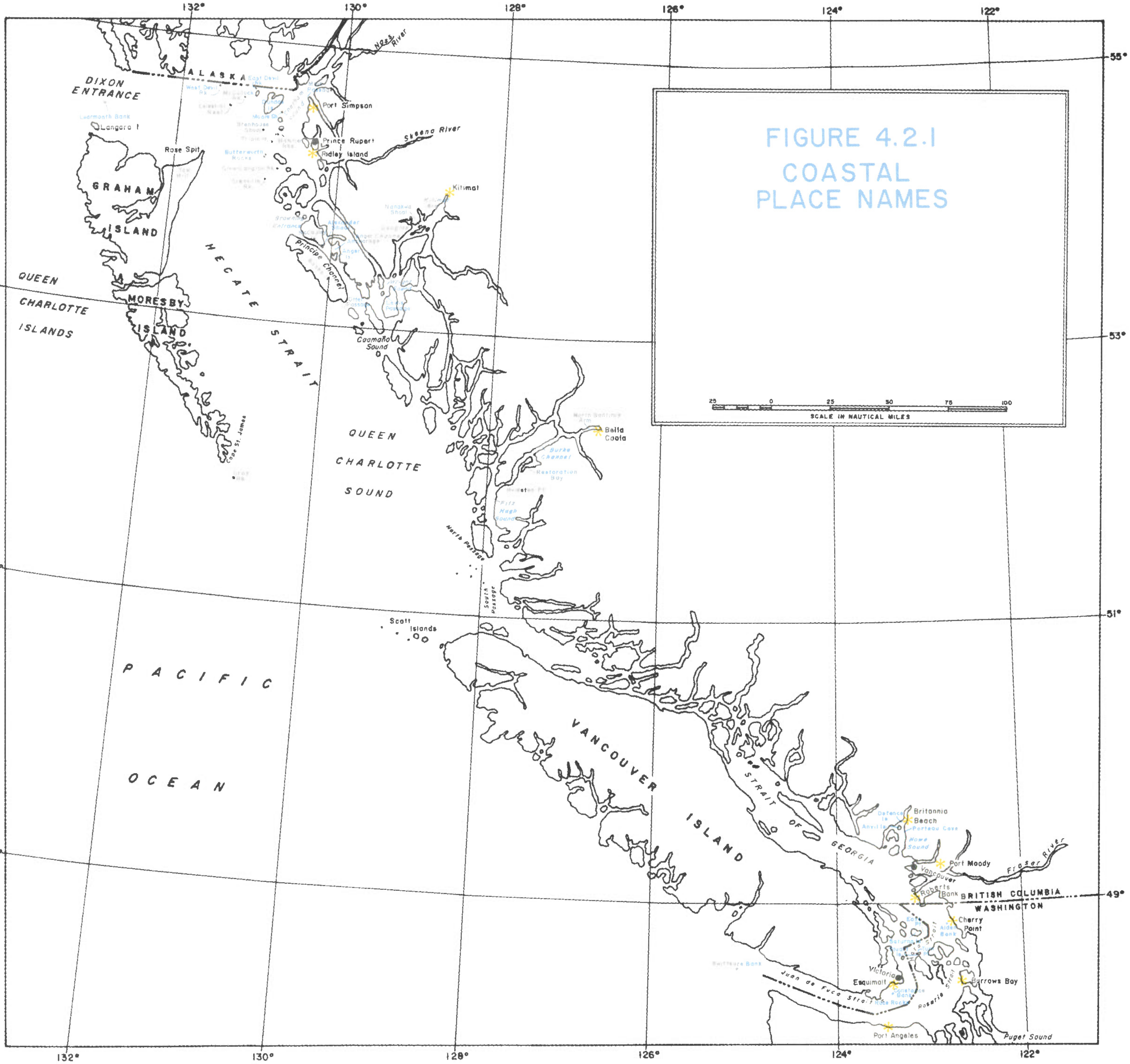
FIGURE 4.2.1
COASTAL
PLACE NAMES
SCALE IN NAUTICAL MILES
ALASKA
DIXON ENTRANCE
Langara I.
Rose Spit
GRAHAM ISLAND
QUEEN CHARLOTTE ISLANDS
MORESBY ISLAND
HECATE STRAIT
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Kitimat
Principe Channel
Caamaño Sound
QUEEN CHARLOTTE SOUND
Bella Coola
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Fraser River
Roberts Bank
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Burrows Bay
Juan de Fuca Strait
Port Angeles
Puget Sound

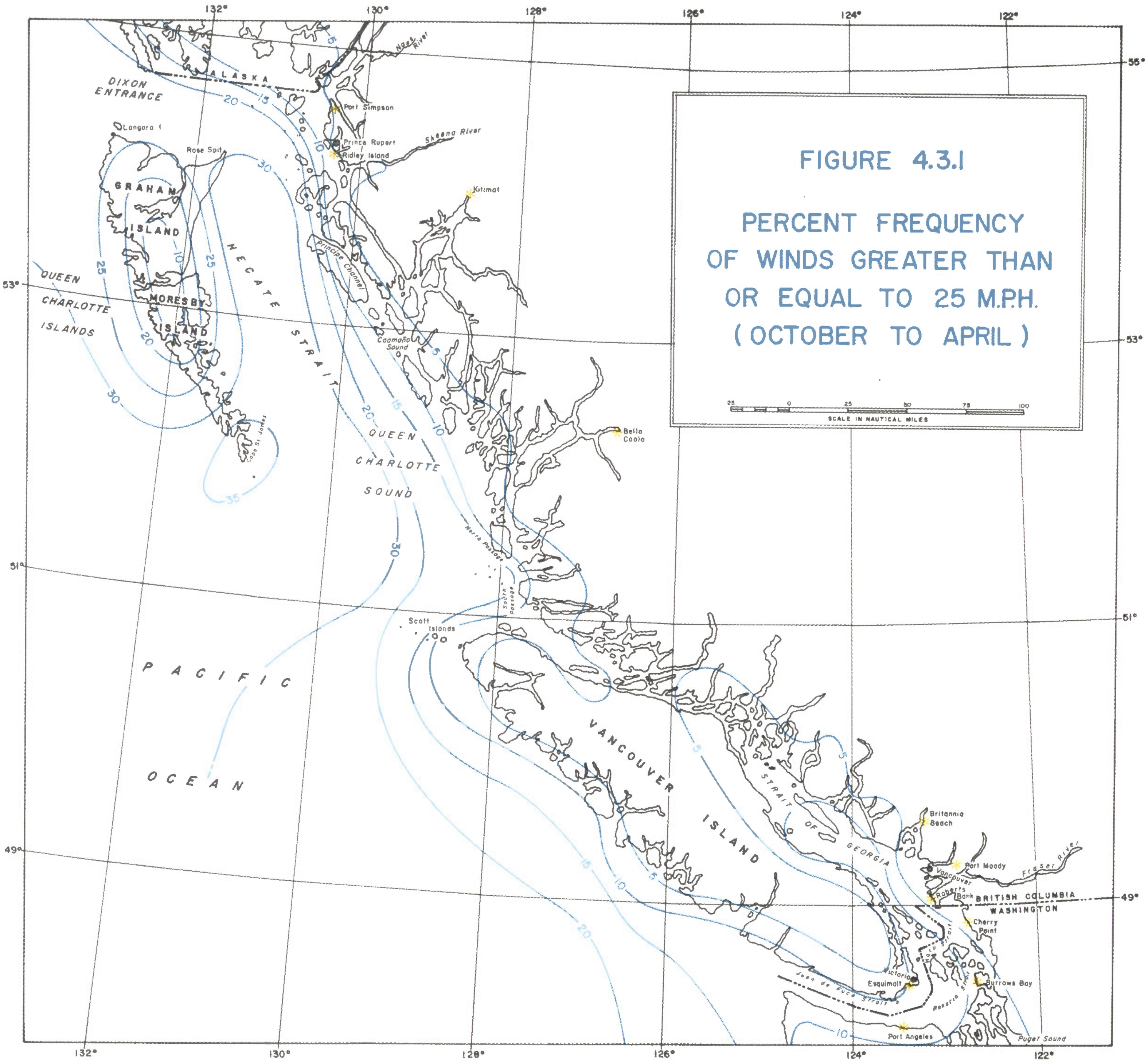
FIGURE 4.3.1
PERCENT FREQUENCY OF WINDS GREATER THAN OR EQUAL TO 25 M.P.H. (OCTOBER TO APRIL)
SCALE IN NAUTICAL MILES
DIXON ENTRANCE
ALASKA
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Kitimat
Langara I
Rose Spit
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
Principe Channel
Caamaño Sound
QUEEN CHARLOTTE SOUND
Bella Coola
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Fraser River
Roberts Bank
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Juan de Fuca Strait
Rosario Strait
Burrows Bay
Port Angeles
Puget Sound

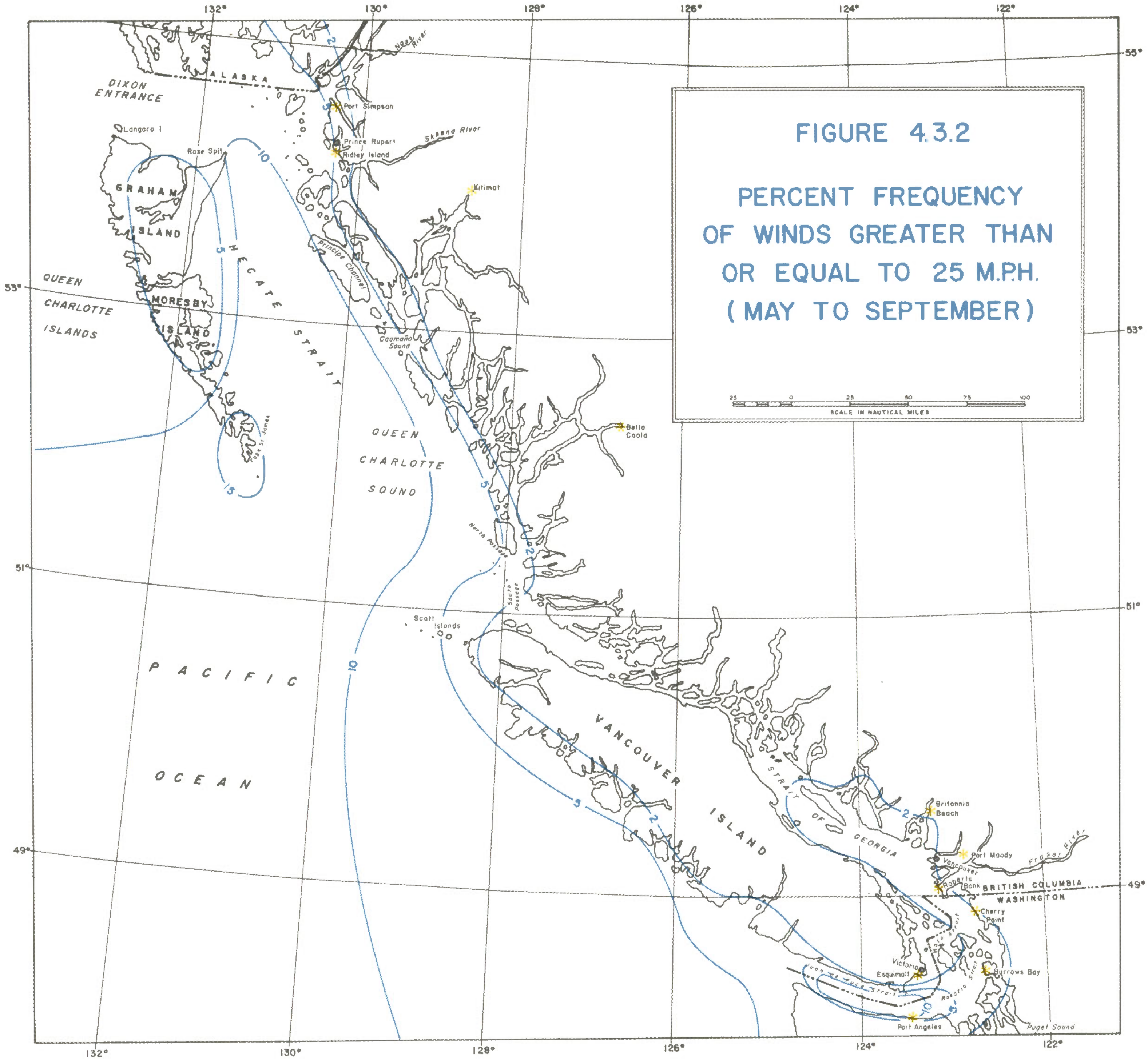
FIGURE 4.3.2
PERCENT FREQUENCY
OF WINDS GREATER THAN
OR EQUAL TO 25 M.P.H.
(MAY TO SEPTEMBER)
SCALE IN NAUTICAL MILES
DIXON ENTRANCE
ALASKA
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Nass River
Kitimat
Langara I
Rose Spit
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
Principe Channel
Caamaño Sound
QUEEN CHARLOTTE SOUND
Bella Coola
North Passage
South Passage
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Roberts Bank
Fraser River
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Juan de Fuca Strait
Rosario Strait
Burrows Bay
Port Angeles
Puget Sound

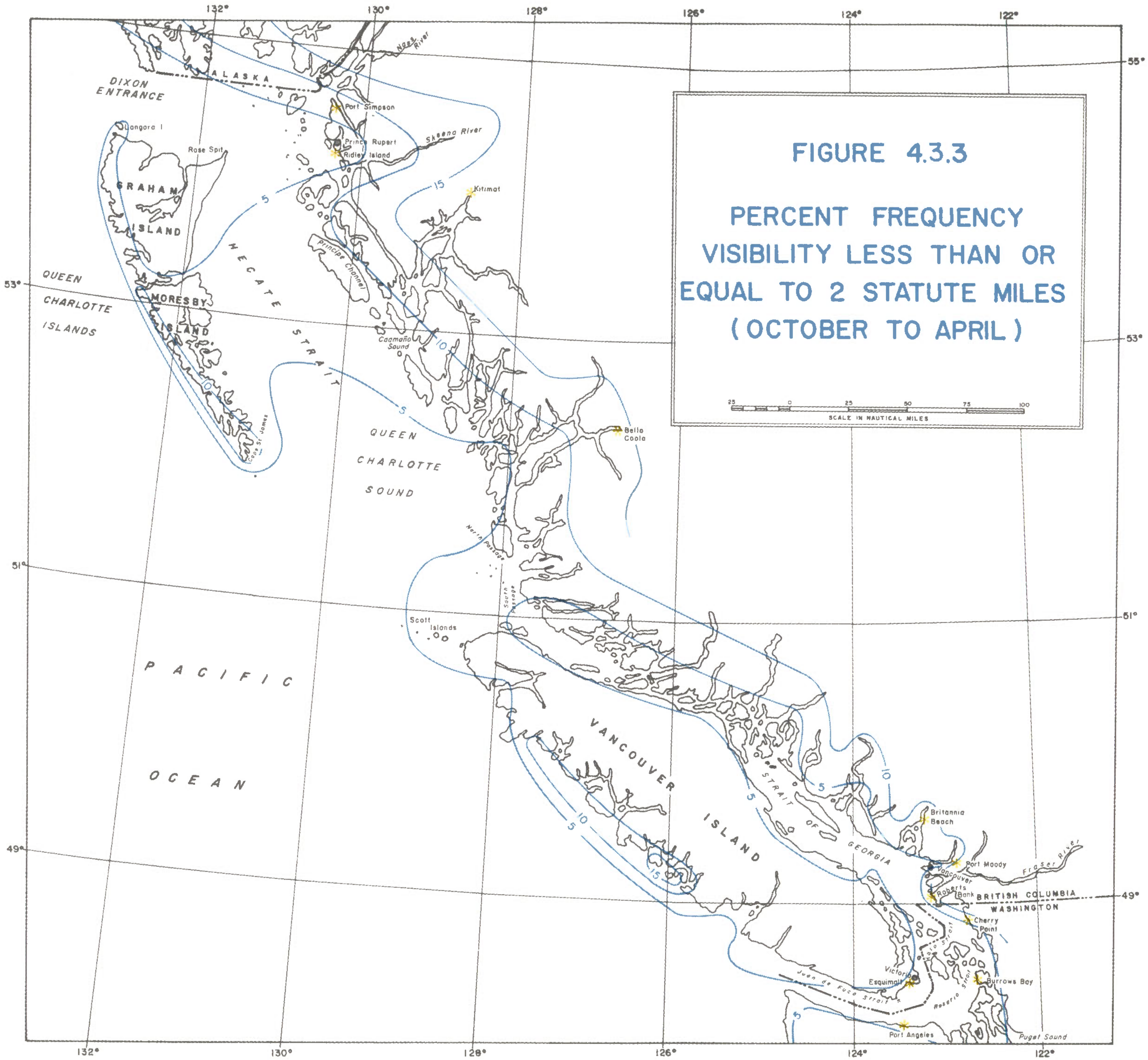

FIGURE 4.3.3

PERCENT FREQUENCY VISIBILITY LESS THAN OR EQUAL TO 2 STATUTE MILES (OCTOBER TO APRIL)

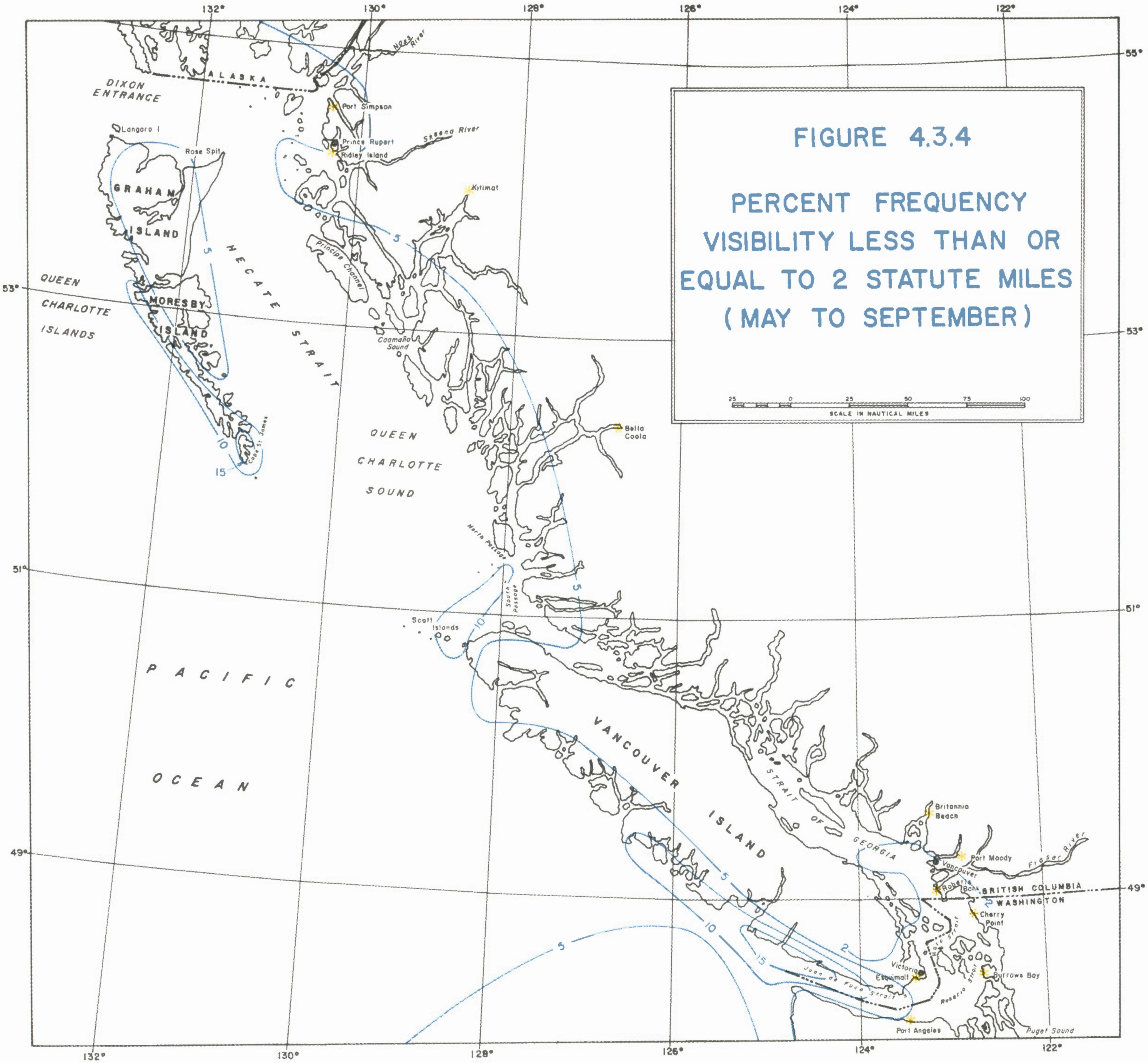
FIGURE 4.3.4
PERCENT FREQUENCY
VISIBILITY LESS THAN OR
EQUAL TO 2 STATUTE MILES
(MAY TO SEPTEMBER)
SCALE IN NAUTICAL MILES
ALASKA
DIXON ENTRANCE
Langara I
Rose Spit
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
Cape St James
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Nass River
Kitimat
Principe Channel
Caamaño Sound
Bella Coola
QUEEN CHARLOTTE SOUND
North Passage
South Passage
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Roberts Bank
Fraser River
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Haro Strait
Victoria
Esquimalt
Juan de Fuca Strait
Rosario Strait
Burrows Bay
Port Angeles
Puget Sound
55°
53°
51°
49°
132°
130°
128°
126°
124°
122°


FIGURE 5.1.1
DISTRIBUTION OF THE HERRING FISHERY
SCALE IN NAUTICAL MILES
25 0 25 50 75 100
132°
130°
128°
126°
124°
122°
55°
53°
51°
49°
DIXON ENTRANCE
ALASKA
Nass River
Port Simpson
Langara I.
Rose Spit
Prince Rupert
Ridley Island
Skeena River
Kitimat
GRAHAM ISLAND
HECATE STRAIT
Principe Channel
QUEEN CHARLOTTE ISLANDS
MORESBY ISLAND
Caamaño Sound
Cape St. James
Bella Coola
QUEEN CHARLOTTE SOUND
North Passage
South Passage
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Fraser River
Roberts Bank
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Juan de Fuca Strait
Rosario Strait
Burrows Bay
Port Angeles
Puget Sound

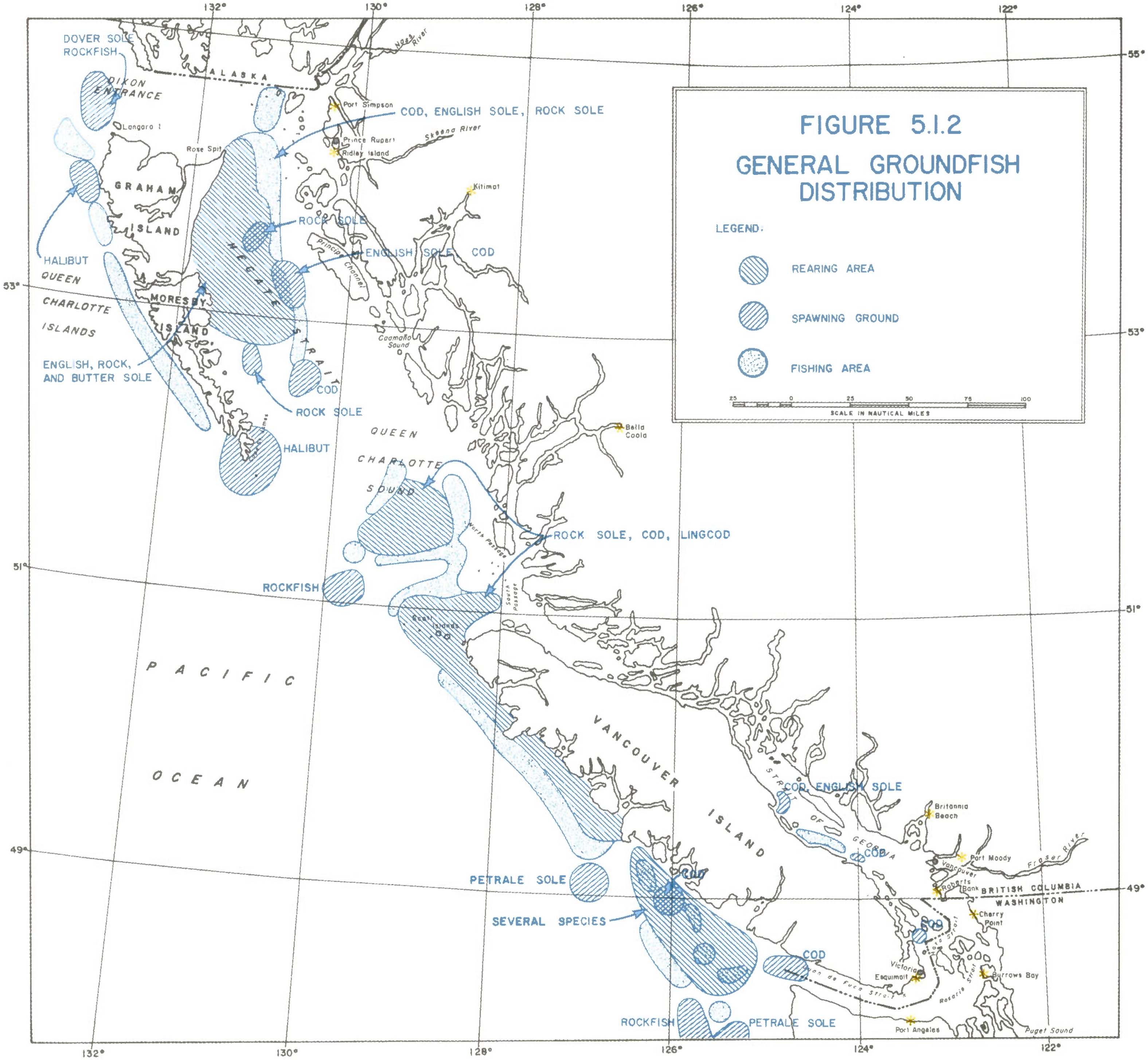
FIGURE 5.1.2
GENERAL GROUNDFISH DISTRIBUTION
LEGEND:
REARING AREA
SPAWNING GROUND
FISHING AREA
SCALE IN NAUTICAL MILES
DOVER SOLE
ROCKFISH
DIXON ENTRANCE
ALASKA
COD, ENGLISH SOLE, ROCK SOLE
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Kitimat
GRAHAM ISLAND
ROCK SOLE
ENGLISH SOLE COD
HALIBUT
QUEEN CHARLOTTE ISLANDS
MORESBY ISLAND
HECATE STRAIT
ENGLISH, ROCK, AND BUTTER SOLE
COD
ROCK SOLE
HALIBUT
Bella Coola
QUEEN CHARLOTTE SOUND
ROCK SOLE, COD, LINGCOD
ROCKFISH
PACIFIC OCEAN
VANCOUVER ISLAND
COD, ENGLISH SOLE
STRAIT OF GEORGIA
COD
Britannia Beach
Port Moody
Fraser River
Vancouver
BRITISH COLUMBIA
WASHINGTON
Cherry Point
PETRALE SOLE
SEVERAL SPECIES
COD
Victoria
Esquimalt
Burrows Bay
ROCKFISH
PETRALE SOLE
Port Angeles
Puget Sound

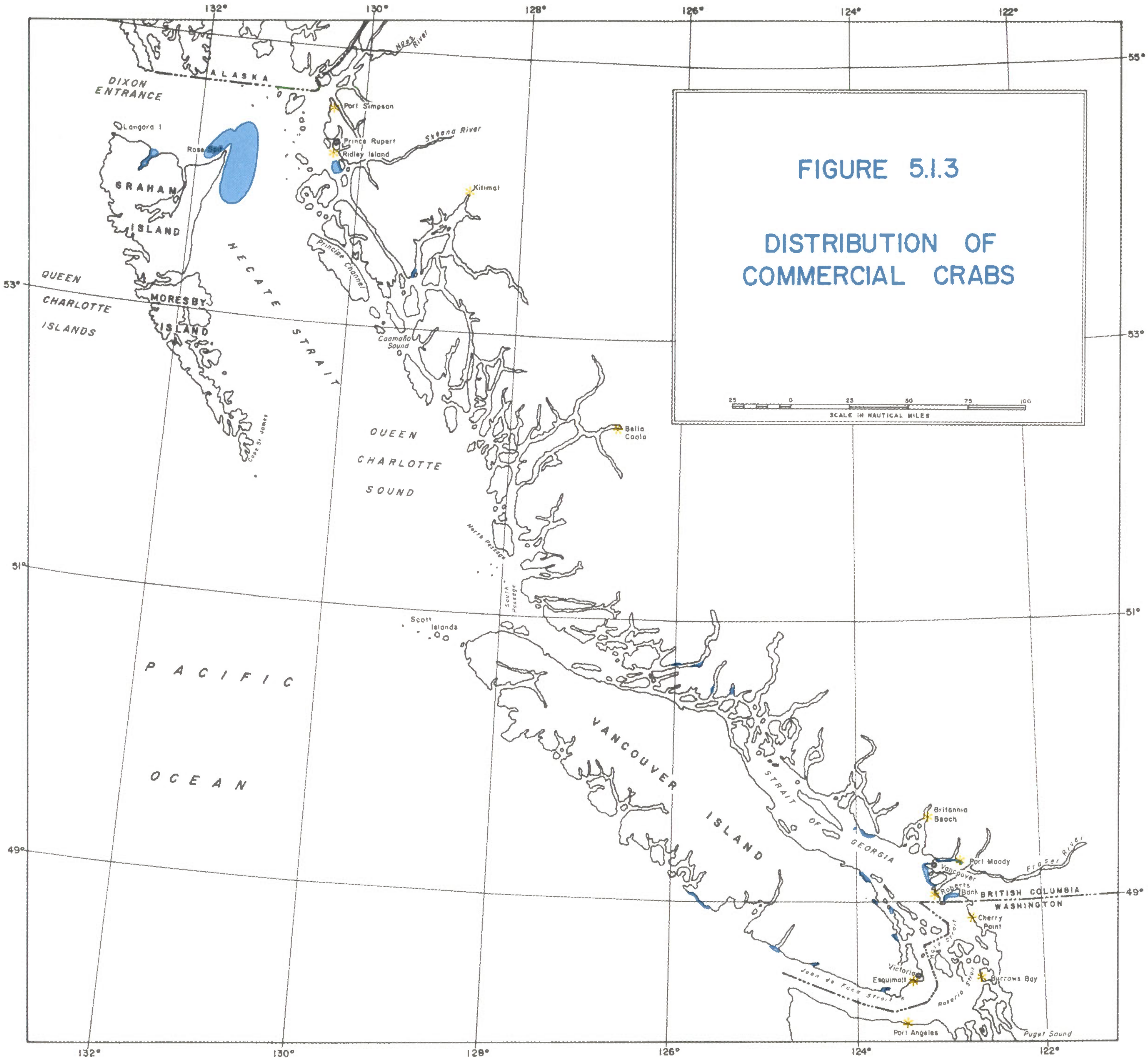

FIGURE 5.1.3

DISTRIBUTION OF COMMERCIAL CRABS

FIGURE 5.1.4
DISTRIBUTION OF SHRIMPS AND PRAWNS
SCALE IN NAUTICAL MILES
DIXON ENTRANCE
ALASKA
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Kitimat
Langara I
Rose Spit
GRAHAM ISLAND
HECATE STRAIT
QUEEN CHARLOTTE ISLANDS
MORESBY ISLAND
Principe Channel
Caamaño Sound
QUEEN CHARLOTTE SOUND
Bella Coola
North Passage
South Passage
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Roberts Bank
Fraser River
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Juan de Fuca Strait
Rosario Strait
Burrows Bay
Port Angeles
Puget Sound


FIGURE 5.1.5
DISTRIBUTION OF SCALLOPS AND OTHER MOLLUSCAN SHELLFISH
LEGEND:
SHELLFISH BEACH
SCALLOPS
SCALE IN NAUTICAL MILES
DIXON ENTRANCE
ALASKA
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Nass River
Kitimat
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
Principe Channel
Caamaño Sound
QUEEN CHARLOTTE SOUND
Bella Coola
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Roberts Bank
Fraser River
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Juan de Fuca Strait
Burrows Bay
Port Angeles
Puget Sound

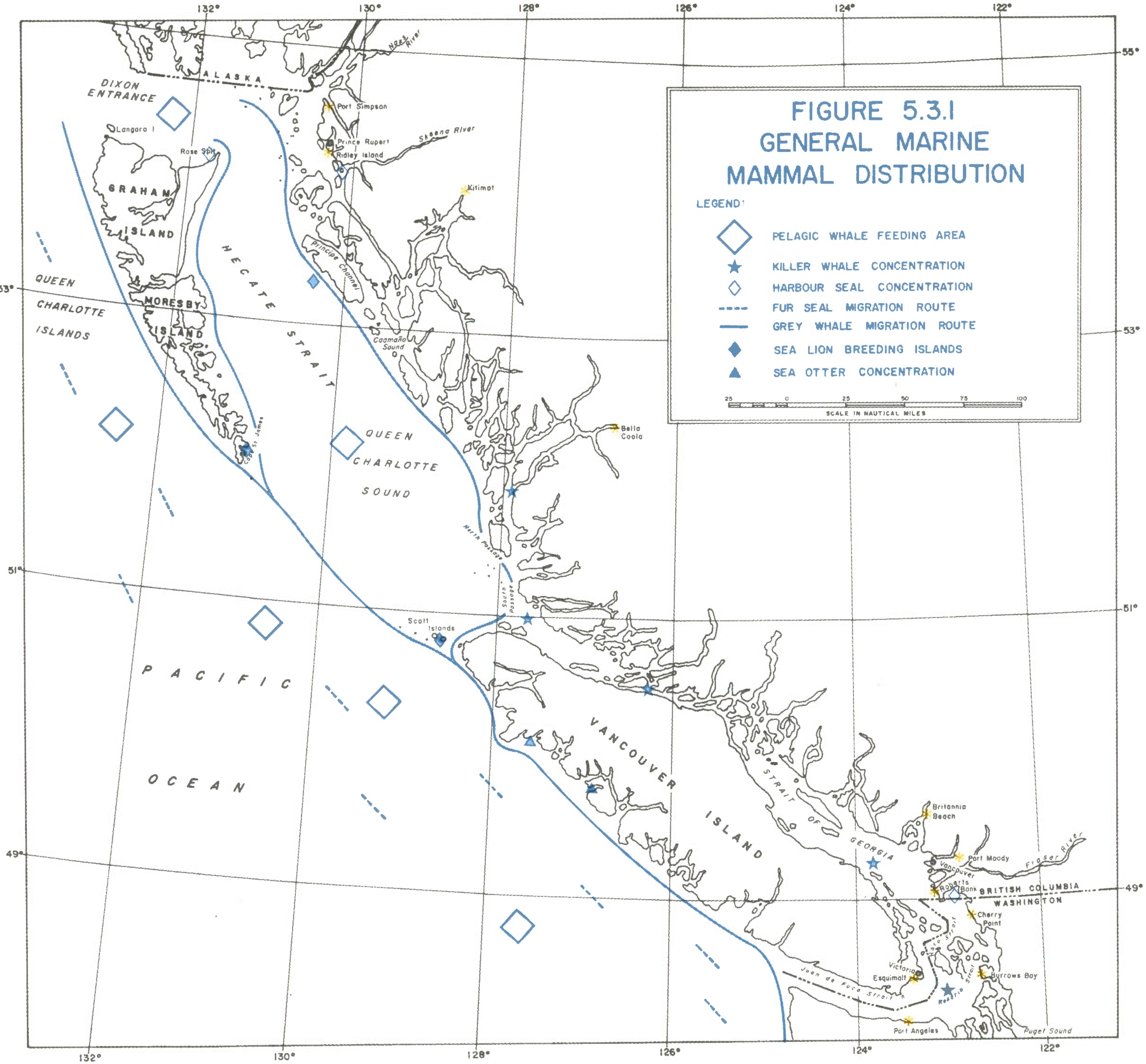

FIGURE 5.3.1
GENERAL MARINE
MAMMAL DISTRIBUTION
LEGEND:
PELAGIC WHALE FEEDING AREA
KILLER WHALE CONCENTRATION
HARBOUR SEAL CONCENTRATION
FUR SEAL MIGRATION ROUTE
GREY WHALE MIGRATION ROUTE
SEA LION BREEDING ISLANDS
SEA OTTER CONCENTRATION
SCALE IN NAUTICAL MILES
ALASKA
DIXON ENTRANCE
Langara I
Rose Spit
GRAHAM ISLAND
QUEEN CHARLOTTE ISLANDS
MORESBY ISLAND
HECATE STRAIT
QUEEN CHARLOTTE SOUND
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Nass River
Kitimat
Principe Channel
Caamaño Sound
Bella Coola
North Passage
South Passage
Scott Islands
Britannia Beach
Port Moody
Vancouver
Fraser River
Roberts Bank
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Juan de Fuca Strait
Rosario Strait
Burrows Bay
Port Angeles
Puget Sound

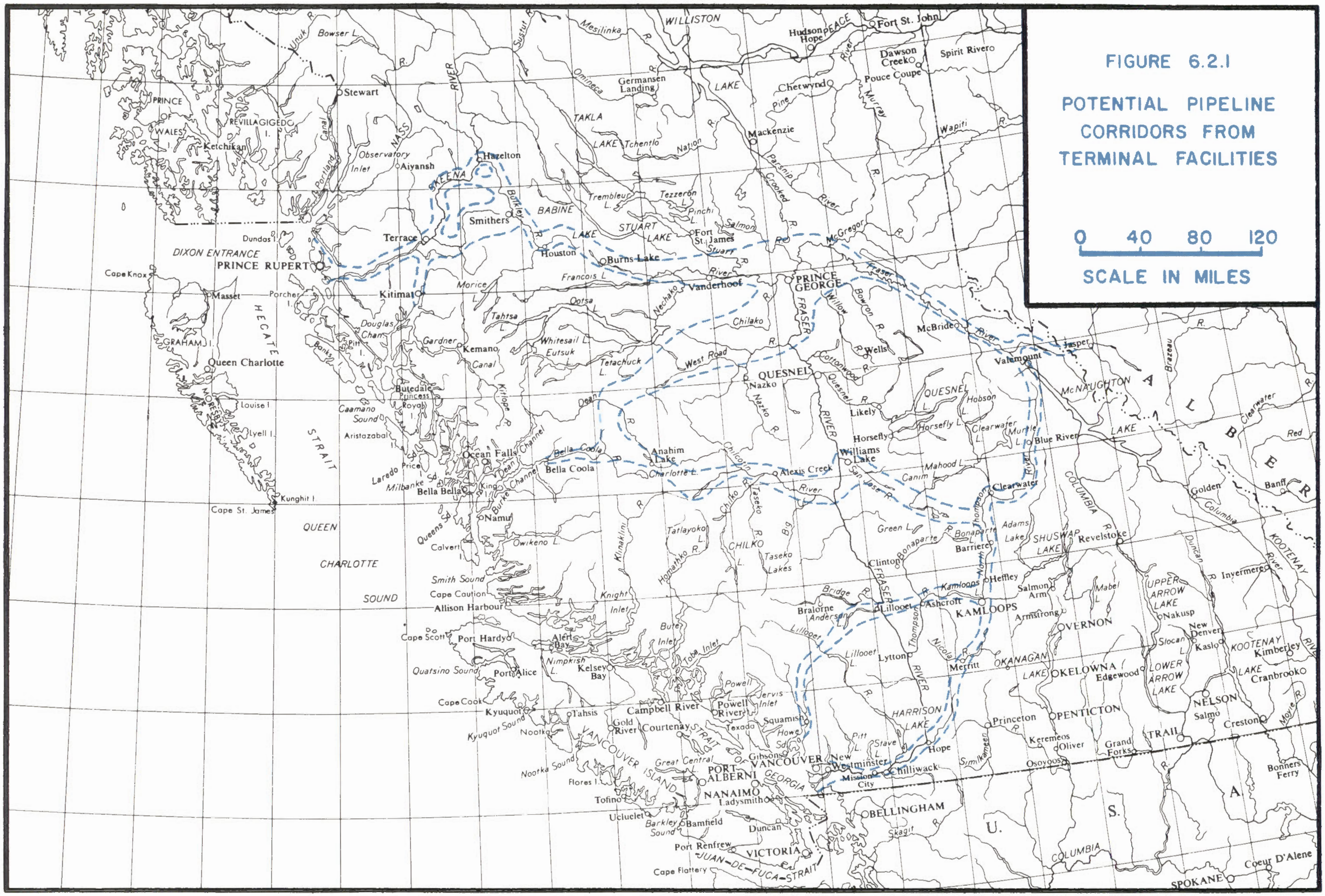

FIGURE 6.2.1

POTENTIAL PIPELINE CORRIDORS FROM TERMINAL FACILITIES

0 40 80 120

SCALE IN MILES

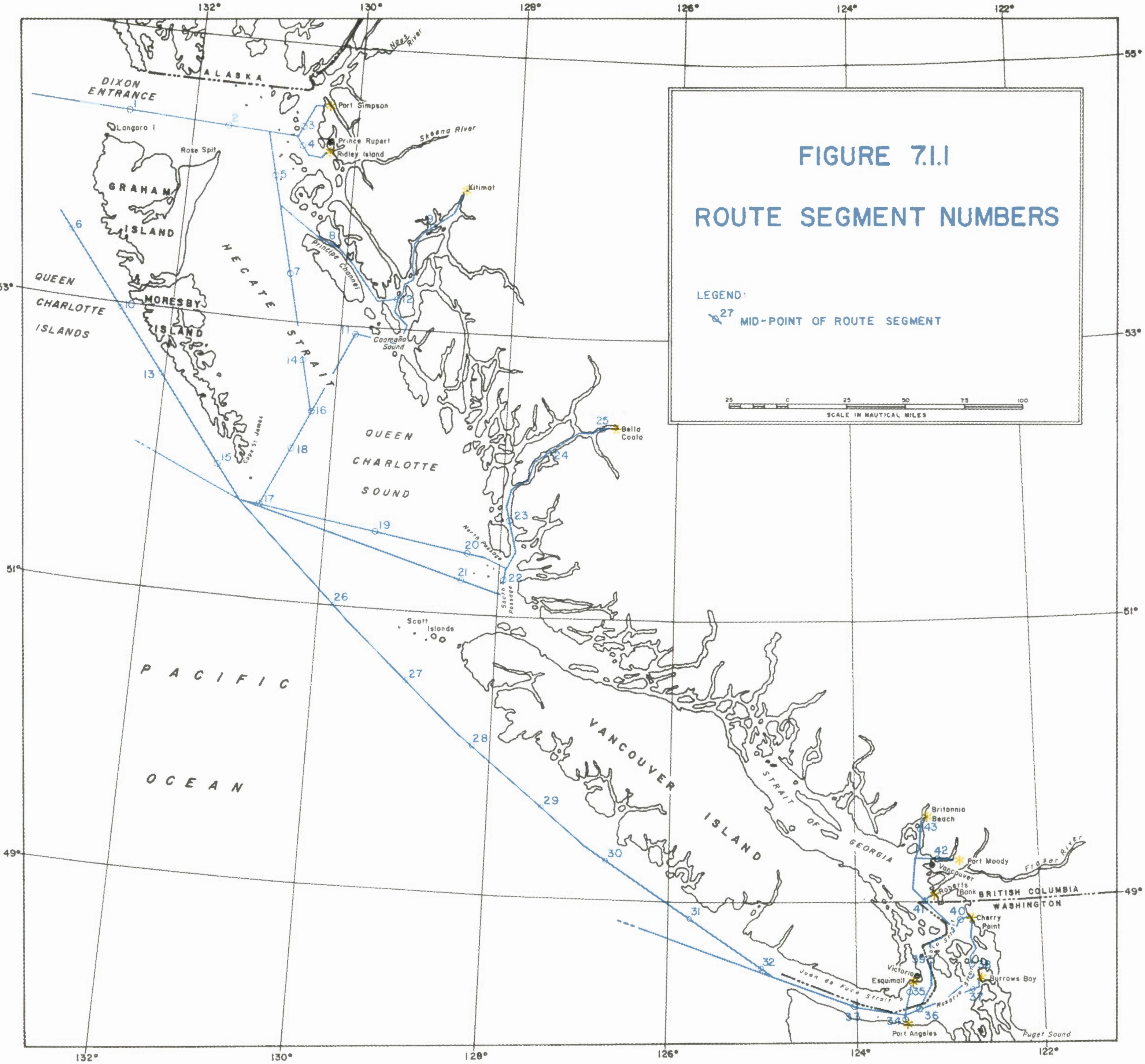
FIGURE 7.1.1
ROUTE SEGMENT NUMBERS
LEGEND:
27 MID-POINT OF ROUTE SEGMENT
SCALE IN NAUTICAL MILES
ALASKA
DIXON ENTRANCE
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Nass River
Langara I
Rose Spit
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
Principe Channel
Kitimat
Caamaño Sound
Cape St. James
QUEEN CHARLOTTE SOUND
Bella Coola
North Passage
South Passage
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Fraser River
Roberts Bank
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Juan de Fuca Strait
Rosario Strait
Haro Strait
Burrows Bay
Port Angeles
Puget Sound

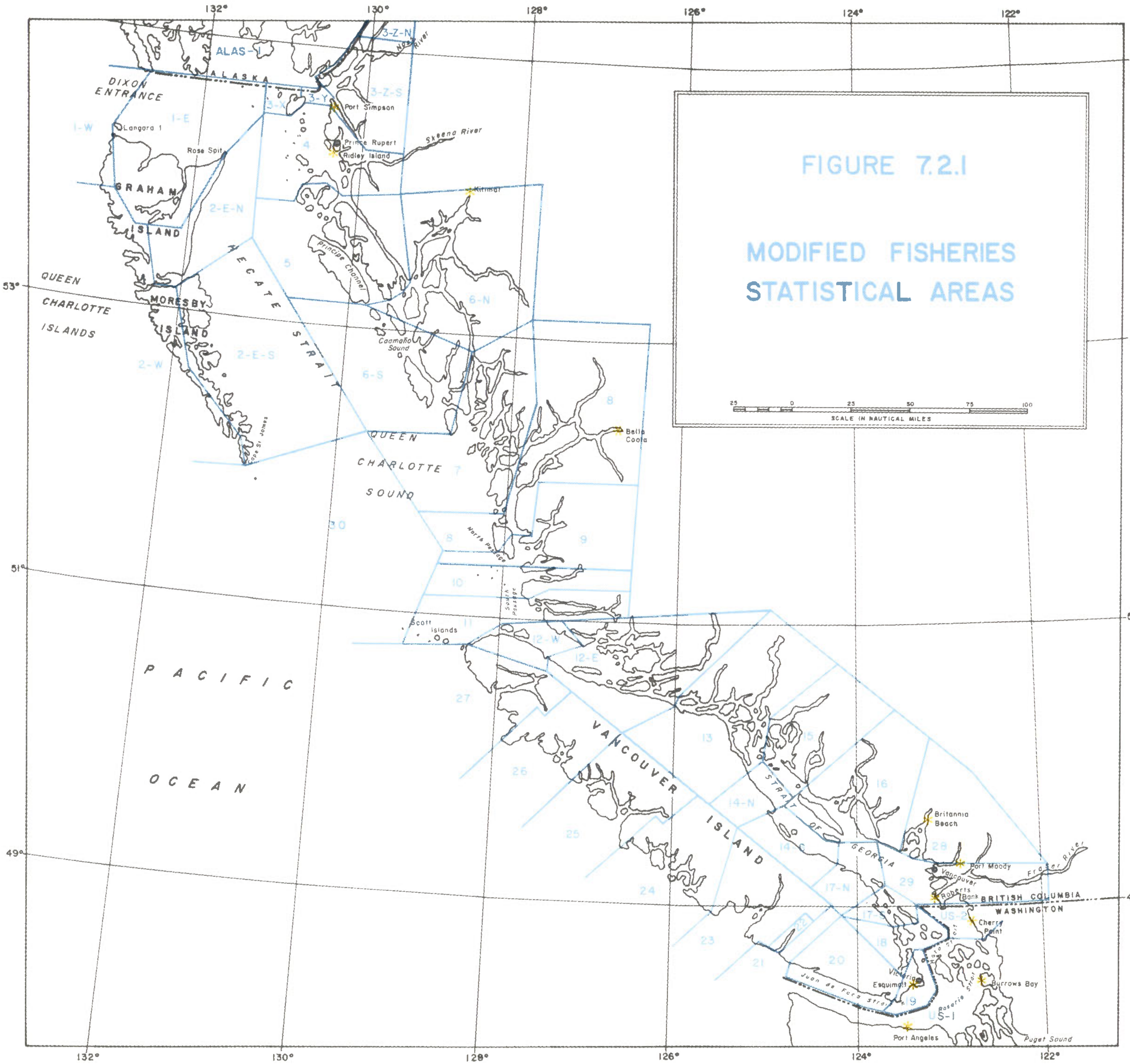

FIGURE 7.2.1

MODIFIED FISHERIES STATISTICAL AREAS


FIGURE 7.2.2
MARINE - ASSOCIATED BIRD AREAS (WINTER)
LEGEND
1 Bird Area Number
(2) Composite Rating
25 0 25 50 75 100
SCALE IN NAUTICAL MILES
ALASKA
DIXON ENTRANCE
Langara I.
Rose Spit
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Nass River
Kitimat
Principe Channel
Caamaño Sound
Cape St. James
QUEEN CHARLOTTE SOUND
Bella Coola
North Passage
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Roberts Bank
Fraser River
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Juan de Fuca Strait
Burrows Bay
Port Angeles
Puget Sound
1 (10)
2 (12)
3 (6)
4 (8)
7 (13)
8 (10)
5 (7)
6 (8)
9 (11)
10 (12)
11 (5)
12 (8)
13 (11)
14 (5)
15 (11)
16 (10)
17 (10)
18 (14)
19 (11)
20 (9)
132°
130°
128°
126°
124°
122°
55°
53°
51°
49°


FIGURE 7.2.3
MARINE-ASSOCIATED BIRD AREAS (SUMMER)
LEGEND
1 Bird Area Number
(2) Composite Rating
SCALE IN NAUTICAL MILES
25 0 25 50 75 100
132° 130° 128° 126° 124° 122°
55° 53° 51° 49°
DIXON ENTRANCE
ALASKA
Nass River
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Kitimat
Langara I.
Rose Spit
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
Principe Channel
Caamaño Sound
Cape St. James
QUEEN CHARLOTTE SOUND
Bella Coola
North Passage
South Passage
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Fraser River
Vancouver
Roberts Bank
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Burrows Bay
Victoria
Esquimalt
Juan de Fuca Strait
Rosario Strait
Haro Strait
Port Angeles
Puget Sound
1 (12)
2 (8)
3 (13)
4 (10)
5 (11)
6 (12)
7 (11)
8 (5)
9 (12)
10 (15)
11 (11)
12 (8)
13 (10)
14 (11)
15 (10)
16 (11)
17 (10)
18 (11)

FIGURE 7.2.4
ECONOMIC AND SOCIAL COASTAL SECTIONS
LEGEND
MODIFIED ECONOMIC VALUE ZONES FOR THE VANCOUVER REGION
SCALE IN NAUTICAL MILES
DIXON ENTRANCE
ALASKA
QUEEN CHARLOTTE ISLANDS
GRAHAM ISLAND
MORESBY ISLAND
HECATE STRAIT
QUEEN CHARLOTTE SOUND
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
BRITISH COLUMBIA
WASHINGTON
SKEENA - QUEEN CHARLOTTES - MAINLAND
SKEENA - QUEEN CHARLOTTES - ISLANDS
KITIMAT - STIKINE
CENTRAL COAST
MT. WADDINGTON - MAINLAND
MT. WADDINGTON - EAST ISLAND
MT. WADDINGTON - WEST ISLAND
COMOX STRATHCONA - MAINLAND
COMOX STRATHCONA - EAST ISLAND
COMOX STRATHCONA - WEST ISLAND
POWELL RIVER
SUNSHINE COAST
SQUAMISH - LILLOOET
GREATER VANCOUVER
ALBERNI - CLAYOQUOT
NANAIMO
COWICHAN - EAST ISLAND
COWICHAN - WEST ISLAND
CAPITAL
NORTH PUGET SOUND
JUAN DE FUCA
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Nass River
Kitimat
Langara I
Rose Spit
Principe Channel
Caamaño Sound
Cape St James
Bella Coola
Scott Islands
Britannia Beach
Port Moody
Roberts Bank
Cherry Point
Victoria
Esquimalt
Burrows Bay
Port Angeles
Puget Sound
Juan de Fuca Strait
Rosario Strait
Haro Strait
Fraser River
B
A

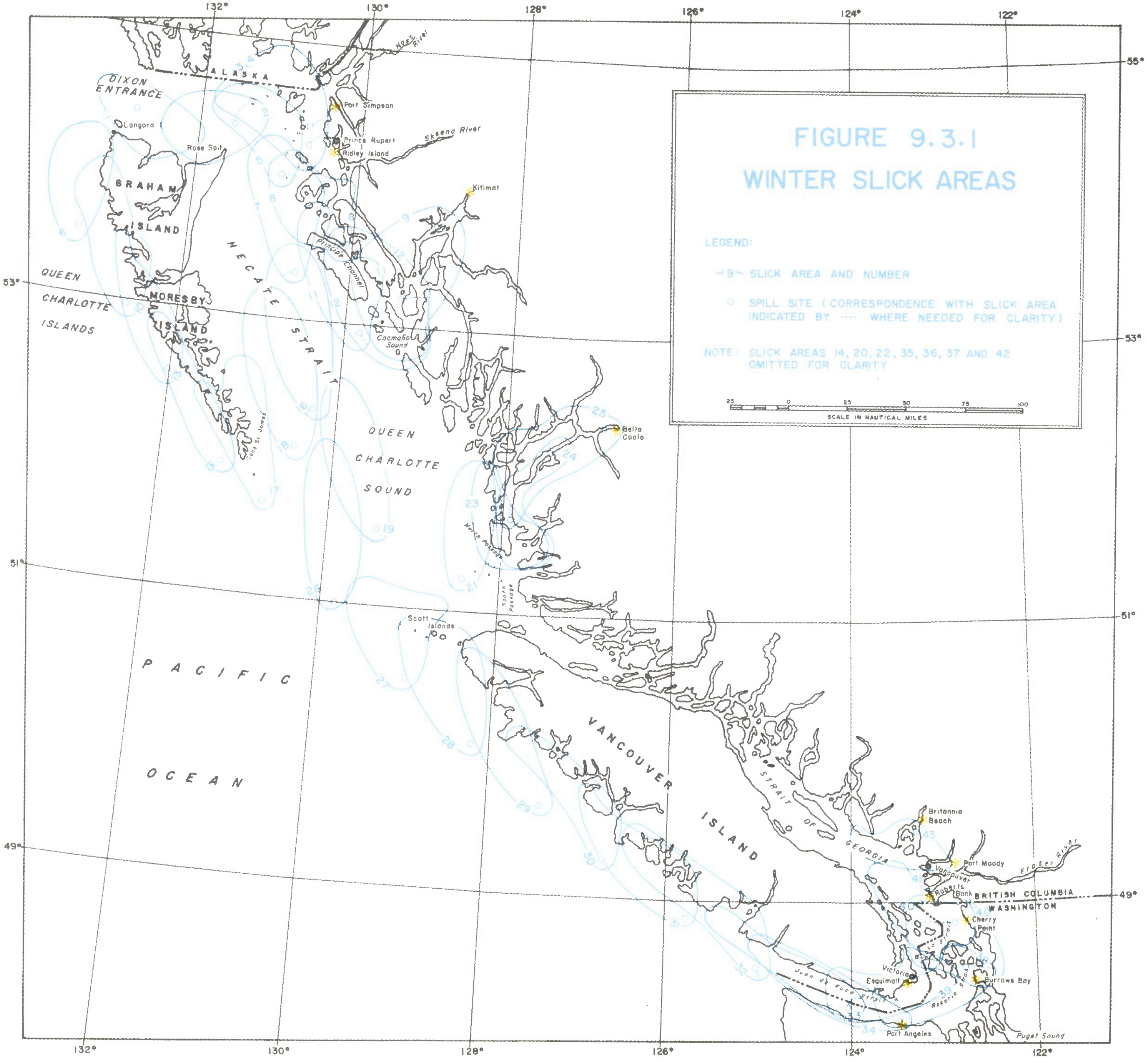
FIGURE 9.3.1
WINTER SLICK AREAS
LEGEND:
-9- SLICK AREA AND NUMBER
○ SPILL SITE (CORRESPONDENCE WITH SLICK AREA INDICATED BY --- WHERE NEEDED FOR CLARITY)
NOTE: SLICK AREAS 14, 20, 22, 35, 36, 37 AND 42 OMITTED FOR CLARITY
SCALE IN NAUTICAL MILES
DIXON ENTRANCE
ALASKA
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Kitimat
Langara I.
Rose Spit
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
Principe Channel
Caamaño Sound
QUEEN CHARLOTTE SOUND
Bella Coola
Cape St James
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Fraser River
Roberts Bank
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Burrows Bay
Juan de Fuca Strait
Port Angeles
Puget Sound
Nass River
North Passage
South Passage
Rosario Strait
55°
53°
51°
49°
132°
130°
128°
126°
124°
122°

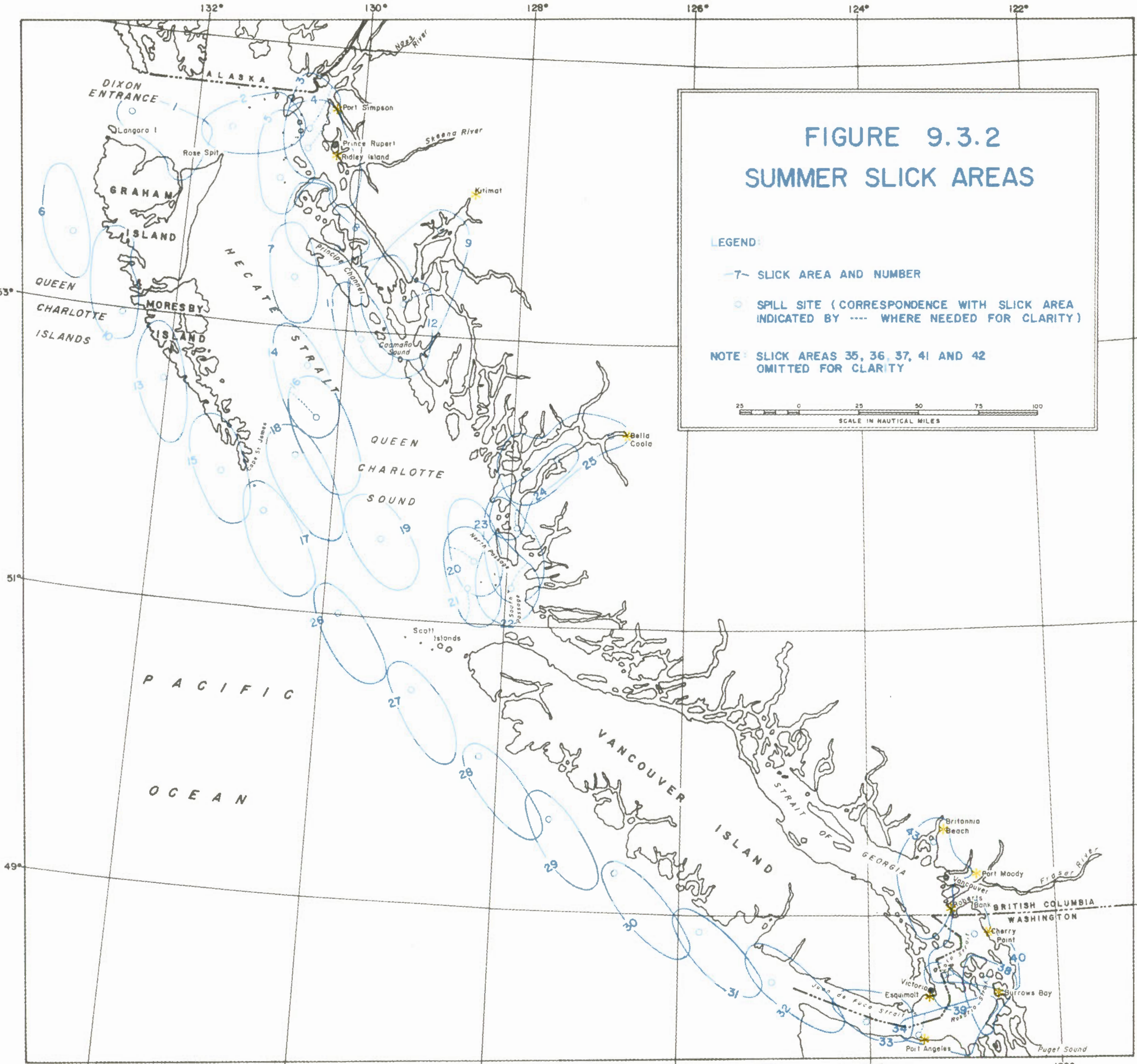

FIGURE 9.3.2
SUMMER SLICK AREAS
LEGEND:
7 SLICK AREA AND NUMBER
SPILL SITE (CORRESPONDENCE WITH SLICK AREA INDICATED BY ---- WHERE NEEDED FOR CLARITY)
NOTE: SLICK AREAS 35, 36, 37, 41 AND 42 OMITTED FOR CLARITY
SCALE IN NAUTICAL MILES
DIXON ENTRANCE
ALASKA
Port Simpson
Prince Rupert
Ridley Island
Skeena River
Kitimat
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
QUEEN CHARLOTTE SOUND
Bella Coola
Scott Islands
PACIFIC OCEAN
VANCOUVER ISLAND
STRAIT OF GEORGIA
Britannia Beach
Port Moody
Vancouver
Fraser River
BRITISH COLUMBIA
WASHINGTON
Cherry Point
Victoria
Esquimalt
Burrows Bay
Port Angeles
Puget Sound
Juan de Fuca Strait

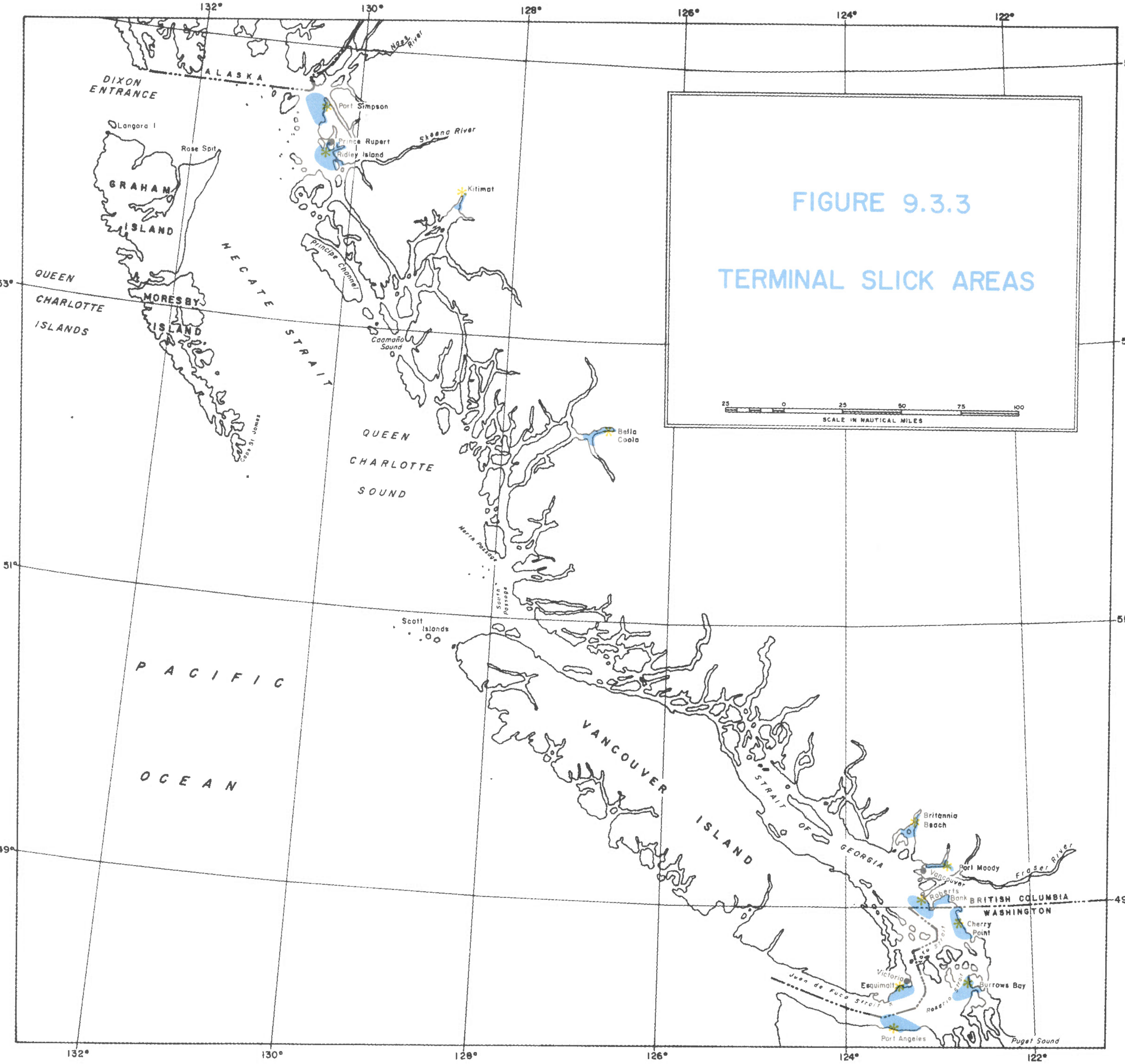

FIGURE 9.3.3

TERMINAL SLICK AREAS