MARINE BIRDS AND AQUACULTURE IN BRITISH COLUMBIA:
Assessment and Management of Interactions
PHASE II REPORT: ASSESSMENT OF GEOGRAPHICAL OVERLAP

WHITEHEAD

Jacqueline Booth
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LIST OF ACRONYMS

B.C. - British Columbia

CWIF - Coastal Waterfowl Inventory File

CWS - Canadian Wildlife Service, Government of Canada

dBase 3+ - dBASE III PLUS, copyright 1985, 1986 Ashton-Tate

DFO - Department of Fisheries and Oceans, Government of Canada

GIS - geographic information system

HEP - Habitat Evaluation Procedures

HSI - Habitat Suitability Index

IP - investigative permit

MAF - Ministry of Agriculture and Fisheries, B.C. Government

MCL - Ministry of Crown Lands, B.C. Government

MEP - B.C. Ministry of Environment and Parks, B.C. Government

SIF - standard interchange format

SPANS - Spatial Analysis System, copyright 1988 TYDAC Technologies Inc.

PREFACE

This report comprises Phase II of a project sponsored by the federal Departments of Environment and Supply and Services that is aimed at assessing the effects of British Columbia's growing aquaculture industry on its marine bird populations. The project is comprised of three phases. Phase I reviewed the relevant literature, describing the nature of interactions that can occur between marine birds and the various types of aquaculture, and providing an analytical framework for the subsequent phases (Booth and Rueggeberg, 1988). In Phase II, a computer database and geographical information system is developed to examine the overlap between areas of current and potential aquaculture development and areas that provide prime marine bird habitat. Phase III consists of two studies that examine on-site interactions between birds and aquaculture, one dealing with salmon farming (Rueggeberg and Booth, 1989a) and the other with mussel farming (Rueggeberg and Booth, 1989b).

ABSTRACT

This report documents the results of Phase II of a project aimed at assessing the effects of British Columbia's growing aquaculture industry on its marine bird populations. In this phase, the extent of geographical overlap between areas of current and potential aquaculture development and areas used by marine birds was examined, indicating the bird species, types of aquaculture and areas of the coast involved.

A computer-based geographic information and spatial analysis system was used to store, analyze and display the distributions of aquaculture and marine bird use within the study area. The location and size of sites currently committed for finfish, shellfish and marine plant culture were digitally mapped. Areas classified as biophysically suitable for salmon farming were also compiled and digitally mapped. Distribution data for 24 bird species and species groups were collected from compiled survey data and mapped, as were the size and location of colonies of 14 species and of summer moulting concentrations of 3 species.

The overlap between bird use and aquaculture was determined as the proportions of total areas occupied by each type of aquaculture that were ranked as being of high, medium, low, no or uncertain use by each bird group/species. Overlap with aquaculture sites was consistently "high" for goldeneye sp., and was considered "medium" for Bufflehead, scoters, cormorants, grebes, gulls, loons, Mallards, mergansers and raptors. This indicates that relatively high numbers of these species have been recorded in the same areas occupied by a significant proportion of aquaculture sites. The current overlap between aquaculture and bird colonies and moulting concentrations was relatively low.

In general, overlapping use suggests the potential for displacement of birds from habitats. Whether birds would actually be displaced depends on the nature of their use of the area and their behavioral response to the physical structures and activities at these sites. However, aquaculture development should avoid encroaching on breeding habitats, especially where colonies are large and the surrounding areas are intensively used.

Where bird distribution data is missing, habitat models can be helpful in indicating the potential importance of an area to a particular bird species. The extent of potentially good habitat was calculated and mapped for 7 bird species/groups using habitat models. The results of the models were compared to distribution data for that region with good correlations for most species. Model predictions must be treated with caution, however, due to the lack of knowledge regarding species-habitat relationships and poor distribution data by which to "truth" the models. However, the method has applications for species for which knowledge of habitat requirements is relatively good but distribution data is poor, particularly when management decisions must be made regarding the importance of an area to a bird species.

The advantages of using a computer-based geographic information system were also demonstrated. The database and maps created in this study can be easily updated and spatial analyses can be readily performed to incorporate a wider suite of variables.

RESUME

On trouve dans le présent rapport les résultats de la phase II d'un project visant à évaluer les effets d'une industrie croissante en Colombie-Britannique, l'aquaculture, sur la population d'oiseaux marins. Au cours de la deuxième phase, on a examiné le degré de chevauchement des sites actuels et potentiels d'aquaculture et des aires utilisées par les oiseaux marins, en tenant compte des espèces d'oiseaux et des zones côtieres touchés, de même que du type d'aquaculture pratiqué.

Un système informatique d'information géographique et d'analyse spetiale a été utilisé pour enregistrar, analyser et visualiser la distribution des aires servant à l'aquaculture et des aires utilisées par les oiseaux marins au sain de la région étudies. On a dressé des cartes numériques illustrant la situation géographique et la superficie des aires où l'on pratique actuellement l'élevage du poisson, des mollusques et des crustacés et la culture des plantes marines. Les régions classées comme se prâtant, du point de vue biophysique, à l'élevage du saumon ont également été répertoriées et cartographiées numériquement. Des données sur la distribution de 24 espèces et groupes d'espèces d'oiseaus, tirées de données compilées au cours d'études antérieures, ont été cartographiées; on a également dressédes carte illustrant la taille et la situation géographique de colonies de 14 espèces d'oiseaux et de ressemblements de trois espèces d'oiseaux en mue estivale.

Le chavauchement des aires utilisées par les oiseaux et des aires d'aquaculture a été déterminé en termes de la proportion de l'aire totale consacrée à chaque type d'aquaculture faisant l'objet d'une utilisation importante, moyenne, faible, nulle où incertaine par chaque espèce/groupe d'espèces d'oiseaux. Le chevauchement entre les aires d'aquaculture et les

aires utilisées par le garrot commun et la garrot de Barrow a été uniformément "élevé"; le chevauchement a été jugé "moyen" en ce qui concerne le petit garrot, les macreuses, les cormorans, les grèbes, les goélands (Larus sp.), les huartes, le canard malard, les becs-scie et les oiseaux rapaces. Ces r sultats indiquent qu'on a relevé un nombre relativement élevé d'oiseaux de ces espèces dans les régions où l'on trouve une proportion importante des installations d'aquaculture. Le chevauchement actuel entre les activitée d'aquaculture, les colonies d'oiseaux et les ressemblements d'oiseaux pendant la mue était relativement faible.

En général, le chevauchement indique du'il est possible que les oiseaux quittent les habitats. Le déplacement affectif des oiseaux dépend comportementale aux structures physiques et aux activités sur les sites d'aquaculture. Il demeure que les aires d'aquaculture ne devraient pas empiéter sur les aires de reproduction des oiseaux, particulièrement si on y trouve d'importantes colonies et que les aires voisines sont également intensivement utilisées par les oiseaux.

Lorsqu'on ne dispose pas de données sur la distribution des oiseaux, des modèles d'habitats peuvent aider à déterminer l'importance possible d'une région pour une espèces donnée. De tels modèles ont permis de calculer et de cartographier l'étendue des habitats potentiellement appropriés pour 7 espèces/groupes d'espèces d'oiseaux. Pour la plupart des espèces, on a obtenu une bonne corrélation entre les résultats de la modélisation et les données de distribution de la région. Toutefois, les prédictions obtenues au moyen de modèles. La méthode peut cependant être appliquée dans le cas des espèces dont on connaît assez bien les exigences en termes d'habitats, mais dont la distribution est mai connue, particulièrement lorsque des décisions administratives doivent être prises quant à l'importance d'une région pour une espèce donnée.

On a également démonstré les avantages de l'utilisation d'un système informatique d'information géographique. La bese de données et les cartes élaborées dans le cadre de la présente étude peuvent facilement être mises à jour et des analyses spatiales peuvent aisément être effectuéres pour incorporer un plus grand numbre de variables.

1. INTRODUCTION

As the aquaculture industry expands in British Columbia, interactions with resident and migrant marine bird populations will increase. The interactions that can occur between marine birds and the various types of aquaculture can be classified as "direct" or "indirect" (Booth and Rueggeberg, 1988).

Direct interactions are those that occur as a result of birds and aquaculture being in immediate contact, and include predation of farmed stock by birds and bird injury or mortality resulting from predator control measures. These interactions are being considered in other parts of this project in the context of salmon farming (Rueggeberg and Booth, 1989a) and mussel farming (Rueggeberg and Booth, 1989b).

Indirect interactions are defined as those that displace birds from areas of suitable habitat, or that reduce the efficiency with which birds utilize such areas. They can occur in two ways:

- *habitat degradation*: The physical presence of farm structures may change the natural environment. For example, sedimentation of excess food and faeces from salmon farms may cause changes in the composition and abundance of marine flora and fauna around farm operations (Leonardsson and Näslund, 1983; Parjala, 1984; Weston, 1986). Marine plant or shellfish operations can shade eelgrass and kelp beds, reduce the productivity of these areas as sources of food for diving ducks. Chemicals released by farm operations may be taken up in the local food chain, which may in turn have a detrimental effect on bird populations.

- *habitat alienation*: Shoreline or nearshore feeding areas can be made inaccessible by the presence of net pens, longlines, ramps, etc. Dredging or filling activities in nearshore or inter-tidal areas can also destroy bird habitat. Human presence and activities associated with aquaculture can have an effect; some bird species adapt readily to noise and human activity, but many are less efficient in their use of an area that is continuously disturbed.

Proper planning of farm locations and husbandry techniques on the farm should minimize the types of impacts that lead to habitat degradation. However, the general alienation of birds from coastal habitats is more difficult to assess, particularly in the short term (less than 5-10 years). It should be noted that aquaculture may increase favourable habitat for certain bird species. The presence of farm stocks or of wild fish and shellfish that concentrate around farms attracts many marine bird species to farm sites. Farm structures may provide roosting sites. So long as the birds do not pose a threat to the viability of the farm's crops, the birds can benefit from the increased food supply or resting area. There are even "symbiotic" relationships between some birds and fish farm operations; e.g., scoters eat the mussels that foul net pens on salmon farms and oyster trays on oyster farms, an activity that benefits both the farmer and the birds (Rueggeberg and Booth, 1989a).

Nonetheless, there are interactions that force farm operators to take actions to deter birds from farm sites; for example, Great Blue Herons preying on farmed fish or scoters eating mussels on mussel farms (Rueggeberg and Booth, 1989a,b). These types of interactions are of special concern when they involve bird species that are particularly vulnerable to loss of coastal habitat; for example, species that breed or form concentrations on the coast or that are rare or endangered. Consequently, care must be taken in planning and locating aquaculture operations to prevent the alienation of important marine bird habitat.

1.1. Purpose

The overall purpose of this project is to assess the effects of British Columbia's growing aquaculture industry on its marine bird populations. The purpose of Phase II is to estimate the extent of geographical overlap between marine bird use and aquaculture development along the coast of B.C., so as to indicate which species, types of aquaculture and areas of the coast are likely to be subject to indirect interactions. Its specific objectives are to design a system that would assist wildlife and aquaculture managers to:

* estimate the relative importance of an area to a marine bird species and its present or potential use by aquaculture.

* determine the species of marine birds and types of aquaculture with greatest potential overlap.

* determine the areas of the B.C. coast where these interactions are most likely to occur.

* identify data gaps, notably bird species or regions for which there is insufficient information to assess actual or potential bird or aquaculture use.

1.2. General Approach and Organization of Report

Determining the extent to which aquaculture overlaps geographically with marine bird use of the B.C. coast requires an assessment of the importance of any given coastal area both for marine bird use and for aquaculture development. Two basic strategies are taken to carry out this assessment.

The first strategy is to identify and map <u>current</u> use of coastal areas by aquaculture and by marine bird populations (chapters 2 and 4). This type of analysis, however, does not take two important factors into account:

- aquaculture will continue to expand along the B.C. coast such that current distributions will quickly become out-of-date.

- our knowledge of the use of the coast by marine birds is limited. Not all areas have been surveyed, and most surveys have been done on an irregular basis. Seasonal, annual and random variations in bird abundance and distribution means that surveys may not detect all areas of importance to a marine bird species.

The second strategy attempts to deal with these two factors by identifying and mapping areas of potential aquaculture development and bird use based on the presence or absence of key biological and physical characteristics that fulfil basic requirements of each. With regard to aquaculture development, while all aspects of aquaculture continue to grow in B.C., the salmon farming industry is undergoing a particularly rapid expansion, and it was therefore considered most relevant to concentrate on this aspect of aquaculture in dealing with areas of potential development (chapter 3). The approach taken to determine potential habitat use by marine birds is a modification of the "Habitat Evaluation Procedures" developed by the U.S. Fish and Wildlife Service (1980a,b) (chapter 7 and Appendix A).

Maps of the distributions of aquaculture development and marine bird use, both current (or known) and potential, are compared to assess the overlap between them (chapter 6). Conclusions on the bird species that are most likely to overlap with aquacultural use of the B.C. coast and the regions of the study area in which will occur are summarized.

1.3. Study Area

The project as a whole covers the Sechelt Peninsula/Sunshine Coast region, north-eastern Vancouver Island and adjacent islands and mainland coast, and northwestern Vancouver Island, from Cape Beale to Port Hardy (Booth and Rueggeberg, 1988). In this Phase, the study area is divided into 10 regions (Figure 1-1) to facilitate comparisons of bird and aquaculture distributions across the study area. Wihin these regions, the study area was defined to encompass all of the water area between Vancouver Island and the mainland including the mainland fjords, and all coastal waters (including fjords) on the coast of Vancouver Island to a distance of approximately 3 km offshore. This yields a total area of roughly 15025 km^2.

1.4. Mapping: a Geographical Information System

A computer-based geographic information system (GIS) was used to store, analyze and display the distribution of present and potential aquaculture development and distribution of known and possible marine bird use within the study area. A computer GIS has several advantages over manual methods of mapping:

- the database and the maps that are generated can be easily updated as new or revised information is made available.

- quantitative analyses (e.g., total areas used by birds or aquaculture, total area of overlapping distribution) can be readily performed.

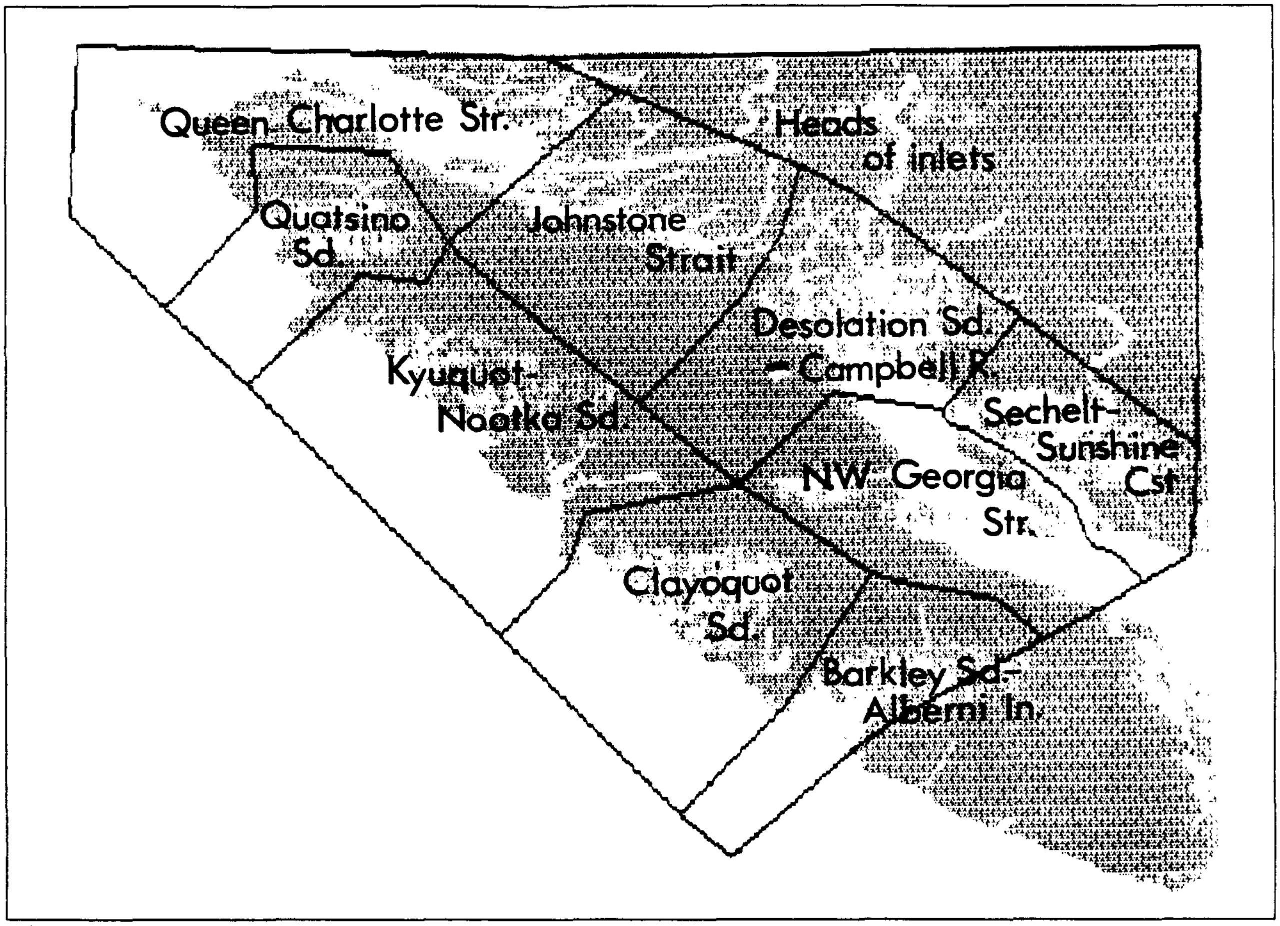

Figure 1-1: Regions of the study area.

- analyses can be expanded by incorporating more variables (e.g., to include other coastal uses) in the database and mapping exercises.

The specific GIS used was SPANS (Spatial Analysis System), a microcomputer-based system developed by TYDAC Corp. of Ottawa, Canada. SPANS was recently purchased by the Canadian Wildlife Service and therefore could be used in any future applications of the results of this project. SPANS was well suited for this project due to its excellent point mapping, overlay and modelling capabilities. Its major disadvantage was the fact that SPANS was undergoing major program revisions which, while increasing the power of the program, required a significant amount of debugging during its application in this project. In addition, as with all computer GIS programs, the command language and concepts are relatively complex, requiring considerable time and effort to become familiar with the program.

SPANS uses a rastor-type format called "quadtree" which stores spatial information in a grid-like structure where each grid cell is assigned an attribute value. The quadtree structure allows for variable grid sizes which is an advantage in data storage in that fixed grid sizes require significantly more memory and computer time to manipulate with the same degree of resolution. The alternate type of spatial data storage format is vector format, which can have greater resolution than raster or quadtree formats, but is considerably slower and more cumbersome for carrying out area-based analyses.

A digitized base map for the study area was purchased from the Canada Lands Data Service of Environment Canada. The base map was developed from 1:250,000 NTS map sheets and converted into SPANS format at a resolution of 398.4 m in a Lambert Azimuthal equal area projection. All subsequent layers of spatial information were converted to this projection. The maximum level of resolution used in this study was 24.9 m. The minimum level of resolution was 398.4 m although the information that was entered did not necessarily have this degree of accuracy.

The general application of SPANS is described in the following chapters. Details on the database files, SPANS files and programs and instructions on their use are given in the User Manual that accompanies this report.

2. EXISTING AQUACULTURE OPERATIONS

2.1. Data Sources and Methods

Three types of aquaculture were covered:

a) salmon farms;
b) shellfish farms (mostly oyster but including 2 mussel farms);
c) marine plant farms (kelp and nori).

A computer file of current (January 1989) leases, licenses of occupation (LOC's) and investigative permits[1] was obtained from the B.C. Ministry of Crown Lands (MCL). The file contained data on locations (latitude and longitude), present status (active or non-active), size (ha), type of culture and the type of tenure for most of the farm sites. The contents of the file was entered and translated directly into SPANS. Locational data for a number of farm sites were absent from the computer file, in which case locations were taken from site files at MCL regional offices, plotted on topographic map sheets, and digitized into SPANS. The aquaculture site information was stored in SPANS as a point file, which allowed other area-based attributes of the sites (e.g., region) to be appended as needed.

2.2. Results and Discussion

As of January 1989, 556 aquaculture leases and LOC's had been issued within the study area (Table 2-1). This represents 88% of the total number of sites in B.C. (B.C. Ministry of Crown Lands, 1989). A further 162 applications were under consideration and 75 investigative permits (IP's) had been issued. In total, all leases, LOC's, applications and IP's covered 43.5 km^2 or approximately 0.3% of the study area.

Leases and LOC's were assumed to represent currently operating sites. Applications were assumed to represent potential operating sites; based on trends since 1986, 40-50% of applications will be approved for leases or LOC's (T. Cockburn, Min. Forests and Lands: pers. comm.). IP's indicate areas of interest for development but do not represent a firm commitment to site development. IP's are regularly issued for the purpose of investigating potential sites for finfish farming[2], but are seldom issued for prospective shellfish or marine plant farms unless there is some competition for the site. Only about 25% of IP's will end up as leases or LOC's (*ibid.*).

Salmon farms: As of January 1989, 190 leases and LOC's occupying an area of 10.23 km^2 had been issued for salmon farms in the study area. This represents 92% of all such tenures issued for finfish farms in B.C. An additional 73 IP's had been issued and 94

[1] See Appendix B for a description of the types of aquaculture tenure in B.C.

[2] The requirements and application process for IP's and tenures are described in Appendix B.

REGION	SALMON: Tenure*	Appl.*	IP*	SHELLFISH: Tenure	Appl.&IP	PLANTS: Kelp	Nori
1. Sechelt/Sunshine Coast	60	8	3	39	17	-	-
2. NW Georgia St.	4	2	0	113	10	-	-
3. Desolation Sd/ Campbell River	56	11	8	149	20	-	-
4. Johnstone St.	17	13	6	3	4	-	-
5. Heads of mainland inlets	2	0	2	0	0	-	-
6. Q.Charlotte St.	3	22	23	1	4	-	4
7. Quatsino Sd.	9	10	2	2	0	-	-
8. Kyuquot/Nootka Sounds	6	18	18	9	3	-	-
9. Clayoquot Sd.	26	6	2	19	2	-	-
10.Barkley Sd./ Alberni Inlet	7	4	8	30	6	1	-
ALL REGIONS	190	94	73	365	66	1	4
TOTAL AREA (km^2)	10.23	8.69	5.08	14.62	3.9	0.03	1.08

* Tenure = lease or licence of occupation; Appl. = application;
IP = investigative permit

Table 2-1: Regional distribution of aquaculture sites in the study area.

applications were under consideration. The mean size of farm sites was 5.4 ha (s.d.= 5.15); the majority were under 10 ha.

The greatest densities of salmon farms occur in the Sechelt-Sunshine Coast and Campbell River-Desolation Sound regions which together account for 60% of existing leases and LOC's (Map 1). The distributions of applications and IP's indicate future growth of the industry to be northward, along the northwest and northeast coasts of Vancouver Island and northern parts of the mainland coast; over 50% of applications and

IP's are located in the Kyuquot-Nootka, Queen Charlotte Strait and Johnstone Strait regions.

Shellfish and marine plant farms: There were 365 leases and LOC's issued for shellfish culture by January 1989, the majority of these being for oyster farms. This represents 87% of all shellfish tenures in B.C. They occupied 14.6 km^2, about 89% of the total area under shellfish culture in B.C. Two IP's and 64 applications were also active.

Shellfish farms were concentrated in Baynes Sound in the northwest Georgia Strait region (39% of tenures) and in the Campbell River-Desolation Sound region (27%) (Map 2). Expansion of shellfish culture is low compared to salmon farming and shows no northerly trend; 61% of applications are located in areas of current use (northwest Georgia Strait and Campbell River-Desolation Sound regions). Cooler water temperatures and less sheltered coastlines in the northern parts of the B.C. coast are not favourable for this type of aquaculture.

Marine plant farms were as yet few and far between (Map 2). There was only 1 kelp farm and 4 applications for nori farms within the study area as of January 1989.

3. POTENTIAL AREAS FOR SALMON FARMING

3.1. Data Sources

Among the various types of aquaculture, salmon farming is undergoing the most rapid expansion in B.C. Two extensive studies of areas suitable for salmon farming along the B.C. coast have already been carried out for the Aquaculture and Commercial Fisheries Branch of the B.C. Ministry of Agriculture and Fisheries (MAF). While the final reports and maps from these studies have not yet been released, MAF generously provided draft copies of the maps and reports to allow their application in this study.

The studies commissioned by MAF classified areas on the B.C. coast according to their biophysical suitability for salmon farm development. The first study covered the Sunshine Coast/Sechelt Peninsula and Desolation Sound/Discovery Passage areas (Ricker, 1987); the second covered the north and west coasts of Vancouver Island (Ricker *et al.*, 1988). Each study produced a report (presently in draft) and series of maps indicating areas of good, medium, poor or no potential for salmon farming. Mapping for the Sechelt-Sunshine Coast and the Desolation Sound-Johnstone Strait regions was done at a scale of 1:50,000 while mapping of the north and west coasts of Vancouver Islands was done at 1:125,000.

The information derived from these studies was subject to the following rules and assumptions (Ricker, 1987; Ricker *et al.*, 1988).

1. Classifications were done solely on the basis of biophysical characteristics and did not take into account accessability, foreshore ownership or other factors regarding infrastructure, market accessibility or other existing or planned land and water uses.

2. The classifications were based on the biophysical requirements for chinook salmon. Chinook are the most sensitive in terms of their tolerances to biophysical parameters, making the classifications conservative estimates of an area's potential for salmon farming.

3. Only netpen systems that are open to surrounding sea conditions were considered. While enclosed-system techniques have been developed to overcome poor oxygen, temperature or other environmental conditions, they were not considered.

4. Water depths of at least 10 m were assumed necessary for netpen systems; areas with water depths of less than 10 m were therefore ruled not acceptable.

5. The first study (Sechelt/Sunshine Coast) assumed that most salmon farms are located within 300 m of shore, and therefore, a distance of 600 m (300 m plus a 300 m buffer) was taken as the coastal corridor for classifying salmon farming capability. This corridor was narrowed if the 200 m contour was closer to the shoreline and widened to enclose sheltered bays. Areas outside this corridor were not classified for suitability for salmon farming. In the second study (north and west Vancouver Island), the classification scheme was extended further offshore and an additional

class was assigned to indicate suitability was dependent on the use of open-sea technology.

6. Sixteen biophysical variables were used to assess and rank coastal areas. An asterisk marks those variables considered by Ricker (1987) to be essential factors to the health of fish and therefore primary determinants of an area's rank; i.e., if one of these was rated "poor" or "not acceptable" than the area was ranked as such:

   - temperature *
   - salinity *
   - oxygen levels *
   - water depth *(if <10 m)
   - currents
   - waves
   - wind and exposure
   - snowfall and freeze-up
   - marine vegetation (kelp and eelgrass beds)
   - intertidal substrate
   - presence of predators
   - pollution hazards *
   - plankton blooms *
   - hydrology
   - shoreline instabilities (slides, debris flows, avalanches)
   - freshwater availability.

   Each variable was assigned "good-medium-poor-not acceptable" ranking limits. Sections of the coast were assessed for each of the 16 criteria, and a class for each section was determined based on the worst of any of the important variables (Ricker, 1987) or on a "compromised aggregate score" (Ricker *et al.*, 1988).

3.2. Methods

The maps produced in the MAF studies were either hard copy or in a CAD[1] format, which meant that the information they contained had to be digitized before it could be imported into SPANS. The classes of salmon farming suitability used in the MAF studies were too detailed for the purposes of this study and were therefore grouped (Table 3-1). Polygons indicating good, medium, poor, not acceptable and unclassified areas for salmon farming were drawn on overlays of 1:50,000 and 1:250,000 topographic maps of the study area. These overlays were digitized using Intergraph; the files were exported in Standard Interchange Format (SIF) and then imported into SPANS.

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[1] Computer Assisted Design: a computer map file that is used simply as a drafting tool with no accompanying data that provides details on the subject matter being mapped. Maps generated using CAD cannot be easily imported into SPANS.

SPANS NO.	CLASS CODE	DESCRIPTION
5	G	Good: may have minor, correctable problems. Includes MAF studies' ranks: G, G*, G-M, G-P*, G-Pw, G-P.
4	M	Medium: caution required. Includes MAF studies' ranks: M, M-P, M-P*, M-Pw, M-G.
3	P*	Qualified Poor: an area is downgraded from M due to cold year-round temperatures, low seasonal oxygen levels or high wave exposure. Includes MAF studies' ranks: P*, Pw, Pw-P, P*-P, P-M, Pw-M, P*-M, M*.
2	P	Poor: many problems. Incorporates MAF studies' ranks: P, P-NA, NA-P, P-P*, P-Pw.
6	NA?	Too far offshore for salmon farms (Sechelt/Desolation Sound) or suitable for open-sea cage technology (northeast and west coast Vancouver Island).
1	NA	Not acceptable.
7	U	Unclassified: most assumed to be NA.

Table 3-1: Salmon farming suitability classes used in this study.

3.3. Results

In total, 0.5% of the study area was classed as good for salmon netpen farming, 5.8% was rated medium, 28% was rated poor or a qualified poor, 41% was rated not acceptable and 25% was unclassified (Table 3-2; Map 3). 71% of the unclassified area was in the NW Georgia Strait region, most of which was not covered in the MAF studies. The majority of the areas classed as good were found in the Queen Charlotte Strait (49%) and Kyuquot-Nootka Sound (44%) regions. About one-third of the areas rated as medium was also located in the Kyuquot-Nootka Sound region, with the remainder found in Johnstone Strait (14%), Queen Charlotte Strait (13%), Clayoquot (14%) and Barkley Sounds (15%). On a regional basis, Kyuquot-Nootka Sound had the highest percentage of its area classified as good or medium (20%) followed by Barkley Sound (17%) and Johnstone Strait (12%).

A comparison of suitable areas with current salmon farms, applications and IP's indicated little overlap between the location of sites and the distribution of areas classified as suitable (good or medium) for salmon farming (Figure 3-1; Map 4). Most of the overlap that did exist occurred in Kyuquot-Nootka Sound; 42% of the 99 sites that were located in areas classed as good or medium occur in this region.

REGION	AREA (km²) CLASSIFIED AS: G	M	P*	P	NA?	NA	U	REGION TOTAL
1. Sechelt-Sunshine Cst.	0	15	14	128	368	87	349	961
2. NW Georgia Str.	0	0	0	2	5	0	2709	2516
3. Desolation Sd-Campbell River	4.5	46	89	225	846	171	137	1518
4. Johnstone Str.	0	120	284	153	110	114	240	1022
5. Heads of inlets	0	0.7	0.6	73	91	27	372	564
6. Q.Charlotte Str.	40	114	310	94	777	2231	0	3566
7. Quatsino Sd.	0	19	96	47	0	801	0	964
8. Kyuquot-Nootka Sd.	36	301	0	41	50	1276	0	1704
9. Clayoquot Sd.	1.5	126	3	123	0	983	0	1236
10. Barkley Sd.-Alberni Inlet	0	131	39	34	153	419	0.3	776
ALL REGIONS	82	873	835	918	2400	6110	3807	15025
% OF TOTAL AREA	0.5	5.8	5.6	6.1	16	40.7	25.3	

Table 3-2: Area in each salmon farming suitability class by region.

3.4. Discussion

Only 995 km² or about 6% of the study area was deemed to be suitable for salmon netpen farming. There were differences in these percentages between the first (Ricker, 1988) and the second MAF study (Ricker *et al.*, 1989). Of the regions covered by the first study, only 2.1% was classed as good or medium suitability, compared to 9.1% of the regions covered by the second; 9% of regions covered by the first study versus 19% of areas covered in the second were classed as qualified poor (P* or NA?). The regions covered by the second study (the northeast, northwest and west coasts of Vancouver Island) may indeed have a higher percentage of suitable area, but the second study was also less conservative in the criteria it used to define suitability classes. As well, the second study used a map scale of 1:125,000 compared to 1:50,000 used by the first study, which may have resulted in larger areas being assigned as good or medium suitability in the second study relative to the first.

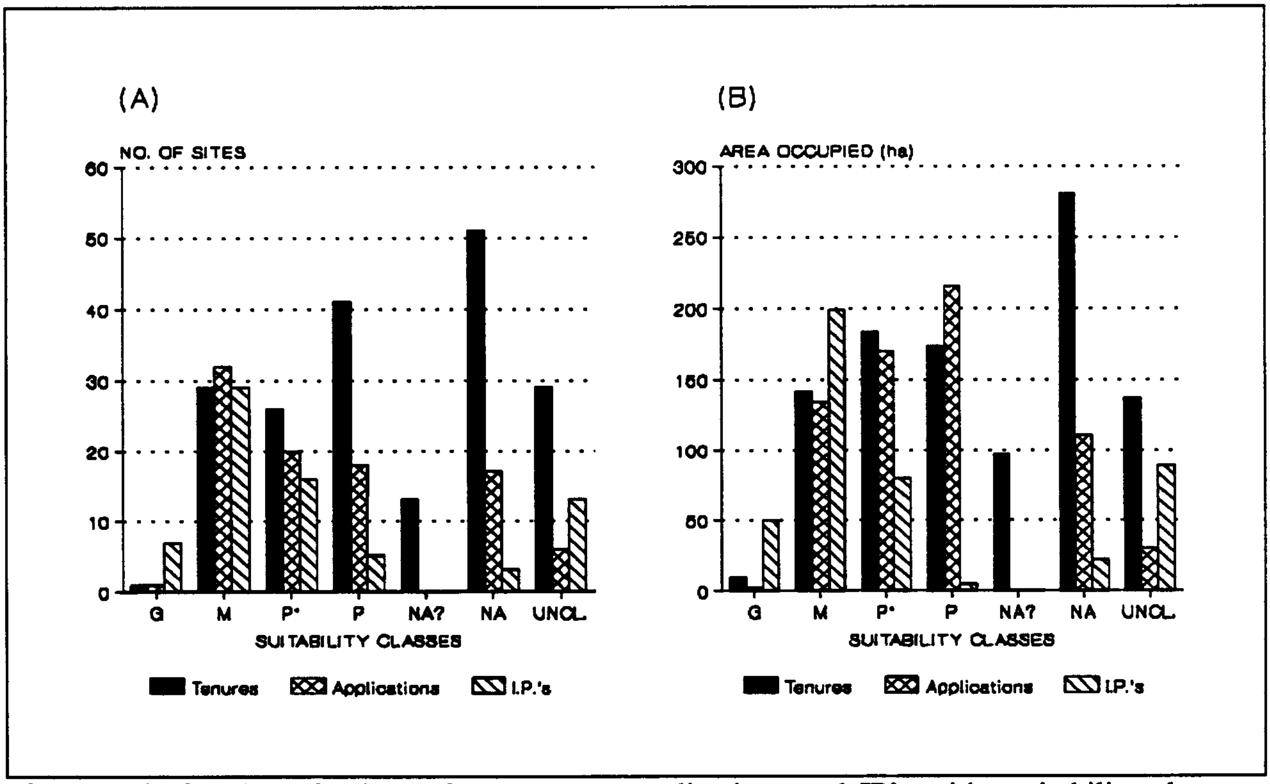

Figure 3-1: Overlap of salmon farm tenures, applications and IP's with suitability classes: (A) number of sites located in each suitability class; (B) total areas of sites located in each suitability class.

The overlap between areas classed as good or medium for salmon farming and the location of existing and proposed farm sites was surprisingly low. Only 15% of all salmon farm tenures are located in areas classified as good or medium suitability (Figure 3-1). It is emphasized, however, that the classification of the coast was done on a large scale relative to individual aquaculture sites, such that pockets of suitable areas were likely missed. In addition, the intention of the classification was not to predict the location of sites but to provide broad guidance for efficient expansion of the industry. In this regard, most areas that have already been developed for salmon farming are relatively close to markets, transportation and service facilities - factors that likely outweighed biophysical limitations in the early development of the industry. As the biophysical limits of the developed areas are reached, however, and as more of the coast becomes accessible by road and services, a greater percentage of the areas that are biophysically suitable for salmon farming will likely be exploited. This is reflected in the fact that greater proportions of salmon farm applications and IP's are located in areas of higher biophysical suitability (Figure 3-1). From these results we can conclude that although they do not reflect present coastal use, the MAF study broadly indicates areas that could be developed for salmon farming in the future.

It is important to note that salmon farms need to be spaced so as not to reduce the quality of their own environment. Current policy of the B.C. government is to require a minimum spacing of 3 km between farms and 1 km from parks, public beaches, Indian reserves, and other areas of public use. This requirement is not always met in areas where salmon farms were established prior to the policy (e.g., Sechelt Peninsula). If exercised, however, this policy will result in the establishment of a maximum density of 1 farm per 9 km^2 in future areas of development.

4. MARINE BIRD DISTRIBUTIONS

Data on marine bird distributions were organized on the basis of species or species group and season. Seasons were defined as:

- spring migration: March, April, May
- fall migration: September, October, November
- overwintering: December, January, February
- summer (moulting, coastal breeders, failed or nonbreeders): June, July, August

4.1. Fall, Winter and Spring Distributions

4.1.1. Data sources

The Coastal Waterbird Inventory File (CWIF) was the main source of data regarding the winter, spring and fall distributions of marine birds. This file, compiled by the Wildlife Branch of the B.C. Ministry of Environment and Parks, contains records from aerial, boat and shoreline surveys carried out from 1967 to 1982 under a waterfowl inventory program sponsored by provincial and federal wildlife management agencies. The records are organized on a geographical basis in the following manner:

- the coast is divided into 93 major zones.
- each zone is further subdivided into 2-15 subzones.
- subzones are subdivided again into biophysically homogeneous "areas".

Each record consists of the number of birds in one of 54 bird categories (species or group) that was sighted during a given survey in a given "area".

The CWIF did not provide coverage of bird distributions for the entire study area for all months of the year. For example, there were 324 surveys of 105 subzones made in January (over all years), while there were only 3 surveys made in 3 subzones in June. The most complete coverage was made in January and October. The Sechelt/Sunshine Coast was poorly covered; additional data was provided from surveys carried out by G. Kaiser (CWS) in 1981-82.

4.1.2. Methods

The study area encompassed 34 of the 93 zones (zones 1-6, 13-23, and 29-45 inclusive); these 34 zones contained 141 subzones. Bird counts were tabulated on a per-survey basis using subzones as the basic geographic unit. Subzones were used instead of "areas" because use of "areas" would have led in many cases to very few observations per geographic unit due to infrequent surveying and inconsistent definition of the boundaries of "areas". A survey was defined as all observations carried out in a subzone in a given month and year. Subzones were defined in the CWIF on a linear basis as a section of fairly biophysically uniform shoreline between two points. To convert these sections of coast into polygons that could be mapped in SPANS, a seaward boundary of 2 km from the shoreline was set. Polygons representing the subzones were drawn accordingly from

GROUP/SUBGROUP/ SPECIES	ACRONYM	REGIONS WITH HIGH USE: 1	2	3	4	5	6	7	8	9	10	MOULT CONC.
DABBLING BIRDS:												
Geese	GEESE		X				X		X	X	X	
Swans	SWANS				X	X					X	
Mallard	MADU				X	X	X	X	X		X	
Wigeon	WIGE			X	X		X			X	X	
Northern Pintail	PINT		X		X			X			X	
Green-winged Teal	GWTE				X		X	X			X	
DIVING BIRDS:												
Scaup	SCAU		X		X						X	
Bufflehead	BUFF	X	X	X	X						X	
Goldeneyes	GOLD	X	X	X	X	X		X			X	
Mergansers	MERG		X	X	X	X					X	
Scoters	SCOTE		X	X		X					X	
Surf Scoter	SUSC	X	X	X		X				X	X	M
White-winged Scoter	WWSC		X							X	X	M
Oldsquaw	OLDS	X	X								X	
Harlequin Duck	HADU	X	X		X							M
Grebes	GREBE	X		X	X					X	X	
Loons	LOON	X	X	X	X				X	X	X	
Cormorants	CORM		X				X			X	X	
OTHERS:												
Shorebirds	SHORE	X			X				X		X	
Black Oystercatcher	BLOY								X	X	X	
Gulls	GULL	X	X	X	X	X	X		X	X	X	
Alcids	ALCID			X		X					X	
Raptors	RAPT	X	X	X	X	X	X		X	X	X	
Great Blue Heron	GBHE		X		X		X				X	

REGIONS:

1 - Sechelt/Sunshine Cst.
2 - NW Georgia Strait
3 - Desolation/Campbell R.
4 - Johnstone Strait
5 - Heads of inlets
6 - Q. Charlotte Str.
7 - Quatsino Sound
8 - Kyuquot/Nootka
9 - Clayoquot Sd.
10 - Barkley/Alberni

Table 4-1: Marine bird groups/species for which distribution data were generated and mapped.

1:250,000 topographic maps, digitized and entered into SPANS (Map 5). A database was created using dBase 3+ which linked information on the dates (month and year) of each survey, types of surveys, and the number of birds of all bird species or species groups sighted during all surveys[1] to the CWIF polygon.

Birds covered in the CWIF records were consolidated into 24 species or species groups (Table 4-1). Species were put into group categories if there were very few or no

[1] See the User's Manual for details regarding the structure of the database.

records for that species (e.g., Tufted and Horned Puffins - the few sightings were added to the "Alcids" group), or if the category was used inconsistently (e.g., large and small Alcids - consolidated into the "Alcids" group). Some species were recorded individually as well as in a group category, such that analyses could be carried out on the individual species as well as on the group as a whole (e.g., Scoters group and species). Some groups consisted almost entirely of one species; for example, the vast majority of sightings in the raptor group were of Bald Eagles.

For each bird group/species and each season, each subzone (polygon) was ranked on the basis of the maximum number of birds seen in any survey conducted in that subzone. Maximum numbers were chosen over means or medians because maxima were considered to be the least biased and to best reflect the potential of a subzone to support marine birds. Eight ranks were used:

1 - < 3 surveys conducted, no birds recorded.
2 - $\geq$ 3 surveys conducted, no birds recorded.
3 - 1-10 birds (maximum) recorded in any survey.
4 - 11-50 " " " "
5 - 51-100 " " " "
6 - 101-500 " " " "
7 - 501-1000 " " "
8 - >1000 " " "

Maps of the distribution ranks across all subzones were generated for each species/group for each season.

BIRD USE CATEGORIES (#Birds/subzone):

LOW	MEDIUM	HIGH	GROUP/SPECIES
1-100	100-500	>500	Gulls
1-50	50-500	>500	Scoters
1-10	10-100	>100	Geese, Mallard, Wigeon, Scaup, Bufflehead, Goldeneye, Mergansers, Grebes
1-10	10-50	>50	Swans, Oldsquaw, Cormorants, Alcids
	1-10	>10	Pintail, Green-winged Teal, Harlequin Duck, Loons, Raptors, Black Oystercatcher, Great Blue Heron
Rank 1 = uncertain bird use			All
Rank 2 = no bird use			All

Table 4-2: Bird use categories derived from bird distribution ranks.

For analytical purposes, bird distribution ranks 3-8 were grouped into categories of high, medium and low bird use. The categories were defined for each bird species/group on the basis of its population size and flock size (Table 4-2). The maximum of the 3 seasonal distribution ranks were used to allocate a bird use category to a subzone. Subzones of bird rank 1 were categorized as "uncertain" and those of bird rank 2 were categorized as "no bird use".

4.1.3. Results

In total, the database and maps of fall, winter, and spring distributions derived from the CWIF contain data on 5929 sightings of the bird groups/species in the 141 subzones that comprise the study area. A database file and 3 seasonal distribution maps were generated for each group/species. Seasonal distribution maps for Goldeneye are reproduced here (Map 6); the entire suite of distribution maps can be viewed in SPANS.[2]

Gulls were generally the most abundant in terms of total numbers of birds recorded. Scoters, Goldeneye sp. and grebes were also abundant in fall and winter. Some groups/species, such as gulls, loons, and goldeneyes, were found throughout the study area while others, such as swans, Harlequin Duck, Oldsquaw and Black Oystercatcher, were more localized in their distribution (Table 4-1). Regions 2 (NW Georgia Strait), 4 (Johnstone Strait) and 10 (Barkley Sound-Alberni Inlet) were particularly important to a variety of bird groups/species.

4.1.4. Discussion

A number of assumptions accompany the use of subzones and their associated bird use categories.

i) Subzones were used as the geographic unit for presenting bird distributions because of the consistency of the data that was available at that scale, as well as the fact that covering the entire study area at a finer scale was beyond the resources of this project. Defined as polygons, the subzones ranged in size from 1.5 to 233 km^2. It was assumed that subzones were defined in the CWIF so as to represent fairly biophysically uniform areas.

ii) A seaward boundary of 2 km for the polygons representing the subzones was assumed to represent the outer limit of use of the coastal zone by most of the bird groups/species. (The 2 km boundary may have exaggerated the area used for some species.)

iii) The maximum number of birds recorded in any one season in a subzone is assumed to be a good indicator of the importance of that area to the species/group.

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2 See the User's Manual for appropriate SPANS files.

iv) Bird use of a subzone was assumed to be uniform such that the entire subzone could be designated the same rank. However, bird use could vary considerably within a subzone, especially the larger ones. In such cases, ranking the entire subzone may have exaggerated the area of importance to a bird group/species. Furthermore, the distribution rank did not take the duration of use in any one season into account. A single large flock migrating through in the fall, if recorded in the surveys, would result in a subzone being ranked quite high whereas a smaller flock using the area throughout the year may result in a lower rank.

Using subzones as the spatial unit meant that the bird distribution information was quite coarse. This factor, along with the assumptions stated above, must be kept in mind in applications of the bird use data; for example, in indicating overlap of bird use with aquaculture development (chapters 5 and 6), or in comparing potential bird habitat with observed bird distribution (chapter 7). In general, maps and analyses of bird distributions derived from the CWIF surveys have greater levels of uncertainty associated with them than do maps representing existing aquaculture use where boundaries of tenures and applications are clearly defined.

While any of these assumptions could be changed to derive more or less conservative estimates of bird use, it must also be remembered that the bird survey data were limited, making knowledge of actual bird distributions in many regions of the coast incomplete.

4.2. Colony Distributions

During the summer many marine bird species leave the coast to breed inland or in arctic regions. Two kinds of marine bird concentrations are found in coastal waters during the summer; breeding colonies and flocks of moulting and failed or non-breeding birds.

4.2.1. Data sources

Fifteen marine bird species nest on the southern B.C. coast (Table 4-3). The locations and sizes of seabird colonies were obtained from a database recently compiled for CWS (M. Rodway and M. Lemmon, unpub. data). Information on Great Blue Heron colonies was obtained from Butler (1989). Little is known about the locations of Marbled Murrelet nests, other than they tend to have solitary nests in old growth forests. As such, their nesting habitat is not likely to be directly impacted by aquaculture, and they were not included in the analysis of colony distributions.

4.2.2. Methods

Colonies were located by the central position of the island, islet or other landform on which they were situated. A colony was considered to be surrounded by a habitat area that varies in size and intensity of use according to the size of the colony (number of nests or breeding pairs) and the habitat needs of the species.

SPECIES	ACRONYM	NUMBER OF COLONIES	MAXIMUM #NESTS/ COLONY	# NESTS IN STUDY AREA
Cassin's Auklet	CAAU	11	376,000	853,610
Rhinoceros Auklet	RHAU	7	89,500	185,150
Pigeon Guillemot	PIGU	71	361	2,241
Tufted Puffin	TUPU	11	24,900	37,425
Horned Puffin	HOPU	4	7	18
Common Murre	COMU	4	4,980	5,250
Fork-tailed Storm Petrel	FTSP	10	50,800	105,600
Leach's Storm Petrel	LSPE	15	191,000	447,850
Double-crested Cormorant	DCCO	2	21	21
Brandt's Cormorant	BRCO	4	31	60
Pelagic Cormorant	PECO	68	464	2,437
Glaucous-winged Gull	GWGU	114	1,922	13,470
Black Oystercatcher	BLOY	108	45	386
Great Blue Heron	GBHE	15	44	660

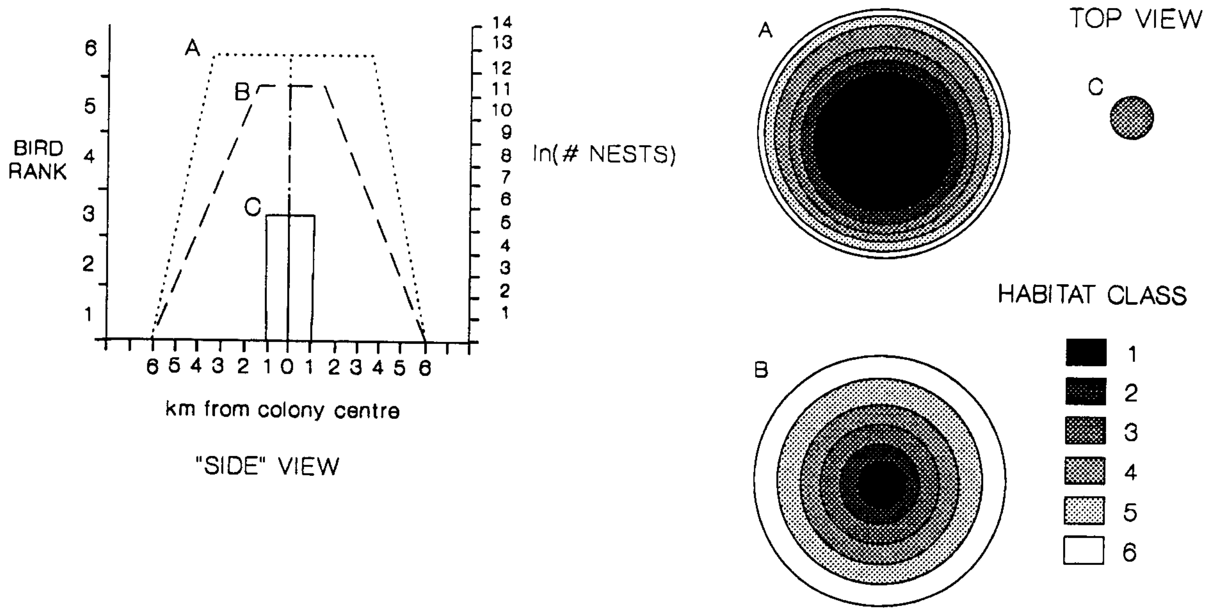
Table 4-3: Size and number of marine bird colonies in the study area.

Each colony and its respective habitat area was mapped as a circle, the size of which was directly proportional to the known number of nests. The circle was divided into two zones: a more intensely used "inner zone" and an "outer zone" of decreasingly important use. The inner zone was defined as the area of the circle that represents an average density of 10,000 nests/km . Its radius was calculated by the formula:

$$\text{Radius} = \sqrt{\frac{\#\ \text{nests}}{10{,}000\ \text{nests/km}^2 * \pi}}$$

Since not all colonies or species reach this density, a minimum area for the inner zone was set at 3.14 km^2 (radius = 1 km). Hence, the radius of the circle representing a colony was 1 km or the result of the above formula, whichever was greater. Two exceptions were made. A smaller minimum habitat area (area = 0.78 km^2; radius = 0.5 km) was applied to Black Oystercatchers which do not use the area surrounding their colonies to the same extent as other species. A larger minimum area was considered critical to the two petrel species because of their vulnerability to predators when lights are present at night (area = 12.56 km^2; radius = 2.0 km).

An outer zone was defined only for those colonies which had an inner zone density of more than 100 nests/km^2. Given the minimum area of 3.14 km^2, this was equivalent to a colony size of 314 nests or greater for most species and 78 and 1256 nests for Black Oystercatchers and petrels respectively. The radius of an outer zone in these situations was calculated by:



Cassin's Auklet Colonies
Examples of Potmap Model

Colony	# nests	ln(# nests)	Habitat Circle Radius Inner	Habitat Circle Radius Outer-Inner
A: Sartine Island	376,000	12.84	3.46	2.54
B: Beresford Island	66,000	11.10	1.45	4.35
C: Storm Island	300	5.70	1.00	0

Figure 4-1: Colony classing scheme.

$$\text{Radius} = \sqrt{\frac{\#\ \text{nests}}{100\ \text{nests/km}^2 * \pi}}$$

A maximum habitat area (inner and outer zones combined) was set at 113 km or a radius of 6 km. Only colonies with greater than 11,310 nests would have the radius of their habitat circle truncated as a result of this maximum.

To further delineate intensity of use, classes of habitat areas were defined as a function of colony size. Six classes were defined:

Class 1	= <10	nests/km²	Class 4	= 1001-10,000	nests/km²
Class 2	= 11-100	"	Class 5	= 10,001-100,000	"
Class 3	= 101-1000	"	Class 6	= >100,000	"

The inner zone of a colony circle was classed directly according to the known number of nests. The outer zone was classed in concentric circles of decreasing importance defined as a linear function of the natural log of the colony size (Figure 4-1). If the area designated as important habitat to one colony overlapped with that of another colony of the same species, the class was decided as a function of the total number of birds at that point. Colony sites which have recently been abandoned or which are suspected but have not been surveyed were mapped with the minimum class and area for that species.

NESTING SPECIES	HABITAT AREA (KM^2) OF CLASS: 1	2	3	4	5	6	TOTAL
Pigeon Guillemot	71	51	13	2			137
Tufted Puffin	57	33	24	19			133
Horned Puffin	7						7
Cassin's Auklet	196	62	38	22	21	39	378
Rhinoceros Auklet	22	20	18	14	11	13	98
Common Murre	5		3			2	10
Fork-tailed Storm Petrel	66	29	48	36	24	10	213
Leach's Storm Petrel	273	97	63	61	62	18	574
Double-crested Cormorant	2	3					5
Brandt's Cormorant	5	5					10
Pelagic Cormorant	77	37	17	1			132
Glaucous-winged Gull	132	56	70	12	8	5	283
Black Oystercatcher	32	25					57
Great Blue Heron	8	6					14
TOTAL AREAS IN CLASS:	953	424	294	167	126	87	2051

Table 4-4: Areas occupied by colonies and accompanying important habitats of species that nest within the study area.

4.2.3. Results

Defined in the way described, bird colonies and their important habitat occupied about 2051 km^2 (Table 4-4). Leach's Storm Petrel had the largest overall colony habitat area (574 km^2) as well as the largest area of high intensity use (80 km^2 for classes 5 and 6 combined). Cassin's Auklet had the largest area in class 6 alone, meaning that most colonies were greater than 100,000 nests/km^2. This reflects the fact that Cassin's Auklet is the most abundant breeder on the B.C. coast; Triangle Island, off the northwest coast of Vancouver Island, alone contains 360,000 breeding pairs, which constitutes 40% of the world's breeding population (Vermeer *et al.*, 1979). By comparison, the small areas for Horned Puffins, Double-crested and Brandt's Cormorants and Common Murre reflect the small breeding populations of these species within the study area.

The species varied in the distribution of their colonies. Cassin's and Rhinoceros Auklets are very localized in the distribution of their colonies, whereas Pigeon Guillemots have many small colonies scattered throughout the study area. Map 7 shows the distribution and classification of Cassin's Auklet colonies; the entire suite of colony distributions can be viewed in SPANS.

4.2.4. Discussion

A high class number indicates an area that is intensely used by a large colony; a low number indicates the outer fringes of a large colony or that the colony itself is small (i.e., few nests). That areas around colonies are important to the inhabitants appears to be a valid assumption; for example, Rhinoceros Auklets form large post-breeding and moulting concentrations near colonies prior to dispersing for the winter (Kaiser, 1985). Together, the size and classification of the circle representing a colony are not meant to be an accurate quantitative description of the area used by any given colony, but simply to provide an index of the significance of that area as breeding habitat to the species involved that can be used to indicate the relative impact of overlapping use by aquaculture (chapter 5).

The procedure used to map colony habitat was derived through discussions with CWS personnel. It was apparent, however, that more information on the use of habitat around colonies is needed.

4.3. Summer Moulting Concentrations

4.3.1. Data sources and methods

Data regarding summer moulting concentrations of Harlequin Ducks, Surf Scoters and White-winged Scoters were obtained from compilations done by J.P. Savard (CWS) of CWS surveys and sighting records held at the Royal B.C. Museum. Moulting concentrations were located and mapped in the same way as colonies. A circle was located in the central position of sightings of concentrations and the size of the circle was defined according to the size (number of birds) recorded. The area of the circle was classed using the same scheme as for colonies.

4.3.2. Results

Moulting concentrations for White-winged Scoters, Surf Scoters and Harlequin Ducks ranged in size from 10 to 4000 birds (Table 4-5). White-winged and Surf Scoters occurred in considerably higher densities than Harlequin Ducks. Moulting concentrations for all 3 species occurred primarily in the NW Georgia Strait, Clayoquot Sound and Barkley Sound regions (Map 8).

4.3.3. Discussion

Data on the location and size of moulting concentrations are poor as not systematic surveys of these concentrations have been conducted along the coast (J.-P. Savard, pers. comm.). This points to the need to revise the database as more accurate information

SPECIES	MEAN NO. BIRDS	HABITAT RANGE	AREA (km^2) OF CLASS: 1	2	3	4	5	TOTAL
Wh-winged Scoter	249	10-4000	19	50	32	4	1	106
Surf Scoter	354	10-4000	21	48	33	9	1	111
Harlequin Duck	77	10-400	2	44	23			70

Class: 1 = <10 2 = 10-100 3 = 100-1000
(birds/km^2) 4 = 1000-10,000 5 = 10,000-100,000

Table 4-5: Characteristics of moulting concentrations and their important habitat areas.

becomes available. As with colonies, the size and classification of the circles representing moulting concentrations are intended simply to provide an index of the significance of that area to the species. They can then be used to indicate the relative impact of overlapping use by aquaculture (chapter 5).

4.4. Other Data Sources

The extensive bird records at the Royal B.C. Museum and from Christmas bird counts have not been included in this database due to their variable quality of this data and vast sizes. With some effort, however, these records could be added to the database.

5. OVERLAPPING USE OF COASTAL AREAS BY AQUACULTURE AND MARINE BIRDS

5.1. Bird Distributions

5.1.1. Methods

Areas of overlapping use by aquaculture and marine birds were determined by appending the appropriate CWIF subzone identification number to the SPANS point files of aquaculture sites. For each species/group, the maximum rank from fall, winter and spring distributions was then applied in each subzone. The areas occupied by aquaculture sites were then classified as to their concurrent level of bird according to the bird use categories defined in chapter 4 (Table 4-2):

uncertain	- if the site fell into a CWIF subzone with a bird distribution rank of 1.
no bird use	- if the site fell into a subzone of bird distribution rank 2.
low, medium or high use	- if the site fell into a subzone of bird distribution rank 3 or greater, its area was designated as "low", "medium" or "high" bird use as described in chapter 4 (Table 4-2).
unclassified	- if the site fell outside the CWIF subzones and could not be rated for bird use.

Levels of overlap between each bird group/species and each type of aquaculture were then assessed on the basis of the percentage of the total area occupied by that aquaculture category that was ranked of high, medium and low use by that bird group/species. Regional analyses were carried out to discern the areas of the coast where overlap with aquaculture was the greatest for any given bird group/species. Types of aquaculture for which bird use was uncertain were also assessed.

5.1.2. Results

Levels of bird use in areas occupied by aquaculture were consistently high for Goldeneye sp., Bufflehead, loons, gulls, and raptors (Table 5-1; Figures 5-1 and 5-2). For example, over 50% of areas occupied by aquaculture were considered to be of high use by Goldeneye (high use for this species was defined as >100 birds/subzone). Most of the overlap between finfish aquaculture and Goldeneye sp. occurred in the Sechelt-Sunshine Coast region (Map 9); most with shellfish aquaculture occurred in the NW Georgia Strait (Baynes Sound) region.

Over 75% of the areas occupied by aquaculture were ranked as either high or medium use by loons and raptors (there was no "low" category for these bird groups). Other groups/species where overlapping use was significant (greater than 50% of areas occupied by aquaculture were rated as high or medium use by birds) were: Mallard, scoters, mergansers, gulls, cormorants, and alcids. Regions of significant overlap included Desolation Sound-Campbell River, Kyuquot Sound and Clayoquot Sound.

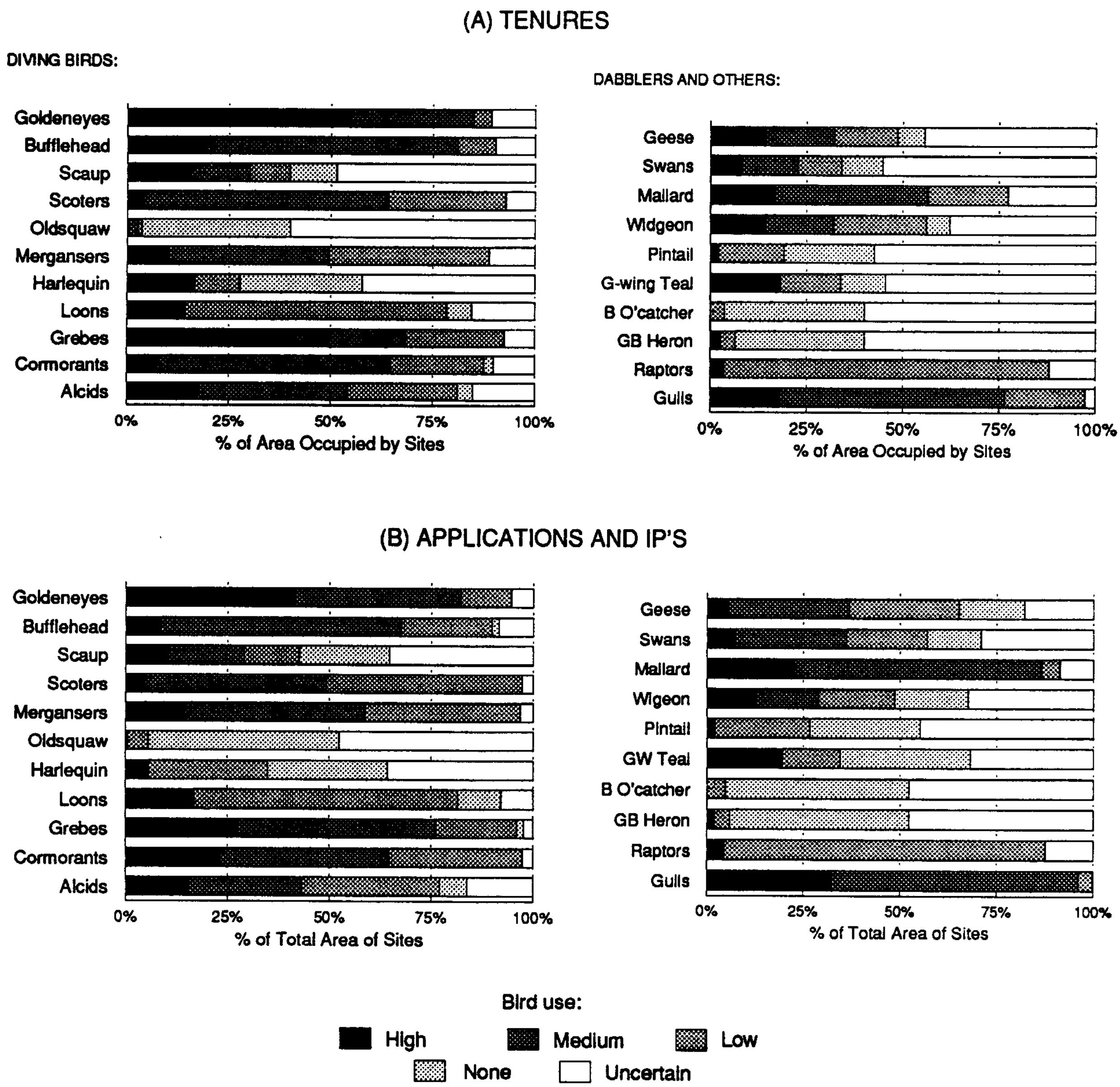


Figure 5-1: Overlap between bird use and finfish tenures, applications and IP's as percentages of the areas occupied by each type of site.

GROUP/SPECIES	FINFISH SITES[1]	SHELLFISH SITES[1]
Goldeneyes	High	High
Bufflehead, Cormorants, Grebes, Gulls, Loons, Mallard, Mergansers, Raptors, Scoters	Medium	Medium
Alcids	Medium	Low
Wigeon	Low	Medium
Geese, Harlequin Duck, Scaup	Low	Low
Swans	Low,*	Low
Green-winged Teal, Pintail	Low,*	Low,*
Oldsquaw	None,*	Low
Bl.Oystercatcher, Great Blue Heron	None,*	Low,*

High = >50% of area occupied by sites classified as high use by birds
Medium = >50% of area classified as high or medium use by birds
Low = 10-50% of area classified as high or medium use by birds
None = <10% of area classified as high or medium use by birds
* = >50% of area had no birds but surveyed less than 3 times

[1] includes tenures, applications and IP's

Table 5-1: Overlap between aquaculture and marine bird distributions.

There were a number of species for which bird use was ranked as uncertain over a large proportion of the area occupied by aquaculture (Table 5-1). This means that in these areas, while no birds were recorded, less than 3 surveys were carried out such that the absence of birds could not be stated with confidence. Groups or species for which over 50% of the area occupied by aquaculture was rated "uncertain" included swans, Oldsquaw, Black Oystercatcher, Great Blue Heron, Pintail, Green-winged Teal, wigeons and scaups. Regions where a large percentage of "uncertain" ranks occurred included Sechelt-Sunshine Coast, Desolation Sound-Campbell River and Johnstone Strait.

Of the total 43.6 km^2 in the study area occupied by aquaculture leases, LOC's, applications and IP's, about 31% was unclassified for bird distributions and could therefore not be assessed for marine bird use. The Desolation Sound-Campbell River region had the largest area occupied by aquaculture that was unclassified for bird use, due in part to the concentration of aquaculture sites in this area as well as a relative lack of survey data.

5.1.3. Discussion

The assessment of overlapping use by birds and aquaculture was subject to the assumptions regarding the use of bird distribution ranks and bird use categories discussed in chapter 4: that high bird distribution ranks were indicators of high use by a bird

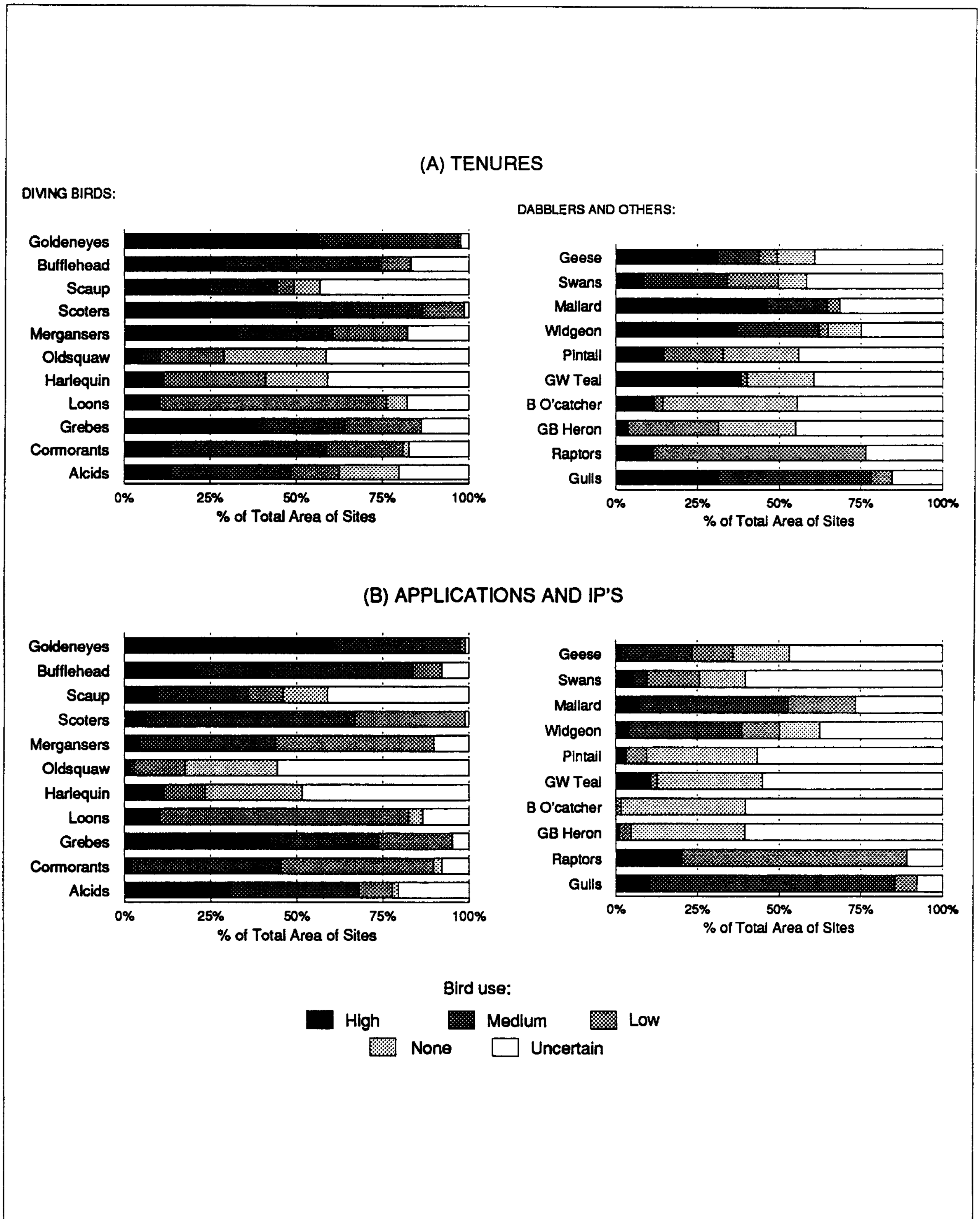


Figure 5-2: Overlap between bird use and shellfish tenures and applications as percentages of the areas occupied by each type of site.

group/species and that bird use is uniform throughout a subzone. However, due to the coarseness of the bird distribution data, some aquaculture sites within subzones rated as high use may actually be subject to little or no bird occupancy. Equating the areas of all aquaculture sites within such a subzone may overstate the level of overlap with bird use. It was also assumed that the area of overlap is equal to the registered area of the tenure or application. In many cases, however, not all of the tenured area is used by the holder, and often the entire area requested in an application is not granted.[1] Hence, this assumption may have also exaggerated the level of overlap.

Despite these limitations, the analysis of overlap did provide an indication of the potential spatial impact of aquaculture on bird habitat. It suggests the species and types of aquaculture involved and the parts of the coast where overlapping use may be significant. Of the types of aquaculture sites, salmon farms may have the greatest potential to displace birds from habitat areas due to the higher levels of human activity that occur around them. Bird groups/species such as Goldeneye sp., loons, gulls, and raptors may be more vulnerable to displacement from habitat areas by finfish farming because it appears that their use of the same areas may be the greatest among the species examined. Applications for permanent tenure and IP's have future displacement potential, with applications have greater potential in this regard because they indicate a greater commitment to farm development than IP's.

Regions where overlapping use was frequently high indicate where the potential for aquaculture to displace marine birds from their habitat is of greatest concern. These regions include the Sechelt-Sunshine coast, Desolation Sound-Campbell River, and Clayoquot Sound for finfish leases and LOC's; Kyuquot Sound, Desolation Sound-Campbell River and Queen Charlotte Strait for finfish applications and IP's; and NW Georgia Strait, Desolation Sound-Campbell River, and Sechelt-Sunshine Coast for shellfish tenures and applications. These are areas where marine bird habitat and aquaculture development are most likely to conflict and should be the focus of planning and management.

A rating of "uncertain" for bird use was a function of few bird surveys, but the visibility and distribution of the bird groups/species could also be factors. Some of the species for which "uncertain" ratings were significant are low in number, occur singly or in groups of only a few birds, and are widely dispersed; therefore, the probability of sighting them in a given survey is low. This is true of Great Blue Herons, Black Oystercatchers and Harlequin Ducks. Other species, such as swans, Pintail and Oldsquaw, occur in greater numbers, but their aggregations are highly concentrated and they may be present in any given coastal region for only short periods of time. Finally, birds such as Scaup sp. may be present but often occur among large aggregations of other species (e.g., scoters and goldeneyes) from which they are difficult to pick out. These characteristics reduce the chances of seeing these birds.

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[1] The provincial government requires tenure holders to show "diligent use" of their sites in order to discourage speculative operators from "sitting on" productive sites. Nonetheless, it is acceptable to have a site that is large enough to allow portions of it to lie fallow when other parts of being utilized.

5.2. Bird colonies and moulting concentrations

5.2.1. Methods

For each colonial nesting species, colony habitat classes were appended to the aquaculture site point file in SPANS. Areas of overlapping were then calculated using dBase. The same procedure was followed for moulting concentrations.

5.2.2. Results

Ten aquaculture sites overlapped with colony habitat areas of 6 marine bird species (Table 5-2). In all cases, the classes of the areas involved were relatively low. Similarly, the occurrence of aquaculture sites in areas used by moulting concentrations was relatively low (Table 5-3).

SPECIES	TYPE OF SITES	AREA OF OVERLAP(ha)	HABITAT CLASS OF OVERLAP	% OF TOTAL AREA IN CLASS
Pigeon Guillemot	finfish, shellfish tenures	6.1	1,2	6.7
Pelagic Cormorant	shellfish tenures	2.7	2	7.2
Glaucous -winged Gull	shellfish tenures	2.7	1	2.0
Fork-tailed Storm Petrel	finfish, shellfish fish tenures, finfish applic.	4.7	1	7.1
Leach's Storm Petrel	finfish, shellfish fish tenures, finfish applic.	4.7	1	7.1
Great Blue Heron	shellfish tenures	9.9	1	1.2

Class 1 = <10 nests Class 2 = 11-100 nests

Table 5-2: Overlap between aquaculture and marine bird colonies.

SPECIES	TYPE OF SITES	AREA OF OVERLAP(ha)	HABITAT CLASS OF OVERLAP	% OF TOTAL AREA IN CLASSES
Surf Scoter	shellfish tenures and application	86.58	2,3	1.1
W.W. Scoter	shellfish tenures and application	93.85	1,2,3	0.9
Harlequin Duck	shellfish tenures	56.48	3	2.5

Class: 1 = <10 birds/km² 2 = 10-100 birds/km² 3 = 100-1000 birds/km²

Table 5-3: Overlap between aquaculture and moulting concentrations.

5.2.3. Discussion

While there were few instances of overlap between aquaculture and bird colonies, the relative importance of the overlap depends on the size of the breeding populations of the species involved, the size of the colonies affected, the intensity of bird use of the area of overlap and the type of aquaculture involved. Pigeon Guillemots, Pelagic Cormorants, and Glaucous-winged Gulls all have greater than 50 colonies within the study area but only 1 or 2 overlapped with aquaculture sites, and the habitat areas affected were of low-intensity use (class 1 or 2). While Fork-tailed and Leach's Storm Petrel colonies are not as numerous, only 7.1% and 1.7% respectively of relatively low-intensity habitat area was affected by aquaculture sites. The overlap with colony habitat of Great Blue Herons is similarly low. Therefore, none of the species appear to be seriously impacted in terms of the number of colonies or the amount of important habitat area that overlap with aquaculture operations. Although the area of overlap of moulting concentrations with aquaculture was larger than that with colonies, the proportion of the total area important to moulting seaducks was quite low.

However, this is not to say that aquaculture is of little concern with respect to its overlap with breeding and moulting habitat. Increasing numbers of aquaculture sites in areas of importance to breeding and moulting birds can have deleterious effects on these populations in the long term, particularly if sites are established in proximity to species that have few, large colonies that make intensive use of the surrounding area and for which there are few alternate breeding habitats (e.g., auklets and puffins). The location of bird colonies in particular, and the intensity of use of the surrounding areas, should be a major consideration in the management of aquaculture development.

6. OVERLAP BETWEEN BIRDS AND SUITABILITY FOR SALMON FARMING

6.1. Methods

The areas of overlap between each CWIF subzone and the 7 classes of suitability for salmon farming (chapter 3) were determined using SPANS. For each bird group/species and in each subzone, the maximum of the fall, winter, and spring distribution ranks was taken as the rank for that subzone. Bird distribution ranks were grouped as "high", "medium", "low", "none" and "unknown" (see chapter 4, Table 4-2). Areas were simultaneously classed as "good", "medium" or "poor" (which included classes P*, P, and NA?; see chapter 3, Table 3-1) for salmon farming. Total areas of overlap between each bird use category and each salmon farming suitability were then calculated for each species using dBase.

The distributions of suitable salmon farming areas and bird colonies were similarly compared to determine if any colonies fall into areas of suitable for salmon farming. The same analysis was carried out for moulting concentrations.

6.2. Results

6.2.1. Bird distributions

Overlap between areas classed as highly suitable (good or medium) for salmon farming and subzones ranked as high/medium bird use ranged in size from 150 to 850 km^2. Greater overlap occurred with areas classed as marginally suitable (poor classes) for salmon farming (Figure 6-1). From a marine birds' perspective, less than 20% of the total areas of subzones with high or medium bird use overlap with areas of good or medium suitability for salmon farming (Figure 6-2). From a salmon farming perspective, 60-90% of highly suitable areas were found within subzones with high/medium bird use (Figure 6-3). Map 10 provides an example of overlap between suitability for salmon farming and bird use, in this case for goldeneyes.

6.2.2. Colonies

Only 6 species had colony habitat areas located in highly suitable areas for salmon farming (Figure 6-4). In general, only small percentages of total colony areas overlapped with these areas. Furthermore, the majority of colony habitat areas that overlapped with highly suitable salmon farming areas were of relatively low-intensity use (class 1 and 2: <100 nests/km^2); none of the overlapping areas exceeded class 3. Only Black Oystercatchers and Great Blue Herons had colony areas of maximum class (class 2) that fell in areas suitable for salmon farming. Map 11 is an example of overlap between colonies and salmon farm suitability, in this case for Pelagic Cormorant colonies in the Barkley Sound-Alberni Inlet region.

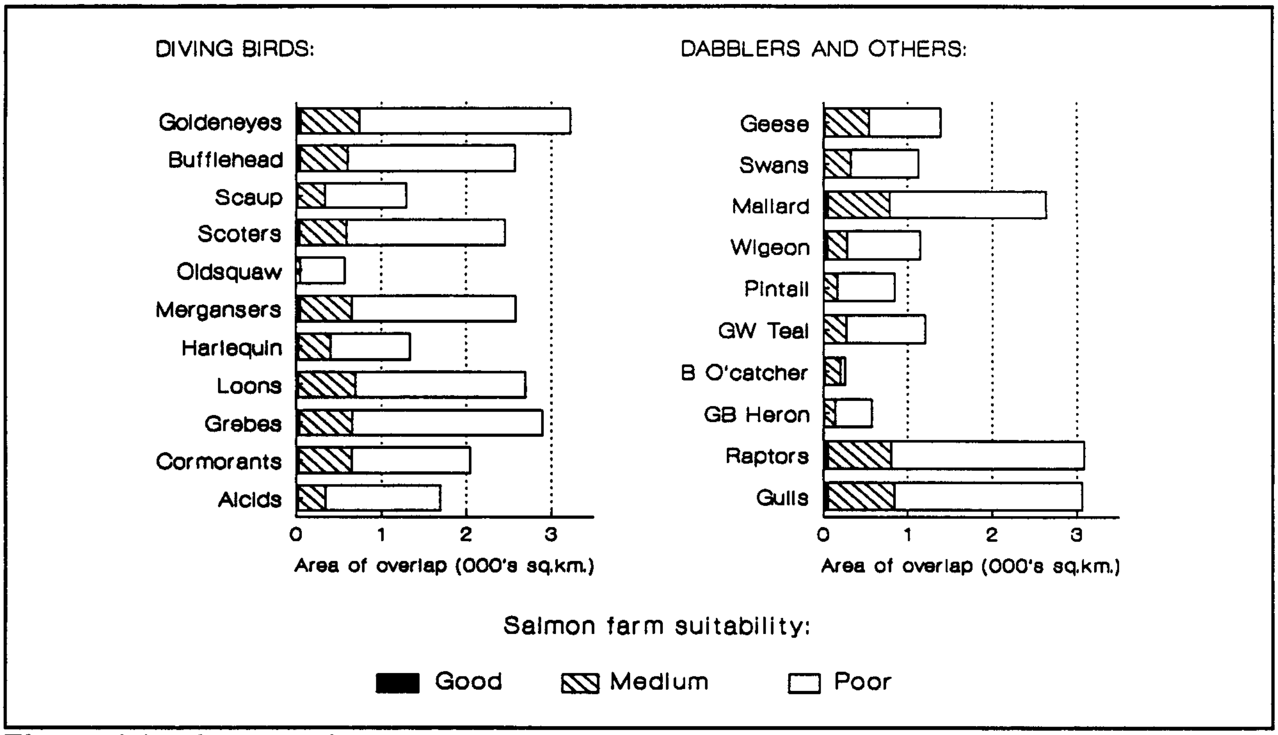

Figure 6-1: Overlap of subzones with high/medium bird use with areas suitable for salmon farming.

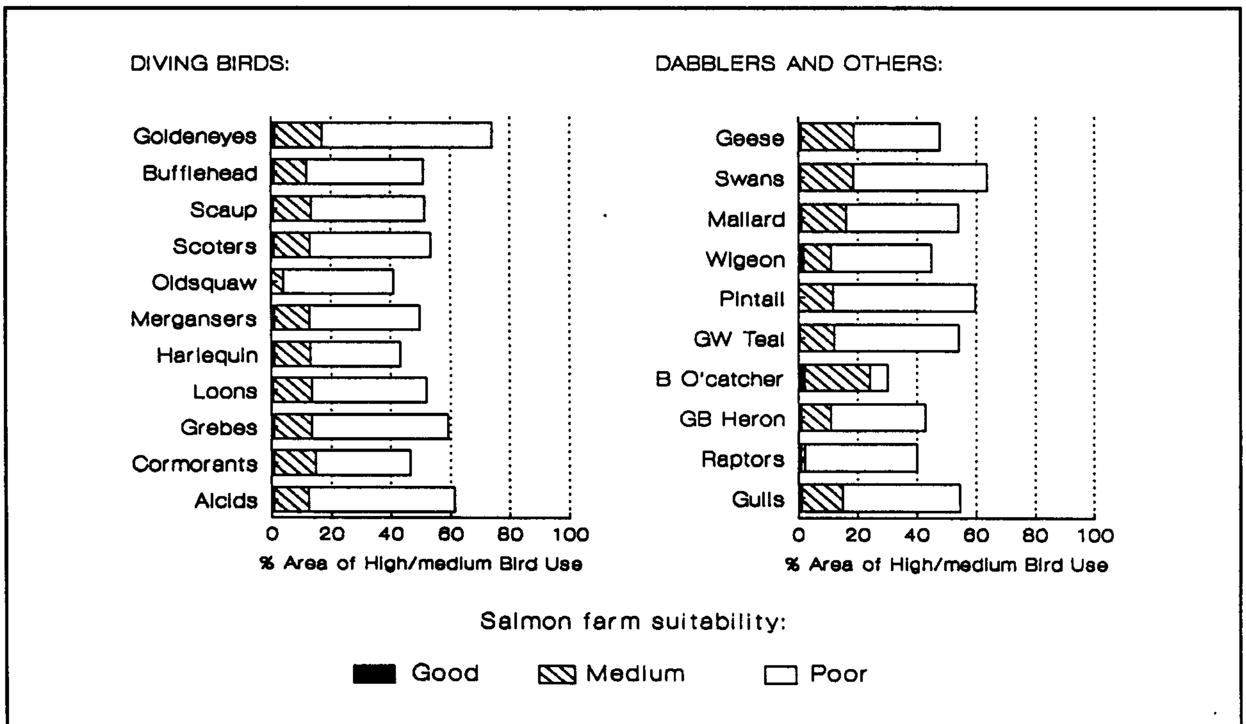

Figure 6-2: Overlap of subzones with high/medium bird use with areas suitable for salmon farming as percentages of areas of high/medium bird use.

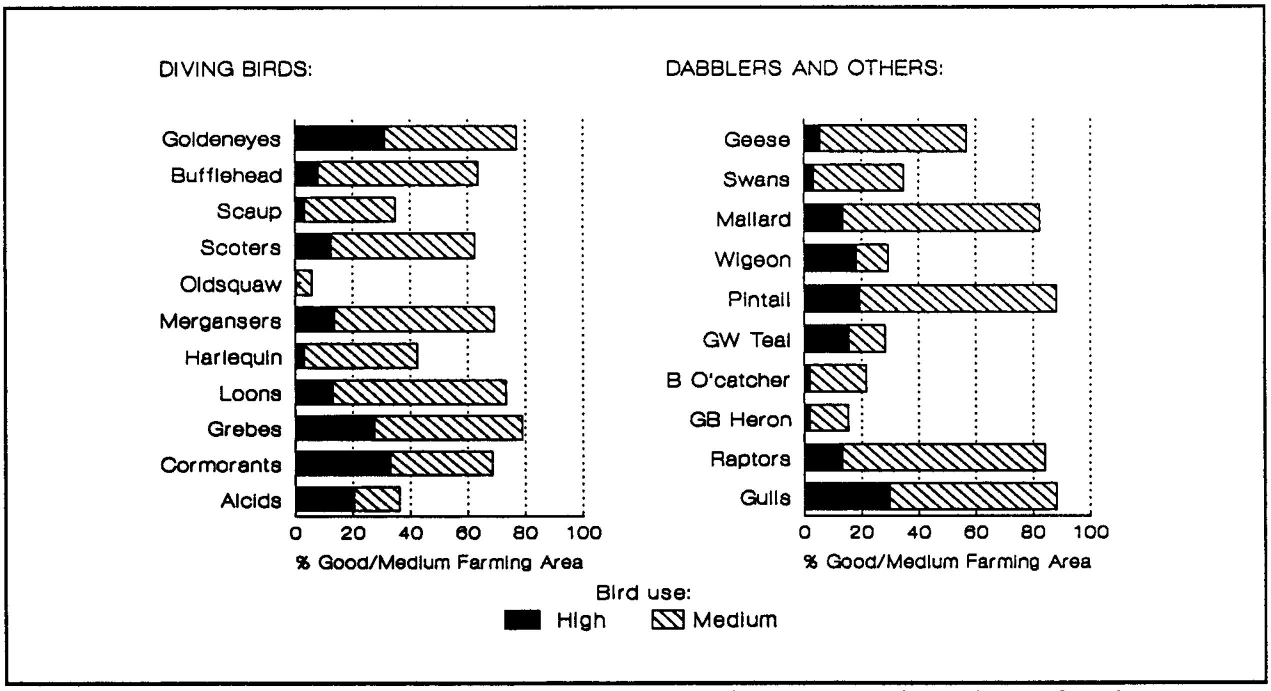

Figure 6-3: Overlap of high/medium bird use and suitable areas for salmon farming as percentages of areas classed as good/medium for salmon farming.

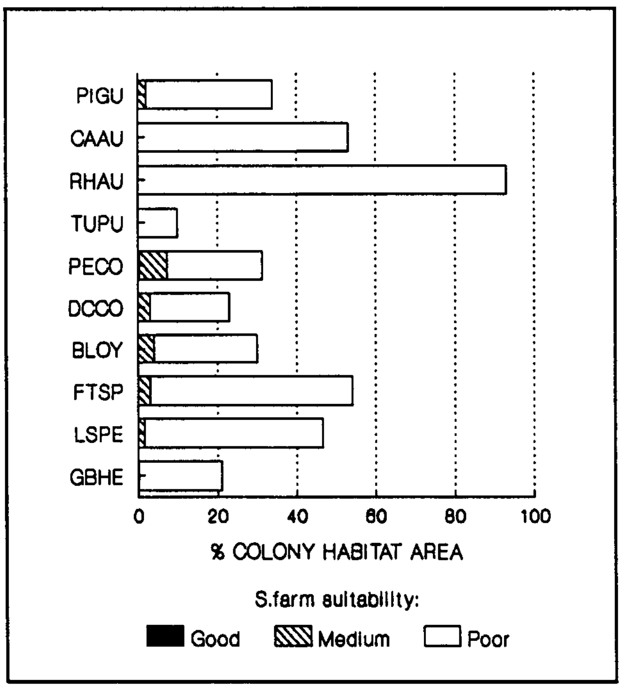

Figure 6-4: Overlap of colonies with areas suitable for salmon farming as percentages of colony habitat area.

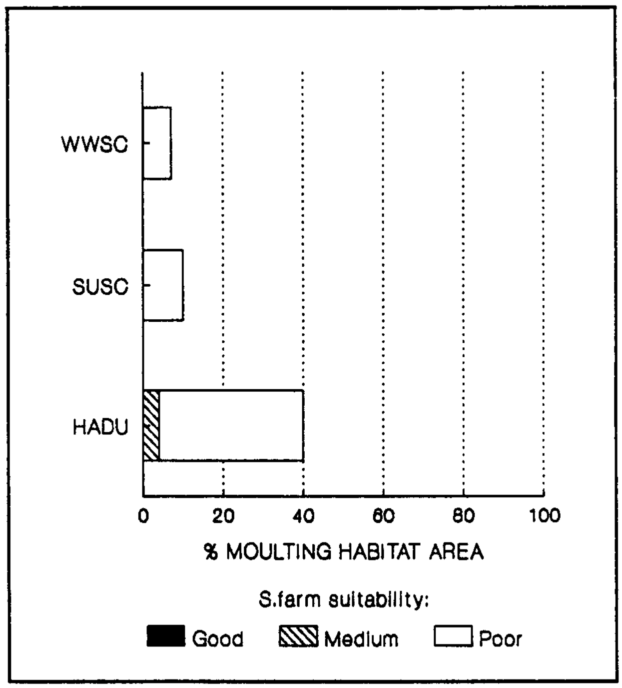

Figure 6-5: Overlap of moulting concentrations with areas suitable for salmon farming as percentages of moulting habitat area.

6.2.3. Moulting concentrations

Harlequin Ducks had 7% of moulting habitat located in areas classified as medium suitability for salmon farming. Moulting habitats for the Scoter species were located in areas classified as poor, not suitable or unclassified for salmon farming (Figure 6-5).

6.3. Discussion

The results that substantial proportions of areas classed as good or medium for salmon farming were located in subzones considered to be of high bird use suggests that in general, coastal areas considered to be highly suitable for salmon farming also make for favourable marine bird habitat. However, the corollary that areas favoured by birds may also be suitable for salmon farming is not reflected in the results; the majority of areas of high/medium use were found in areas classed as poor or not suitable for salmon farming (a small percentage of these areas were not covered by the MAF studies and were unclassified for salmon farming suitability). However, this is likely a function of the differences with which areas suitable for salmon farming and subzones of high/medium bird use are defined as much as it is reflection of differences in habitat needs. Areas suitable for salmon farming were defined as a function of combined biophysical characteristics with the objective of identifying such areas as accurately as possible; bird distribution subzones were intended to include as much area as can be reasonably assumed to be used by birds. This would result in quite broadly defined bird use areas and narrowly defined salmon farming areas. Furthermore, given that birds may not be uniformly distributed throughout a subzone (see chapter 4), individual areas classed as highly suitable for salmon farming that are located within subzones of high bird use may actually not be heavily used by birds. These two factors may tend to overstate the level of overlap between bird use and areas that are highly suitable for salmon farming.

In general, there appeared to be little overlap between areas occupied or used by bird colonies and moulting concentrations and areas classed as good or medium for salmon farming. It must be remembered, however, that the scheme for classifying salmon farming suitability is intended largely to provide some guidance, based on current knowledge of farming requirements, as to possible areas for future farm establishment. The poor correlation between the distribution of suitable salmon farming areas and operating farm sites indicates that other factors may continue to influence the geographic growth of the industry. Hence, areas judged to be poor or even not suitable for salmon farming may well be developed in the future; overlaps between these areas and bird use should not be overlooked.

7. POTENTIAL AREAS FOR MARINE BIRD HABITAT

7.1. Methods

Current bird distribution data does not provide a complete picture of the potential importance of many parts of the B.C. coast to marine birds. To address this problem, a method for determining areas of potential importance as marine bird habitat through the formulation of habitat models was developed. This method, based on the Habitat Evaluation Procedures developed by the U.S. Fish and Wildlife Service (1980a,b)[1], entailed the following steps (sec.7.1.1-7.1.9).

7.1.1. Species selection

Nine species (Table 7-1) were chosen for the development of habitat models on the basis of the following criteria:

- sufficient information was available on life requisites (food, shelter) to identify important habitat variables.
- distribution data was available by which to "truth" the model.
- the species is fairly common to the study area.

7.1.2. Identification of habitat variables

Biophysical parameters to be applied in the models as habitat variables were initially derived from a review of the literature of the feeding and habitat characteristics of each bird species or group selected for modelling. Literature specific to B.C. was used where available. However, the variables were often not defined in the literature in a way that could be meaningfully mapped, or data regarding a variable were not available in the format required. Consequently, the models and habitat variables were modified to find the best compromise among the requirements of the models, the available data and the ease with which the data could be mapped in SPANS. Given these considerations, 6 variables were derived (Table 7-1), and 2 or more nominal values were defined for each habitat variable (Table 7-2). The variables are described in greater detail in Appendix A.

7.1.3. Development of habitat models

Similarities in life requisites allowed 2 models to be applicable to more than 1 species; hence, 7 habitat suitability models were formulated for the 9 species. The models and pertinent background information are presented in Appendix A.

[1] See Appendix A for a discussion of the modified format of the "Habitat Evaluation Procedures" used in this study.

HABITAT MODELS:

VARIABLES:	SUSC	WWSC	BUFF BAGO	COGO	HADU	WEGR	RDGR HOGR
Depth	*	*	*	*	*		*
Herring spawn	*	*	*	*	*	*	
Bottom substrate	*	*		*	*		
Kelp or eelgrass		*			*		
Exposure	*		*	*	*	*	*
Estuaries/creeks	*		*			*	*
Other			*				

BAGO - Barrow's Goldeneye
BUFF - Bufflehead
COGO - Common Goldeneye
HADU - Harlequin Duck
HOGR - Horned Grebe
RDGR - Red-necked Grebe
SUSC - Surf Scoter
WEGR - Western Grebe
WWSC - White-winged Scoter

Table 7-1: Habitat variables used in the models for marine bird species. "*" denotes the use of that variable in the model for the species.

7.1.4. Selection and application of a study region

The Barkley Sound-Alberni Inlet region was chosen for applying the habitat models because data for most of the biophysical parameters as well as for bird distributions to test the models' predictions were available for this region. Data on the distribution of the habitat variables in the Barkley Sound-Alberni Inlet region were collected and drawn on overlays of 1:50,000 topographic maps (92C/14 and 15, 92F/2 and 3). The overlays were digitized in Intergraph and translated into SPANS. Maps of the distribution of these variables in the Barkley Sound-Alberni Inlet region were generated (Maps 13a-f) and areas occupied by each nominal value were derived (Table 7-2).

7.1.5. Application of models and mapping of habitat

For each species, maps of the pertinent habitat variables were overlaid in SPANS and a "unique conditions" listing of all combinations of those variables was generated. The unique conditions were classified for their suitability as habitat by applying a SPANS modelling equation that emulated the model for that species.[2] Four classes of habitat

[2] See the User's Manual for listings of the programs.

VARIABLE	NOMINAL VALUES	AREA OCCUPIED (km^2)	% OF STUDY REGION
Herring spawn	- regular: >37 out of 50 years	5.0	0.7
	- frequent: 26-37 out of 50 years	9.2	1.4
	- infrequent: 1-25 out of 50 years	36.6	5.4
	- no spawning occurs	630.6	92.5
Bottom substrate	- sand dominant	16.5	2.4
	- sand present but not dominant (gravel-cobble dominant)	25.0	3.7
	- sand not present (boulder-bedrock dominant)	639.9	93.9
Eelgrass or kelp	- kelp beds present	40.7	6.0
	- eelgrass beds present	27.6	4.1
	- neither present	621.7	91.2
Exposure	- protected	114.0	16.7
	- semi-protected	214.2	31.5
	- exposed	353.3	51.8
Estuaries or creeks	- estuary present	12.9	1.9
	- creek mouth present	24.6	3.6
	- neither present	643.9	94.5
Depth	- $\leq$ 10 m	107.3	15.7
	- > 10 m	574.4	84.3

Table 7-2: Habitat variables and their nominal values.

suitability were defined:

Class 1 - (high) the most suitable habitat for the species or species group, containing few or no limitations to use.

Class 2 - (medium) habitats in which the species or guild is generally found, but which contains moderate limitations to use.

Class 3 - (low) habitat that contains significant limitations to use. It includes areas where use by a species could be considered to be casual or transitory.

Class 4 - (none) unsuitable as habitat.

For each species, the distribution of each class of habitat was mapped and its total area calculated.

7.1.6. Testing the models

Testing the models consisted of comparing the distribution of habitat predicted by the models to known distributions of birds derived from the CWIF database to see whether there was a correlation between good (class 1 and 2) habitat and the occurrence of birds.

The Barkley Sound-Alberni Inlet region contained 5 CWIF subzones and part of a sixth (Map 12). The subzones were already ranked for each bird group/species according to the maximum number of birds recorded in each season (chapter 4). For each species, the map of habitat suitability was overlaid on the distribution map and a map of the overlap of between habitat suitability and distribution ranks were generated (e.g., Maps 14a-b). The percentages of the area classed as good habitat that overlapped with each rank were calculated.

7.2. Results and Discussion

SPECIES	KM² OF HABITAT CLASS: 1	2	3	4
SUSC	25	68	16	573
WWSC	19	18	63	582
BAGO	32	68	16	566
COGO/BUFF	22	77	16	566
HADU	23	37	37	584
WEGR	60	93	528	-
RNGR/HOGR	15	46	267	353

Table 7-3: Results of the models: area of each class of habitat for each species. Total area of the study region = 681 km^2.

According to the models, Western Grebe had the largest area of good habitat in the Barkley Sound-Alberni Inlet region (153 km^2); the total area of good habitat was smallest for White-winged Scoters (37 km^2; Table 7-3).

The underlying assumption in testing the models against the CWIF distribution ranks is that the areas classed as good (class 1 and 2) habitat for a species would fall into subzones which had high bird distribution ranks. The results indicate a correspondence between predictions of good habitat and high bird ranks for scoters, Harlequin Ducks and grebes (Figure 7-1). For example, for Surf Scoters, 70.5% of class 1 and 2 areas were found in CWIF subzones with relatively high numbers of birds. In a few cases, the correspondence between predicted and observed bird use can be attributed to specific habitat variables; for example, the subzone with a high distribution rank for White-winged Scoters was also the only subzone where herring spawning occurred frequently.

Poorer correlations were evident for goldeneye sp. and Bufflehead. There are 2 ways in which predictions of good habitat may not correspond with observed bird distributions: (a) where predictions indicate good habitat but observations indicate low numbers of birds, and (b) where predictions indicate poor habitat but observations suggest high numbers of birds.

A type (b) result implies that the models are not catching all types of good habitat, and would be of concern only if all of the area of a subzone with a high bird distribution rank was classed as poor habitat. This, however, is never the case. The 5 subzones covering the Barkley Sound-Alberni Inlet region ranged in size from 4.7 to 216 km^2. Although subzones were chosen to represent fairly homogeneous environments, each contained a variety of habitats that may be of different suitability classes. Therefore, while the bird distribution rank of an entire subzone may be high, the birds may be concentrated in only those portions that comprise good habitat. Other areas within the same subzone may be poor habitat but the bird distribution data is too coarse to pick up these differences. The system of ranking bird numbers at the subzone level, while useful in indicating trends in bird distributions throughout the study area, did not indicate bird distributions on as fine a scale as that with which habitat areas were generated. Greater effort in determining bird distributions on a geographical scale finer than the subzones used in this study is required in order to more precisely test the models.

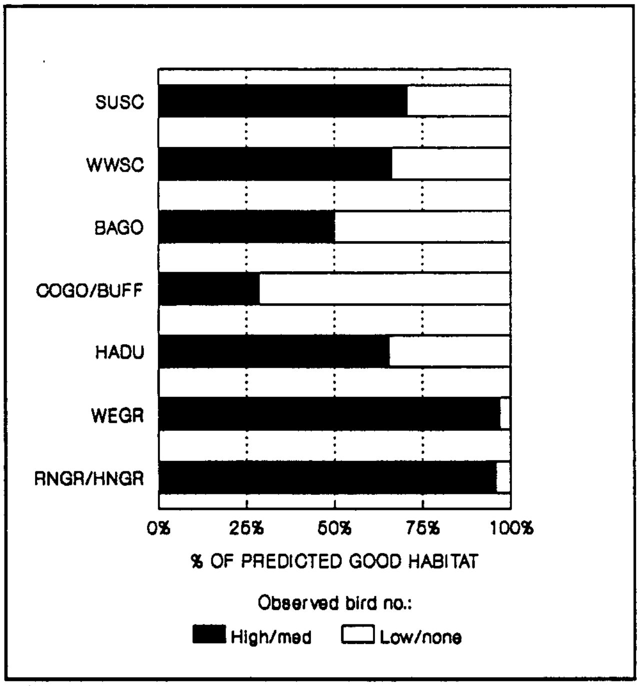

Figure 7-1: Correspondence between areas predicted as good (class 1+2) habitat and bird distributions.

There are 3 sources of error that can lead to a type (a) result (predictions that indicate good habitat but observations that indicate low numbers of birds). There may be errors in the habitat variables resulting from inaccuracies in the source data or errors in transferring the source data to the distribution maps. This may lead to areas of good habitat being missed or being erroneously classed. There may also be inaccuracies in the raw bird distribution data. The surveys covered in the CWIF are only samples of coastal bird populations taken at a limited number of times and places, and they may not capture the full extent of marine bird use of the coast.

The third source of error arises from the assumptions made in the habitat models. Several authors have pointed out the major limitations of modelling natural systems (Farmer *et al.*, 1982; Cole and Smith, 1983; Schamberger and Krohn, 1982). Habitat models typically include only a subset of the variables that define habitat, and may exclude some types of habitat information (e.g., other species presence) that have a more subtle effect on populations. Farmer *et al.* (1982) note that habitat models almost always emphasize "breadth" (incorporate many habitat variables) or "depth" (incorporates many variations for each variable), but rarely both. Habitat models also assume that we understand the way in which a variable meets the "life requisites" of a particular species and that we can express that relationship accurately, but this is rarely the case. The factors that determine habitat suitability are generally not well known due to the complexity of the relationships between organisms and their environment. Also, no one particular habitat supplies all of the life requisites of a given species. Marine birds make use of coastal areas for a variety of activities, and many species exhibit a high degree of adaptability to changes in their environment. All these factors make the identification and quantification of relevant habitat variables difficult.

In this study, errors in model assumptions could have resulted in the classification of areas as good habitat when they were not, or more likely, in missing important types of good habitat. For example, a fiord-type environment could not be directly reflected in the models given the variables used, and may be a reason for the poor correspondence between the predicted distribution of good habitat and observed distributions of goldeneyes and Bufflehead.

Overall, the comparison of the models' predictions to the distribution data are suspect due to differences in the scales of bird and habitat measurements and in some cases, low reliability of the survey data. The models themselves suffer from uncertainties in identifying and quantifying habitat characteristics. In most cases, considerable work on habitat-species relationships is required in order to derive better models.

Because of these types of problems, many scientists dismiss efforts to operationally define habitats with models. It is important to realize, however, that resource managers must still make decisions based on the best available information. The main purpose of such models is not to be able to make accurate predictions about a population's use of its habitat, but rather to "provide a format for the systematic use of habitat requirement information in making value judgements about the effects of different management options" (Farmer *et al.*, 1982: p.56). Habitat models can also offset a lack of bird distribution data and the costs in time, funds and other resources in collecting such data. As such, habitat models may provide a more precise, if not accurate, picture of potential bird use than bird distribution data, simply because data on the distribution of biophysical variables may be available on a finer spatial scale than is data on bird distributions.

In summary, the models and their predictions should be viewed cautiously. The models are presented, however, as tools in indicating potential areas of importance to marine birds where data on their distribution are not available. The format of the models allows flexibility in adding, deleting or altering habitat variables and generating revised results based on improved knowledge of life requisites.

7.3. Overlap of Potential Habitat with Aquaculture Sites

Using the 7 bird species/groups for which habitat models were formulated, areas of good habitat were compared to the distribution of aquaculture sites in the Barkley Sound-Alberni Inlet region in order to indicate the overlap of these sites with areas of potentially good bird habitat. The number and total area of each type of site located in each class of habitat for each species was generated (Map 15).

A total of 57 sites occupying 2.12 km^2 were located in the Barkley Sound-Alberni Inlet region as of January 1989. Over 70% of these sites were located in areas of potentially good (class 1 or 2) habitat for all of the bird species except White-winged Scoter and Harlequin Duck (Table 7-4). The high number of sites that fall into areas of good habitat suggests that further development of aquaculture may favour areas of good bird habitat. This is of some concern as aquaculture continues to grow in the area.

SPECIES	# SITES THAT OVERLAP WITH CLASS 1 OR 2 HABITAT AREAS:					
	Finfish			Shellfish		
	tenures	applic.	IP's	tenures	appl./IP's	Total
SUSC	7	1	7	23	6	44
WWSC	1	0	3	13	0	17
BAGO	7	2	6	24	5	44
COGO/BUFF	6	1	6	22	5	42
HADU	2	0	2	7	2	13
WEGR	7	2	5	28	5	47
RNGR/HOGR	5	1	5	25	5	41
Total in region	8	4	9	30	6	57

Table 7-4: Overlap between aquaculture and potentially good bird habitat in the Barkley Sound-Alberni Inlet region.

While the number of aquaculture sites that fall into good habitat areas is high, the proportion of good habitat area currently occupied by these sites is quite low (Figure 7-2). For all species, less than 2.5% of potentially good habitat area is occupied by these sites. This would suggest that bird displacement from potentially good habitat is as yet insignificant. Furthermore, over 65% of the sites are for shellfish tenures or applications, which have low impact in terms of disruptive activities.

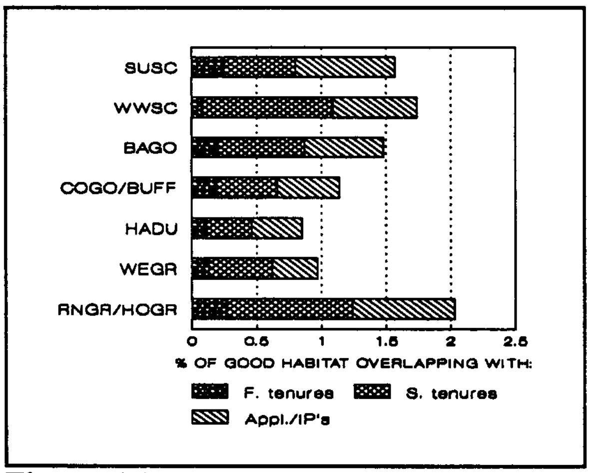

Figure 7-2: Percentage of good habitat areas occupied by aquaculture sites.

There is some correspondence between the overlap of aquaculture sites with potential habitat and the overlap of sites with bird distributions in the Barkley Sound-Alberni Inlet region. Over 70% of sites fell into areas of good habitat for all bird species except White-winged Scoter and Harlequin Duck. Similarly, the overlap of sites with bird use was high or medium for all species or grouped species except Harlequin Duck (Figure 7-3; the distribution of White-winged Scoter was not differentiated from Surf Scoter in the available data). This supports the idea that habitat models can serve as indicators of potential areas of high bird use.

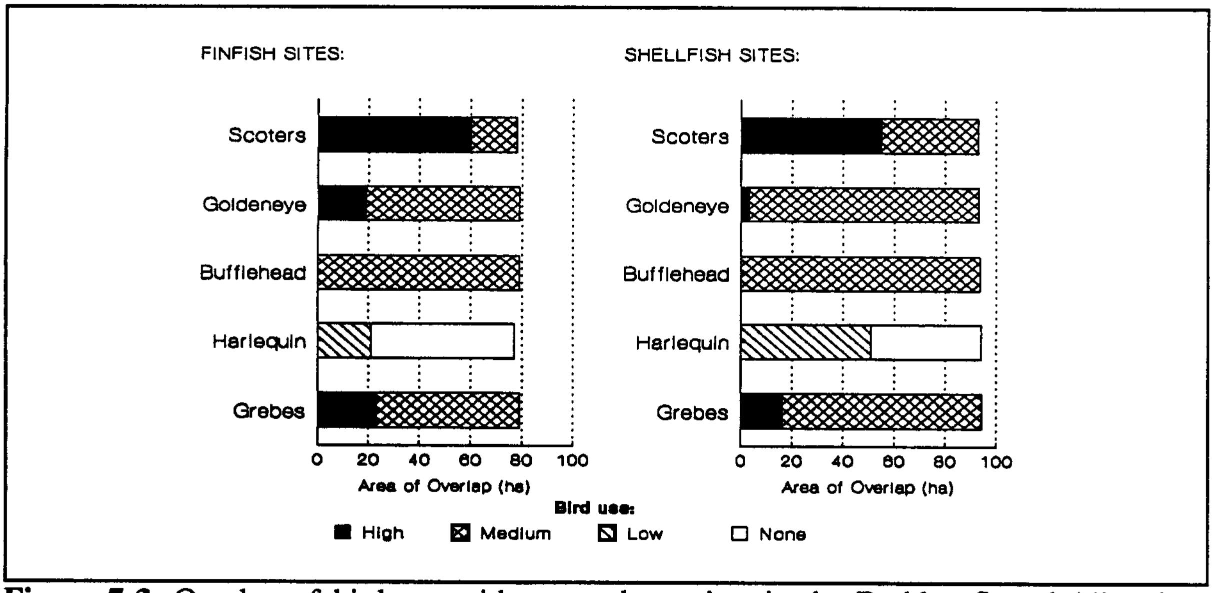

Figure 7-3: Overlap of bird use with aquaculture sites in the Barkley Sound-Alberni Inlet region.

8. CONCLUSIONS

8.1. Aquaculture in the Study Area

- Of the 43.5 km^2 committed to aquaculture in the study area, 57% is occupied by operating sites, 31% is under application, and the remaining 12% is being investigated for future development. Of the area occupied by operating sites, 41% are finfish (primarily salmon) farms and 59% are shellfish (primarily oyster) farms. According to past trends, 40-50% of applications may be operating in the near future (1-3 years). Areas covered under IP's have a lower probability of becoming operational on a site-specific basis but do indicate areas of interest for future development.

- Salmon farming is currently the most rapidly expanding type of aquaculture in B.C. Growth is northward on both Vancouver Island and the Mainland coast. Shellfish farming is expanding much more slowly and is centred around the mid-east and west coasts of Vancouver Island and the Mainland. The rate and location of growth of marine plant farming is as yet uncertain.

- Operating sites obviously have the greatest potential impact on marine bird use of coastal areas. Salmon farms likely have greater effect than shellfish or marine plant farms due to the more intensive use of space and level of human activity.

- The classification of areas suitable for salmon farming suggests where salmon farm development, , may take place in the future. Areas classed as good or medium for salmon farming covered 955 km^2, only 3% of the study area, and were located predominantly in the Kyuquot-Nootka Sound and Queen Charlotte Strait regions. Notably, only 15% of currently operating sites are located in areas classed as good or medium for salmon farming, but 34% of applications and 43% of IP's fall into such areas, indicating that biophysically suitable areas are becoming increasingly exploited.

8.2. Marine Bird Distributions

- Distribution data for 24 bird species or species groups were presented as numerical ranks based on the maximum number of birds recorded in any survey within a given season within a coastal subzone. Subzones for which bird distribution ranks were assigned varied in size from 1.5 to 233 km^2. The large size of subzones limited the precision with which bird distribution could be presented, but the method provided a useful indicator of relative bird use throughout the study area.

- Colonies for 14 species that breed in the study area and moulting areas for 3 species were presented as point locations with surrounding "important habitat areas", the sizes of which were a function of the colony size (number of nests) or moulting concentration (number of birds). Defined in this way, colonies and their habitat areas occupied 2051 km^2; moulting concentrations occupied some 780 km^2. The intensity of use varied within these areas as a function of the size of a colony or moulting concentration.

8.3. Overlapping Use of Coastal Areas by Marine Birds and Aquaculture

- The overlap between bird use and aquaculture was determined as the proportions of total areas occupied by each type of aquaculture sites that were ranked as being of high, medium, low, no or uncertain use by each bird group/species. Overlapping use was consistently "high" with goldeneye sp., and was considered "medium" for Bufflehead, scoters, cormorants, grebes, gulls, loons, Mallard, mergansers and raptors. This suggests that relatively high numbers of birds use the same areas as a significant proportion of aquaculture sites.

- The overlap between aquaculture and colonies and moulting concentrations was relative low. The importance of breeding habitat, however, means than potential displacement of birds from breeding areas should be minimized, particularly with species that have few, large, intensively-used colonies. Many of these species colonize remote, exposed locations that are not conducive to aquaculture development; for example, Cassin's Auklet colonies on Triangle Island. Colonies of other species, including Glaucous-winged Gulls, Great Blue Herons, Pelagic Cormorants, Pigeon Guillemots and petrels, are located in areas that are more vulnerable to aquaculture development, and should be considered in current expansion of the industry.

- In general, overlapping use suggests the potential for displacement of birds from habitat areas. Whether birds would actually be displaced depends on their behavioral response to the physical structures and activities at these sites. Some species may actively avoid areas of human activity while other are indifferent or are even attracted to them as potential sources of food or as resting sites and feeding perches. Displacement may also depend on the degree to which aquaculture sites may cause changes to the environment that would cause deterioration of feeding habitat. For example, effluent from fish farms can smother bottom flora and fauna in the immediate area, which can reduce food sources for bottom feeders. On the other hand, fish farms can enhance food sources by providing additional growing substrates or food, in the form of excess feed, for local wild stocks. Finally, if birds are perceived as interfering with or threatening farm production, site operators may actively deter birds from use of the area. Hence, aquaculture sites can become "active" rather than just "passive" displacement factors.

- The location of areas classed as suitable for salmon farming in areas of bird use give a broad indication of where overlap and potential displacement may arise in the future. Areas suitable for salmon farming frequently fell into subzones class as high or medium use by birds, but these areas occupied 20% or less of the total high/medium use areas for all species. However, areas of importance to birds are much less precisely defined in this study than are areas suitable for salmon farming, such that concluding that the potential overlap is insignificant from the perspective of the birds' habitats may be misleading. Greater precision in determining bird use of coastal areas is needed to generate a clearer picture of the overlap.

8.4. Modelling Bird Habitat

- Potential habitat areas within the Barkley Sound-Alberni Inlet region were defined for 9 marine bird species using habitat models comprised of a variety of biophysical variables. The extent of potentially good habitat was calculated and mapped for each species. Comparisons of the results of the models with distribution data suggested greatest correlations with grebe sp. and poorest correlations with goldeneye sp. and Bufflehead. Reasons for poor correlations included coarseness of the bird distribution data relative to habitat data, errors in mapping habitat variables, and limitations in modelling habitat requirements. The lack of knowledge regarding species-habitat relationships and in many cases, the poorness of bird distribution data means that model predictions should be treated with caution. Nonetheless, the method has applications for species for which knowledge of habitat requirements is relatively good but distribution data is poor. It is particularly relevant when management decisions must be made regarding the importance of an area to a bird species.

8.5. Information Needs

- The record of aquaculture sites was current as of January 1989. This file will have to be periodically updated to reflect the changing status of the industry.

- The analysis of suitable areas for salmon farming did not cover the northwest part of the Straits of Georgia; however, it is unlikely that this area will support many salmon farms due to conflicts with other coastal uses. The distribution of salmon farm suitability reflects current understanding of the requirements for Chinook salmon net-pen culture in B.C. As farming technology improves, many biophysical restrictions to farming may be overcome, necessitating changes to the assumptions regarding suitability and changes to the maps of suitable areas.

- There were several regions of the study area for which there were few or no bird surveys. These included Sechelt-Sunshine Coast, the heads of mainland fiords, west coast Vancouver Island from Brooke's Peninsula to Esperanza Inlet and Hot Spring's Cover to Tofino, the northern tip of Vancouver Island and the northern end of Johnstone Strait (Map 16).

- Certain bird species (e.g., Oldsquaw, Black Oystercatcher, Great Blue Heron) were not well covered in the CWIF for parts of the study area. In many cases, fewer than 3 surveys were carried out in the subzones involved. However, populations for some of these species are indeed small throughout B.C. In addition, other species may not be very visible in surveys because they may be cryptically coloured, occur singly, are widely dispersed, etc.

- Mapping habitat importance around colonies and moulting concentrations was based on the opinions of local authorities in the field. For most species, however, the extent and intensity of use of habitat around colonies is not well known. This should be determined to ensure that aquaculture operations are situated at appropriate distances away from colonies.

- Habitat requirements of marine birds require research in order to derive more accurate habitat models. Many parts of the coast have been mapped for some habitat variables but this is by no means complete. In addition, in order to truth the bird habitat models, test areas need to be surveyed for bird use on a finer scale than was applied.

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APPENDIX A:

HABITAT SUITABILITY MODELS
FOR
SELECTED MARINE BIRD SPECIES

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APPENDIX A. HABITAT SUITABILITY MODELS FOR SELECTED MARINE BIRDS

A.1. METHOD

A modified version of the "Habitat Evaluation Procedures" (HEP) was applied in the development of habitat suitability models for the 12 marine bird species selected. The HEP were established to provide a standardized process for modelling wildlife habitat (U.S. Fish and Wildlife Service, 1980a,b). They involve identifying relevant habitat variables (biological, physical or anthropogenic) for a particular wildlife species and quantifying their relationship to the population abundance and distribution of that species. They are then used to assess a given area on the basis of these variables. The potential value of an area is defined in terms of a Habitat Suitability Index (HSI) that is specific to a particular life requisite, life stage and seasonal usage of the species. It is calculated from a model incorporating suitability indices (SI) for each of the habitat variables that are considered critical to the species. Each SI value quantifies in a relative sense the importance of the habitat variable and the habitat needs of the species.

In the modified version of HEP applied in this study, relevant habitat variables were identified but were not assigned SI's, nor were HSI's calculated. Instead, classes of habitat suitability for each species were qualitatively derived based on nominal values assigned to each of the relevant variables. Accordingly, the following steps were followed:

i) *Set objectives:* For the 12 species, the life requisites (feeding, breeding, staging, etc.) for which the models were developed were determined based on the species' use of study area. Most of the species of interest use the B.C. coast for feeding and overwintering.

ii) *Define habitat variables:* The variables that determine habitat suitability for supporting the life requisites of each species were defined (see chapter 5).

iii) *Define variable values:* For each species, the relevant variables were assigned 2 or more nominal (descriptive) values, each of which were defined in terms of its relative suitability in meeting the habitat needs of the species.

iv) *develop decision models:* A decision model consists of a series of "Yes/No" decisions regarding the suitability of an area based on the presence or absence of specific values of the applicable variables. Certain exceptional variables which were considered by themselves to define highly suitable (herring spawn) or unsuitable (depth) habitat were not combined with other variables. A decision model was derived for each species or species group, programmed in SPANS and applied to the Barkley Sound-Alberni Inlet region.

iv) *Define habitat suitability classes:* Classes of habitat suitability were derived qualitatively for each species from the applicable "decision model". The habitat suitability classes can be described as follows:

CLASS 1: the most suitable habitat for the species or species group, containing few or no limitations to use. All or almost all questions in a decision model regarding the presence of favourable variable categories have a "yes" answer. These habitats may be used for extended periods of time or very intensively for short durations. The presence of an exceptional variable (e.g. herring spawn) may by itself qualify an area for this class.

CLASS 2: habitats in which the species or guild is generally found, but which contains moderate limitations to use. Usually 1 or 2 "no" responses are encountered in a decision model.

CLASS 3: habitat that contains significant limitations to use. It includes areas where use by a species could be considered to be casual or transitory. Areas that fall into this class have "no" responses for several variables.

CLASS 4: "unusable" habitat. In some cases, 1 variable alone (e.g., depth or exposure) may be sufficient to define an area as unusable as habitat.

A.1.1. Habitat Variables

The following biophysical parameters were selected as habitat variables for application in the models. Information on the distribution on several of the variables was taken from the *Coastal Resources Folio: Barkley Sound-Alberni Inlet, British Columbia* (Romaine *et al.*, 1983).

Depth:

Depth is an important factor for diving species that feed on the bottom (Scoters, Harlequin Duck, Bufflehead, Goldeneye sp.). Ten meters was chosen as the feeding depth favoured by most of these species. Using 1:40,000 Canadian Hydrographic Service charts of the Barkley Sound-Alberni Inlet region, polygons containing all areas within the 10 m isobath were drawn. Some species are able to feed only in more shallow depths (Harlequin Duck, Common Goldeneye, Bufflehead), but it was not possible to map the distribution of depths less than 10 m from available hydrographic data. Other species dive to depths greater than 10 m (Surf and White-winged Scoters), but limits in time and resources prevented the digitization of other depth categories. Ideally, polygons representing 10-15 m or 10-20 m depths would be included in modelling exercises for these species.

Herring spawning areas:

Herring concentrations and herring roe present during spawning are an important seasonal food source for many marine bird species, including Surf and Black Scoters (Vermeer and Levings, 1977; Vermeer, 1981), Harlequin Ducks (Vermeer, 1983; Savard, 1988), Common Goldeneye (Vermeer, 1982; Campbell *et al.*, 1989), and Western Grebe (Vermeer, 1983; Savard, 1988).

Data on the distribution of spawning areas were derived from annual records of spawning sites along the B.C. coast collected and analyzed by the Department of Fisheries and Oceans since 1937 (Hay and Kronlund, 1987; Hay *et al.*, 1989). The B.C. coast was divided into 1-km segments and the number of years spawning was observed in each segment out of the total of 50 years over which data has been collected was recorded. The 1-km segments were grouped and categorized on the following basis:

spawn occurs in 1-25 out of 50 years = infrequent
spawn occurs in 26-37 out of 50 years = frequent
spawn occurs in >37 out of 50 years = regular

These are the same categories used by the authors of the DFO studies to rate individual 1-km segments. The major difference in application in this study is that the 1-km segments were grouped wherever the occurrence of spawning was contiguous; the highest frequency of spawning within a grouped segment was taken as the value by which that segment was categorized in SPANS. The grouped segments were drawn as polygons on overlays of 1:50,000 topographic maps, digitized and encoded into SPANS.

Bottom substrate:

Eight of the 9 marine bird species examined in this study are bottom feeders in intertidal and subtidal coastal zones. The presence of bottom-dwelling food organisms is dependent on three main factors: 1) the degree of wave shock or exposure, 2) the texture of the bottom substrate, and 3) the tidal exposure (Ricketts and Calvin, 1968). The distribution of fine-grained (silt, sand, gravel) substrates was focused on. Fine-grained substrates are inhabited by food organisms (clams and snails) of importance to White-winged Scoters (Hirsch, 1980; Bellrose, 1976). Rocky shorelines are of greater importance to Surf Scoters and Harlequin Ducks.

Data on bottom substrate in the inter- and subtidal zones were derived from the "Physical Shorezone" map and accompanying descriptions contained in the *Coastal Resources Folio*. This map provided detailed classifications of the shorezone on the basis of texture (composition of materials and sediments), form, width of the intertidal zone, and nearshore slope. Texture was the primary characteristic used here. Units of the shorezone were defined and coded in the "Physical Shorezone" map to indicate the source and dominant size of shoreline materials (Table A). An example of a texture code is "C:bcp" which meant that the unit was composed of clastic materials of which 50-75% was boulder, 25-50% was cobble and <25% was pebble.

For this study, areas dominated by fine, medium and coarse shoreline materials were differentiated (Table A). Polygons were drawn around units dominated by sand, silt or clay clastic sediments or fine biogenic sediments (shellhash) and given a code of "1". Polygons were also drawn around areas where these types of substrates were present but not dominant, and encoded "2". All remaining shorezone areas were assumed to be

SOURCE OF MATERIALS	SIZE OF MATERIALS	POLYGON CLASSES
A - anthropogenic	b - boulder (246 mm)	1 = C:s_, C:c_, C:m_, or B:fine
B - biogenic	c - cobble (64-246 mm)	
C - clastic	p - pebble (2-64 mm)	2 = C:p_, C:g_, C:cp-s, or B:coarse
R - bedrock	s - sand (.063-2 mm)	
	s - silt (.0039-.062 mm)	remainder = C:b-c, R, etc.
	c - clay (<.0039 mm)	
	d - randomly sorted in clay matrix	
	g - gravel (mixed pebble, cobble)	
	m - mud (mixed sand, silt, clay)	
	r - rubble (angular pebble, cobble)	

Table A: Classification of texture used to define bottom substrate.

predominantly cobble, boulder, bedrock or of anthropogenic materials (debris, concrete, rubble, logs, etc.).

Along with the "Physical Shorezone" maps from *Coastal Resources Folio*, which covered all of the study region except for the Broken Islands, similar data were derived from coastal analyses of Pacific Rim National Park (Harper and Sawyer, 1983).

Zostera and Macrocystis beds:

White-winged Scoters have been found frequently feeding over eelgrass (*Zostera*) beds (Hirsch, 1980; Vermeer and Bourne, 1984). Harlequin Ducks also prefer habitat of gently sloping shores with sand with eelgrass or cobble with kelp beds (*Macrocystis*) (Hirsch, 1980; Morgan, 1987).

The "Seaweeds, Salt Marshes and Marine Mammals" maps of the *Coastal Resources Folio* were the primary source of information on the distribution of these kelp and eelgrass; additional information was derived from MAF's study of salmon farm suitability (Ricker *et al.*, 1988). However, not all parts of the Barkley Sound-Alberni Inlet region have been surveyed for the distribution of these plants; consequently, data are missing for some areas to which the habitat models were applied. It should also be noted the location of beds may shift with changes in the coastal physical regime. The areas mapped are therefore considered to be only approximations of areas where these beds have been observed.

Exposure:

Some bird species are tolerant of exposed shorelines while others prefer more protected waters. For instance, Hirsch (1980) found that while they appear to prefer bays, White-winged Scoters were found in deeper open water in the Puget Sound area. Exposure ratings will differ somewhat in nature and scale depending on whether the area is located between Vancouver Island and the mainland (Georgia or Johnstone Straits) or on the west side of Vancouver Island.[1]

For the Barkley Sound-Alberni Inlet region, the "Physical Shorezone" maps accompanying the *Coastal Resources Folio* provided data on fetch (including orientation, arc of exposure, length and direction of fetch) at regular intervals along the shoreline. Seasonal direction, frequency and speed of winds were provided for selected locations. This information was used to derive a coarse, subjective rating of exposure for segments of the coast. Three categories of exposure (protected, semi-protected and exposed) were so derived based on the degree of protection afforded from prevailing winds in winter, spring and fall (the main seasons of use by the species of interest). Polygons were drawn on topographic maps around inshore, nearshore and offshore areas and coded according to whether they were considered to be protected or semi-protected; all areas not included in a polygon were assumed to be exposed.

Creek mouths and estuaries:

Surf Scoters and Barrow's Goldeneye have been found to be in greater abundance in areas of lower salinity. Because they swallow mussels whole with seawater inside, the net energy balance of these ducks is decreased as the amount of salt they must excrete increases. Consequently, "salinity apparently is an important habitat barrier in mussel-feeding ducks" (Vermeer, 1989). Western, Horned and Red-necked Grebes are also known to favour estuarine environments (Robertson, 1974; Savard, 1988; Campbell *et al.*, 1989).

Areas of lowered salinity were coarsely predicted on the basis of proximity to creeks and river mouths. Creeks and estuaries were located on 1:50,000 topographic maps of the study region. Areas within a 500 m radius of creeks and 1 km radius of estuaries were assumed to be of lower salinity than normal seawater. Creeks were differentiated from rivers on the basis of apparent size depicted on a 1:50,000 topographic map; the mouths of larger rivers are typically distinguished as estuaries whereas creeks are shown simply as lines running to the shoreline. Polygons of the creeks/estuaries and their accompanying areas of lowered salinity were mapped and digitized.

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[1] For example, in inside waters, exposure to polar outflows from inlets that penetrate interior wind currents would also need to be considered.

A.2. SURF SCOTER (*Melanitta perspicillata*)

Background

Surf Scoters occur from the Aleutian Islands to Baja California (Palmer, 1976; Campbell *et al.*, 1989). In B.C., Surf Scoters have the highest densities of all the sea ducks (Vermeer, 1981; Vermeer *et al.*, 1983), being common to very abundant in appropriate habitats during migrations and abundant to locally very abundant in winter. In summer, Surf Scoters are common to abundant where large moulting flocks occur in several coastal locations (Campbell *et al.*, 1989; Savard, 1988). They breed primarily in the Arctic (Bellrose, 1976; Campbell *et al.*, 1989).

Blue mussels (*Mytilus edulis*) are the chief food of Surf Scoters along the B.C. coast. Most of the mussels consumed are first year stock under 3 cm long. The proportion of mussels in Surf Scoter diets varies with location and season, ranging between 2 and 96%; in spring, herring spawn may comprise 100% of the food eaten (Vermeer, 1981; Vermeer and Ydenberg, 1989). Other food species recorded in B.C. studies include a variety of bivalves (*Mya arenaria, Protothaca stamminea, Venerupis japonica, Clinocardium nuttallii*), gastropods (*Batillaria zonalis, Lirularia lirulata*), crustaceans (barnacles, crabs and isopods), vascular plants, and algae.

Surf Scoters are primarily bottom feeders, although they are also known to feed on mussels attached to rock faces along fiords (Vermeer, 1989). The average water depth of areas used by Surf Scoters is 9.7 $\pm$ 7.9 m (Hirsch, 1980). In B.C. they are reported to use beaches, spits and points where depths are generally less than 6m (Campbell *et al.*, 1989) but are known to dive to depths greater than 20m (Hirsch, 1980; B.Baden, pers. comm.).

As with most diving ducks, Surf Scoters occur in highest numbers in sheltered straits, bays and inlets (Robertson, 1974; Vermeer, 1983; Campbell *et al.*, 1989). They utilize rocky shorelines more extensively than other habitats (Vermeer and Ydenberg, 1989), but will also feed over gravel, sand and mud bottoms on gradual or steep slopes (Hirsch, 1980). During the months of July and August, Savard (1988) observed Surf Scoters along rocky shores 56% of the time and along sandy shores 44% of the time; none were seen over muddy shores. Vermeer (1989) found that the distribution of Surf Scoters in inland fiords was negatively correlated with salinity, and that their seasonal distribution within Jervis Inlet changed with the changing salinity levels. They also showed a preference for areas off creek mouths and waterfalls.

Habitat Suitability Model

This model is applicable to the B.C. coast for habitat for wintering, migrating, non-breeding, and post-breeding Surf Scoters. The variables considered to be important in determining suitable habitat for Surf Scoters are those that determine the availability of food species (spawning areas, depth, and substrate), provide adequate shelter (exposure), and reduce physiological stress (salinity) (Table A-1). The occurrence of regular or frequent herring spawning (V1) automatically designated class 1 habitat (Figure A-1). The species' diving limits are taken into account in V2, although ideally a range of 10-20 m

CODE	HABITAT VARIABLE	VALUES	SUITABILITY
V1	Herring spawn	Regular or frequent Occasional or never	high* -
V2	Depth	≤ 10 m > 10 m	high low-unusable
V3	Exposure	Protected/semi-protected Exposed	high medium-low
V4	Bottom substrate	Rock dominant or present Sand/silt/mud dominant	high low
V5	Estuary or creek	Present Not present	high medium-low

* Suitability then determined by combination of other variables.

Table A-1: Habitat variables and values for Surf Scoters.

would be designated as "medium" in value (see discussion of depth in previous section). Their preference for protected or semi-protected areas are indicated in V3. Areas of rocky bottom and lower salinity were considered to provide more favourable habitat (V4 and V5).

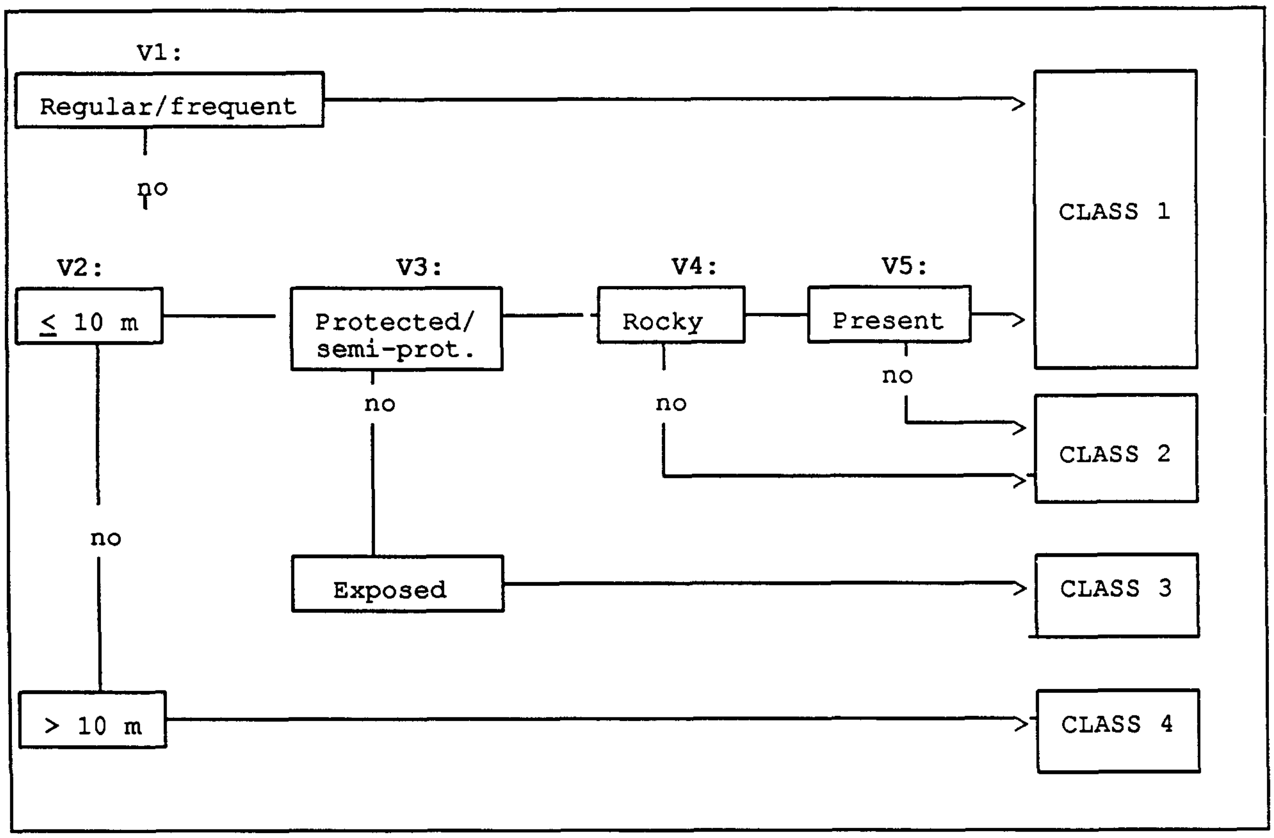


Figure A-1: Habitat suitability model for Surf Scoters.

A.3. WHITE-WINGED SCOTER (*Melanitta fusca*)

Background

White-winged Scoters winter along the Pacific coast from southeast Alaska to Baja California, as well as on the north Atlantic coast and the Great Lakes (Bellrose, 1976). In B.C., they are very common to very abundant in appropriate habitats during spring and fall migrations. They are abundant to very abundant in winter, with concentrations in Georgia Strait, on the north coast near Prince Rupert, and on the north coasts of the Queen Charlotte Islands (Robertson, 1974; Vermeer *et al.*, 1983; Campbell *et al.*, 1989). Numbers are low in the mainland inlets (Vermeer and Bourne, 1984). In summer, nonbreeding, postbreeding and moulting males are found in heavily used wintering areas, although the distribution is more restricted (Savard, 1988). They breed throughout eastern B.C. and the prairies, north to the Arctic Ocean (Bellrose, 1976).

White-winged Scoters feed primarily on mollusc and crustaceans. In Georgia Strait, they have been recorded to feed mostly on clams and snails, although crustaceans (especially barnacles) were used heavily at times (Vermeer, 1983; Vermeer and Bourne, 1984). In Puget Sound, food components were recorded as 11% snails and 84% clams (Hirsch, 1980); in Humbolt Bay California, they were 80% clams and 20% crabs and snails (Bellrose, 1976). They feed extensively on herring spawn in the spring (Vermeer and Ydenberg, 1989).

White-winged Scoters dive an average of 10.9m, with maximum depths of approximately 12m (Hirsch, 1980), but they prefer to feed at low tide when food is not so deep (Bent, 1929). They are found in bays, inlets, estuaries and around rocky headlands (Bellrose, 1976; Campbell *et al.*, 1989). In B.C., White-winged Scoters are mostly found feeding over mud, silt and sandy bottoms, but frequently use gravel and cobble bottoms (Savard, 1979; 1988; Hirsch, 1980; Morgan, 1987; Butler and Campbell, 1988). Vermeer and Bourne (1984) and Hirsch (1980) note that White-winged Scoters frequently feed over eel grass beds. In Alaska, use of shell and boulder-cobble substrates have been recorded (Sanger and Jones, 1984).

Habitat Suitability Model

This model is applicable to the entire B.C. coast for habitat for wintering, migrating, non-breeding, and post-breeding White-winged Scoters. The variables considered to be important are those that determine the availability of food species and provide adequate shelter (Table A-2). The occurrence of regular or frequent herring spawning (V1) automatically designates the area as class 1 habitat (Figure A-2). The species' diving limits are taken into account in V2, and its preference for protected or semi-protected areas are indicated in V3. The presence of eelgrass beds (V4) is assumed to increase the value of an area for feeding. The sandy bottoms which White-winged Scoters prefer are accounted for in V5.

CODE	HABITAT VARIABLE	VALUES	SUITABILITY
V1	Herring spawn	Regular or frequent Occasional or never	high* -
V2	Depth	≤ 10 m > 10 m	high low -unusable
V3	Exposure	Protected, semi-protected Exposed	high low
V4	Eel grass	Present Absent	high medium-low
V5	Bottom substrate	Sand dominant or present Rocky (boulder,bedrock)	high low

* Suitability then determined by combination of other variables.

Table A-2: Habitat variables and values for White-winged Scoters.

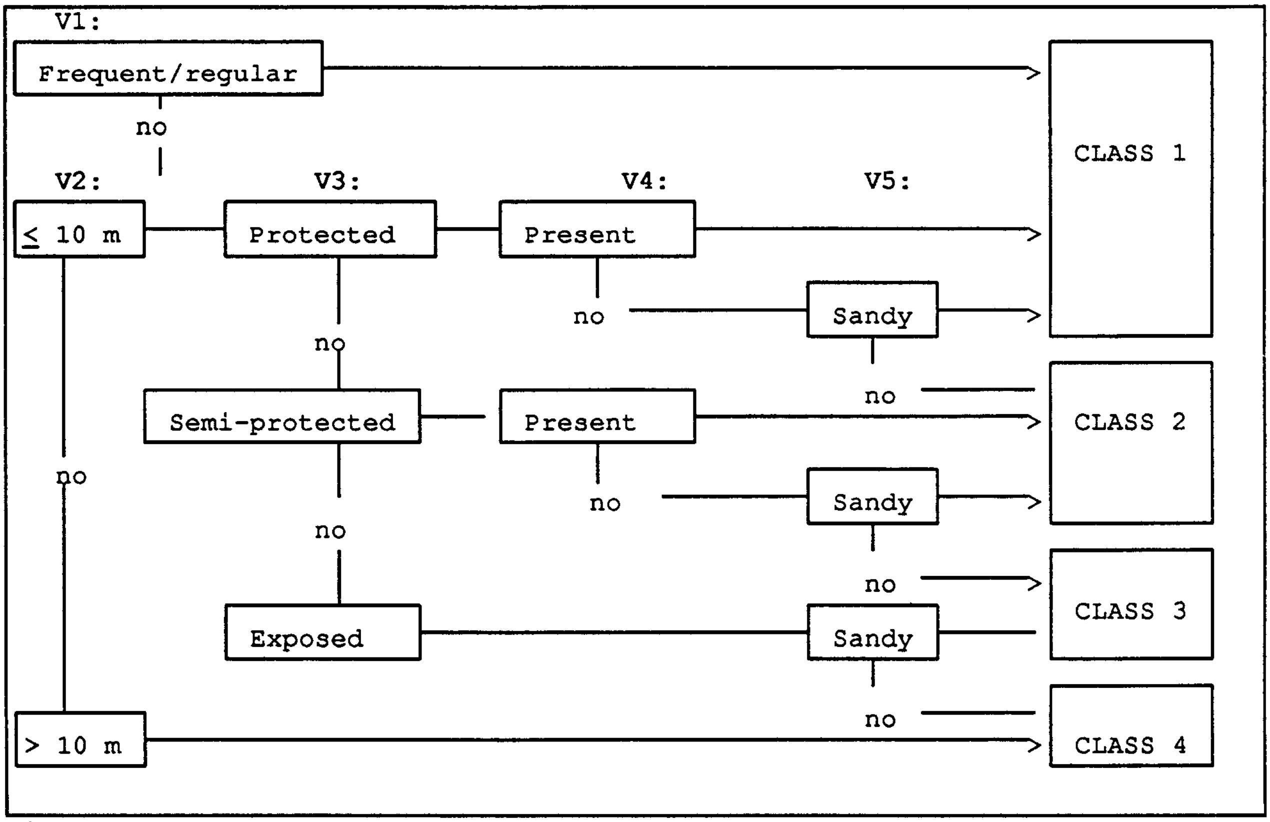


Figure A-2: Habitat suitability model for White-winged Scoters.

A.4. BARROW'S GOLDENEYE (*Bucephala islandica*)

Background

Barrow's Goldeneyes are found along the Pacific coast from northern California to the Alaskan panhandle (Palmer, 1976; Campbell *et al.*, 1989). They are fairly common to locally abundant migrants and winter visitants to the B.C. coast but are rare in summer (Campbell *et al.*, 1989). The majority of the world's population winters along the B.C. coast (Bellrose, 1976) with their center of abundance being the mainland inlets (Vermeer, 1982). Barrow's Goldeneyes breed in the mountain areas of western Canada and southern Alaska (Bellrose, 1976; Campbell *et al.*, 1989).

Food organisms are similar to those of Surf and Black Scoters. Blue mussels are the primary food (Vermeer, 1981) followed by gastropods, other bivalves and crustaceans. Herring spawn is a dominant food species during spawning season. In Alaska, Barrow's Goldeneye have been recorded as diving up to 2 meters for crustaceans and molluscs at low tide and up to 4 m for mussels at high tide (Koehl *et al.*, 1984).

In mainland fiords, Barrow's Goldeneyes occur predominantly in two habitats; along steep rocky fiord walls where they feed on the mussels growing on the rock and in sand and cobble estuaries (Koehl *et al.*, 1984; Vermeer and Ydenberg, 1989). Vermeer (1989) found that highest abundances in the fiords occurred around rapids and at log storage sites. He also found that along with Surf Scoters, the distribution of Barrow's Goldeneye was negatively correlated with salinity, and that their seasonal distribution within Jervis Inlet changed with the changing salinity levels. They also showed a preference for areas off creek mouths and waterfalls. In the Fraser Estuary, Barrow's Goldeneye are found around breakwaters, jetties and pebble beaches (Butler and Campbell, 1988).

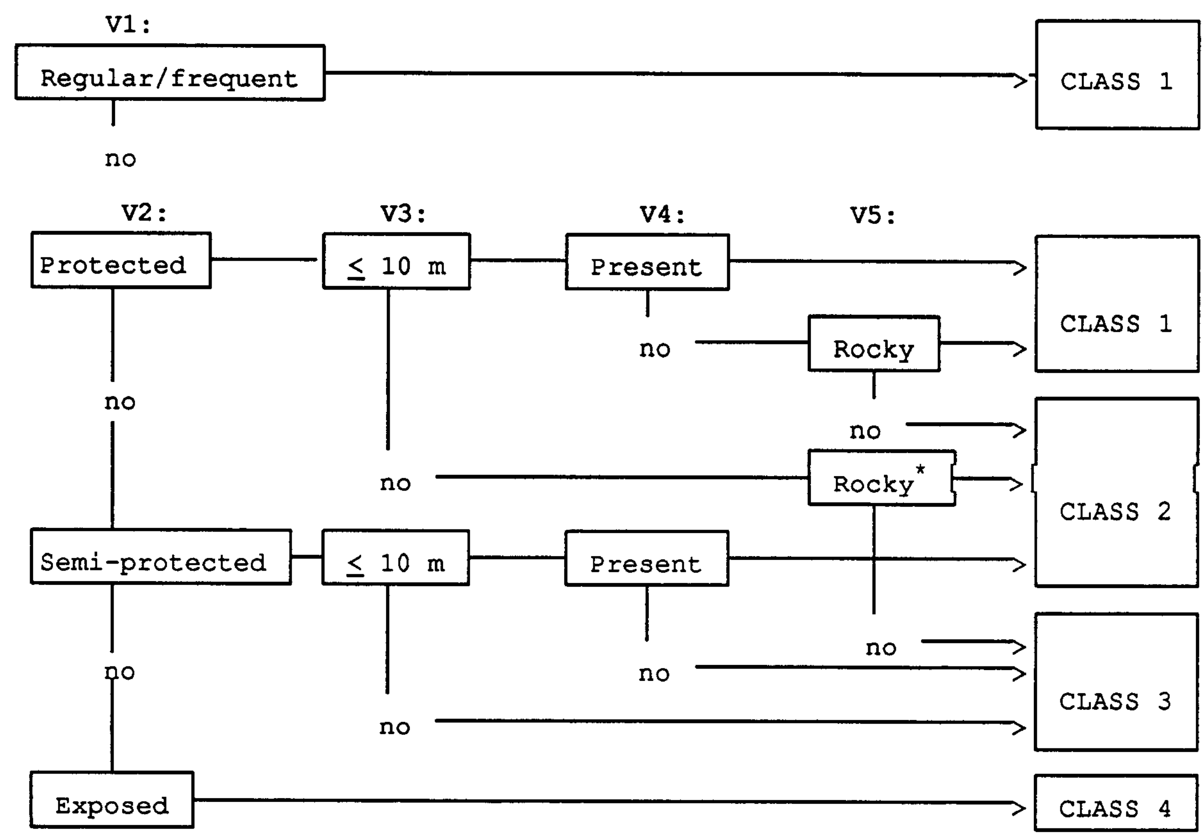
CODE	HABITAT VARIABLE	VALUES	SUITABILITY
V1	Herring spawn	Regular or frequent	high*
		Occasional or never	-
V2	Exposure	Protected/semi-protected	high-medium
		Exposed	low
V3	Depth	$\leq$ 10 m	high
		> 10 m	medium-low
V4	Estuaries, creeks	Present	high
		Not present	medium
V5	Substrate	when $\leq$10m, rocky	high
		when >10m, rocky but assumes a steep shoreline	high

* Suitability then determined by combination of other variables.

Table A-3: Habitat variables and values for Barrow's Goldeneye.

Habitat Suitability Model

This model is applicable to the B.C. coast for habitat for wintering, migrating, non-breeding, post-breeding and moulting Barrow's Goldeneye. Areas subject to frequent or regular herring spawning (V1) are designated Class 1 (Table A-3, Figure A-3). Level of protection (V2) is given high priority. The species' diving limits are reflected in the variable for depth (V3). However, depths greater than 10 m in combination with protected areas and rocky shorelines are assumed to reflect fiord-like environments and are rated accordingly. In other circumstances, depths of greater than 10 m are largely unusable to the species. A preference for estuaries and creek mouths is taken into account (V4).



* This assumes a steep rock face.

Figure A-3: Habitat suitability model for Barrow's Goldeneye.

A.5. BUFFLEHEAD (*Bucephala albeola*) and COMMON GOLDENEYE (*Bucephala clangula*)

Background

These diving duck species winter along both coasts of North America and throughout the continental United States. On the Pacific coast, both species occur from the Aleutian Islands to Baja California but are uncommon south of Puget Sound (Bellrose, 1976; Palmer, 1976). In B.C., the two species are fairly common to abundant in appropriate habitats during migrations and in winter (Vermeer *et al.*, 1983; Campbell *et al.*, 1989). Their centres of abundance are the Fraser Estuary (Butler and Campbell, 1988), the sheltered bays of Georgia Strait (Vermeer, 1983), the inlets of the west coast of Vancouver Island (Robertson, 1974), and the north and east coasts of the Queen Charlotte Islands (Savard and Kaiser, 1982). Both Bufflehead and Common Goldeneye breed throughout the central and southern interior of Canada and the northern USA (Bellrose, 1976; Palmer, 1976).

Buffleheads and Common Goldeneye are primarily bottom feeders. Common Goldeneye seem to rely more on crustaceans and less on mussels than do Barrow's Goldeneye (Vermeer, 1982; Koehl *et al.*, 1984). Snails and bivalves make up most of the balance of their diets (Erskine, 1972; Vermeer, 1983; Butler and Campbell, 1988). Both species feed extensively on herring spawn in the spring (Vermeer, 1982; Campbell *et al.*, 1989). Hirsch (1980) found these birds to have a similar diet in Washington state except that 15% of the volume of food items found in Common Goldeneye was the penpoint gunnel or blenny (*Apodichthys flavidus*).

These species occur in higher numbers in sheltered bays and inlets than on exposed coasts, and are seldom seen far from shore (Robertson, 1974; Palmer, 1976; Vermeer, 1982; 1983; Vermeer *et al.*, 1983). Both species have been recorded using a variety of fresh water and marine habitats (Palmer, 1976). Both occur over rock, boulder, cobble, sand and silty shorelines (Savard, 1979; Hirsch, 1980; Vermeer, 1982). On the north coast, Savard (1979) found that Common Goldeneyes preferred sandy shores while Buffleheads were more common along rocky shorelines. Elsewhere, Buffleheads prefer sandy and silty bottoms (Erskine, 1972). Vermeer (1989) found that in Jervis Inlet, Common Goldeneye had their highest densities in estuaries.

Hirsch (1980) recorded these species in average depths of 2.7 m and 3.2 m respectively. According to Palmer (1976), the preferred feeding depths are 2-3 m for Buffleheads and 1-4 m (maximum 6 m) for Common Goldeneyes.

Habitat Suitability Model

This model is applicable to the B.C. coast for habitat for wintering, migrating, non-breeding, and post-breeding Bufflehead and Common Goldeneye. The model equates suitable habitat with available feeding areas (herring spawn (V1) and depth (V2)) and level of protection (V3); Table A-4, Figure A-4). A preference for sandy substrates (V4) that would harbour higher populations of crustaceans is taken into account.

CODE	HABITAT VARIABLE	VALUES	SUITABILITY
V1	Herring spawn	Regular or frequent Occasional or never	high* -
V2	Depth	≤ 10 m > 10 m	high-medium unusable
V3	Exposure	Protected, semi-protected Exposed	high low
V4	Estuary or creek mouth	Present Not present	high medium-low
V5	Bottom substrate	Sand dominant or present Boulder/bedrock dominant	high medium-low

* Suitability then determined by combination of other variables.

Table A-4: Habitat variables and values for Common Goldeneye and Bufflehead.

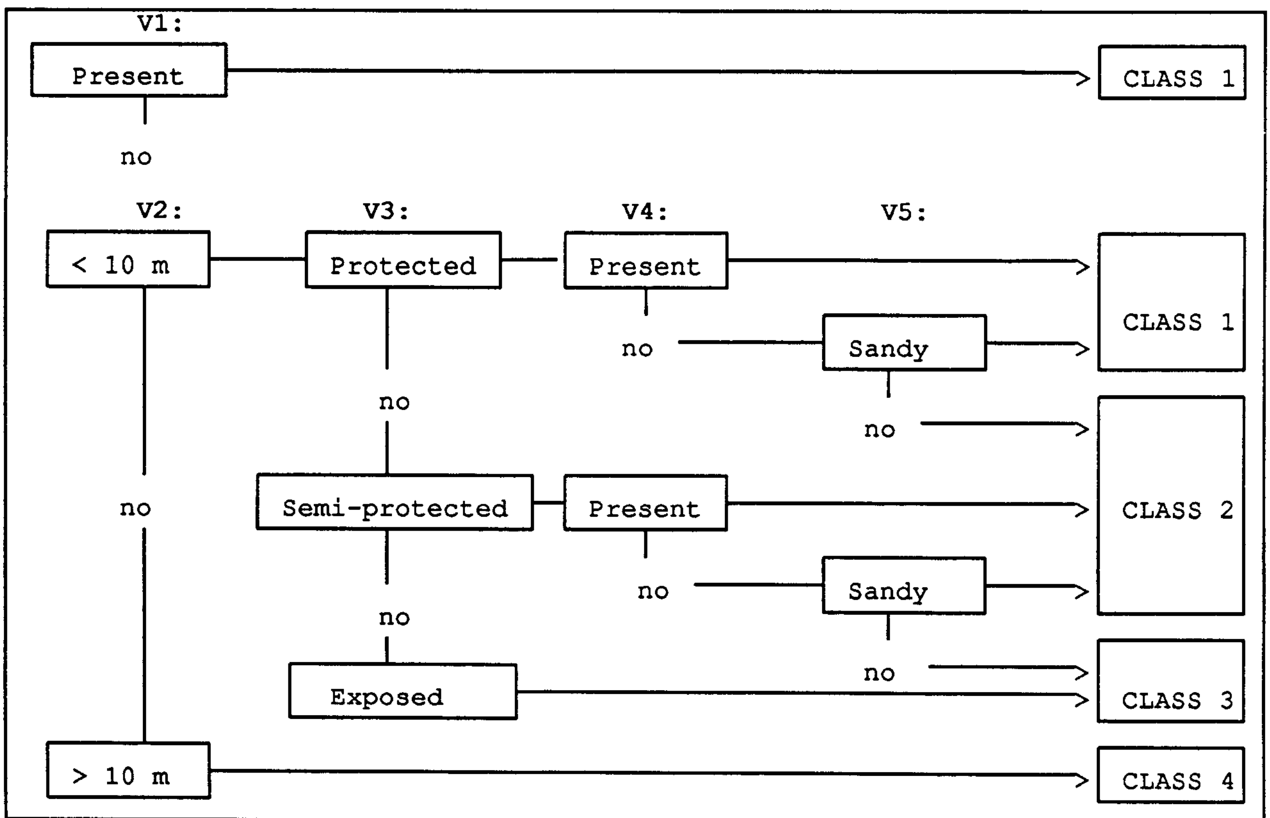


Figure A-4: Habitat suitability model for Common Goldeneye and Bufflehead.

A.6. HARLEQUIN DUCK (*Histrionicus histrionicus*)

Background

Harlequin Ducks winter along the Pacific coast from southern Alaska to central California and on the Atlantic coast from southern Labrador to New York (Bellrose, 1976). In B.C., they are common to locally very common migrants and summer visitants and fairly common to locally common in winter. Concentrations of moulting birds are known to occur at the northern end of Georgia Strait and the north and east coasts of the Queen Charlotte Islands (Vermeer *et al.*, 1983; Savard, 1988; Campbell *et al.*, 1989). In general, records indicate that Harlequin Ducks occur in the lowest numbers of any diving ducks on the B.C. coast (Vermeer *et al.*, 1983), although their tendency to stay close to shore, their cryptic coloration and their long periods of inactivity make them very difficult to distinguish on either aerial or boat surveys (Savard, 1988). Harlequin Ducks breed in the mountainous areas of Alaska, B.C. and the mid-western U.S., and in eastern North America from southern Baffin Island to central Quebec and eastern Labrador (Bellrose, 1976).

The principal food species recorded in the Fraser Delta are snails and limpets (29.3% wet weight; 90.0% occurrence) followed by fish and fish eggs (21.9% wet weight; 18.5% occurrence) (Vermeer, 1983). Harlequin Ducks feed on herring spawn in the spring but not to the same extent as other diving ducks (Vermeer and Ydenberg, 1989). Other food organisms include crabs, chitons, algae, bivalves, amphipods, shrimp, echinoderms and barnacles (Vermeer, 1983; Savard, 1988).

Harlequin Ducks feed the closest to shore and in the shallowest water of all of the diving ducks. At White Rock B.C., they stay within 50 m of shore while in Washington, they stay 60 m from shore in water averaging 1.1 m deep (Savard, 1988). Palmer (1976) gives diving depths of 2 to 4 meters.

In Washington, the preferred habitat of Harlequin Ducks is gently sloping shores, either in areas of sand with eelgrass or cobble with kelp (Hirsch, 1980). On the B.C. coast, they "frequent the often turbulent waters adjacent to rocky islets and rocky shore and bays, feeding amongst kelp beds and moving to the islets and exposed rocks or reefs to loaf and preen" (Campbell *et al.*, 1989). In the Fraser Delta, they occur along rocky, marine shores and especially along jetties and breakwaters (Butler and Campbell, 1988; Savard 1988). At Saltspring and Cortez Islands and in Saanich Inlet, they forage close to boulder-strewn shores, over rocky and to some extent gravel substrates and in kelp beds (Vermeer, 1983; Morgan, 1987). In Saanich Inlet they used shallow bays half as much as rocky shorelines (*ibid.*). On the north coast and on the west coast of Vancouver Island, they were observed in larger numbers on the open rocky coast than along sandy coasts or in the inlets (Savard, 1979; Robertson, 1974).

Habitat Suitability Model

This model is applicable to the entire B.C. coast for habitat for wintering, migrating, non-breeding, post-breeding and moulting Harlequin Ducks (Table A-5, Figure A-5). The species' preference for shallow depths (V1), more exposed shorelines (V2), rocky substrates (V3), and kelp or eelgrass (V4). Herring spawn (V5) increases the value as habitat.

CODE	HABITAT VARIABLE	CATEGORIES	SUITABILITY
V1	Depth	≤ 10 m > 10 m	high-low unusable
V2	Exposure	Semi-protected Exposed or protected	high medium-low
V3	Bottom substrate	Cobble, boulder, rock dominant or present Sand, mud, silt dominant	high medium-low
V4	Kelp, eelgrass	Present Absent	high medium
V5	Herring spawn	Regular or frequent Occasional or never	high -

Table A-5: Habitat variables and values for Harlequin Ducks.

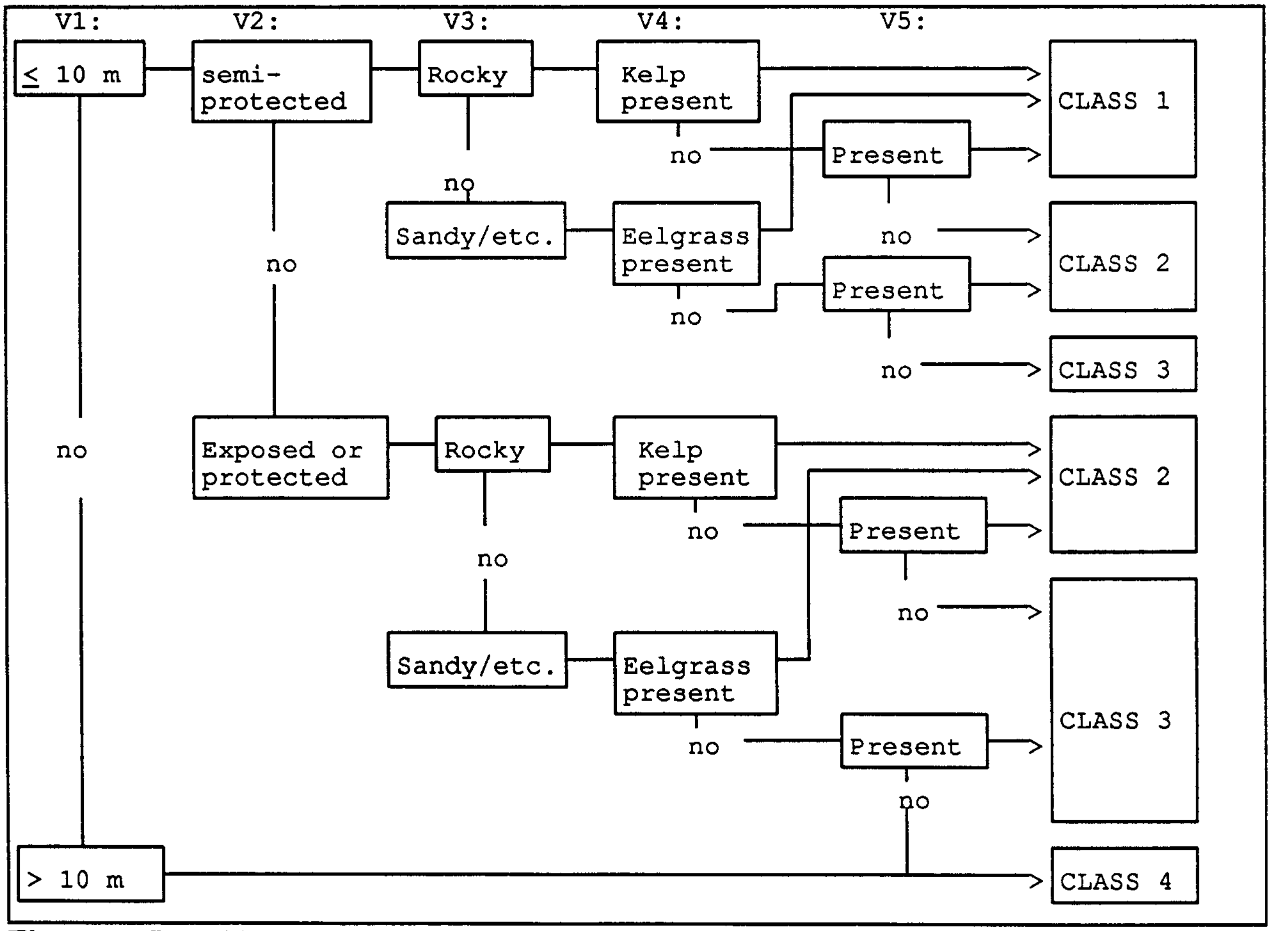


Figure A-5: Habitat suitability model for Harlequin Duck.

A.7. WESTERN GREBE (*Aechmophorus occidentalis*)

Background

Western Grebes winter along the Pacific coast and in some interior lakes from southeastern Alaska to Mexico (Palmer, 1962). They winter regularly in B.C. waters where they are abundant to very abundant on a localized scale; individual flocks may reach 10,000 to 15,000 birds (Campbell *et al.*, 1989). The center of abundance in winter is in Georgia Strait (Vermeer *et al.*, 1983; Vermeer, 1983; Campbell *et al.*, 1989). They are also common to very abundant spring and autumn migrants and are locally very common in the summer (Campbell *et al.*, 1989).

Compared to other diving birds, there is little detailed information in the literature on the food of Western Grebes. They are primarily fish eaters, with Pacific herring (Clupea harengus) and herring spawn comprising the bulk of their diet (Munro, 1941; Phillips *et al.*, 1957; Robertson, 1972; Vermeer, 1983). Other marine fish recorded in their diet include sculpins (*Leptocottus* sp.), sea perch (*Cymatogaster* sp.) and fish of families *Stichaeidae*, *Embiotocidae*, and *Cottidae*. Other food organisms are shrimp, small crabs and polychaetes (Munro, 1941). Western Grebes may follow the movements of the fish on which they are feeding in large flocks (Bent, 1919), and are known to gather in large numbers at herring spawn sites in March (Savard, 1988).

The Western Grebe occurs to some extent in exposed coastal waters within 2 - 3 km of land (Campbell *et al.*, 1989), but is most abundant in the sheltered waters of bays, inlets, lagoons, estuaries and islands (Robertson, 1974; Savard, 1979; Vermeer, 1983; Campbell *et al.*, 1989), where it generally remains offshore in deeper water (Jewett *et al.*, 1953; Savard, 1979; Morgan, 1987; Savard, 1988; Butler and Campbell, 1988). Small numbers are frequently found on slow-moving coastal rivers, large tidal sloughs and lakes (Campbell *et al.*, 1989). Vermeer (1989) found that they were uncommon in the deep mainland fiords but when they did occur there they were most abundant in estuaries where they would be most likely to find fish.

Habitat Suitability Model

This model is applicable throughout coastal B.C. and applies to the habitat of wintering, migration, nonbreeding and postbreeding Western Grebes (Table A-6, Figure A-6). It is assumed that suitable habitats are those that provide populations of suitably sized fish, particularly schooling herring, with open, sheltered water areas (V2). The latter may be a requirement of the species but may also reflect the requirements of their food species; turbulent conditions could potentially interfere either with fish behaviour or the ability of the birds to locate their prey. Herring spawning areas (V1) are given priority. A potential preference for estuaries is taken into consideration (V3).

CODE	HABITAT VARIABLE	VALUES	SUITABILITY
V1	Herring spawn	Regular, frequent or occasional	high
		Never	-
V2	Exposure	Protected	high
		Semi-protected	medium
		Exposed	low
V3	Estuaries	Present	high
		absent	medium

Table A-6: Habitat variables and values for Western Grebe.

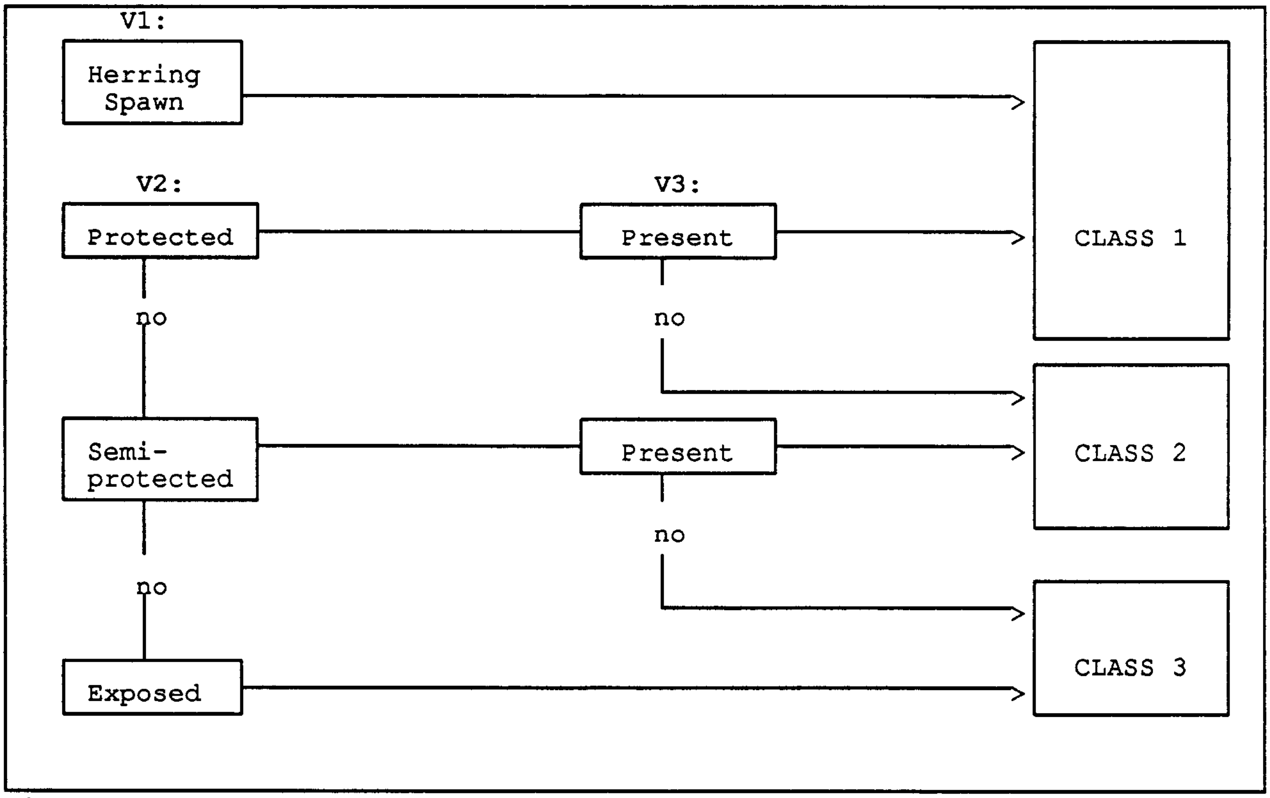


Figure A-6: Habitat suitability model for Western Grebe.

A.8. HORNED GREBE (*Podiceps auritus*) and RED-NECKED GREBE (*Podiceps grisegena*)

Background

Both of these Grebes occur mostly in marine habitats along the west coast of North America from southern Alaska to central California during migrations and/or winter (Palmer, 1962). They are rated as fairly common to very common along the B.C. coast in winter, reaching their highest densities on the southeast coast of Vancouver Island (Campbell *et al.*, 1989), but are also abundant during migration on the Queen Charlotte Islands (Vermeer *et al.*, 1983). Both breed from Alaska and the Mackenzie Delta south throughout B.C., Alberta, Saskatchewan, Manitoba and into western Ontario, including adjacent US states (Palmer, 1962).

There is little information in the literature on the food organisms of Red-necked and Horned Grebes. Jewett *et al.* (1953) lists crustaceans, snails, mollusc and small fish, in addition to various fresh-water species, in Washington State. In Georgia Strait, shrimp and fish have been recorded (Vermeer, 1983; Vermeer and Ydenberg, 1989). Munro (1941) lists small fish such as sandlance, herring, sculpins and blennies, as well as small crustaceans.

These species are generally considered to prefer bays, inlets, harbours, coves, narrows and estuaries, although both species can be found well offshore during migration (Palmer, 1962; Campbell *et al.*, 1989). In the Fraser Estuary, Butler and Campbell (1988) notes that the Horned Grebe frequents nearshore areas and the Red-necked Grebe "is widely distributed in marine and riverine habitats in winter." On the west coast of Vancouver Island, Robertson (1974) noted that they were generally close to shore in shallow water. In Jervis Inlet, both species prefer log booms, estuaries and rapids, while steep rocky shorelines and open water were used least (Vermeer, 1989). In Saanich Inlet, Morgan (1987) found these species most frequently in shallow bays as opposed to beaches or rocky shores, and that they were least common in open water. In southern Georgia Strait, Savard (1988) found that Horned Grebes, along with Harlequin Ducks, were the most abundant species within 200 m of rocky shorelines from November to February, and Red-necked Grebes were the second most numerous bird in November and early December.

Habitat Suitability Model

This model is applicable between September and April and applies to habitat of migrating and wintering Red-necked and Horned Grebes (Table A-7, Figure A-7). Because these Grebes are more abundant in inlets and bays and other sheltered waters, it is assumed that they require shelter from strong winds and large surf (V1). No information was found in the literature on water depths used by Grebes, but as they are usually close to shore in areas of shallower water, it is assumed that shallower depths are favoured (V2). An apparent preference for estuaries and other areas with freshwater influence is taken into consideration (V3).

CODE	HABITAT VARIABLE	VALUES	SUITABILITY
V1	Exposure	Protected Semi-protected Exposed	high medium low
V2	Depth	≤ 10 m > 10 m	high medium-low
V3	Estuaries, creeks	Present Not present	high medium

Table A-7: Habitat variables and values for Red-necked and Horned Grebes.

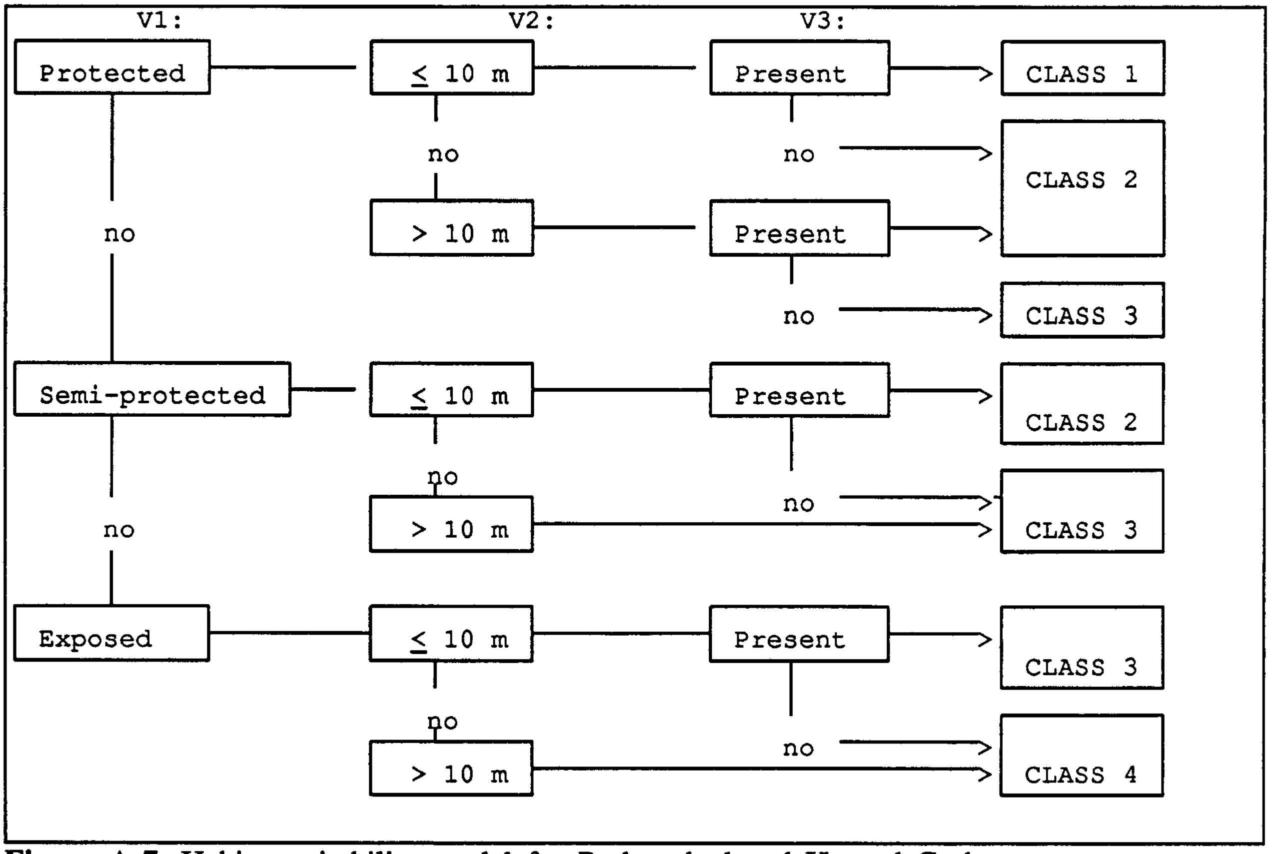


Figure A-7: Habitat suitability model for Red-necked and Horned Grebes.

APPENDIX B:

TYPES OF AQUACULTURE TENURE

APPENDIX B: TYPES OF AQUACULTURE TENURE

Crown land and foreshore areas in British Columbia are available for aquaculture under three forms of tenure issued under the provincial *Lands Act*.

Investigative permit (IP):

An IP allows the holder to study a site for suitability for aquaculture development. IP's are issued for a maximum term of one year at an annual rent of $500.00. No other tenures applications are accepted for that site during the term of the permit. Application for an IP does not require submission of a development plan; at the same time, no permanent structures, improvements to the land, commercial production or harvesting are allowed under an IP.

Licence of occupation (LOC):

A LOC or a lease are required before a fish or shellfish farm can be developed and go into production. LOC's are available for terms of up to 10 years at a minimum annual rent of $500.00. A marine farm development plan must be submitted with an application for a LOC detailing information on size and location of operations on the site, biophysical and operational information on site suitability, information related to other coastal resource users, and a schedule of improvements and production projections. Applicants are required to notify in writing all tenure owners within 1 km in either direction and 300 m inland of the site. The upland owner's consent is required where the planned improvements may affect the owner's access to deep water along his/her property line. Compliance with an Environmental Monitoring Program is mandatory for all fish farms (B.C. Ministry of Environment, 1988).

Lease:

Leases are the most long-term form of tenure; an initial lease is available for 10 years and replacement leases available for up to 20 years. Substantial construction and improvements are allowed under leases. The same applications, notifications and monitoring programs as for LOC's are required.

Application process:

Applications for all types of tenure are made to the regional offices of the B.C. Ministry of Crown Lands (MCL). Applications are referred by MCL to a variety of other government agencies for review. The principal agencies are:

a) B.C. Ministry of Agriculture and Fisheries for review of technical and operational suitability.

b) B.C. Ministry of Environment and Parks for environmental impact, impact on parks, ecological reserves and recreational values.

c) federal Department of Fisheries and Oceans for impact on wild fish stocks and fish habitat.

d) Coast Guard for navigational hazards.

e) district Forestry office for impact on coastal log handling and forest recreation areas.

f) local or municipal government (if the site lies within 1 km seaward or to either side of a municipality's shoreline boundary) for planning and zoning requirements, development permits, infrastructure support and public acceptability. This may require review by local residents, interest groups, advisory committees or councils.

g) Indian bands if the proposed site lies within 1 km seaward or to either side of a reserve's shoreline boundary.

In addition to acquiring the appropriate land/foreshore tenure, an aquaculture operator is required to obtain: navigation approval (Coast Guard); a federal aquaculture licence (DFO); zoning compliance and development permits (municipal or regional government if applicable); and a business licence (local/regional government). If a hatchery is proposed, the operator is also required to obtain a water licence, waste management permit, and sewage disposal permit from the provincial government. Applications for any form of aquaculture tenure must be advertised by the applicant in a newspaper local to area in which the site is located as well as in the B.C. Gazette.

Satisfactory levels of development and/or production must be evident in order for LOC's or leases to be renewed; i.e., the farmer must be utilizing the site effectively.

Current status:

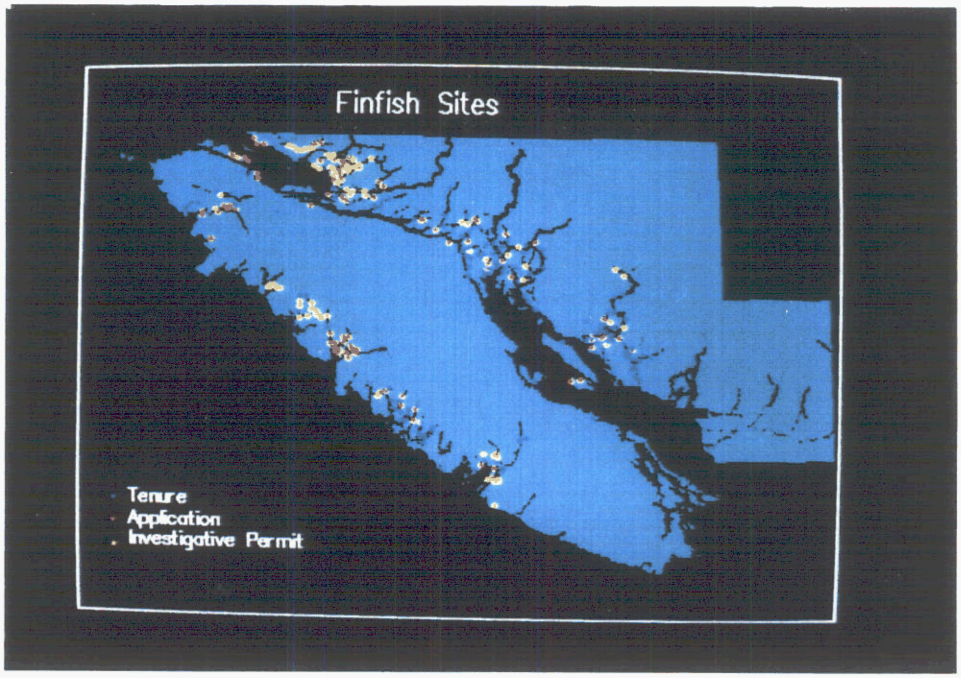
Statistics for aquaculture tenures throughout B.C. are summarized in Table B-1. Based on trends since 1986, 40-50% of applications will be approved for leases or licences; only 25% of IP's will end up as tenures (T. Cockburn, Min. Forests and Lands: pers. comm.).

Table B-1: Aquaculture tenure statistics as of April 10, 1989 (B.C. Min. Crown Lands, 1989).

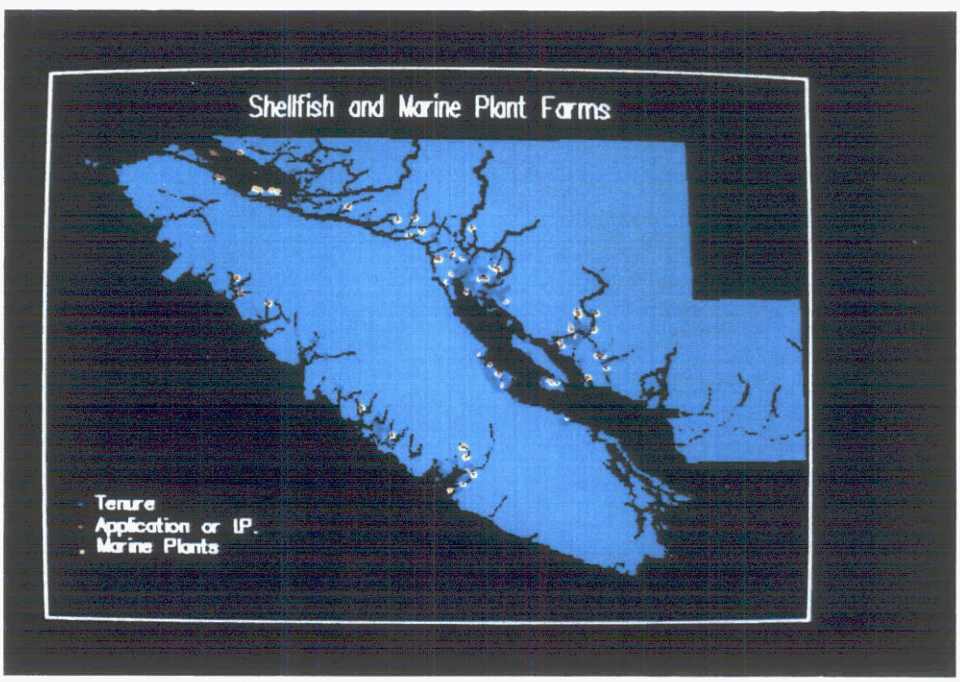
	Finfish			Shellfish			Plants			TOTALS		
	L	LO	IP	L	LO	IP	L	LO	IP	L	LO	IP
ACTIVE AQUACULTURE TENURES												
No.	13	199	88	120	292	4	0	6	0	133	630	92
Area (ha)	66	1121	552	555	1097	29	0	88	0	621	2306	581
ACTIVE AQUACULTURE APPLICATIONS												
No.	31	100	45	17	86	6	0	3	0	48	189	51
Area (ha)	332	859	540	51	504	124	0	95	0	383	1540	664

MAPS

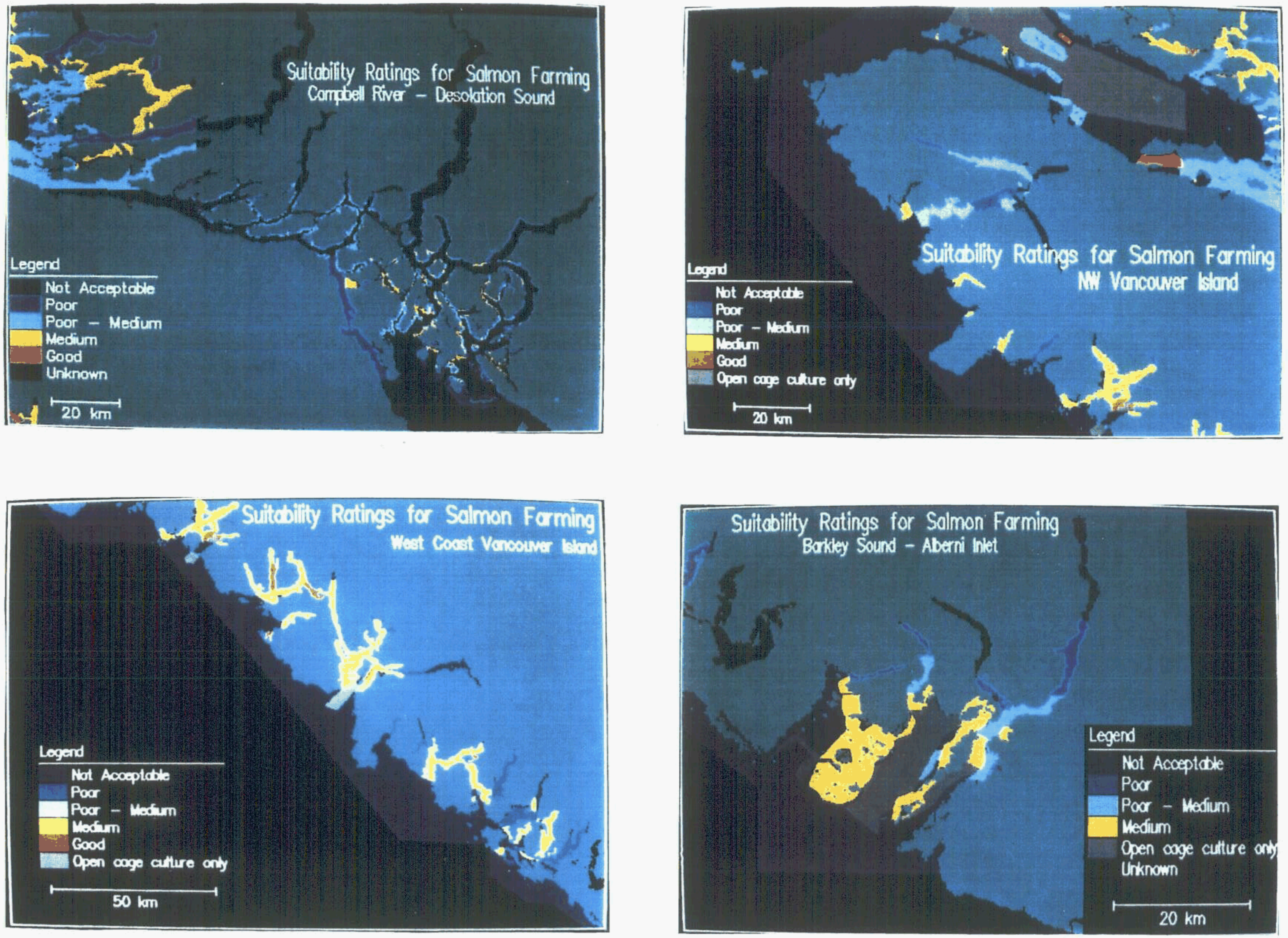
NOTE: Reference is made to examples of distribution maps throughout this report. Due to the expense of colour reproduction, only a limited number of copies with maps were printed. Copies containing the maps are available on loan from: Canadian Wildlife Service, Pacific and Yukon Region, P.O. Box 340, Delta, British Columbia, V4K 3Y3.



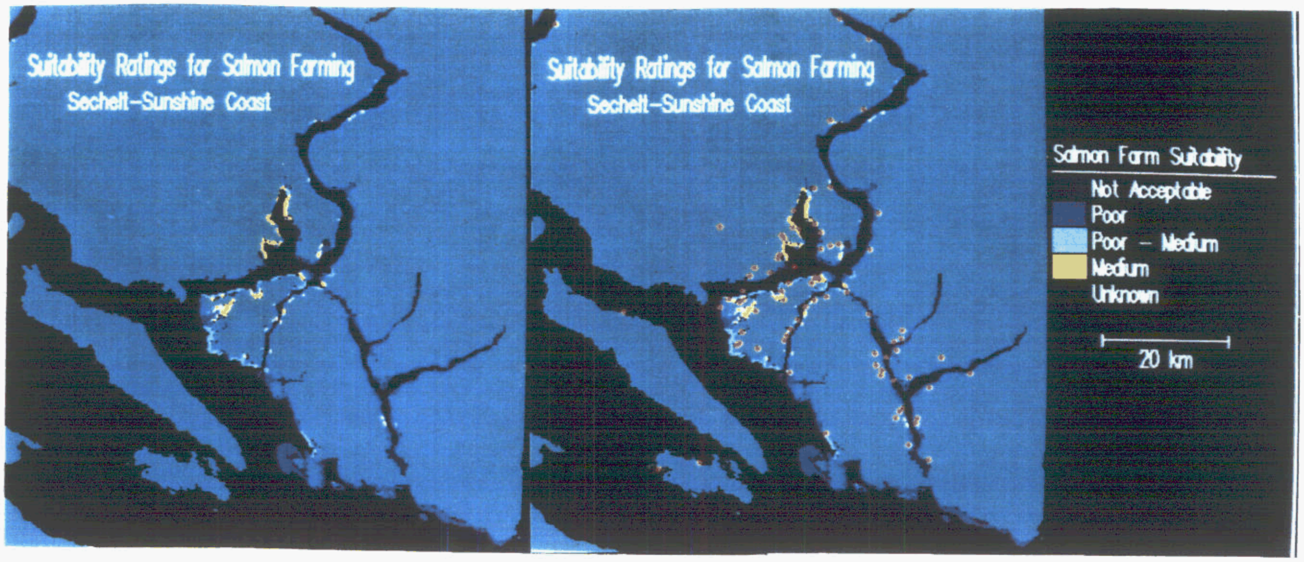
Map 1: Finfish tenures, applications and IP's in the study area.



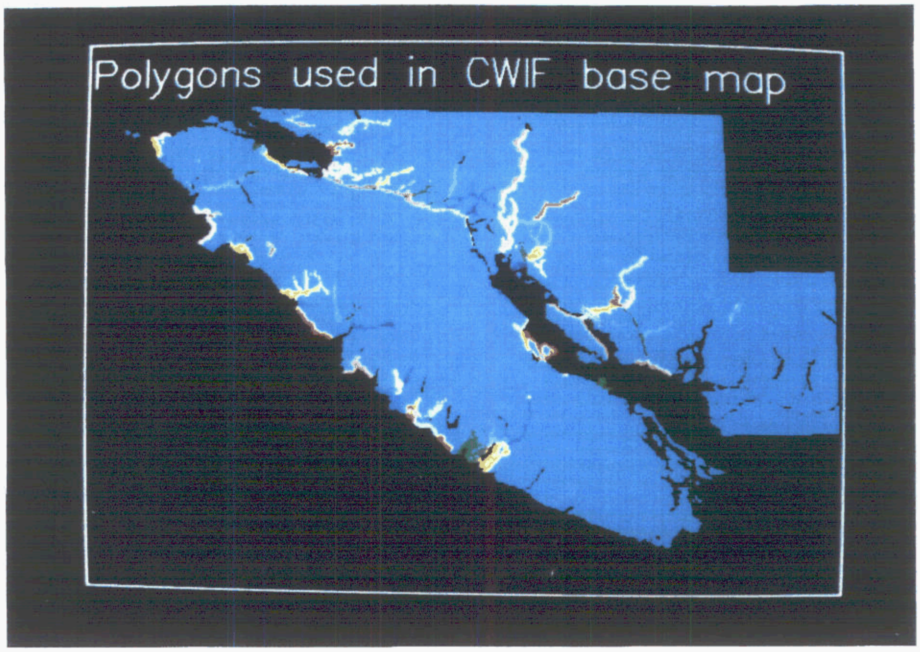
Map 2: Shellfish tenures, applications and IP's in the study area.



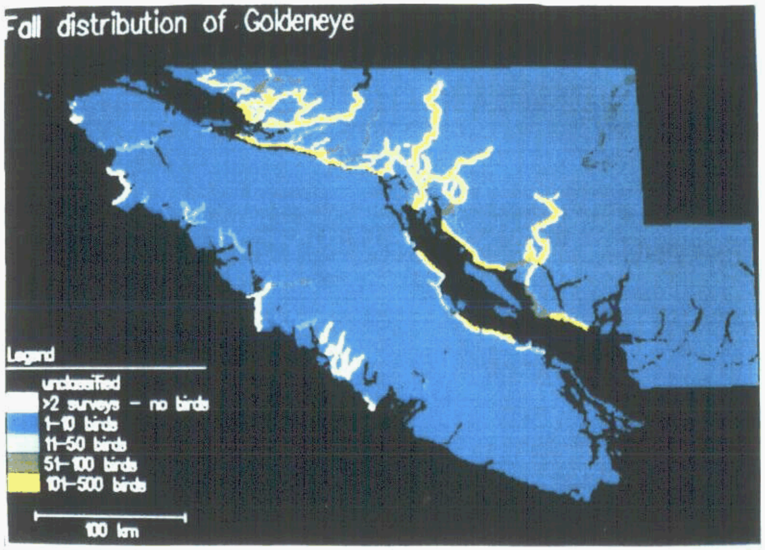
Map 3: Classification of suitability for salmon farming in: Campbell River-Desolation Sound; Queen Charlotte Strait; mid-west Vancouver Island; Barkley Sound-Alberni Inlet.

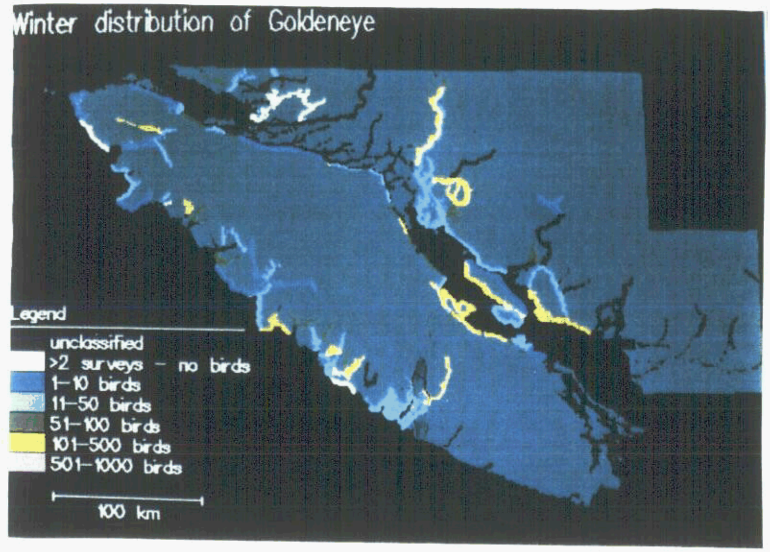


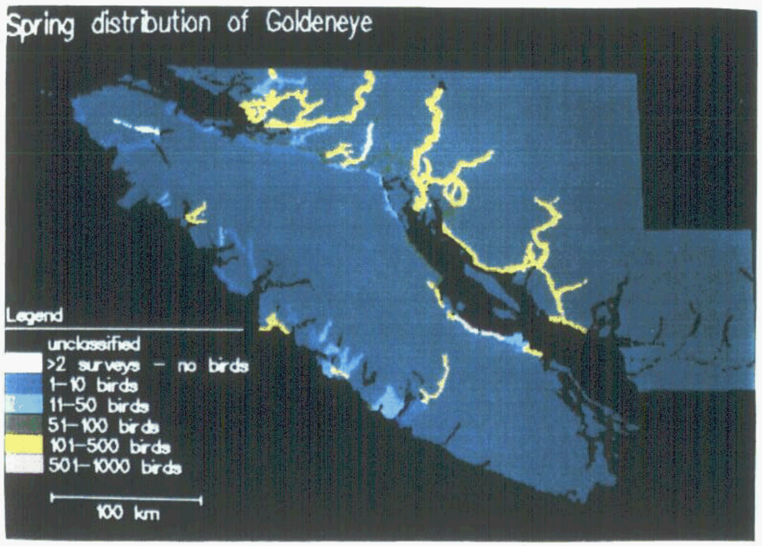
Map 4: Suitability for salmon farming in Sechelt-Sunshine Coast: alone and overlap with salmon farm leases, LOC's, applications and IP's.



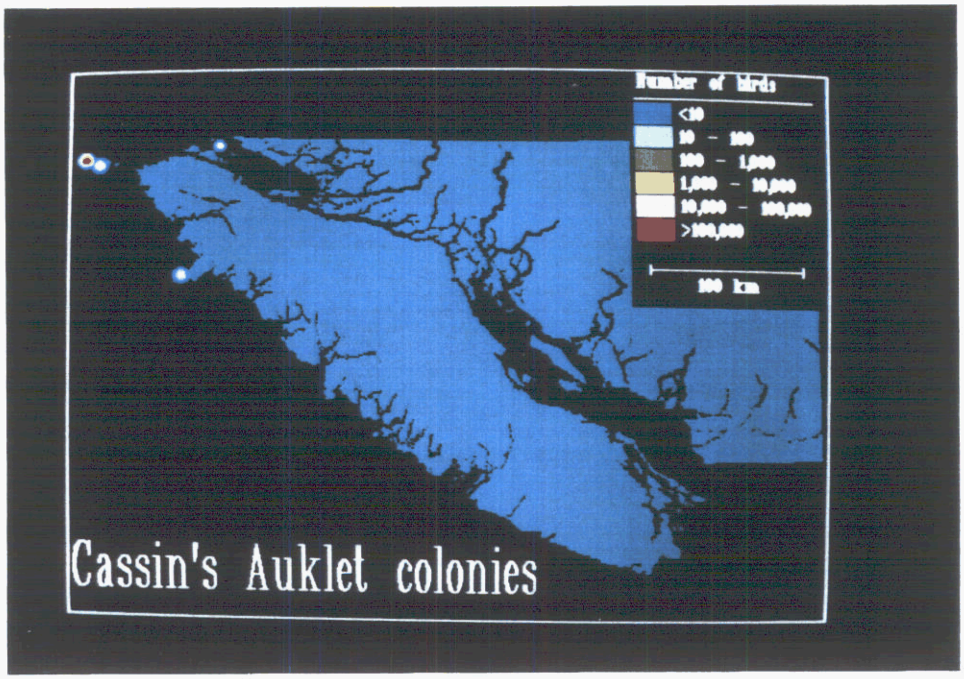
Map 5: CWIF subzones (polygons).



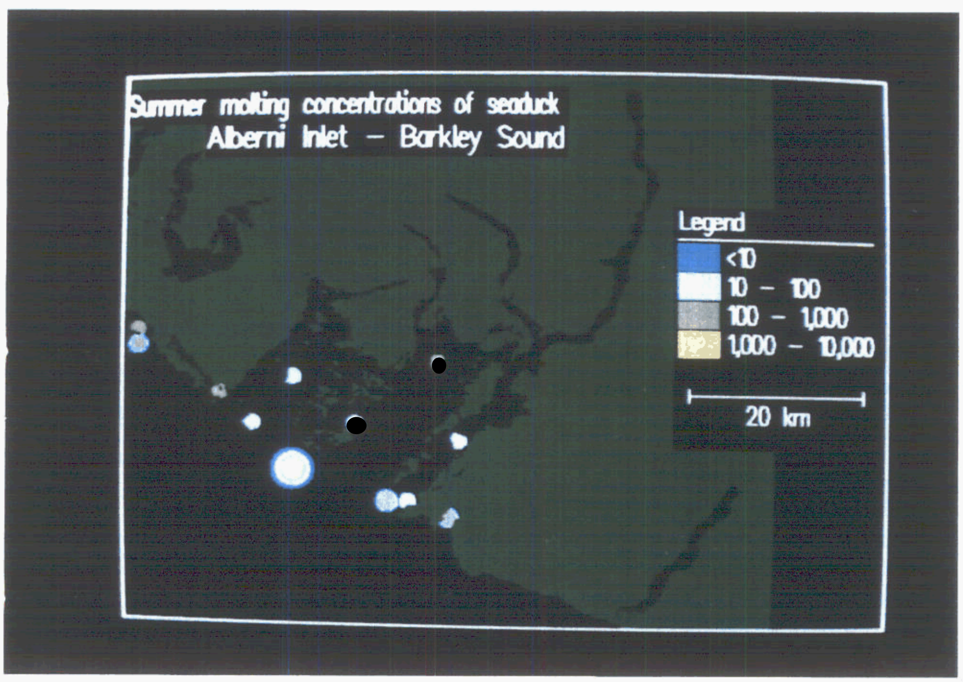




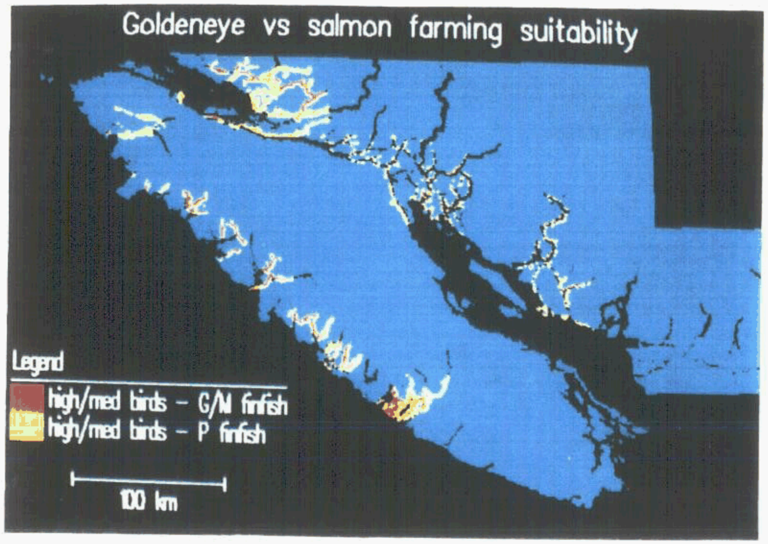
Map 6: Distribution of goldeneye (as subzone ranks) throughout the study area: fall, winter, spring.



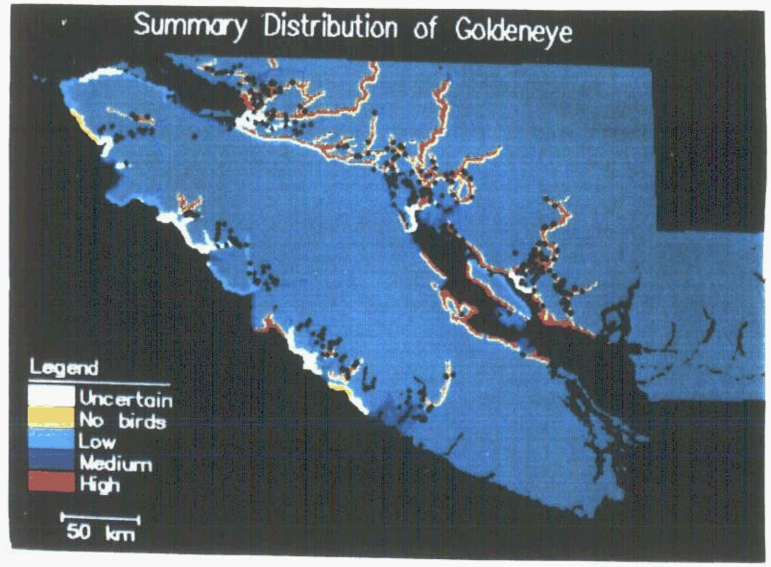
Map 7: Distribution of Cassin's Auklet colonies.



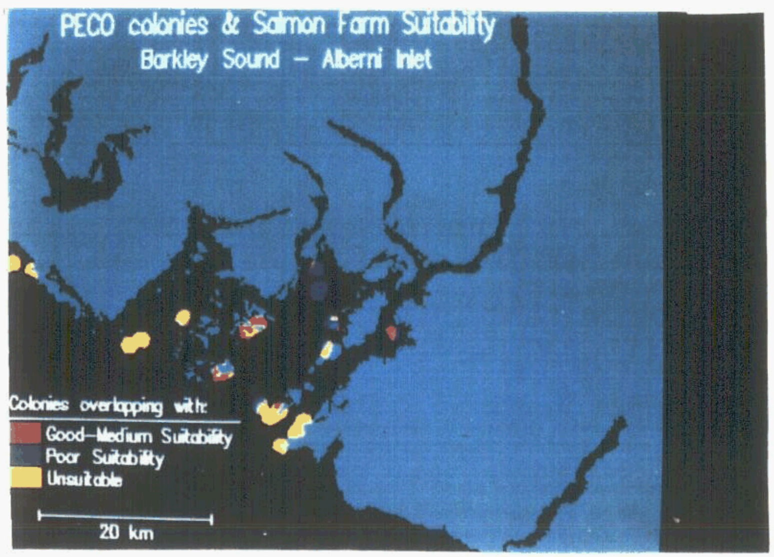
Map 8: Distribution of moulting concentrations of White-winged Scoter, Surf Scoter, and Harlequin Duck.



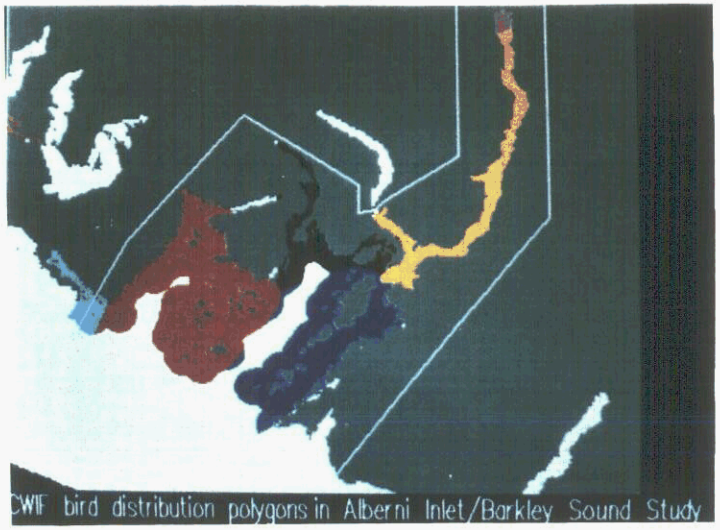
Map 9: Overlap of goldeneye distribution and finfish sites.



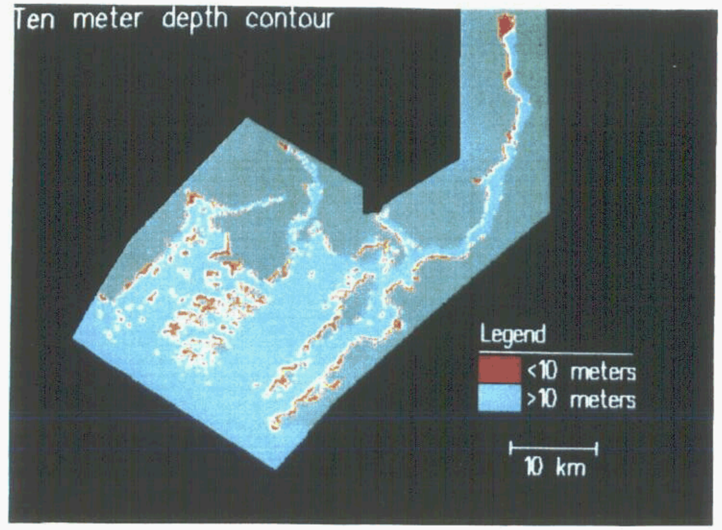
Map 10: Overlap of goldeneye distribution and areas suitable for salmon farming.

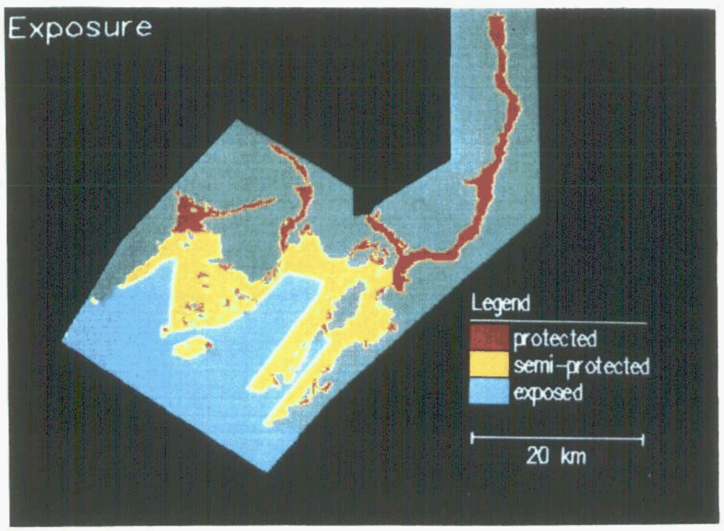


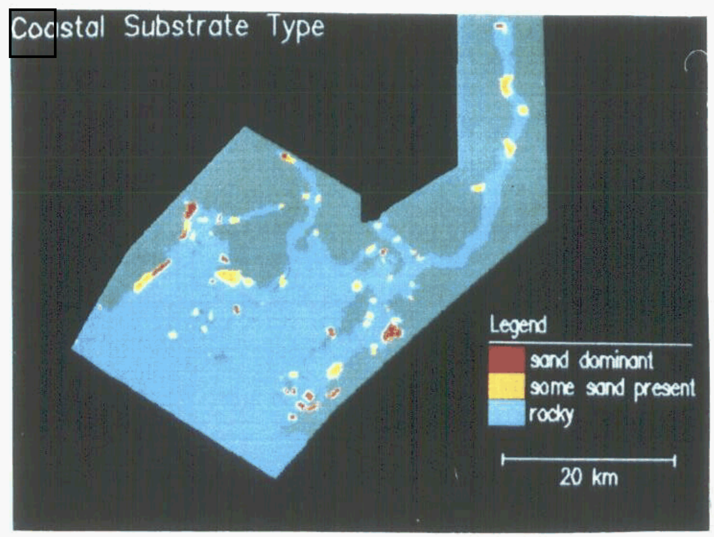
Map 11: Overlap of Pelagic Cormorant colonies and areas suitable for salmon farming in Barkley Sound-Alberni Inlet.



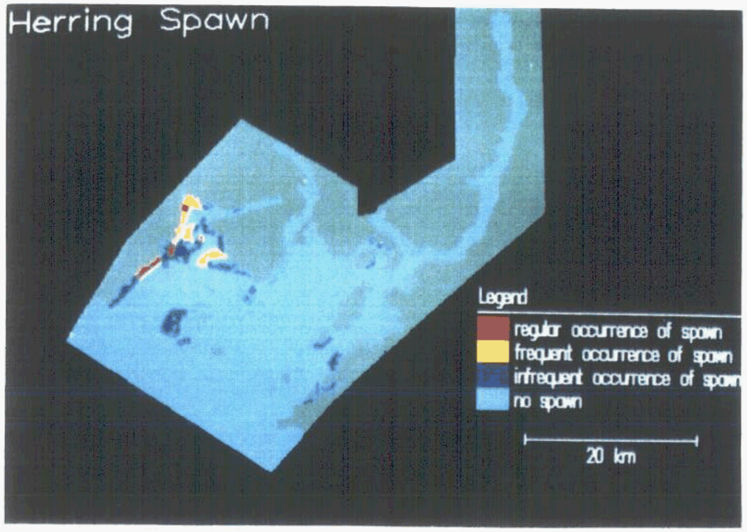
Map 12: CWIF subzones in the Barkley Sound-Alberni Inlet region.

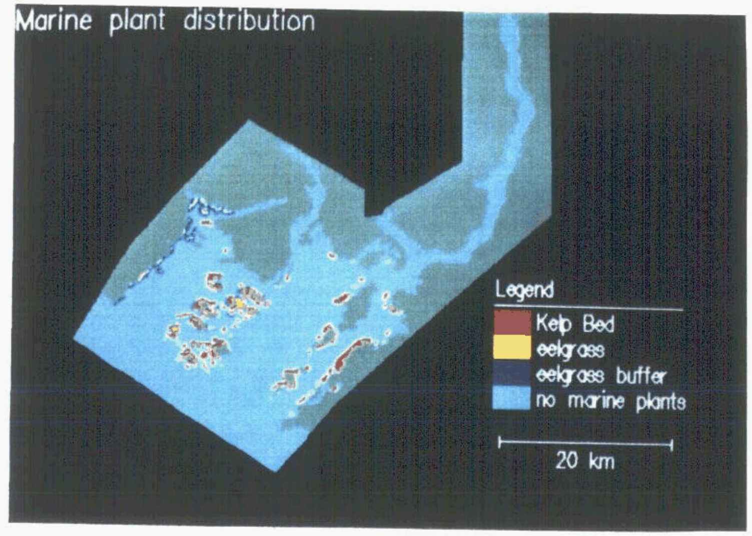


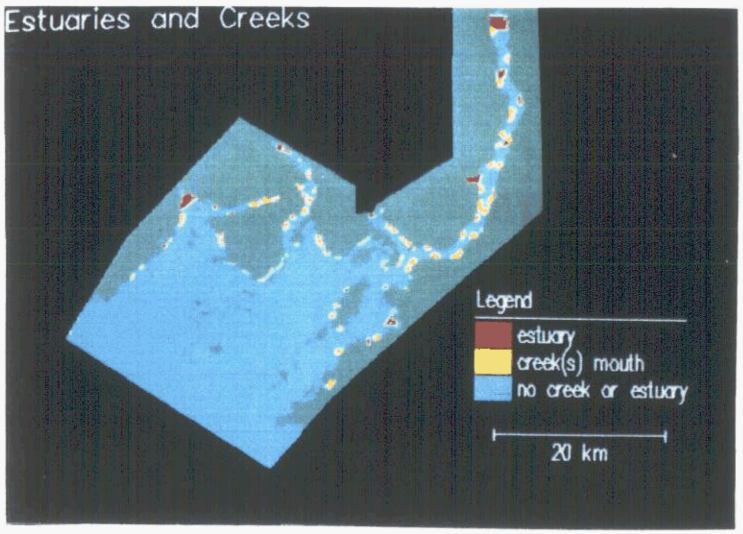




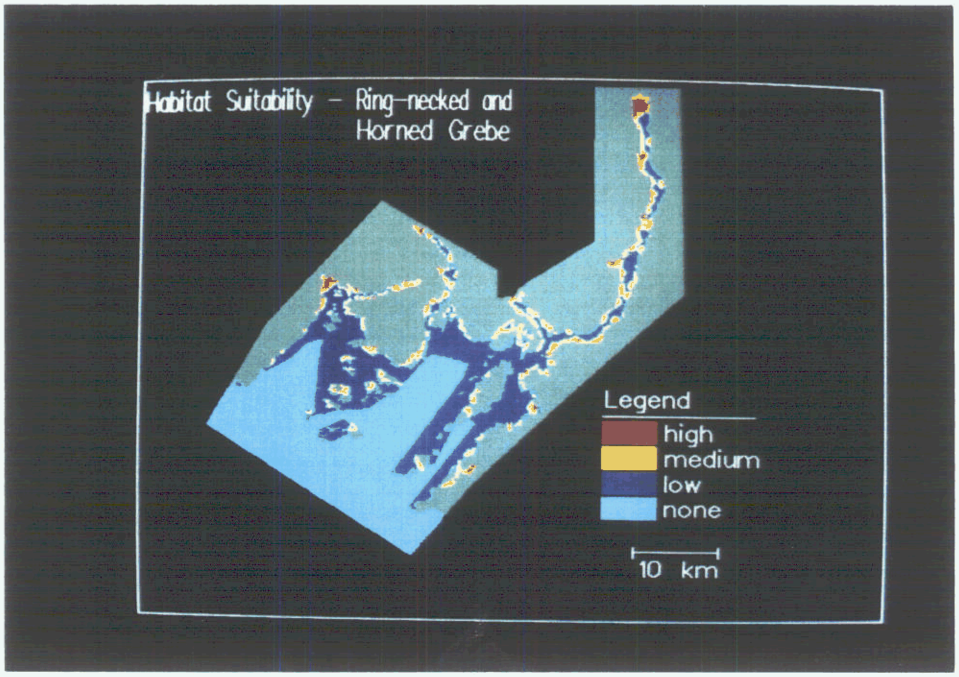
Map 13: Distribution of habitat variables in the Barkley Sound-Alberni Inlet region: a) depth, b) exposure and c) substrate.

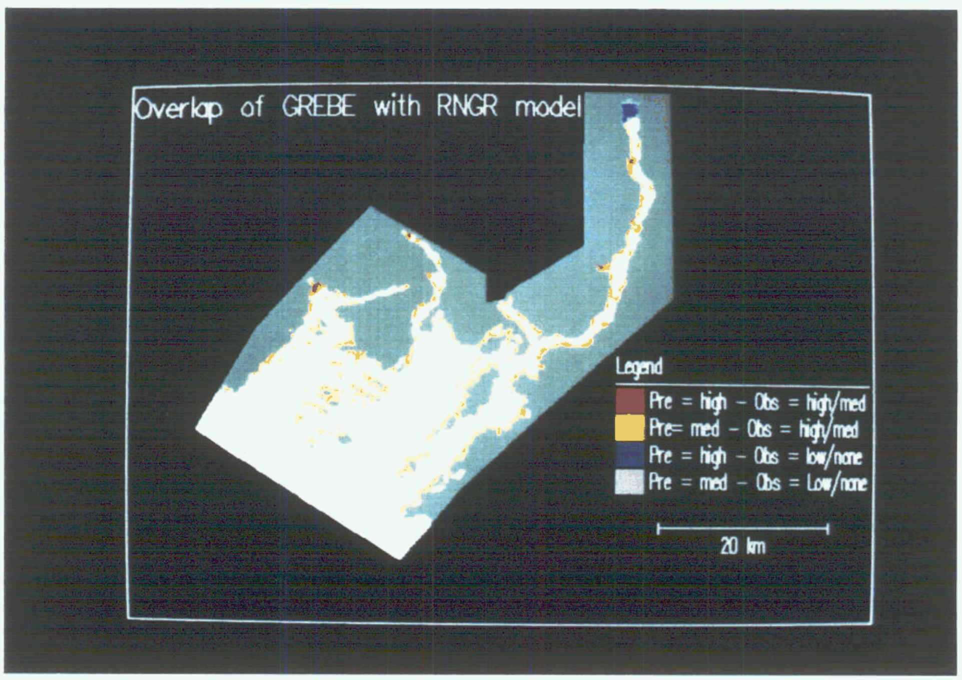






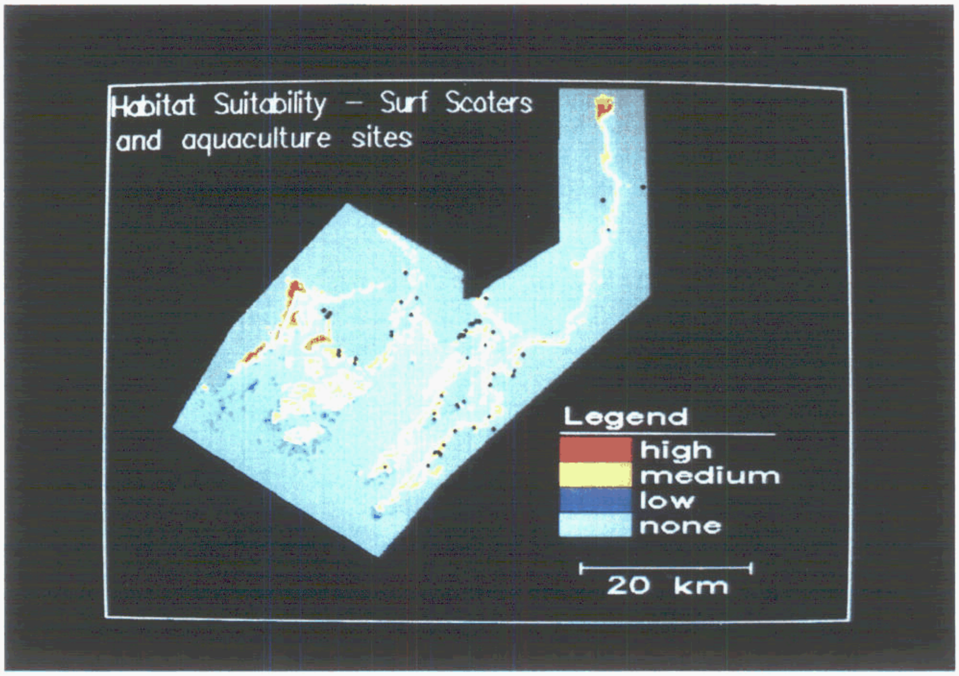
Map 13: Distribution of habitat variables in the Barkley Sound-Alberni Inlet region: d) herring spawning, e) eelgrass and kelp beds, and f) creek mouths and estuaries.



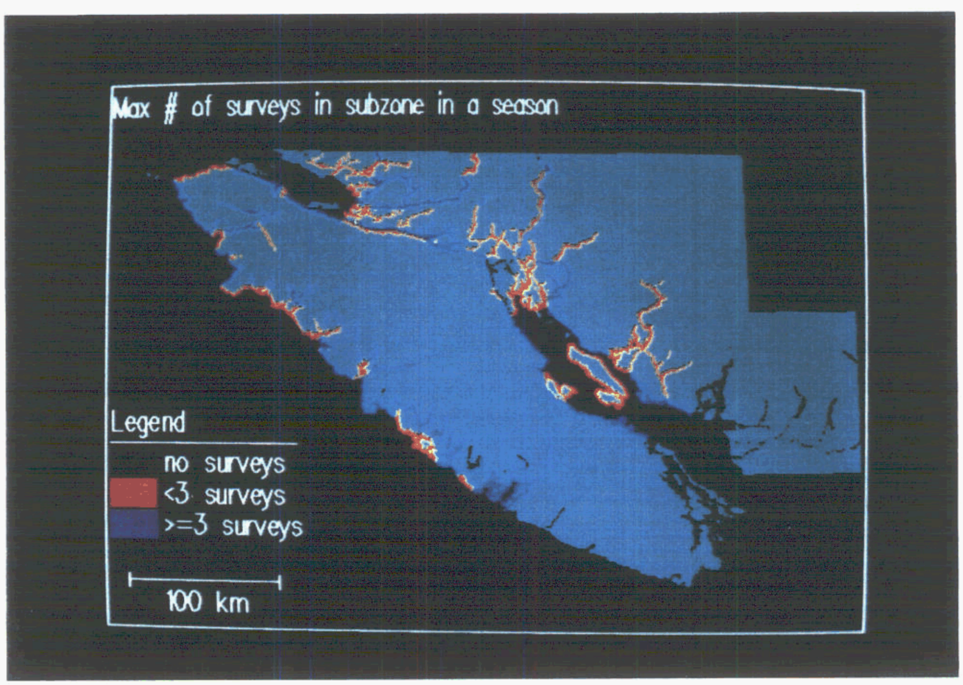


Map 14: Distribution of habitat classes and overlap with bird distribution for Horned and Red-necked* Grebe in the Barkley Sound-Alberni Inlet region.

*note: map title erroneously says "Ring-necked Grebe"



Map 15: Overlap of habitat classes for Surf Scoters with finfish and shellfish tenures in the Barkley Sound-Alberni Inlet region.



Map 16: CWIF survey coverage of the study area.