Copy

New Westminster 27th Septr 1863

Sir

Having heard that you were about going home I address you in the hope that you not leave without coming to some decision about my land as you are the person that understands the case before any one in the Colony and as it is of vital importance to me however insignificant it may seem to those that have the cares of a Colony to attend to I will enumerate a few of the most striking points

In June or July 1859 in company with one Red Head did settle upon a piece of land by directions and permission of you and planted vegetables for a market garden to supply the camp with vegetables when I came back and applied for to purchase it, it was not contradicted but the size of the piece only was disputed my application in writing is or was a short time ago in the Land office

In August 1859 I applied in writing to purchase the same according to terms of proclamation the same application in writing I lodged at the office of Lands and works

In January 1860 I registered my preemption claim to the same after taking the precaution of enquiring what was meant by Indian Settlements when I was referred to a letter from his Excellency the Governor where it stated that each Village was to have reserved 1000 acres to them and as there was considerable more than that already reserved on the maps and to make doubly sure I was advised to leave room for 1000 acres putting the house or dwelling in the centre of any Indian dwelling that was near I did so and have been in possession by residence ever since also in 1860 I complained personally to the Govenor in presence of yourself and others when you promised the Govenor that you would send a party of Royal Engineers down and survey my Land for me and put me in formal possession of it

Also your having sent a party of Royal Engineers with myself to assist down to survey my land consisting of

Corporal Conroy

privates Murry

J Shannon

Bowden and I believe

two others with instructions to leave sufficient room for 1000 acres wherever they saw any Indian living which they did by surveying my land by compass and chain slightly altering my original stakes after which after which I saw my land marked down in the official chart or what was then used as the official chart

Since then I have been repeatedly assured by yourself and other officials belonging to the Lands and Works that the Government does not require it for anything at the same time I am told my paying for it does not settle the question of ownership and latterly I have been greatly inconvenienced and put considerable loss by the delay in procuring a title deed my case being a very hard one having spent all my time and every farthing I have earned these four years on the improvement of it being an actual and bonafide settler with the object of residing and improving it to the end of my days never having yet offered it for sale believing you are the only man I can look to for redress I earnestly pray that you will give an early and favourable decision in order that I may be warranted in borrowing sufficient to bring my wife to it as a settled home

I remain your
humble obedient
servant
George Tranfield.

to Col Moody
Chief Commissioner
Lands and Works

Pemberton
$\frac{32}{556}$

Recd 4.10.64

Victoria Vancouver Island
3rd October 1864

Sir

Scotts claim at Chemainus

With respect to this enquiry we find that Scott took up the Land in question subject to the terms of a Letter from the Land Office of July 29th 1859 in which occurs the following proviso

"Provided further that none of "these persons shall occupy or allow "other persons to occupy Land in any "way improved fenced or cultivated "or at any time occupied by Indians "which likewise would entail forfeiture "similar to that above stated" (forfeiture for nonpayment of the price of the Land after survey)

Scott or those from whom he claims subsequently held on the terms of the Proclamation of 1861 which contains the following provision "That British subjects &c " shall pre-empt unsold crown Land " in the Districts of Victoria &c not " being an Indian Reserve or " Settlement &c"

Thus we think Scott was at all events liable to the rights of

The Hon:
The Acting Colonial Secretary

Indians wherever they could lay claim to a Settlement

We understand an Indian Settlement tobe not a permanent standing Village but such a Village or Home as Indians are accustomed to have and it appears tobe an understood custom with the Indians of this District as with many others to leave their Homes or Villages for months together taking their Houses with them

It is asserted on one side that no Settlement existed in 1859 on the portion now an Indian Reserve but has sprung up since, and on the other side that the portion of Land in question has always been an Indian Settlement in the Indian sense of the word, a place which the Indians looked on as their Home which they from time to time inhabited and it is conceded that no inhabited Houses actually stood on the spot when the Land was taken up

This fact of an Indian Settlement existing on the spot is one which we think can only be decided satisfactorily by the evidence of reliable Indians of the tribe or White men who have known the spot for some years and more particularly by a careful examination of the spot itself which to the eye of one experienced in Indian matters will we are told bear indisputable evidence of continued occupation and residence if such there ever were for any lengthened period of time even before 1859.

We think that Scott must submit to be deprived of so much of his Land as can be shown to come within what we consider to be the reasonable meaning of an "Indian Settlement" as explained above.

We have the Honor to be
Sir
Your most Obedient Servants
Thos. L. Wood Acting Attorney [General]
J. D. Pemberton Surveyor General
[illegible] Watson. Treasurer

M 100/1102

This Report leaves the Question where it was before — ask the Actg Surveyor Genl how he proposes to have these facts ascertained & settle the Matter
[illegible] Oct 4/64

Forwarded to the Acting Surveyor General accordingly
Henry Wakeford
Acting Colonial Secretary
4. 10-64

(To be returned)

Sarulld.

I would respectfully suggest that Mr. Scott be offered the sum of Two Hundred dollars ($200.) as Compensation for Work (clearing &c.) done, in error, by him on Indian Lands at Chemainus. This sum more than represents the actual labor expended on the Land in question, ~~which, from all I can~~ learn, consisted of clearing 2 or 2½ acres of Willow bush. Mr. Scott should have known that the Land was in the possession of the Indians.

B. W. Pearse
Actg. Surveyor Genl.
5th Oct. 1864.

The Honble.
The Actg. Colonial Secretary

Inform Mr. ~~Scott to this purport~~
A.G.Y. Oct. 6/64

Done H.W. 6.10.64

R 32/5576 October 3rd. 1864
Report on Scott's Claim to land at Chemainus.

THE BRITISH COLUMBIA HISTORICAL QUARTERLY

APRIL, 1937

The
BRITISH COLUMBIA HISTORICAL QUARTERLY

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The
BRITISH COLUMBIA HISTORICAL QUARTERLY

VOL. I. APRIL, 1937. No. 2

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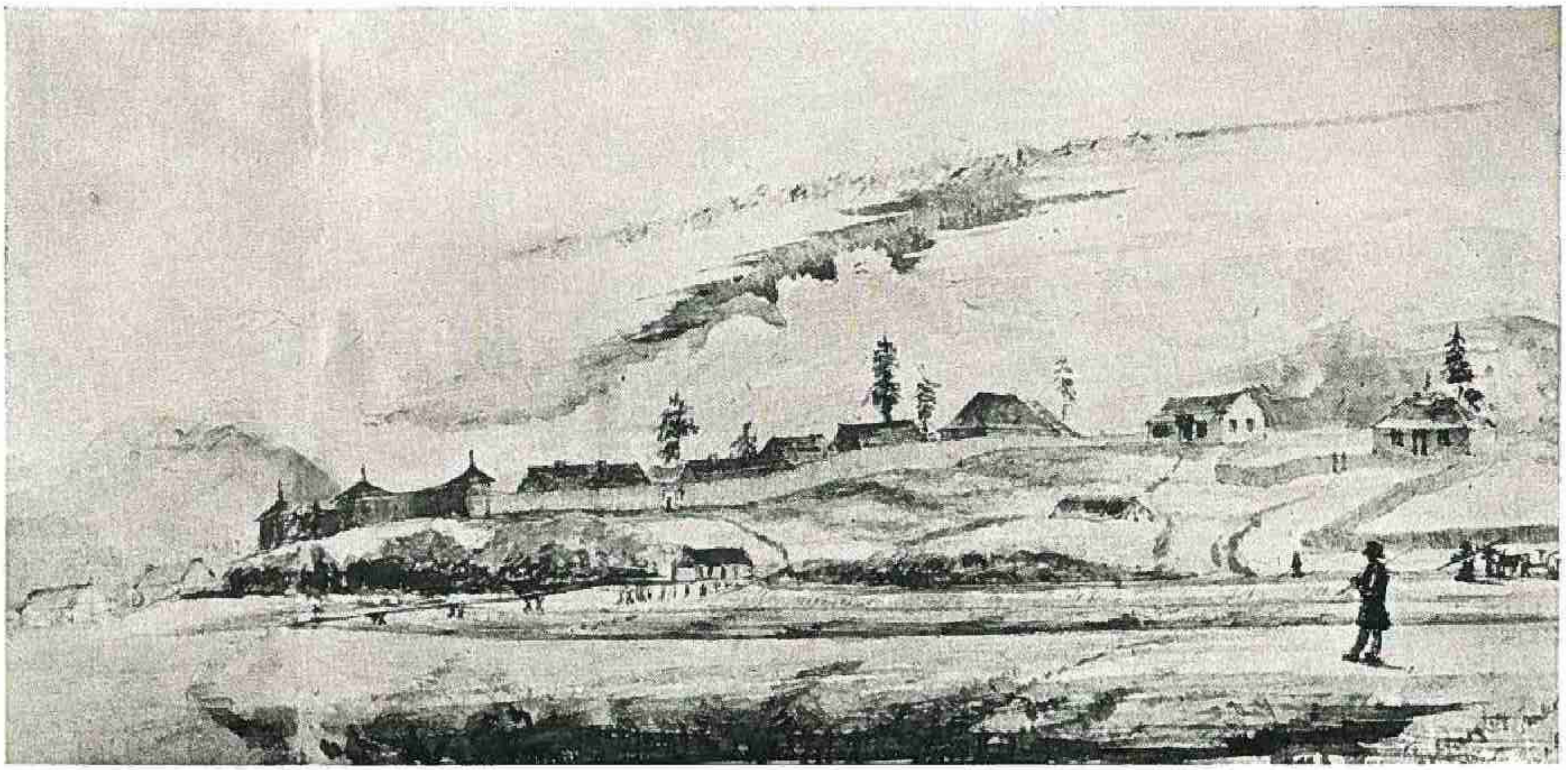
"Any country worthy of a future should be interested in its past."



Fort Langley, north view. From an original drawing made in 1859 by E. Mallandaine.

EARLY DAYS AT OLD FORT LANGLEY.

*Economic Beginnings in British Columbia.**

Agriculture, the salmon fishery, and the foreign commerce of British Columbia had their origin and early development in the almost forgotten settlement of Fort Langley on the Lower Fraser River, during the years 1827 to 1864.

This was not the first settlement in the Province. The Spaniards settled at Nootka in 1789. But there were disputes between England and Spain as to the ownership of Vancouver Island, which ended in 1795 by the Spanish Commander Manuel de Alava destroying the buildings which his countrymen had erected, and transferring possession to Sir Thomas Pearce, the English representative.[1] The place reverted to the Indians, and though for years after fur-traders resorted there for otter skins, it ceased to be an outpost of civilization. Hudson's Bay posts were established in the interior before Fort Langley was built, but they were carried on merely for the fur trade.

Some twenty years after the abandonment of Nootka, European civilization began again on the Columbia River. From that point, Hudson's Bay traders explored the country to the north, and in 1827, Fort Langley, on the Fraser, came into existence.

Up to the present time little has been known of the early activities of the company at Fort Langley, especially from 1830 to 1843. Thanks to the courtesy of the Hudson's Bay Company, in London, and the kind assistance of Mr. Leveson Gower, the archivist, and Mr. J. Chadwick Brooks, the secretary, much new material dealing with this period has been made available, and permission given for its use. This will be referred to here, with dates, as " H.B. Archives." It is proposed in this paper to deal shortly with matters which have been hitherto available to students, and in greater detail with the new material.

In 1824, George Simpson, one of the Hudson's Bay Co.'s governors in North America, first visited the Pacific Coast. He

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* A paper read at the May, 1936, meeting of the Royal Society of Canada. Reprinted by permission from the *Transactions* of the Society, Section II., 1936, pp. 89–102.

(1) Manning, *Nootka Sound Controversy* (Am. Hist. Assn. Rept., 1904, p. 471).

NEWS RELEASE
COMMUNIQUÉ

NR-PR-92-27E

FOR IMMEDIATE RELEASE
December 7, 1992

AFS PACIFIC COMMERCIAL LICENCE RETIREMENT PROGRAM

VANCOUVER -- John C. Crosbie, Minister of Fisheries and Oceans, today announced a pilot retirement program for full fee Pacific commercial fishing licences under the Federal Aboriginal fisheries strategy (AFS). The purpose of the program is to test ways of reducing catching power in the commercial fleet so that fishing opportunities for commercial operators will not be affected when fishing opportunities are transferred to Aboriginal groups. Up to $7 million dollars will be available over the next year for adjustment payments to licencees who agree to have their licences retired.

The program is based on the recommendations of the B.C. Fisheries Commission (BCFC), an organization representing commercial fishing interests from the seine, gillnet and troll sectors, recreational fishermen and the United Fishermen and Allied Workers Union (UFAWU). The BCFC received funding under the AFS to facilitate consultations with fishing interests and develop proposals for a licence retirement program.

Licence retirements will be voluntary. Later this month, current licence holders will be invited to submit proposals for payments which they would require if their licence was retired. The Department of Fisheries and Oceans will accept those proposals which represent a fair and cost-effective retirement of catching capacity. The Department will be advised by a Licence Retirement Selection Committee composed of representatives of commercial fishing interests and Aboriginal peoples.

Catching power retired under the pilot program will represent "reallocation credits" necessary to transfer a like number of sockeye to the Aboriginal fishery. The effects of allocation transfers on actual catches for remaining commercial fishery participants will be reviewed after the completion of the pilot program to determine whether and how a larger program should be implemented.

.../2

The main features of the pilot program:

- Full fee licence holders will be invited to submit retirement proposals to a DFO-appointed program administrator.
- Only licences will be retired. Licencees will retain their vessels and gear.
- A Licence Retirement Selection Committee composed of the UFAWU and gear sector representatives from the BCFC and representatives selected by the Aboriginal leadership will advise on proposals and make recommendations on acceptance to the DFO program administrator.
- Assessment of retirement proposals will occur every two weeks during the duration of the pilot program. A longer period will be allowed for submission of proposals before the first assessment and acceptence of any proposals.
- DFO will not be obligated to accept all or any of the proposals received during any period.
- There will be no negotiating with applicants. Proposals received during each period will be either accepted or rejected as submitted. Unsuccessful applicants may submit new proposals at any time.
- The primary criterion for acceptance of proposals will be lowest cost per sockeye equivalent of licenced catching power retired.
- Catching power will be calculated as average annual catch, in sockeye equivalents, for the gear type and vessel length licenced, over the previous four years.
- Secondary criteria, such as length of time in the fishery--with preference for long-term fishermen--may be applied to decide among proposals which are tied on the primary criteria.
- Acceptance of proposals may be adjusted to maintain balance in retirements across gear sectors, should this measure be deemed appropriate during the conduct of the program.

The program will commence by the end of December and will run until the earlier of next spring or until the available funds are expended.

.../3

Mr. Crosbie cited the program as a concrete example of the government's commitment to working with all interested parties to ensure fair and equitable treatment for all stakeholders as DFO establishes a new relationship with Canada's Native peoples through the Aboriginal fisheries strategy.

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For information:

Michelle James
Chief, Economic and
Commercial Analysis
Fisheries and Oceans
Vancouver, B.C.
(604) 666-3866

NEWS RELEASE
COMMUNIQUE

NR-PR-93-08E

FOR IMMEDIATE RELEASE
February 24, 1993

CROSBIE ANNOUNCES ALL-PARTY BOARD

VANCOUVER – Representatives of all sectors in British Columbia's fisheries agreed Tuesday to establish a new high-level body to advise the federal government on Aboriginal fisheries policy and to be kept informed on all aspects of the policy and agreements reached.

At an all-day meeting chaired by John C. Crosbie, Minister of Fisheries and Oceans, leaders of commercial, recreational and Aboriginal groups established the general lines of an advisory and consultative board to be established immediately.

The first meeting of the new body will be held within the next two weeks. One of the agenda items will be a detailed plan to complement the new board's policy-advice role with a series of regional groups to advise on implementation at the local level.

"I am encouraged by the constructive attitude expressed on all sides today," Mr. Crosbie said.

"We have made progress in establishing effective mechanisms to achieve real dialogue from now on among all players. Everyone shares our basic objective, which is to meet society's obligations to Native people within a stable, profitable and predictable industry."

The new board will:

- provide advice on how to meet objectives of the government's Aboriginal Fisheries Strategy and on the strategy's further development and implementation;
- consist of about 25 members representing all sectors, and a smaller number of executive directors to provide overall guidance to the board's activities;
- be served by a permanent secretariat which will organize meetings, coordinate information exchanges among all parties and follow up between meetings.

.../2

Mr. Crosbie said Tuesday's meeting received reports on current negotiations with Native groups under the Aboriginal Fisheries Strategy, and plans to improve monitoring and enforcement programs this year. A representative of the Government of B.C. also attended the meeting.

-30-

For more information:

Patrick S. Chamut
Regional Director General
Department of Fisheries and Oceans

(604) 666-6098

Bulletin

DEPARTMENT OF FISHERIES AND OCEANS

POLICY FOR

THE MANAGEMENT OF ABORIGINAL FISHING

POLITIQUE DU MINISTÈRE DES PÊCHES ET DES OCÉANS

SUR LA GESTION DES PÊCHES AUTOCHTONES

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A. PURPOSE

This policy provides principles and procedural guidelines for DFO's management of Aboriginal fishing reflecting the Department of Fisheries and Oceans' (DFO) Aboriginal Fisheries Strategy (AFS) and the current state of the law on Aboriginal fishing rights, particularly the decision of the Supreme Court of Canada in the Sparrow case. The policy applies to all species of fish.

B. POLICY

1. Aboriginal Fishing

Taking into account the current state of the law on Aboriginal fishing rights, DFO has adopted the following policies related to Aboriginal fishing:

a) Aboriginal fishing should occur within the areas that were used historically by the aboriginal group or First Nation.

b) Aboriginal fishing opportunities will be provided to the First Nation having historical use and occupancy of the area in question. The First Nation will administer the fishing opportunities for the benefit of its members collectively rather than individually.

c) Aboriginal fishing for food, social and ceremonial purposes will have first priority, after conservation, over other user groups. Aboriginal fishing for such purposes will only be restricted to achieve a valid conservation objective, to provide for sufficient food fish for other Aboriginal

A. OBJET

Énoncer les principes et lignes directrices qui sous-tendent la gestion des pêches autochtones du Ministère des Pêches et des Océans (MPO) à la lumière de l'état du droit en matière de droits de pêche Autochtones, et plus particulièrement en égard à la décision rendue par la Cour suprême du Canada dans l'affaire Sparrow et à la Stratégie relative aux pêches autochtones (SRAPA) du MPO. La politique s'applique à toutes les espèces de poisson.

B. POLITIQUE

1. Pêche autochtone

Considérant l'état du droit en matière de droits de pêche autochtones, le MPO fait siennes les orientations suivantes relative aux pêches autochtones:

a) La pêche autochtone devrait être pratiquée dans les zones historiquement utilisées par le groupe autochtone ou la Première nation concernée.

b) La possibilité de pratiquer la pêche autochtone dans une zone est accordée à la Première nation (et non pas directement à des individus) qui a utilisé et occupé historiquement cette zone. La Première nation doit administrer cette possibilité au profit de ses membres.

c) La pêche autochtone à des fins alimentaires, sociales et rituelles a priorité, après la conservation, sur toute autre utilisation. On ne peut restreindre ce type de pêche que pour des motifs valables de conservation, pour laisser suffisamment de poissons comestibles aux autres groupes

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people, to achieve a valid health and safety objective, or to achieve other substantial and compelling objectives.

2. Regulation of Aboriginal Fishing

DFO will provide for the management of Aboriginal fishing which includes, but may not be limited to, fishing for food, social and ceremonial purposes, in the following ways:

a) Where necessary to ensure that the total harvest by all harvesters of a fish stock does not exceed the conservation limit, Aboriginal fishing will be conducted under the authority of a Communal Licence issued under the Fisheries Act.

b) DFO shall endeavour to negotiate with the representatives of First Nations, mutually agreeable arrangements for Aboriginal fishing, such arrangements to be described in Aboriginal fishing agreements under the AFS.

c) Where agreement cannot be reached on the management of Aboriginal fishing, DFO shall provide a First Nation with access to fish for food, social and ceremonial purposes through a Communal Licence, imposing only such restrictive conditions as are necessary to achieve a valid conservation objective, to provide sufficient food fish for other First Nations, to achieve a valid health and safety objective, or to achieve other substantial and compelling

autochtones, pour des motifs de santé ou de sécurité ou pour réaliser d'autres objectifs tangibles et primordiaux.

2. Réglementation des pêches autochtones

Le MPO établira un processus de gestion des pêches autochtones qui inclura la pêche à des fins alimentaires, sociales et rituelles, mais s'en y être limité, en se basant sur les modalités suivantes:

a) Là où il est nécessaire, pour s'assurer que le total des prises récoltées par tous ceux qui pêchent un stock donné ne dépasse pas la limite de conservation, la pêche autochtone sera pratiquée en vertu d'un permis communautaire délivré en vertu de l'application de la Loi sur les pêches.

b) Par négociation avec les représentants des Premières nations, le MPO s'efforce d'assujettir la pêche autochtone à des ententes mutuellement acceptables, qui doivent être incluses dans les ententes de pêches autochtones découlant de la SRAPA.

c) En cas de désaccord sur la gestion des pêches autochtones, le MPO délivre à la Première nation un permis communautaire autorisant la pêche à des fins alimentaires, sociales et rituelles, en ne restreignant cette pêche que pour des motifs valables de conservation, pour laisser suffisamment de poissons comestibles aux autres groupes autochtones, pour des motifs de santé ou de sécurité ou pour réaliser d'autres objectifs tangibles et primordiaux.

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objectives.

d) Aboriginal fishing agreements will define and establish **Aboriginal Fishing Authorities** which will be responsible for managing fishing under the Agreements, in cooperation with DFO, according to the terms of the Agreements.

e) Aboriginal Fishing Authorities will be responsible for:

i) designating individuals to fish under allocations made to a First Nation;

ii) providing individuals designated to fish under allocations made to a First Nation with suitable evidence of the nature and extent of their designation;

iii) monitoring and reporting to DFO on harvests; and

iv) participating in enforcement.

f) Aboriginal Fishing Authorities will carry out monitoring and enforcement activities by means of Native Guardians who will be employed by the First Nation, trained through programs offered by DFO and designated as Fishery Guardians under the Fisheries Act. The duties of Guardians will be described in Guardian Subagreements which will accompany Aboriginal Fishing Agreements.

g) Aboriginal Fishing Agreements

d) Les Ententes de pêches autochtones doivent définir et constituer les **Administrations de pêches autochtones** qui seront chargées de gérer, en collaboration avec le MPO, les activités halieutiques découlant de ces ententes.

e) Les administrations de pêches autochtones seront responsable de:

i) désigner les individus habilités à pêcher les allocations accordées à la Première nation concernée;

ii) fournir aux individus désignés une preuve adéquate de la nature et de l'étendue de cette désignation;

iii) surveiller les prises et faire rapport au MPO; et

iv) participer à l'application de la réglementation.

f) Les administrations de pêches autochtones exercent leurs responsabilités de surveillance et d'application des règlements par l'entremise de gardes-pêche autochtones qui seront employer par la Première nation, formés au moyen de programmes du MPO et désignés gardes-pêche au sens de la Loi sur les pêches. Les ententes de pêches autochtones doivent être accompagnés d'ententes auxiliaires énonçant les fonctions de ces gardes-pêche.

g) Les ententes de pêches

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will be without prejudice to the position of either party with respect to Aboriginal and treaty rights.

h) Aboriginal Fishing Authorities may be funded in whole or in part through Contribution Agreements.

i) The terms and conditions of a Communal Licence will require the First Nation to:

i) designate individuals to fish within the First Nation's allocation;

ii) provide individuals designated to fish under allocations made to a First Nation with suitable evidence of the nature and extent of their authorization; and

iii) monitor and report to DFO on its harvest.

j) Persons fishing under the authority of a communal licence must provide proof of designation by the Aboriginal Fishing Authority identified in the Licence in the form specified in the licence.

3. <u>Definition of Aboriginal Fishing</u>

a) In this policy, Aboriginal fishing means fishing under the authority of a Communal Licence issued pursuant to the Aboriginal Communal Fishing Licences Regulations under the <u>Fisheries Act</u>.

b) Aboriginal fishing under a

autochtones ne doivent aucunement porter atteinte à la position de l'une ou l'autre partie concernant les droits ancestraux ou issus de traités.

h) Le financement des administrations de pêches autochtones peut provenir en partie ou en totalité d'ententes de contribution.

i) Le permis communautaire impose les termes et conditions suivantes à la Première nation:

i) désigner les individus habilités à pêcher les allocations attribuées à la Première nation;

ii) fournir aux individus désignés une preuve adéquate de la nature et de l'étendue de cette désignation; et

iii) récolter les données sur la pêche et en faire rapport au MPO.

j) Les personnes pratiquant la pêche en vertu d'un permis communautaire doivent démontrer (selon les modalités prévues au permis) qu'elles ont été ainsi habilitées par l'administration de pêches autochtones.

3. <u>Définition de la pêche autochtone</u>

a) Dans la présente politique, "pêche autochtone" s'entend de la pêche pratiquée en vertu d'un permis communautaire délivré sous le régime de la réglementation afférente à la <u>Loi sur les pêches</u>.

b) La pêche autochtone pratiquée

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Communal Licence includes fishing for food, social and ceremonial purposes. In a limited number of cases, it also may include fishing for sale under test sale projects negotiated as part of an Aboriginal Fishing Agreement. The terms of the Communal Licence will set out the extent of the authority of the Aboriginal group to fish.

c) In the absence of an Aboriginal Fishing Agreement, all Aboriginal fishing under a Communal Licence will be limited to fishing for food, social and ceremonial purposes.

4. <u>Issuance of Food Fish Permits to Individuals</u>

As stated in an announcement by the Minister of Fisheries and Oceans in December 1992, and in response to the report on the Pearse Investigation regarding management of sockeye salmon returns on the Fraser River in 1992, food fish permits will no longer be issued to individuals.

5. <u>Identification of First Nations for the Purpose of Establishing Aboriginal Fishing Authorities</u>

a) For the purposes of this policy "First Nation" includes any organization which represents a group of Aboriginal people who have continuously used the fisheries resource in the area in question from pre-European contact to the coming into effect of the <u>Constitution Act, 1982</u>. Such organizations include groups representing Indians registered or entitled

en vertu d'un permis communautaire comprend la pêche à des fins alimentaires, sociales et rituelles. Dans certains cas, la pêche peut avoir un but commercial si elle s'insère dans un projet pilote négocié en marge d'un entente de pêches autochtones. Les conditions du permis communautaire préciseront l'étendue de l'autorisation conférée au groupe autochtone.

c) En l'absence d'entente de pêches autochtones, la pêche autochtone pratiquée en vertu d'un permis communautaire sera limitée à des fins alimentaires, sociales et rituelles.

4. <u>Délivrance de permis individuels de pêche alimentaire</u>

Conformément à l'annonce faite en décembre 1992 par le ministre des Pêches et des Océans à la suite de la publication du rapport de la Commission d'enquête Pearse sur la gestion des remontes de saumon rouge dans le fleuve Fraser, aucun permis individuel de pêche alimentaire ne sera délivré.

5. <u>Définition de "Première nation" aux fins de l'établissement des administrations de pêches autochtones</u>

a) Pour l'application de la présente politique, "Première nation" désigne toute organisation représentant un groupe d'autochtones (Indiens inscrits ou habilités à être insqrits en vertu de la <u>Loi sur les Indiens</u>, Inuits, Indiens non inscrits et métis) qui ont utilisé de façon continue les ressources halieutiques d'une zone depuis l'époque présédant

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to be registered under the Indian Act, Inuit, non-status Indians and Métis. DFO may require that a First Nation produce evidence of historical use of the resource in an area.

b) First Nations will be responsible for identifying the organization that is to represent them during negotiations on Aboriginal Fishing Agreements and are encouraged to form tribal, regional or watershed based Aboriginal Fishing Authorities for the purposes of negotiations and to administer Aboriginal Fishing Agreements.

c) Where the members of an Indian Band are not known to be represented in negotiations through a First Nation or organization of First Nations, DFO shall request that the Band Council identify a group which represents the Aboriginal fishing interest of its members. If no such group is identified, DFO will initiate negotiations with the Band Council.

d) This policy does not apply where a Comprehensive Land Claim Agreement is in place.

e) Consultations between DFO and Indian Bands that have established fishing by-laws are encouraged to improve the management of the fishery resource.

l'arriver des européens jusqu'à l'entrée en vigueur de la Loi constitutionnelle de 1982. Le MPO peut exiger d'une Première nation la preuve de l'utilisation historique des ressources dans cette zone.

b) Il incombe aux Premières nations de déterminer quelle organisation parlera en leur nom durant les négociations sur les ententes de pêches autochtones, et, en vue de la négociation ou de la mise en oeuvre de ces ententes, on les encourage à former des administrations de pêches autochtones représentant une tribu, une région ou un bassin versant.

c) Quand il n'est pas établis que les membres d'une bande indienne sont représentés aux négociations par une Première nation ou une organisation de Premières nations, le MPO demandera au conseil de la bande indienne de désigner un groupe représentant les intérêts de ses membres en matière de pêches autochtones. Si aucun groupe n'est désigné, le MPO entamera des négociations avec le conseil de bande.

d) La présente politique ne s'applique pas là où une entente de règlement d'une revendication territoriale globale est conclue.

e) Pour mieux gérer les ressources halieutiques, on encourage les consultations entre le MPO et les bandes qui se sont dotées de règlements de pêche.

Bulletin

6. <u>Consultations and Negotiations</u>

a) DFO shall consult with Aboriginal people before taking decisions or actions that may affect Aboriginal fishing for food, social and ceremonial purposes.

b) During 1993, negotiations under the Aboriginal Fisheries Strategy will focus on attaining Aboriginal Fishing Agreements with First Nations that have not signed agreements under the Comprehensive Land Claims Policy, in areas where DFO administers fisheries.

c) DFO will also attempt to negotiate **Watershed Framework Agreements** with all First Nations which share the Fraser and **Skeena** watersheds. These agreements will provide for structures which will coordinate the fisheries management and enforcement activities of DFO and signatory First Nations on a watershed basis.

d) DFO shall make reasonable efforts to conclude an Aboriginal Fishing Agreement with a First Nation prior to issuing a Communal Licence. Where an Aboriginal Fishing Agreement is signed, the Communal Licence will reflect the allocation and terms and conditions contained in the agreement.

e) In some cases, where it is not feasible because of time limitations or for other reasons, to negotiate an Aboriginal Fishing Agreement, the terms and conditions of a

6. <u>Consultations et négociations</u>

a) Le MPO doit consulter les autochtones avant de prendre toute décision ou mesure pouvant toucher la pêche autochtone pratiquée à des fins alimentaires, sociales et rituelles.

b) En 1993, les négociations afférentes à la SRAPA viseront d'abord la conclusion d'ententes de pêches autochtones dans les zones où le MPO gère les pêches avec des Premières nations qui n'ont pas signé d'entente découlant de la Politique sur les revendications territoriales globales.

c) Le MPO s'efforcera également de négocier, avec toutes les Premières nations qui se partagent les bassins versants de la rivière **Fraser** et de la rivière **Skeena**, des ententes cadres visant à coordonner à l'échelle de chaque bassin versant, les activités de gestion et d'application des règlements signés entre le MPO et les Premières nations.

d) Avant de délivrer un permis communautaire, le MPO doit faire un effort raisonnable pour conclure une entente de pêches autochtones avec la Première nation. Lorsqu'une telle entente est signée, le permis communautaire s'y afférent, reflètera l'allocation et les conditions prévues dans l'entente.

e) S'il est impossible de négocier une entente de pêches autochtones par manque de temps ou pour une autre raison, on peut négocier les conditions du permis communautaire sans

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Communal Licence may be negotiated without developing an Agreement.

f) Where it is not possible to reach agreement on an allocation or another term or condition of a communal licence, DFO shall issue a Communal Licence to the First Nation for food, social and ceremonial purposes. The allocation contained in such a Communal Licence shall reflect the last offer made by DFO before termination of negotiations with respect to allocations for these purposes.

g) DFO shall communicate openly with the commercial and recreational fishing sectors and other interested parties, regarding the government's policies with respect to Aboriginal fishing.

7. <u>Aboriginal Fishing Allocations</u>

a) DFO shall give first priority of access to fish, after conservation needs are met, to Aboriginal people to meet their needs for food, social and ceremonial purposes, to the extent possible given the availability of fisheries resources within areas used historically by the group. DFO will provide for such needs through Aboriginal Fishing Agreements and Communal Licences with First Nations.

b) DFO will consult with respect to allocations. Information on community size (including but not necessarily limited to band membership), recent food

conclure d'entente.

f) En cas de désaccord sur l'allocation ou une autre condition du permis communautaire, le MPO délivre à la Première nation un permis communautaire de pêche à des fins alimentaires, sociales et rituelles, où l'allocation correspondera à la dernière offre présentée par le MPO avant la fin des négociations.

g) Le MPO doit entretenir des communications franches avec les pêcheurs commerciaux et sportifs, ainsi qu'avec les autres parties intéressées, en ce qui concerne la politique du MPO sur la gestion des pêches autochtones.

7. <u>Allocations pour les pêches autochtones</u>

a) Une fois que les exigences de conservation sont respectées, la priorité d'accès aux ressources halieutiques est accordée aux autochtones pour des fins alimentaires, sociales et rituelles; pour ce faire, dans la mesure permise par l'abondance du stock de poisson dans les zones utilisés historiquement par le groupe, le MPO conclut des ententes de pêches autochtones avec les Premières nations et leur délivre des permis communautaires.

b) Le MPO consultera les intéressés pour établir les allocations. En vue de déterminer les besoins alimentaires des membres de la

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fishery harvests, trends in such harvests, current food preferences and use and availability of other foods may be used to establish the reasonable food requirements of members of the community represented by the First Nation.

c) Allocations may also provide fish for sale under pilot projects. Allocations for commercial purposes may be expressed as a percentage of the allowed catch from a particular stock.

d) Agreements providing for pilot projects related to sale will include monitoring and enforcement provisions designed to prevent illegal sale, to keep the fishery within its allocation and to maintain the quality of any products entering the market.

e) Agreements containing pilot project sale provisions shall include a provision requiring the Aboriginal Fishing Authority to acknowledge that it has consulted with the members of the Aboriginal community it represents and confirms on their behalf that the allocation includes any allocation needed for food, social and ceremonial purposes during the term of the agreement.

collectivité représentée par la Première nation, en égard à leurs préférences alimentaires actuelles ainsi qu'à l'utilisation et à la disponibilité d'autres sources de nourriture, on peut recourir à des informations sur la taille de la collectivité (notamment la population de la bande), le volume récent et l'évolution des prises de poisson comestible.

c) Les allocations peuvent également prévoir les prises de poisson à des fins commerciales dans le cadre de projets pilotes. La quantité autorisée à de telles fins commerciales peut être exprimée sous forme d'un certain pourcentage des prises permises pour un stock donné.

d) Les ententes relatives à de tels projets pilotes de vente de poisson devront comprendre des clauses sur les activités de surveillance et d'application des règlements, de manière à empêcher les ventes illégales, à faire respecter l'allocation prévue et à préserver la qualité des produits mis en marché.

e) Les ententes relatives aux projets pilotes de vente de poisson devront comprendre une clause par laquelle l'administration de pêche autochtone reconnaît avoir consulté les membres de la collectivité autochtone qu'elle représente et confirme, en leur nom, que l'allocation englobe toute allocation requise à des fins alimentaires, sociales et rituelles durant la période de l'entente.

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8. **Provisions of Watershed Framework Agreements**

8.1 The migratory nature of salmon demands that some management issues can only be effectively addressed through coordination of the management efforts of all First Nations sharing a watershed. Therefore, Watershed Framework Agreements should contain:

a) a list of First Nations with whom DFO will negotiate Aboriginal Fishing Agreements and the fishing area to be covered by each agreement;

b) the types of fishery management provisions to be included in agreements with individual First Nations and understandings on enforcement as well as sanctions to be employed for violation of agreements;

c) monitoring and enforcement plans to coordinate the efforts of all Aboriginal Fishing Authorities and of DFO for all parts of the river;

d) a mechanism for the establishment of fishing plans to ensure that the total harvest from each stock does not exceed the number of fish made available in the river, after allowing for spawning escapements;

e) a mechanism for in-season modification of these plans as information on run sizes, catches and timing becomes available; and

8. **Modalités des ententes cadres de gestion par bassin versant**

8.1 Vu l'activité migratoire du saumon, certains problèmes de gestion exigent une action coordonnée de toutes les Premières nations partageant un même bassin versant. Par conséquent, les ententes de gestion doivent contenir les éléments suivants:

a) une liste des Premières nations avec lesquelles le MPO négociera des ententes de pêches autochtones, ainsi qu'une description de la zone de pêche couverte par chaque entente;

b) les types de clauses de gestion halieutique devant figurer dans les ententes négociées avec chaque Première nation, et des ententes sur les mesures d'application des règlements et sur les sanctions prévues en cas d'inobservation des ententes;

c) des plans d'application des règlements et de surveillance, pour coordonner l'activité déployée par toutes les administrations de pêches autochtones et le MPO dans l'ensemble des rivières;

d) un mécanisme pour l'établissement de plans de pêche, afin que l'ensemble des prises pour chaque stock ne dépasse pas le nombre de poissons disponibles dans les rivières en question prenant en considération la remonté;

e) un mécanisme permettant de modifier ces plans durant la saison à mesure que l'on obtient des données sur l'importance des montaisons,

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leurs dates et le volume des prises; et

f) a dispute resolution mechanism.

f) un mécanisme de règlement des différends.

8.2 Although the mechanisms for accomplishing these management functions will be established through negotiation, the recommended approach would include two committees:

8.2 Même si les mécanismes ainsi requis seront établis par négociation, on recommande d'établir deux comités:

a) a Fisheries Planning Committee which would:

i) coordinate the development of fishing plans to be included in agreements with First Nations; and

ii) provide recommendations on in-season modification of those plans based on monitoring results and other information provided by DFO.

a) un Comité de planification des pêches, chargé:

i) de coordonner l'élaboration des plans de pêche devant figurer dans les ententes avec les Premières nations; et

ii) de formuler des recommandations sur les modifications à apporter à ces plans durant la saison de pêche, selon les données de surveillance et les autres informations fournies par le MPO.

b) a Monitoring and Enforcement Committee which would:

i) suggest standard monitoring and enforcement provisions which could be included in agreements with individual First Nations;

ii) develop plans for the coordination of the monitoring and enforcement activities of Aboriginal Fishing Authorities and DFO;

b) un Comité de surveillance et d'application des règlements, chargé:

i) de recommander des clauses normalisées en matière de surveillance et d'application, qui pourront être incluses dans les ententes négociées avec les diverses Premières nations;

ii) d'élaborer des plans pour la coordination des activités de surveillance et d'application exercées par les administrations de pêches autochtones et le MPO;

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iii) coordinate monitoring and enforcement activities in-season;

iv) provide information and advice to the Fisheries Planning Committee; and

v) generally act as a clearing house for exchange of information between DFO and First Nation Fishing Authorities.

9. Provisions of Aboriginal Fishing Agreements and Communal Licences

9.1 Allocations, Designations and Monitoring

a) To ensure conservation, all Aboriginal Fishing Agreements and Communal licences shall, as a minimum, contain the following provisions or terms and conditions:

i) An allocation to the Aboriginal fishery for each species or stock to be fished for which other fisheries have "limited access" or are "quota-limited".

ii) Provision for the designation of individuals by the Aboriginal Fishing Authority to fish under the Agreement or Licence.

iii) A form of identification to be carried by all designated individuals to evidence their authority to fish.

iii) de coordonner les activités de surveillance et d'application durant la saison de pêche;

iv) d'informer et de conseiller le Comité de planification des pêches; et

v) de servir de plaque tournante pour l'échange d'information entre le MPO et les administration de pêches autochtones.

9. Modalités des ententes de pêches autochtones et des permis communautaires

9.1 Allocations, désignation et surveillance

a) Pour assurer la conservation de la ressource, tous les ententes de pêches autochtones et les permis communautaires doivent, au minimum, être assortis de clauses ou conditions sur les points suivants:

i) Une allocation de pêche autochtone pour chaque espèce ou stock faisant l'objet d'une limitation d'accès ou d'un contingentement.

ii) Désignation, par l'administration de pêches autochtones, des individus habilités à pêcher en vertu de l'entente ou du permis.

iii) Nature d'une la pièce d'identification devant être portée par tous les individus ainsi désignés, pour attester de leur droit de pêche.

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iv) Provision for monitoring, by the Aboriginal Fishing Authority in cooperation with DFO, of the catch by designated individuals sufficient to ensure that the aggregate harvest does not exceed the allocation.

v) A maximum limit on the number of individuals who may be designated to fish and on the type and amount of gear to be used by those individuals.

9.2 Fishing Plans

Where conservation of the stock requires control over fishing places or times (fishing plans), in addition to control over total harvest, Aboriginal Fishing Agreements and Communal Licences also may contain limits on fishing times and locations to the extent necessary to coordinate fishing under the Agreement or Licence with other fishing and to ensure conservation of stocks.

9.3 In-season Management

An Aboriginal fisheries agreement shall set out procedures for in-season modification of allocations and fishing plans as may be necessary to ensure conservation of stocks. Such procedures shall include consultation with the affected group but will preserve the discretion of the Minister or his delegate to modify times for conservation purposes.

iv) Mise en place par l'administration de pêches autochtones, en collaboration avec le MPO, de mesures de surveillance des prises capturées par les individus désignés, pour assurer que le total des prises ne dépasse pas l'allocation.

v) Limitation du nombre d'individus habilités à pêcher, ainsi que du type et du nombre d'engins utilisés.

9.2 Plans de pêche

Lorsque la conservation du stock exige la limitation des lieux ou des périodes de pêche (plans de pêche), outre le plafonnement des prises totales, les ententes de pêches autochtones et les permis communautaires peuvent prévoir de telles limites, dans la mesure jugée nécessaire pour coordonner la pêche afférente à l'entente ou au permis avec les autres types de pêche et pour assurer la conservation des stocks.

9.3 Gestion en cours de saison

Toute entente de pêches autochtones doit énoncer les procédures prévues pour apporter aux allocations et aux plans de pêche, durant la saison de pêche, les modifications jugées nécessaires à la conservation des stocks. Les procédures comprendront la consultation des groupes concernés, mais maintiendront l'autorité discrétionnaire du Ministre ou de son substitut à modifier les

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9.4 Joint Technical Committees

All groups signing Aboriginal Fishing Agreements should provide members for joint DFO-Aboriginal Technical Committees, which will be organized on a regional basis. Technical Committees will attempt to resolve issues related to the implementation of the agreements including coordination of the implementation of agreements with groups which share stocks.

10. <u>Cooperative Management Subagreements</u>

a) AFS subagreements on the following Cooperative Management activities may be negotiated in conjunction with the negotiation of Aboriginal Fishing Agreements:

i) fishery guardian programs;

ii) participation in habitat management;

iii) habitat restoration;

iv) fishery enhancement;

v) stock assessment and other research carried out by Aboriginal communities in cooperation with DFO;

vi) development and testing of new approaches to delivering economic

horaires de pêches pour fins de conservation.

9.4 Comités techniques mixtes

Les groupes signant une entente de pêches autochtones doivent fournir des représentants pour siéger sur des comités scientifiques mixtes (MPO-Autochtones) constitués à l'échelle régionale. Ces comités scientiphiques tenteront de résoudre les problèmes liés à la mise en oeuvre des ententes, notamment en favorisant une action coordonnée des groupes qui partagent un même stock.

10. <u>Ententes auxiliaires de coopération en matière de gestion</u>

a) La négociation des ententes de pêches autochtones peut s'accompagner de négociations sur l'élaboration d'ententes auxiliaires de coopération en matière de gestion découlant de la SRAPA, portant sur les éléments suivants:

i) programmes de gardes-pêche;

ii) participation à la gestion de l'habitat;

iii) remise en état des habitats;

iv) amélioration des pêches;

v) évaluation des stocks et autres recherches menées par les autochtones en collaboration avec le MPO;

vi) développement et expérimentation de nouveaux moyens pour

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benefits to Aboriginal communities through fisheries; and

vii) issuance to the First Nation of a number of licences to participate in one or more commercial fisheries under the terms and conditions prevalent in that fishery, to be held and administered by the First Nation.

b) Cooperative management activities may be funded in whole or in part through Contribution Agreements or contracts.

11. <u>Designation of Individuals</u>

a) First Nations, through Aboriginal Fishing Authorities, will have discretion in designating individuals, within their membership, who may fish under their Agreements or Communal Licences.

b) Designations shall be personal and non-assignable. Fishing by unauthorized persons shall be considered to be outside of the Communal Licence.

c) Agreements and Communal Licences may provide for the designation of vessels to catch fish under the allocation contained in the agreement during an opening defined by area and time, consistent with any fishing plan contained in the agreement. DFO shall be notified in advance of fishing by any designated vessels.

valoriser les retombées économiques de la pêche des communautés autochtones; et

vii) délivrance à la Première nation d'un certain nombre de permis l'autorisant à participer à une ou plusieurs pêches commerciales selon les conditions régissant cette pêche. Ces permis seront détenus et administrés par la Première nation.

b) Les activités de coopération en matière de gestion peuvent être financées en partie ou en totalité par des ententes de contribution ou des contrats.

11. <u>Désignation des individus</u>

a) Il incombe aux Premières nations, par l'entremise des administrations de pêche autochtone de désigner les individus, à même leur membres, habilités à pêcher en vertu de leurs ententes ou permis communautaires.

b) Ces désignations sont personnelles et incessibles. La pêche pratiquée par des personnes non autorisées est considérée contraire au permis communautaire.

c) Les ententes et les permis communautaires peuvent désigner des navires autorisés à pêcher en vertu de l'allocation prévue à l'entente, dans une zone et une période définies et correspondant à tout plan de pêche compris dans l'entente. Le MPO doit être préalablement avisé de toute activité de pêche pratiquée par ces navires.

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d) Aboriginal individuals who wish to fish in an area outside their historical area must be designated by an Aboriginal Fishing Authority having a communal licence to fish in the area in question. Such designation must be made under the agreement or licence with the relevant fishing authority and any fish harvested pursuant to the designation will be counted towards the allocation under its licence.

12. Control of Fishing Methods

First Nations will have discretion to stipulate the fishing methods which may be used by designated individuals, subject to the provisions of the Aboriginal Fisheries Agreement or Communal Licence.

13. Negotiation Process

a) A separate document will set out the details of the process, roles and responsibilities for negotiations under this policy during 1993.

b) Negotiations of Aboriginal Fishing Agreements shall be led by the **ADM, Policy and Program Planning** who will delegate responsibility for negotiations to headquarters or regional staff under defined negotiation mandates.

c) All AFS agreements, including Aboriginal Fishing Agreements, must be signed by the ADM,

d) Les autochtones qui souhaitent pêcher dans une zone située hors de leur zone historique doivent, pour ce faire, être désignés par l'administration de pêche autochtone titulaire d'un permis communautaire. Une telle désignation se fait en vertu de l'entente ou du permis par l'administration de pêche compétente, et le poisson capturé par les autochtones ainsi désignés fait partie intégrale des prises allouées à cette administration par son permis.

12. Contrôle des méthodes de pêche

Les Premières nations ont le choix de déterminer quelles méthodes de pêche peuvent être employées par les individus désignés, sous réserve des modalités prévues à l'entente de pêche autochtone ou au permis communautaire.

13. Processus de négociation

a) On élaborera en 1993 un document distinct précisant les détails du processus de négociation découlant de cette politique, ainsi que les rôles et responsabilités en la matière.

b) La négociation des ententes de pêches autochtones sont menées par le **Sous-ministre adjoint (SMA), Politiques et planification des programmes**, qui peut, en vertu de mandats de négociation définis, déléguer cette responsabilité au personnel de l'administration centrale ou du bureau régional.

c) Toutes les ententes découlant de la SRAPA, y compris les ententes de pêches autochtones,

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Policy and Program Planning.

d) Signed agreements will be available to the public.

e) Aboriginal Fishing Coordinators will be appointed in each area. They will be responsible for ensuring that:

i) an Aboriginal Fishing Agreement or Communal Licence is in place <u>two weeks</u> before fishing is likely to commence for the species in question;

ii) the First Nation and all concerned DFO staff are informed of the terms of the Agreement or Licence before the commencement of fishing; and

iii) all signed agreements are available to the public.

d) **Framework agreements** under the AFS will not be required before negotiation and signing of an Aboriginal Fishing Agreement.

e) Nevertheless Framework Agreements, setting out the complete range of topics to be covered in negotiating an **Interim Agreement** under the AFS should be negotiated with Aboriginal groups, as time and resources permit. Mandates for negotiating Framework Agreements will originate with the ADM, Policy and Program Planning.

doivent être signés par le SMA, Politiques et planification des programmes.

d) Les ententes signées sont accessibles au public.

e) On doit nommer dans chaque zone un coordonnateur des pêches autochtones, qui aura les responsabilités suivantes:

i) <u>deux semaines</u> avant le début probable de la pêche pour une espèce, s'assurer qu'une entente de pêches autochtones est signée ou qu'un permis communautaire est délivré pour cette espèce;

ii) avant le début de la pêche, s'assurer que la Première nation et tout le personnel concerné du MPO connaissent les modalités de l'entente ou du permis; et

iii) s'assurer que le public est accès à toute entente signée.

d) Il n'est pas nécessaire de conclure une **entente cadre** découlant de la SRAPA avant de négocier et de signer une entente de pêche autochtone.

e) Néanmoins, il faut négocier avec les groupes autochtones, dans la limite des délais et des ressources disponibles, des ententes cadres énumérant tous les sujets devant être couverts dans la négociation d'une **Entente intérimaire** découlant de la SRAPA. Les mandats de négociation des ententes cadres sont confiées par le SMA, Politiques et planification des programmes.

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14. **Enforcement**

a) Subject to the terms of Aboriginal Fishing Agreements, normal enforcement procedures will apply.

b) Where delay will not compromise the effectiveness of enforcement, DFO personnel shall consult with the relevant Aboriginal Fishing Authority before taking any enforcement action.

c) Informal protocols on enforcement may be struck with Aboriginal Fishing Authorities, in accordance with this policy, to clarify consultation procedures.

d) In all cases, DFO personnel will inform and consult with the relevant Aboriginal Fishing Authority after taking any enforcement action.

15. **Native Fishery Guardians**

a) Fishery guardians employed by First Nations (Native Fishery Guardians) may engage in enforcement activities in accordance with Aboriginal Fishing Agreements. The authority of individuals will be set out in their designations and will be consistent with the terms of the relevant agreement and appropriate to their level of training.

b) Native Fishery Guardians will not be authorized to carry weapons or use force in the course of their duties.

14. **Application des règlements**

a) Les procédures habituelles d'application des règlements s'appliquent, sous réserve des modalités prévues aux ententes de pêche autochtone.

b) Avant de prendre une mesure d'application des règlements, le personnel du MPO doit consulter l'administration de pêche autochtone compétente, lorsque cela ne risque pas de retarder la mesure, ni d'en compromettre l'efficacité.

c) Pour clarifier les procédures de consultation, on peut conclure avec les administrations de pêche autochtone des protocoles officieux d'application des règlements, conformément à la présente politique.

d) Après avoir pris une mesure d'application des règlements, le personnel du MPO doit toujours informer et consulter l'administration de pêches autochtones compétente.

15. **Gardes-pêche autochtones**

a) Les gardes-pêche recrutés par les Premières nations (gardes-pêche autochtones) peuvent effectuer des activités d'application des règlements, conformément aux ententes de pêche autochtone. Les pouvoirs qui leur sont conférés seront énoncés en même temps que leur désignation, et doivent être conformes avec l'entente pertinente et leur niveau de formation.

b) Les gardes-pêche autochtones ne sont pas autorisés à porter d'arme ou à faire usage de force dans l'exercice de leurs

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c) Agreements will specify that Native Fishery Guardians will be prohibited from fishing while on duty.

d) Enforcement protocols should be developed with Aboriginal Fishing Authorities to ensure the activities of Native Fishery Guardians and DFO Fishery Officers are fully integrated and to coordinate enforcement activities.

e) Enforcement activities of Native Fishery Guardians should include on-the-job training with DFO Fishery Officers conducted through joint patrols.

16. <u>Responsibilities</u>

a) **Regional Directors General** are responsible for the implementation of these procedures and for ensuring that all personnel involved in the management of Aboriginal fishing are properly informed, are given a copy of this policy, other relevant policies or guidelines, licences and agreements, and are performing their duties in a manner consistent with this policy and the guidelines.

b) **Area Managers/Directors** will be responsible for ensuring that:

i) all consultation requirements set out in Aboriginal Fishing

fonctions.

c) Les ententes doivent préciser qu'il est interdit aux gardes-pêche autochtones de pêcher lorsqu'ils exercent leurs fonctions.

d) Il faudrait élaborer, avec les administrations de pêche autochtone, des protocoles d'application des règlements visant à intégrer pleinement et à coordonner les activités des gardes-pêche autochtones et des agents de pêche du MPO.

e) Les gardes-pêche autochtones devraient recevoir une formation en cours d'emploi et participer à certaines activités d'application en cours de patrouille (conjointe), en compagnie d'agents de pêche du MPO, dans le cadre d'activités d'application des règlements.

16. <u>Responsabilités</u>

a) Il incombe aux **Directeurs généraux régionaux** de mettre en oeuvre ces procédures et de voir à ce que tout le personnel participant à la gestion des pêches autochtones, soit adéquatement informé, reçoive un exemplaire de la présente politique et des autres politiques, lignes directrices, permis ou ententes pertinentes, et exerce ses fonctions en conformité avec les présentes politiques et lignes directrices.

b) Responsabilités des **gestionnaires/directeurs de secteur:**

i) voir au respect des exigences consultatives prévues aux ententes de

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Agreements or Communal Licences within their areas are met; and

ii) the activities of Native Fishery Guardians are coordinated with those of DFO enforcement staff to provide for effective enforcement and training, including on-the-job training through joint patrols.

c) **Aboriginal Fishing Coordinators will be responsible for:**

i) issuing Communal Licences;

ii) ensuring that Aboriginal Fishing Agreements or Communal Licences are in place for all First Nations in their area two weeks before fishing is likely to commence for the species in question;

iii) ensuring that First Nations and all concerned DFO staff are informed of the terms of the Agreements or Licences before the commencement of fishing;

iv) ensuring that all signed agreements are available to the public;

v) coordinating implementation of this policy within the area through consultations with the area manager/ director;

vi) reporting on

pêche autochtone ou aux permis communautaires; et

ii) coordonner l'activité des gardes-pêche autochtones avec celle du personnel du MPO chargé de l'application des règlements, afin d'assurer une application efficace des règlements, pour offrir une formation d'application et pour organiser des patrouilles conjointes.

c) Responsabilités des **coordonnateurs de pêches autochtones :**

i) délivrer les permis communautaires;

ii) deux semaines avant le début probable de la pêche pour une espèce, s'assurer qu'une entente de pêche autochtone est signée ou qu'un permis communautaire est délivré pour cette espèce;

iii) avant le début de la pêche, s'assurer que la Première nation et tout le personnel concerné du MPO connaissent les modalités de l'entente ou du permis;

iv) s'assurer que le public ait accès à toute entente signée;

v) coordonner l'application de la présente politique dans les secteurs, en consultation avec le gestionnaire/ directeur de secteur;

vi) faire rapport au

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implementation of this policy in their area to the regional aboriginal fisheries coordinator; and

vii) maintaining written records of all consultations with First Nations.

coordonnateur régional des pêches autochtones sur l'application de cette politique dans la secteur; et

vii) tenir des dossiers écrits sur toutes les consultations effectuées avec les Premières nations.

UNNAMED CREEK

Stream number 00-0170-0220
Ungauged
Flows into Bonaccord Creek

Drainage Area = 3.8 km²

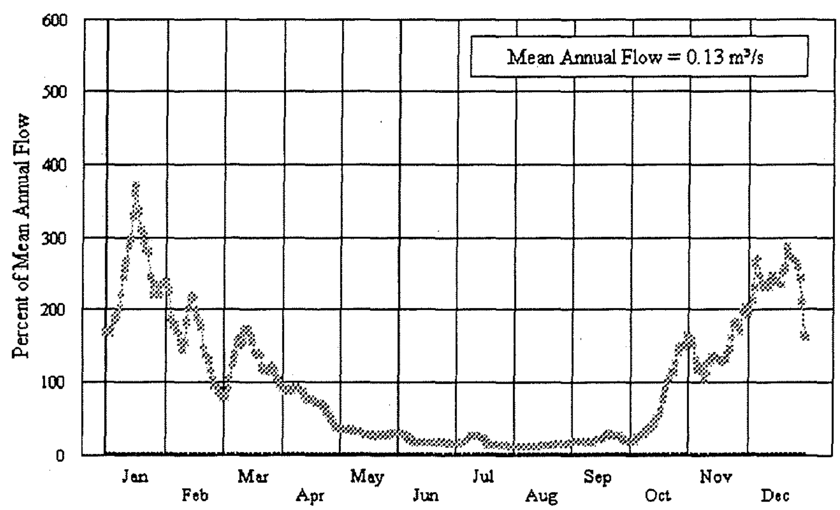
LICENSED WATER DEMAND

Licence Type	Total Licensed Demand	Monthly Demand L/S		
		Feb	Aug	Sep
Domestic	0 g/d			
Irrigation	0 ac.ft.			
Waterworks	0 g/d			
Industrial	0 g/d			
Conservation	0 cfs			

	Feb	Aug	Sep
MEAN STREAM FLOW L/S		20	20

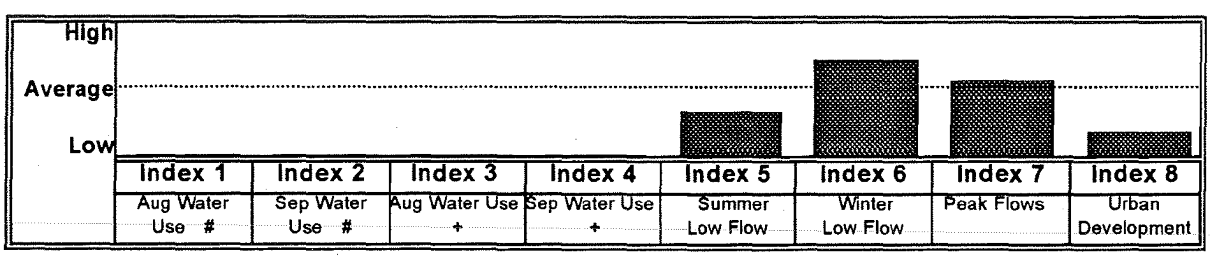
MEAN ANNUAL HYDROGRAPH

(Estimated, using Yorkson Creek station 08MH097)



SENSITIVITY INDICES

The following bar graph shows the sensitivity of this stream relative to others in the same Habitat Management area. An index above average indicates a more severe problem; an index below average indicates a less severe problem.



\# Water use as a proportion of the 7 day low flow
\+ Water use as a proportion of the mean monthly flow for the same month

UNNAMED CREEK 00-0170-0220

SUMMARY NOTES AND RECOMMENDATIONS

1. This creek is a tribuary of Bonaccord Creek. There are no water licences on the creek and urban development is relatively low.

Fisheries and Oceans Science | Pêches et Océans Sciences

C S A S | **S C C S**

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Phase 0 Review of the Environmental Impacts of Intertidal Shellfish Aquaculture in Baynes Sound

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ABSTRACT

Shellfish aquaculture has taken place in coastal British Columbia (BC) since the early 1900s, and Baynes Sound has developed into one of the major production areas for cultured shellfish in BC. There are few scientific studies of the environmental impact of shellfish aquaculture; the most notable management issues centre around land-use conflicts with upland owners, recreational harvesters, wild harvesters, other recreational activities, and navigation. Recently, Simenstad and Fresh (1995) published on the ecosystem concerns regarding intertidal bivalve bottom culture practices . The existing and planned expanded scale of this aquaculture in Baynes Sound has raised concerns among Department of Fisheries and Oceans (DFO) and BC Ministry of Water, Land and Air Protection resource managers, particularly in.

Here, we present a Phase 0 habitat review of Baynes Sound intertidal shellfish aquaculture to provide a baseline with which to advise on alternative management options and to identify where information is lacking. The review: 1) covers the existing scientific literature on the potential environmental impacts of intertidal bottom culture aquaculture on coastal ecosystem processes, specifically relating to fish and fish habitat in the Pacific north-east; 2) describes intertidal bottom culture operations and their potential impacts in Baynes Sound; 3) assesses the need for monitoring and/or a cumulative effects study related to the planned increase of leased area in the intertidal zone of Baynes Sound; 4) identifies gaps in the understanding of ecosystem impacts of extensive, intensive intertidal bottom bivalve aquaculture; and 5) makes recommendations for future research in support of advice on ecosystem-based intertidal bivalve aquaculture management.

We have gathered all information, but have found that studies are relatively few and those available were limited in scope and rigour. The literature is fragmented in its relevance, and much available information has not been scientifically reviewed and published. Views expressed are thus more hypothesis-generating than definitive, which warrants a need for rigorous testing and evaluation.

RÉSUME

La conchyliculture sur la côte de la Colombie-Britannique (C.-B.) remonte au début des années 1900, et la baie Baynes est devenue l'une des principales régions productrices de mollusques cultivés de la province. Peu d'études scientifiques se sont penchées sur l'impact environnemental de la conchyliculture; les questions litigieuses de gestion les plus marquantes concernent les conflits au sujet de l'utilisation des terrains, les propriétaires du littoral, les pêcheurs récréatifs, les pêcheurs commerciaux, d'autres activités récréatives et la navigation. Une publication récente (1995) de Simenstad et Fresh fait état des préoccupations pour l'écosystème reliées aux pratiques de la conchyliculture sur le fond en zone intertidale. L'échelle à laquelle se pratique actuellement l'aquaculture dans la baie Baynes et son expansion prévue inquiètent particulièrement les gestionnaires des ressources du MPO et du ministère de la Protection des eaux, des terres et de l'air de la Colombie-Britannique.

Nous présentons la Phase 0 d'un examen de l'habitat dans lequel se pratique la conchyliculture en zone intertidale dans la baie Baynes qui servira à étayer la prestation de conseils sur des options de gestion de rechange et à cerner les lacunes dans l'information. L'examen consiste à: 1) étudier la documentation scientifique sur les impacts potentiels de l'aquaculture sur le fond en zone intertidale sur les processus écosystémiques côtiers, concernant précisément le poisson et son habitat dans le Pacifique Nord-Est; à 2) décrire les opérations de culture sur le fond en zone intertidale et leurs impacts potentiels dans la baie Baynes; à 3) évaluer le besoin d'exercer une surveillance et/ou d'étudier les effets cumulatifs reliés à l'agrandissement prévu de la superficie louée dans la zone intertidale de la baie Baynes; à 4) établir les connaissances qui manquent pour mieux comprendre les impacts, sur l'écosystème, de la conchyliculture intensive et étendue sur le fond en zone intertidale et à 5) recommander des sujets de recherches futures pour appuyer la prestation de conseils sur la gestion de la conchyliculture en zone intertidale fondée sur l'écosystème.

Nous avons recueilli toute l'information, mais avons constaté que les études sont relativement peu nombreuses, manquent de rigueur et ont une portée limitée. Les documents n'ont pas tous la même pertinence, et une grande partie de l'information disponible n'a pas été revue par des scientifiques ni publiée. Par conséquent, nous énonçons plutôt des hypothèses que des certitudes, ce qui justifie la tenue d'expériences et d'évaluations rigoureuses.

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INTRODUCTION

Shellfish aquaculture has taken place in coastal British Columbia (BC) since the early 1900s, and Baynes Sound is one of the major production areas in the province, with 45% of the total production of clams and oysters, the majority produced on 380 hectares of leased intertidal zone (AXYS et al. 2000).

Baynes Sound falls within the Regional District of Comox Strathcona and includes the foreshore of the City of Courtenay and the Town of Comox. During the past decade, population growth and accompanying changes in regional land use have created marine stressors in a number of environmental areas. For example, in the early 1990s, increases in non-point source pollution from failing septic systems, agricultural runoff, marine mammals and to a lesser extent birds, municipal wastewater and stormwater runoff, and boater waste have lead to increased faecal coliform counts. However, significant improvements have recently been made by the local community, growers and government agencies to address this issue. Land-use conflicts in the intertidal zone occur among shellfish growers, recreational users, and local residents, and there are also increasing concerns by upland landowners that bivalve culture is adversely affecting the local ecosystems, relative abundances of native species, and the monetary value of their upland properties. They are claiming of both ecological change and inappropriate activities in intertidal areas. Groups around the north half of the Strait of Georgia have recently united in a common association to address these issues. Increased pressure to establish ecologically appropriate controls on this industry seems likely to occur.

There have been few scientific studies of the environmental impact of shellfish aquaculture in the Pacific north-east. The majority of aquaculture studies have focussed on the effects of netpen finfish farms, and of the few studies on shellfish aquaculture, most have revolved around off-bottom culture techniques (WGEIM 2000). Because of the dependence of shellfish aquaculture production on high water quality, it has been assumed as having few environmental impacts. The most notable management issues to date have centred around land use conflicts with adjacent upland owners, recreational harvesters, wild harvesters, other recreational activities, and navigation (deFur and Rader 1995).

Ecosystem concerns have been published regarding intertidal bivalve bottom culture practices (e.g. Simenstad and Fresh 1995), and the scale of existing and planned expansion of this industry in BC has raised concerns among both DFO and BC Ministry of Water, Land and Air Protection (WLAP) [formerly the BC Ministry of Environment, Lands and Parks (MELP)] resource managers, particularly in Baynes Sound. Operational activities in Baynes Sound including the delineation of lease areas through the use of Vexar® netting and berms, the use of predator exclusion nets on beach surfaces, modifying substrate and sedimentation characteristics, the repeated tilling of beach surfaces for the thinning and harvest of stock, and the channelisation of estuaries, can all have either direct or indirect environmental impacts.

Elsewhere, these practices have impacted the biodiversity and productivity of the intertidal by altering the compositions of benthic intertidal communities, and excluded some species from foraging areas, reduced the sizes of some finfish spawning, nursery and rearing habitats, and altered the natural coastal hydrography (Simenstad and Fresh 1995). In Baynes Sound, these impacts could be affecting the growth and survival of transient fish and wildlife, such as juvenile chinook, coho, chum, pink and steelhead salmon; herring; and, migratory waterfowl and local shorebirds. Little scientific information exists on the environmental effects of shellfish aquaculture in BC as it is currently practised. This lack of knowledge hampers DFO habitat and fisheries managers to evaluate the potential adverse impacts on fish and fish habitat of new aquaculture proposals or those submitted for farm expansions.

In November 1998, the British Columbia Assets and Land Corporation (BCAL) and Ministry of Agriculture, Food and Fisheries (MAFF) introduced the Shellfish Development Initiative, with the goal of increasing the diversification and stability of coastal and First Nations' economies through the expansion of the shellfish aquaculture industry. The 10-year plan allows a doubling of the farmed area by roughly 10% per year. Thirty-three proposals for expansion of existing shellfish tenures in Baynes Sound were referred to DFO by BCAL in December 1999. Twenty of the 33 required a Subsection 5(1) *Navigable Waters Protection Act* (NWPA) approval, relating to significant impacts to navigation, thus requiring a *Canadian Environmental Assessment Act* (CEAA) screening review. CEAA can also be triggered by NWPA subsection 6(4) or by the *Fisheries Act* subsection 35(2) relating to the harmful alteration, disruption or destruction of fish habitat (HADD). Environmental assessments of the 20 proposals have been, or are being, conducted by the Habitat Management Division (HMD) of DFO. In the absence of previous scientific study of this issue, HMD requested assistance in conducting these reviews. To date, eight of the 20 proposals requiring CEAA screening have been approved. Although HMD had concerns that the projects could add to the cumulative effects in the Sound, it concluded that they would not likely cause significant environmental effects based on the adaptive management approach outlined in the Aquaculture Site Referral Process: Interim Operational – Policy Guidelines (DFO, February 2001). The Interim Policy states that "In such cases, based on the information available at the time of the screening, if it cannot be concluded that the project will likely cause cumulative effects, such effects will not be considered for purposes of preventing a project from proceeding pursuant to s. 20 of CEAA". The Canadian Wildlife Service (CWS) and WLAP expressed concerns about the proposed shellfish lease expansion and the potential impacts on species they are mandated to manage. Given the relatively large number of existing aquaculture leases already present, the cumulative effects of the proposed leases for Baynes Sound must be considered.

The objectives of this paper are to:

1. Review the scientific literature on environmental impacts of intertidal bottom culture on coastal ecosystem processes, specifically relating to fish and fish habitat;
2. Describe the current practices of intertidal bottom culture operations and their potential impacts in Baynes Sound;
3. Assess the need for monitoring and/or a cumulative effects study related to the planned increase in leased area in the intertidal zone of Baynes Sound;
4. Identify gaps in the understanding of ecosystem impacts of extensive, intensive intertidal bottom bivalve aquaculture; and
5. Make recommendations for future research support of ecosystem-based intertidal bivalve aquaculture management.

Like Simenstad and Fresh's (1995) review of aquaculture impacts of intertidal shellfish culture in Washington State, we recognise that the economics and job opportunities associated with aquaculture are often considered acceptable trade-offs for some ecological change. However, the nature of both the ecological changes and their scales arising from existing or proposed activities need to be considered so that the pros and cons of existing and proposed shellfish aquaculture activities can be appropriately assessed. To date, scientific assessment of the impacts of intertidal aquaculture in the bays and estuaries of British Columbia has not been done. Different resource management agencies and citizen groups are now expressing concern that this is an essential component of appropriate marine nearshore stewardship.

What we are presenting here is a Phase 0 habitat review of Baynes Sound intertidal shellfish aquaculture, defined as the following: "a Phase 0 study involves collection of all relevant information on the target species or issue, and from similar species or issues elsewhere, in order to provide a baseline with which to advise on alternative management options and to identify where information is lacking." (Perry et al. 1999). The next step is a Phase 1 study, which if fiscal resources are provided, will involve surveys and more detailed descriptions where the objective is the collection of data required to fill in the information gaps identified in the Phase 0 report, and to explore alternative management options. This phased approach, developed for potential new fisheries, is, we suggest, also relevant to evaluation of previously unassessed habitat impacts.

We have tried to bring together available information for this study, but have found that studies are relatively few and those available limited in scope and rigour. The literature is fragmented, and much of it has not been scientifically reviewed and published. New research suggested below may be more hypothesis-generating than definitive, as baseline information still needs to be gathered and assessed.

DESCRIPTION OF BAYNES SOUND

PHYSIOGRAPHY

The following description defines the boundary of Baynes Sound (Figure 1): the study area is inclusive of the area bounded on the north by a straight line drawn between Cape Lazo on Vancouver Island and Longbreak Point at the northern tip of Denman Island. The southern boundary is a straight line drawn between Mapleguard Point on Vancouver Island and Chrome Island just off the southern tip of Denman Island. The study area extends beyond the area considered on shellfish aquaculture impacts on marine and shorebirds (AXYS et al. 2000) (i.e. north of Union Point) to include the valuable bird habitat of Comox Harbour, and associated land use impacts (contamination, etc.).

The study area is located within the Nanaimo Lowland Ecosection of the Georgia Depression Ecoprovince (Ward et al. 1998). Most of the Vancouver Island portion of the area is located in the Coastal Western Hemlock biogeoclimatic classification zone. The southern portion of the study area on Vancouver Island around Deep Bay, and all of Denman Island are located in the slightly warmer and drier Coastal Douglas-fir biogeoclimatic classification zone (Meidinger and Pojar 1991).

Baynes Sound consists of over 9000 ha of shallow coastal channel fringed by protected bays, open foreshore, tidal estuaries, inshore marshes and adjacent forests. Comox Harbour, which bounds Baynes Sound on the north, is one of the largest low gradient deltaic deposits on the east coast of Vancouver Island. The shoreline has a great diversity of habitat ranging from hundreds-of-metres-wide intertidal mud and sand flats to rocky shorelines bounding deep water. The surficial geology of the area is predominantly glacial marine, overlain in some areas by fluvial or organic deposits. The unconsolidated sands, gravels and tills dominate most of the beaches except on Denman Island and some of the headlands where exposed bedrock forms a significant portion of the coastline.

Foreshore mapping of the study area (Figure 2) outlines the contrast in the physical shoreline properties between Vancouver Island and the western shore of Denman Island (Howes and Thomson 1983). Vancouver Island is characterised primarily by shore units of beaches, interspersed with low-gradient deltas and tidal flats with nearshore widths extending up to 1000m. The northern tip of Denman Island also has beaches and deltas with nearshore widths up to 500m, but the majority of the western shore is characterised by rock platforms with mixed sand-cobble beach veneer.

The following description of the oceanography of Baynes Sound (except where referenced otherwise) is based primarily on the summary by Morris et al. (1979) of surveys carried out during the 1960s. The primary factors controlling the physical oceanography of the Sound are tides, currents and freshwater. The tides are semi-diurnal, with low waters occurring during daylight or near midnight in the summer and winter months, respectively. The tidal range at the northern end of Baynes Sound is greater than in the south by approximately 0.3 m. On the flood tide, northeasterly currents transport waters from the Strait of Georgia into the northern end of the sound, while the ebb tide is characterised by a greater outflow at the southern entrance. Thus, the net circulation of flow through Baynes Sound is from north to south. Freshwater input is predominantly from the Courtenay River in the north, with smaller streams having only a localised effect (Waldie 1952). The freshwater runoff drives the net outflow of surface waters, superimposed on regular tidal activity with occasional modifications by wind-driven currents. The deepwater currents in Baynes Sound are also presumed to flow towards the south, with a total exchange of bottom water taking place approximately every two months. The waters in Baynes Sound are relatively well protected from wave action by Goose Spit, Denman Island, and the smaller islands extending from the northern tip of Denman Island. This protection helps contribute to the vertical stratification of the waters. There are seasonal variations in density, salinity, temperature and dissolved oxygen coinciding with higher summer temperatures, and inputs of freshwater from heavy winter runoff and spring snowmelt.

SENSITIVE ECOSYSTEMS AND PROTECTED AREAS

The east coast of Vancouver Island and the adjacent Gulf Islands form a unique ecological region (Coastal Douglas-fir Biogeoclimatic Zone) in Canada, supporting many rare species of plants and animals, and plant communities. Less than eight percent of this area still supports rare and fragile ecosystems. These natural ecosystems are biologically diverse, supporting a large variety of plant and animal species, and they provide wildlife corridors and linkages. They provide specialised habitat for many rare species that are only known to occur in specific ecosystems. Intense development pressures has resulted in habitat fragmentation, degradation, and loss. The Sensitive Ecosystems Inventory (SEI) project has identified the remaining fragments of natural ecosystems on Eastern Vancouver Island and the adjacent Gulf Islands (Ward et al. 1998). The purpose of this SEI project was to identify, map and evaluate remnants of rare and fragile ecosystems, and to encourage land-use decisions that will ensure the continued integrity of these ecosystem types. Of the seven sensitive ecosystem types that have been identified, three are present along the coast of Baynes Sound including wetlands, riparian and coastal bluff (Figures 3a, 3b, 3c).

Baynes Sound is internationally recognised as important for migratory waterbirds. It has been ranked as the most important wetland complex on Vancouver Island by two of the foremost conservation agencies, the Pacific Estuary Conservation Program (PECP) and the Pacific Coast Joint Venture (PCJV). PECP is a co-operative project funded by Nature Trust of BC, Ducks Unlimited Canada, Wildlife Habitat Canada, MELP, DFO and CWS. PCJV is an international initiative represented by the US Fish and Wildlife Service, Oregon Department of Fish and Game, CWS, Ducks Unlimited, Inc., Ducks Unlimited Canada, the Nature Trust of BC, MELP, California Department of Fish and Game, the Nature Conservancy, and the Washington Department of Fish and Wildlife. The boundaries they used for the region for the most part are those of the Important Bird Area nomination (Booth 2001). Conservation values of Baynes Sound have long been recognised. Since 1973, MELP has actively pursued the protection of the productive estuaries, wetlands, and foreshore habitats within Baynes Sound. These efforts have resulted in Green Belt designations securing property along the south and west portions, Section 6A and DL 30 in Fanny Bay. In 1974, to elevate the importance of Baynes Sound as a wildlife area, MELP was granted a Notation of Interest Map Reserve over the intertidal foreshore from Maple Guard Point to Buckley Bay. A decade later, international recognition was gained when a series of biophysical studies (led by Environment Canada and MELP) identified Baynes Sound as “critical” habitat for waterfowl.

There are presently five small legislated protected areas (total marine area = 91.7 ha, i.e. <1 km^2) within Baynes Sound (Figure 4) (Jamieson and Lessard 2000). The Rosewall Creek Unit of the Qualicum National Wildlife Area (undetermined marine area) was established by CWS in 1974 for the conservation of essential habitat for migratory birds, and is subject to regulations defined by the *Canada Wildlife Act*. From 1991 to 1996, MELP established Wildlife Reserves at Deep Bay (12.9 ha), Rosewall Creek (Mud Bay) (27 ha), Fanny Bay (51.7 ha), and the Comox/Courtenay River Estuary (undetermined marine area) for the preservation of estuarine habitat and management of waterfowl resources. However, there are no specific provisions under the BC *Land Act* with respect to the management of the Wildlife Reserves (Jamieson and Lessard, 2000), and no management plans have been developed for these Wildlife Reserves.

Although not legislated protected areas, there are also two Recreational Shellfish Reserves established by MAFF: UREP 0284188 (est. 1968), which is 14.2 ha of intertidal area; and UREP 1405271 (est. 1991), which is 120 ha of deepwater. These areas preclude shellfish tenures or commercial harvesting. There is also UREP 1404487 (est. 1988), 277 ha of foreshore held by

BC Parks surrounding Sandy Islets Marine Park. This is traditionally an area of First Nations clam harvest and continues to be an important area for recreational and First Nation harvest of shellfish.

INTERTIDAL VEGETATION

Intertidal vegetation in Baynes Sound consists of a mixture of red, brown and green algae, with eelgrass beds in the mid-lower zones and marsh vegetation in higher areas. The most important mid-to-lower intertidal vegetation is eelgrass (*Zostera marina, Z. japonicus*), which provides critical habitat for young fish, invertebrates and other species and stabilises shorelines. It also helps to increase water clarity and reduce erosion by reducing wave energy and trapping loose sediments. The areal extent of eelgrass beds (*Zostera spp.*) in Baynes Sound, which includes a substantial admixture of macroalgae, is estimated to be around 500 ha; Comox Harbour is estimated to have an additional 500 ha of primarily eelgrass beds (Romaine et al. 1976, 1981, 1983). Figure 4 presents the eelgrass occurrence from a 1995 survey of eelgrass beds interpreted from 1:6000 scale aerial photographs (Durance 1996).

WILD BIVALVES

Intertidal bivalves of Baynes Sound form a rich mixture of native and exotic species, with relative distributions and abundance on each beach determined primarily by the area available at each tidal elevation and the substrate type (Figure 5). For the purposes of this review, the major species are divided into epifaunal (species that live on the substrate or attached to solid structures above the substrate) and infaunal (species that live buried in the substrate) components. The epifaunal bivalve community is dominated by two major species groups, mussels (family Mytilidae) and oysters (family Ostreaidae). The infaunal component is dominated by clams of various families, including the Veneridae, Psammobiidae, Myidae, Cardiidae, Mactridae and Tellinidae.

The most common oyster species in Baynes Sound is the “introduced” Pacific oyster, *Crassostrea gigas*. Oysters are found attached to rocks and pilings in the intertidal, as well as loose on the substrate, either singly or in clusters. Much of the intertidal area of Baynes Sound (about ⅓ of the total intertidal area, and a much larger, but unmeasured, percentage of suitable manila clam habitat) is under tenure for aquaculture, and a considerable portion of the oyster stock results from regularly seeding. There are, however, large numbers of oysters on non-tenured ground, resulting from spawning events in the Sound.

The native Olympia oyster, *Ostrea conchaphila*, is found in Baynes Sound at much lower densities than Pacifics. It is the only oyster species native to British Columbia. It was utilised as a commercial species for a brief period early in the 1900s (Gillespie 1999). Quayle (1988) listed Comox Harbour as one of several sites that supported commercially exploited populations of the Olympia oyster. The harbour has not been examined recently for Olympia oyster populations, but Olympia oysters are considered extremely rare throughout Georgia Strait, and only a single specimen was located at Royston, where this species used to be abundant, during intertidal surveys undertaken in 2001 (G. Gillespie, pers. observation). The Olympia oyster was given

"Special Concern" status in 2000 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2001).

Blue mussels, *Mytilus* spp., are common on rocks and pilings, or attached to small pieces of hard substrate over much of Baynes Sound. The species of blue mussel native to BC is the foolish mussel, *Mytilus trossulus*. The exact proportions of mussel species in the Strait of Georgia are unclear and may be changing over time due to possible hybridisation with introduced blue mussel species, *Mytilus edulis* and *Mytilus galloprovincialis*, that were either introduced for culture or arrived in BC as fouling organisms.

The infaunal community is made up of numerous species, with dominant taxa being determined largely by tidal elevations and substrate characteristics. The bivalve found at the highest elevations is the exotic varnish, or dark mahogany, clam, *Nuttallia obscurata*. This species has been recorded from BC since the early 1990s, has quickly expanded its distribution to include the entire Georgia Strait, and is expanding into Puget Sound, Johnstone Strait and the west coast of Vancouver Island (Gillespie, et al. 1999). Varnish clams are primarily found at intertidal elevations above other bivalves but overlap with species found lower in the intertidal.

The next zone of the intertidal is dominated by the exotic Manila clam, *Venerupis philippinarum*. This species was accidentally introduced to BC with Japanese oyster seed in the 1930s, and subsequently spread throughout Georgia Strait, into Johnstone Strait, up the west coast of Vancouver Island and into the Central Coast to nearly 53ºN (Quayle and Bourne 1972; Bourne 1982; Gillespie and Bourne 2000). Manila clams achieved commercial significance in the late 1980s, and currently are the most important commercial wild-harvest clam species in BC.

The distribution of Manila clams overlaps with that of the native littleneck clam, *Protothaca staminea*. This species is found from the mid-intertidal to subtidal depths, is of minor importance in commercial fisheries and is targeted, along with Manilas, in the recreational fishery. Also prominent in this zone is the exotic eastern softshell clam, *Mya arenaria*. This species was deliberately introduced into California in the late 1800s, and subsequently invaded northward, eventually finding its way into the Queen Charlotte Islands and southeastern Alaska (Quayle 1964; Gillespie and Bourne 1998).

The lower intertidal is dominated by littleneck and butter clams, *Saxidomus gigantea*. The latter was the primary commercial species in BC until the development of the live steamer (littleneck clams) market in the 1980s. Butter clams extend from the lower intertidal to at least 40 m depth (Bernard 1983). Horse clams, primarily the fat gaper, *Tresus capax* but also the Pacific gaper, *Tresus nutallii*, are found in the lower intertidal, with the bulk of populations occurring subtidally. The commercially important geoduck, *Panopea abrupta*, although recorded intertidally in other areas of Georgia Strait, is found only subtidally in Baynes Sound.

Other species of infaunal bivalves are found at relatively lower densities. The heart or basket cockle, *Clinocardium nuttallii*, is found on soft substrates and in eelgrass beds at lower tidal levels. A number of *Macoma* species are found, depending on substrate characteristics. The white sand macoma, *Macoma secta*, is found in sandy substrates; the bentnose macoma, *Macoma nasuta*, is found in mud or silt; and the pointed macoma, *Macoma inquinata*, and Baltic macoma,

Macoma balthica, are found in substrates of mixed sand, gravel and mud. Minor clam species that are likely present in the Sound include the rough diplodon, *Diplodonta impolita*; the thin-shelled littleneck, *Protothaca tenerrima*; and the arctic hiatella, *Hiatella arctica*.

The nature of the intertidal habitat in Baynes Sound is such that any stretch of intertidal with mixed substrates will support populations of varnish, Manila, littleneck and butter clams, depending upon the elevation examined. A single day's sampling at the unharvested beach fronting Royston yielded 14 species: blue mussels, Pacific and Olympia oysters, varnish, Manila, littleneck, butter, softshell, horse and butter clams, Baltic, bentnose and pointed macomas and cockles.

The beach area at Seal Island on the north end of Denman Island is the single most productive butter clam beach in southern coastal BC (Quayle and Bourne 1972; Kingzett and Bourne 1998). This may be because it represents the largest area of low subtidal in Baynes Sound. The lower beach is dominated by butter, littleneck and horse clams, with higher tidal elevations supporting populations of littleneck, Manila and, more recently, varnish clams (G. Gillespie, pers. observation).

Most beaches in Baynes Sound support Manila, littleneck, butter and varnish clam populations, with relative abundances determined largely by relative areas at appropriate tidal elevations. Beaches with extensive areas of bedrock and boulder or cobble cover may be dominated by epifaunal mussels and oysters, while beaches with sand and mud substrates will support more softshell clams, macomas and cockles.

SALMONIDS AND PACIFIC HERRING

A minimum of 23 creeks and rivers drain into Baynes Sound, providing spawning and rearing habitat for coho (*Oncorhynchus kisutch*), chum (*O. keta*), chinook (*O. tshawytscha*), pink (*O. gorbuscha*), sockeye (*O. nerka*), coastal cutthroat (*O. clarki*) and steelhead (*O. mykiss*). The intertidal zone of Baynes Sound is utilised as a juvenile rearing area at various times of the year (Healey 1980). The largest system is the Courtenay River, which is formed by the joining of the Puntledge and Tsolum Rivers. The total Sound watershed covers an area of 859 km^2. Small creeks and rivers which drain into Baynes Sound include the Cruikshank, Brown, Tsable Rivers; Hart, Hindoo, Cowie, Cougar Smith, Wilfred (Coal), Waterloo, Rosewall, McNaughton, and Sandy Creeks; plus, numerous other unnamed streams (Figure 6). Millions of wild salmon juveniles are produced within these watercourses. As well, the Puntledge River hatchery releases approximately 10 million juvenile salmon annually into the Courtenay River estuary and Baynes Sound, including 1.5 million chinook, 3 million pinks, 4.5 million chum and 700,000 coho. Table 1 lists the species reported in the DFO/ BC Fisheries FISS (Fish Information Summary System) database for the Baynes Sound watersheds.

The estuaries in Baynes Sound also fulfil important habitat requirements for several life stages of the six salmonid species. The nutrient rich estuaries provide excellent rearing grounds for adult cutthroat, and coho, along with chum and chinook juveniles. Furthermore, the intertidal zone and waters of Baynes Sound are recognised as productive Pacific herring (*Clupea harengus pallasi*) spawning and nursery habitat on the BC coast (Hay and McCarter 2001). Eggs are deposited on intertidal and subtidal marine vegetation in Baynes Sound and Lambert Channel, and hatched larvae from both areas disperse into the stratified waters of the Sound to rear in the adjacent waters of protected bays and inlets (Haegele and Schweigert 1985; Robinson 1989). Figure 7 presents the habitat sensitivity map for Baynes Sound based on cumulative herring spawn data since 1928. The areas of Metcalf and Deep Bays to the south, and the coastal region north of Union Bay and surrounding Longbreak Point have been classified as vital spawning grounds, with areas in between specified as having major or high spawning classification (Hay and McCarter 2001).

BIRD HABITAT AND USAGE

The following summary synthesises Canadian Wildlife Service (CWS) studies of migratory bird abundance and describes use of habitats within the Comox Harbour – Baynes Sound area (the 'subject area').

1980 – 1981 Surveys: Baynes Sound – Comox Harbour area

Baynes Sound – Comox Harbour area is an important staging and wintering area for a wide variety of migratory bird species (Dawe et al. 1998). CWS's interest in the subject area extends over thirty years (see Trethewey 1979, Vermeer and Butler 1989). Designated as an Important Bird Area (IBA), the area includes the Courtenay River estuary to Deep Bay and Mapleguard Point, approximately 35 kilometres to the southeast (Booth 2001). Maximum single day counts recorded during 1980 –1981 surveys found globally significant populations of Pacific Loons, Western Grebes, Brant, Black Turnstones, Mew Gulls, Thayer's Gulls, and Glaucous-winged Gulls (Dawe et al. 1998). Table 2 presents the species and seasons at which they are present in the area; the approximate percentage of the population that uses this habitat; the significance at the global, continental, or national level; and the provincial status for the Baynes Sound IBA (from Booth 2001). Provincial status is ranked according to indigenous species considered to be extirpated, endangered or threatened (red-list), species considered to be vulnerable (blue-list), or indigenous species vulnerable during times of seasonal concentration e.g. breeding colonies (yellow-list).

Bird use of habitats within the Baynes Sound – Comox Harbour study area was not directly studied by Dawe et al. (1998). Shorelines were divided into units from which birds counts were recorded (shoreline vegetation characteristics were obtained from existing information). Refer to Figures 8-16 for location of shorezone units within the study area. The most heavily utilised shoreline units were:

- Unit 23 (near Roy Creek and the Trent River) and Unit 28 (just north of Union Point); these units recorded the highest numbers of birds. The totals of all the birds viewed in both of these units were approximately 12% higher than any other unit. Over the study period, the total for unit 23 included approximately 24,000 ducks (mostly diving ducks), 11,000 Western Grebes, and 11,000 gulls. The total for unit 28 was augmented by more than 19,000 ducks (mostly diving ducks).
- Unit 47 (Metcalf Bay on Denman Island) ranked third in total bird use and Unit 41 (Wildfred Creek to Mud Bay) ranked fourth.

The locations having the lowest bird use were around shorezone Units 32 to 35, 15, 16, 2 and 8.

The number of bird-use days for the Baynes Sound – Comox Harbour area was highest in winter, second in autumn and spring, and lowest during summer (Dawe et al. 1998). It should be noted that this assessment was after aquaculture had been established in much of Baynes Sound, so how it might reflect pre-aquaculture usage by birds is unknown. As the focus of this manuscript relates to the effects of intertidal aquaculture upon ecosystem components, the use of the subject area by migratory birds referenced herein will be those that are more likely to be found utilising nearshore habitats. Loons, grebes, cormorants, and gulls are typically found in deep water areas, but are included in Table 3, as habitat use by these species will extend seasonally into shallow water areas.

It is important to note that Table 3 highlights only some of the pertinent aspects of the survey findings. For example, seasonal use (or lack thereof) of shorezone units by different species has not been included. Although the Pacific Loon was the most abundant bird within the loon species group, the Common Loon was the most abundant within this group in autumn. Other aspects of this survey worth noting are that:

- counts are likely conservative; actual numbers of birds were probably greater than the numbers recorded for the study. For example, night time surveys were not conducted, yet low tides during the winter months are at night;
- for certain species, numbers were recorded at higher taxonomic units; for example, in some instances, Greater Scaup and Lesser Scaup were recorded simply as Scaup species.

The following are further details of the Dawe et al. (1998) study that are not reflected in Table 3:

Loons: on February 21, 1981, a peak number of 1005 Pacific Loons were recorded, 900 of which were viewed from Metcalf Bay. This peak number is noted as being higher than any other one-day count recorded between 1 November and 31 March at six other major estuaries around the Strait of Georgia. A total of 3,028 Common Loon were recorded from most shorezone units; the Deep Bay, Mapleguard Point, and Metcalf Bay areas received the most use. Pacific Loon was the most abundant loon in winter and spring, whereas the Common Loon was the most abundant loon in autumn. Other species included the Yellow-billed Loon and Red-throated Loon.

Grebes: a total of 96,142 Western Grebes (provincially red-listed) were identified, making them the most abundant species in this study. Habitat use in autumn and spring centred primarily around units 23 and 28, while winter usage was associated more around units 40-47. A Christmas Bird Count of 15,174 birds from Deep Bay was recorded on December 27, 1983 *(*Campbell et al. 1990*)*. Horned Grebe ranked second in abundance; Pied-billed Grebe and Eared Grebe were also recorded.

Cormorants: the Pelagic Cormorant is provincially yellow-listed, the Double-crested is blue-listed, and the Brandt red-listed. A combined total of 3,975 cormorants were observed.

Herons: the Great Blue Heron, a provincially blue-listed species, was the only heron species observed, and favoured Unit 21 and adjacent units during autumn, spring and summer. Unit 48 (Henry Bay) received highest use during winter.

Swans: the Trumpeter Swan is provincially blue-listed, and the Tundra Swan yellow-listed. Most swans were observed in winter (80% of bird use days). Comox Harbour is an important wintering area for Trumpeter Swans; in 1978-1979 a maximum of 271 birds was reported by MeKelvey (Trethewey 1979) and an all-time North American high Christmas Bird Count of 712 swans was made on the Comox count of December 16, 1984.

Geese: four species of geese were recorded for a combined total of 20,328 birds. Brant totalled 19,168 birds (94% of all geese), but were present only in spring. Areas of highest use were Units 23-25, with less use around Units 28, 36, 41, 45, 47, and 48. Canada Geese, a White-fronted Goose, and Snow Geese were also observed.

Dabbling Ducks: a combined total of 72,436 dabbling ducks was observed. Dabbling ducks were seen on every survey but counts varied by season; numbers were highest during autumn and spring migrations. Highest numbers of dabbling ducks occurred near Millard Creek in Comox Harbour. American Widgeon, Mallard, Northern Pintail, Green-winged Teal, Blue-winged Teal, Northern Shoveler, Eurasian Widgeon, Cinnamon Teal, and Gadwall were observed.

Diving Ducks: a combined total of 238,678 birds (34% of all birds) were recorded, most during autumn and winter. The three species of scoters – White-winged, Surf (provincially blue-listed), and Black - together accounted for 46% of all diving ducks.

The most numerous diving duck and third most abundant species in the study was the White-winged Scoter with a total of 47,666; preferred locations for this species were from the entrance of Comox Harbour south (units 23 to 48). For the Surf Scoter, higher use was recorded towards the southern end of the study area: Unit 39 and south, and from Units 48 and 47. Surf Scoters used more of the north side of the inner harbour and the area around Goose Spit (Units 1 to 11) than White-winged Scoter, especially in autumn and winter. Black Scoter use of Baynes Sound was concentrated in fewer locations than the other two scoter species. Units 13, 45, and 46 were used primarily during autumn, with more dispersion over units during winter; Units 23, 28, and 40-47 were used during spring, while concentration around Units 22 and 28 was observed during summer.

Greater and Lesser Scaup were likely underrepresented because a total of 11,001 birds were recorded simply as Scaup species.

Highest numbers of Harlequin Duck (3% of all diving ducks) (provincially yellow-listed) were recorded south of Gartely Point and between Union Bay and Buckley Bay. The waterfront west of Comox (Unit 14) and Deep Bay (Unit 45) recorded high counts in spring. During fall, birds were most numerous near Mud Bay (Unit 41).

Common Goldeneyes (3% of all diving ducks) used Metcalf Bay (Unit 47) mostly in the winter; the area north of Union Point (Units 27 and 28), and a stretch of Comox waterfront towards Robb Bluff received higher use during spring. 73% of the Barrow's Goldeneyes seen during spring were at units 27 and 28.

8,959 Bufflehead were recorded, being observed at every location surveyed, with numbers varying between seasons.

Three species of mergansers were observed: the Common Merganser, Red-breasted Merganser, and Hooded Merganser. Other divers observed included Oldsquaw (now referred to as Long-tailed Duck), Canvasback, Ring-necked Duck, and Ruddy Duck.

Rails, Coots and Cranes: most American Coots were observed in autumn (56% of bird-use days); two peaks occurred: 112 birds on October 25, 1980, and 103 birds on 22 November 22, 1980.

Shorebirds: 40,004 shorebirds (6% of all birds) from 19 species were seen during the study: Black Turnstone, Dunlin, Sanderling, Killdeer, Black-bellied Plover, Western Sandpiper, Greater Yellowlegs, Spotted Sandpiper, Long-billed Dowitcher, Short-billed Dowitcher, Least Sandpiper, Lesser Yellowlegs, Surfbird, Black Oystercatcher, Common Snipe, Whimbrel, Lesser Golden-Plover, Semipalmated Plover, and Ruddy Turnstone.

Black Turnstone and Dunlin were the most abundant shorebird species recorded. Baynes Sound supports the largest numbers of wintering Black Turnstones in the province *(Campbell et al. 1990).* In this study, the highest count was 3093 seen on 29 November 1980; 3000 of these were at one roost on log booms north of Union Point (Unit 28). 3560 Black Turnstones were recorded in the 1982 Comox Christmas count *(*Paulson 1993*).* Sanderling was the third most abundant, accounting for 4% of all shorebirds.

Gulls: a total of 124,967 gulls were observed (18% of all birds). The Glaucous-winged Gull, accounting for 44% of all gulls, was the most abundant, followed by the Mew Gull and Bonaparte's Gull. Largest aggregations were around Mud Bay (unit 41), with Trent River (unit 23) having the second largest count. Herring Gull, Thayer's Gull, California Gull, Glaucous Gull, Ring-billed Gull, Western Gull and Franklin's Gull were also observed.

Alcids: of the three species recorded – Common Murre, Marbled Murrelet (red-listed), and Pigeon Guillemot - the Common Murre (red-listed) made up 59% of all observations. High use areas for the Common Murre during winter included Goose Spit (Unit 3) and Rosewall Creek (Unit 43).

1990 – 1991 Surveys: Fanny Bay – Little Bay Surveys

Dawe et al. (1995) conducted weekly surveys between 10 September 1990 and 25 August 1991 in the Fanny Bay – Little Bay wetlands area of Baynes Sound. Over this study period, 123 species of birds were identified, and a total 27,001 birds were recorded. It was estimated that a minimum of 4,099 birds depended on the Fanny Bay wetlands for some aspect of their life history. The study area was divided into 7 Units that reflected the major habitat types (Table 4).

Based on the classification scheme above, Dawe et al. (1995) determined that the intertidal flats received the highest bird use (50%), followed by intertidal marsh north (17%), intertidal marsh east (13%), subtidal habitat (8%), forest (6%), and intertidal marsh south (4%); the freshwater marsh ranked lowest in habitat use overall (1%). Table 5 is a partial summary of the results of the study.

Loons: Common Loons were most frequent in autumn (54%) and spring (29%); Pacific Loons were also observed.

Grebes: four species of grebes - Western, Horned, Red-necked, and Pied-billed - were recorded for a total of 510 birds. Western Grebes utilised primarily one distinct area within the subtidal habitat unit.

Cormorants: three species of cormorants (Pelagic, Double-crested, and Brant) were observed for a total of 383 birds. The Pelagic Cormorant was most abundant, and utilised mostly intertidal habitat. It is important to note that 54% of all cormorants were reported as 'cormorant species'.

Herons: the Great Blue Heron, of which 106 were counted (this was the only heron species recorded), utilised all seven habitat units, with the intertidal marsh north and intertidal marsh south receiving heaviest use. A colony of approximately 16 nests was observed in the forest habitat unit.

Swans: Trumpeter Swans (142) were recorded during the survey, with habitat use varying by season, though a small portion of the intertidal marsh north was utilised over the entire year. Most swans were observed during winter.

Geese: the Canada Goose was the only goose species observed, of which 148 were counted. Habitat use changed with season: in winter, intertidal marsh east was the only habitat used while in spring, intertidal marsh north was preferred.

Dabbling Ducks: nine species (American Wigeon, Green-winged Teal, Mallard, Northern Pintail, Wood Duck, Gadwall, Northern Shoveler, Eurasian Wigeon, and Blue-winged Teal) were recorded for a total of 5,951 birds. The intertidal marsh east was used most by dabbling ducks during autumn, with use shifting to the intertidal marsh north thereafter. However, American Wigeon preferred intertidal marsh north followed by intertidal flats, and in the autumn, intertidal marsh south was preferred.

Diving Ducks: twelve species (Greater Scaup, Lesser Scaup, White-winged Scoter, Surf Scoter, Black Scoter, Common Goldeneye, Barrow's Goldeneye, Common Merganser, Hooded Merganser, Red-breasted Merganser, Harlequin Duck, and Long-tailed Duck (Oldsquaw) were recorded for a combined total of 11,821 birds (44% of all birds). These ducks were seen in all seven habitats, with highest numbers in intertidal flats in all seasons. Scoters (all 3 species) were found primarily in intertidal flats habitat, followed by subtidal habitat. Common and

Barrow's Goldeneyes preferred intertidal flats. Harlequin Ducks utilised intertidal flats habitat 86% of the time, with the remainder spent in the subtidal zone.

Shorebirds: seven species (Dunlin, Western Sandpiper, Killdeer, Greater Yellowlegs, Pectoral Sandpiper, Common Snipe) , for a total of 2,275 birds, used the Fanny Bay wetlands during some part of their life histories. Most shorebirds used intertidal flats, with intertidal marsh east ranking second in usage. Intertidal marsh east attracted the highest number of shorebirds in winter. Dunlin was the most abundant shorebird, and utilised the intertidal flats for 68% of the time during autumn. Intertidal marsh east was most favoured during the winter, utilised 22% of the time.

Gulls and Terns: four species of gulls (Mew Gull, Bonaparte's Gull, Glacuous-winged Gull, and Ring-billed Gull) were recorded for a total of 1542. All habitats were used; overall, the intertidal flats were used most (55%), followed by the intertidal marsh north.

Alcids: two species – Pigeon Guillemot and Marbled Murrelet - were recorded for a total of six birds.

Baynes Sound – Comox Harbour Habitat Assessment /Other Surveys

Bird use of Mud Bay – Rosewall Creek from January through March 1973 and October 1975 through August 1977 was estimated at 9,900 birds (mostly waterbirds, herons, and shorebirds) dependant on this area (Trethewey 1979). R. Davies (MELP, Nanaimo, BC; listed in Trethewey 1979) observed an average of 840 ducks per shoreline mile (522/km) for the Mud Bay – Rosewall Creek – Deep Bay area and an average of 290 ducks per shoreline mile (180/km) for the area north from Mud Bay to Gartley Point during an aerial survey of Baynes Sound conducted in January 1977 (Trethewey 1979). In addition, large numbers of Black Brant (Davies et al. unpublished) and one flock of 4,800 Western Grebes (N. Dawe pers. comm.) were seen (Trethewey 1979). The wintering distributions of diving ducks, based on the results of 10 Christmas Bird Counts, suggests different habitat preferences (Table 6) among the species (Savard 1987).

For the seven habitats identified in the Trent River Delta and Estuary, 38,593 birds were recorded; 124 species were identified, with an average of 35 species using the area weekly (Brooks et al. 1994). With respect to habitat use, of the seven types identified (Intertidal Flats, High Salt Marsh, Salt Marsh, Forest/Residential, Upper Beach, Riparian, and Cultivated Fields), the Intertidal Zone was utilised the most, with 48% of all birds recorded there (Brooks et al. 1994). Table 7 summarises the one-day maximum numbers of each bird species observed in the Trent River estuary, 1987.

Areas within Baynes Sound are important herring spawning sites (see above), which are heavily used by migratory birds. In some cases, certain bird species will switch their diets and forage almost entirely upon herring eggs. Within the Baynes Sound – Comox Harbour area, herring spawning areas considered most important to migratory birds are: inside Comox Harbour, north around Goose Spit onto Comox Bar; south around Gartley Point for about three km; and a five km stretch of the north-central portion of Baynes Sound from Union Bay south to Hindoo Creek

(Trethewey 1979). One heavy spawning at Qualicum in the spring of 1976 attracted approximately 70,000 waterbirds, 53,000 of which were gulls (Trethewey 1979). Approximately 140,000 birds were recorded congregated at a herring spawn site in the area in spring of 1998 (R. Butler, CWS, pers. comm.).

Some species such as Long-tailed Duck (Oldsquaw) may dive to several hundred feet for food, but most diving duck species feed in water up to 11-15 metres (Mitchell 1952). Thus, all intertidal areas between the high tide line and subtidal areas out to 15 m depth are potentially important feeding areas for diving ducks (Trethewey 1979). At least 80 species of birds use the intertidal portion of Baynes Sound (Trethewey 1979).

A variety of migratory bird species, such as Brant in the Comox Harbour estuary, are known to utilise eelgrass and macroalgae beds for foraging purposes. McKelvey (1981) determined that rhizomes of three-square bulrush (*Scirpus americanus*) were the predominant food of wintering Trumpeter Swans. The most heavily-vegetated portions of the Baynes Sound (from Base Flat to Maplegaurd Point) (see Figures 14-16) and Comox Harbour are the areas which also receive the heaviest known use by birds (Trethewey 1979).

OYSTER AND CLAM WILD HARVESTING AND AQUACULTURE IN BC

BIOLOGY AND ECOLOGY

Manila Clam

The first specimens of manila clams found in Ladysmith Harbour in 1936 (Quayle 1964) and were described as a new species, *Paphia bifurcata* (Quayle 1938). They were inadvertently introduced into British Columbia with seed of the Pacific oyster from Japan (Quayle 1941, 1944; Bourne 1982).

Manila clams achieved significant economic importance in the South Coast (Quayle and Bourne 1972). Landings increased dramatically in the 1980's and peaked in 1988 at 3,909 t (Figure 17). Commercial fishery landings subsequently decreased, and currently vary around 1,000 t/yr. Decreased landings are a result of more restrictive management measures in response to concerns of recruitment overharvesting, decreased opportunity to fish due to toxic algal blooms, faecal contamination and establishment of aquaculture tenures (Webb and Hobbs 1997).

Description

Manila clams are generally longer than they are high, resulting in an oblong profile, as compared to the circular profile of the native littleneck clam (Gillespie and Kronlund 1999). The valves are thick, marked with both radial and concentric sculpture. Maximum size is approximately 75 mm (Quayle 1960; Quayle and Bourne 1972; Gillespie and Kronlund 1999).

Distribution and Habitat

Manila clams quickly spread throughout Georgia Strait, and after introduction into Barkley Sound, spread up the west coast of Vancouver Island (Quayle 1964). Intentional introductions to the North Coast and Queen Charlotte Islands failed to produce sustainable populations (Gillespie and Bourne 1998) and recruitment into the Central Coast is likely from pelagic larvae from northern Vancouver Island, perhaps Quatsino Sound (Bourne 1982).

Manila clams are found in the upper half of the intertidal zone on protected beaches, in mixed substrates of mud, sand and gravel (Quayle 1960). No subtidal populations of Manila clams occur in B.C. (Bernard 1983). Manila clams are shallow in the substrate and are susceptible to extremes of temperature, resulting in catastrophic mortalities ("winter kills"). These occur when low tides coincide with below freezing air temperatures and strong winds (Bower et al. 1986; Bower 1992).

Life History

Sexes are separate and at spawning, gametes are released into the water column, where fertilisation occurs. The planktonic larval period is approximately three to four weeks, depending upon temperature and availability of food, after which larvae settle and take up an infaunal existence. Recruitment is variable due primarily to environmental conditions (Bourne 1982; Quayle and Bourne 1972).

Size at first maturity is 20-25 mm total length (TL) (Holland and Chew 1974). Fecundity increases with size and in Hawaii (Yap 1977), estimates ranged from 432,000 eggs/female at 20 mm TL to 2,350,000 eggs/female at 40 mm TL. In China (Ponurovsky and Yakovlev 1992), 188,000 eggs/female at 19 mm TL to 1,503,000 eggs/female were estimated.

Maximum size of 75 mm TL is achieved after 8-10 years, and maximum age in B.C. has been documented at 14 years (Bourne 1987). Age at recruitment to legal size (38 mm total length [TL]) varies from beach to beach and between areas on a single beach. Growth is greatly affected by tidal elevation and substrate characteristics, and can vary as much between different areas within the same beach as among beaches. Under optimal conditions, Manila clams can reach legal size in approximately 3-4 years in Georgia Strait (Quayle and Bourne 1972; Bourne 1982), 4 years on the west coast of Vancouver Island (Bourne and Farlinger 1982), and 3-4.5 years in the Central Coast (Bourne and Cawdell 1992; Bourne *et al.* 1994; Bourne and Heritage 1997; Heritage *et al.* 1998).

Predators

Moonsnails (*Euspira lewisi,* previously *Polinices lewisii*) and sea stars (*Pisaster* sp.) are occasional predators of Manila clams, although the distribution of Manilas at higher tidal elevations generally provides a refuge from these predators. Manila clams are preyed upon by diving ducks [scaups (*Aythya affinis)* and scoters (*Melanitta fusca, M. perspicillata*], that excavate them from the substrate at high tide. Gulls (*Larus glaucescens*) and crows (*Corvus caurinus*) collect them from the beach surface and drop them from flight to break them open.

Parasites and Diseases

Bower *et al.* (1992) examined B.C. Manila clams for disease, parasites and symbionts. No evidence of infectious disease was found, and although many species of parasites and symbionts were documented, none appeared to have pathological effects on their hosts.

Pacific Oyster

Pacific oysters are the only species harvested commercially in BC. They are large oysters, with a maximum length of approximately 300 mm (Harbo 1997). The shell is extremely variable in shape, from long and thin to round and deep, and shell morphology is greatly influenced by environmental conditions.

Distribution and Habitat

Pacific oysters were first introduced to B.C. in Ladysmith Harbour and Fanny Bay in 1912 or 1913 (Bourne and Clayton 1986, Quayle 1988). Natural spawning and dispersal events in 1932 and 1936 began the spread of Pacifics through Georgia Strait. The 1942 spawning is believed to have allowed dispersal of Pacific oysters from Pender Harbour into Pendrell Sound. The combination of "wild" oyster populations and cultured oysters throughout Georgia Strait and in certain locations on the west coast of Vancouver Island now ensure significant natural settlement in these areas in warm-water years.

Life History

Sexes of oysters are separate, though hermaphrodites occasionally occur (Quayle 1988). Sexes may change from year to year, usually in the winter, and changes may be related to environmental conditions. Fecundity is in the range of 50-100 million eggs/female. Breeding can occur within a temperature range of 14-32°C, with the optimum at 23°C. Salinity range required for spawning is between 11-32‰, with the optimum between 20-25‰. Ideal conditions for natural spawning of Pacific oysters occur relatively infrequently, thus, over most of Georgia Strait and the west coast of Vancouver Island spawning and successful settlement occurs only in unusually warm years. A few sites in BC (*e.g.*, Pendrell Sound) have special oceanographic and geographic features that allow relatively regular spawning to occur.

In BC, Pacific oysters usually spawn by June (Quayle 1988). Spawning and fertilisation are external. Once settled, oyster growth varies widely with season, food availability, tidal elevation and substrate characteristics (Quayle 1988). Growth studies are hampered by the inability to determine age in oysters. Oysters grown on hard substrate tend to be round and highly fluted, those grown on softer substrate tend to be smooth, and those grown in mud may be elongated and smooth. In general, growth is greatest between April and October. Quayle (1988) reported growth of spat from under 1 mm diameter in August to approximately 25 mm in November, and 90 mm by October of the following year. Oysters and other bivalves grow rapidly when young and more slowly with age. Reduction of growth rate in Pacific oysters occurs at 4 to 5 years.

Predators

Juvenile oysters are preyed upon by the exotic flatworm *Pseudostylochus ostreopagus*, the exotic oyster drills *Ceratostoma inornatum* and *Urosalpynx cinera*, native drills *Nucella* spp., three species of cancrid crabs (*Cancer magister*, *C. productus* and *C. gracilis*), several species of sea stars (*Pisaster ochraceus*, *P .brevispinis*, *Evasterias troschelli* and *Picnopodium helianthoides*), and black oystercatchers (*Haematopus bachmani*), scaups and scoters (Quayle 1988).

Parasites and Diseases

Pacific oysters host a number of diseases and parasites, though most cause little or no mass mortality (Bower *et al*. 1994). Two diseases that cause mortalities in BC are nocardiosis and Denman Island disease. Nocardiosis is caused by an actinomycete bacterium (*Nocardia* sp.) that is found in western North America from B.C. to California and in Japan (Bower *et al*. 1994). Denman Island disease (*Mikrocytos mackini*) attacks connective tissue cells in the oyster, and can result in fairly large mortalities (ca. 30%). The disease affects primarily older oysters held at low tide levels. Mortality generally occurs in April and May after a 3-4 month period of cooler temperatures (<10°C). The disease is endemic to Georgia Strait and certain locations on Vancouver Island (Bower *et al*. 1994).

THE COMMERCIAL WILD BIVALVE FISHERY

Intertidal clams have long been a traditional food source for First Nations people in BC, and have supported commercial fisheries since the late 1800s (Quayle and Bourne 1972). In the late 1970s, market demand in the commercial fishery shifted from butter clams to live steamer clams, both Manila and native littleneck clams. The intertidal clam fishery currently concentrates on Manila clams, with relatively minor landings of littlenecks, butters and razor clams (Figure 17). There is also interest in developing a fishery for varnish clams (Gillespie *et al*. 1999).

The wild fishery for Manila clams is undertaken at low tide, when harvesters rake or scrape the clams from the substrate. Because low tides from October to March are at night, and this is the time of year of peak bivalve condition, much harvesting is conducted with lights. The wild fishery is managed using a minimum size limit of 38 mm total length (TL), area licensing, licence limitation and time and area closures related to harvest targets based on historic production (Gillespie and Bond 1997). The depuration fishery is managed with TACs based on population estimates from assessment surveys and a sliding scale of harvest rates based on legal density thresholds (Gillespie 2000). The recreational fishery is managed using daily bag limits.

Baynes Sound is a portion of Clam Area D, which also includes clam grounds on Lasqueti Island and historic production from the Parksville and Craig Bay areas (Figure 18). Baynes Sound, as defined for this paper includes Pacific Fisheries Management Subareas 14-8, 14-11, 14-14 and 14-15. Commercial clam landings are reported either by Clam Management Area (plant hails to the Fishery Manager) or Pacific Fisheries Management Area (PFMA, DFO Catch Statistics from sales slips), depending upon the data source used (Tables 8 and 9). In either case, landings are not summarised in a form that readily allows separation of Baynes Sound landings.

Historic production from PFMA 14 decreased in the early 1990s due to increased clam aquaculture on grounds that previously held wild fisheries and loss of harvestable clam stocks due to faecal contamination. The 1997 season was only open for two days. The large number of diggers holding Area D licences resulted in intensive effort on the remaining open areas in the fishery. After licence limitation in 1998, the number of licensed diggers in Area D dropped from over 500 to under 200, allowing for a more manageable fishery. In recent years, plant hails have allowed separation of Baynes Sound production from Area D and PFMA 14 landings. Hailed Manila clam landings for Baynes Sound were 90.7 t in 1996, 48.5 t in 1997, 105.7 t in 1998, 117.5 t in 1999 and 84.8 t in 2000 (R. Webb, DFO, Parksville, pers. comm.).

Limited licensing has increased the annual days of fishing from 3 days per year in 1995-1997 to eight days of harvesting in 1998 and 1999 (Table 8). The overall annual landing has remained fairly consistent, but it now takes longer to harvest due to a decreased daily effort. Recent declines in harvest are believed attributable to loss of productive ground to aquaculture tenures and closures due to faecal contamination and Paralytic Shellfish Poisoning. The effects of intertidal shellfish aquaculture could be more readily assessed were it known how much productive clam ground was under aquaculture tenure and the spatial locations of tenures.

The paper does not address habitat impacts from commercial or recreational harvesting as these have not been documented. However, commercial and recreational harvesters likely do not cause as large an impact as does shellfish farming operations. Both wild harvest and farming involves turning the substrate and removing target species.

Landings increased in 1998 due to increased opportunity in both the wild and depuration fisheries (depuration fisheries - those that occur in faecally-polluted waters), but have decreased since, due to loss of ground to contamination closures, aquaculture tenure expansions, and closures due to conservation measures. This has resulted in a further concentration of fishing in smaller areas, again leading to concerns or recruitment over-harvesting in Area D.

The specific beaches remaining to the commercial fishery in Baynes Sound are:

- A small portion of the south-eastern end of Beach 8 in Deep Bay (all numbered beaches refer to the beach codes in Harbo *et al.* 1997) between tenured grounds and the closure around the Deep Bay wharf.
- A small portion of the north-western portion of Beach 8 above lease number 395.
- A small portion of the extreme south-western end of Beach 7 in Mud Bay.
- The western portion (approximately half) of Beach 96 on Base Flats.
- A portion of Beach 15 at Union Point and the Coal Hills (excluding the closure inside the breakwater at Union Bay).
- The reef at Denman Island light, 0.3 nautical miles north-west of the ferry landing.
- Various locations along Beach 93 south of the contamination closure at Argyle Road.
- The large beach at Tree Island (Beach 1). Most of this beach has a lower tidal elevation than is inhabited by Manila clams. There are large stocks of butter and littleneck clams on the lower beach (Kingzett and Bourne 1998) and populations of Manila clams on the south-eastern portion of the beach in PFMA 14-10.

The depuration fishery currently harvests only one beach in Baynes Sound, a 4.1 ha portion of the beach at Gartley Point (Beach 17, Harbo *et al.* 1997). Other depuration beaches in Baynes Sound were:

- Royston, which was harvested for depuration between 1992 and 1995, when it was given a prohibited fishery status due to high faecal coliform counts. It is currently used as an unharvested reference beach for the depuration assessment program (Gillespie2000).
- Mud Bay, which was harvested for depuration between 1993 and 1999 (Gillespie 2000). Most, if not all, of the 16.5 ha that were harvested were removed from the fishery by aquaculture tenure expansions in 2000.

Base Flats, which was fished for depuration in 1994, was re-opened to the wild fishery after water quality reclassification in 1995, when agricultural contamination sources were remediated with the assistance of shellfish growers (Dave Walker, pers.comm.).

OYSTER AND CLAM AQUACULTURE PRODUCTION IN BAYNES SOUND

The most widely cultured species in the Pacific Northwest is the Pacific oyster. Although first introduced from Japan in the early 1910s, significant cultivation did not take place in BC until 1926 (Quayle, 1988). Table 10a shows the volume and value of Pacific oyster production, province-wide, since 1986, and in Baynes Sound since 1993. Historically, intertidal production of Pacific oysters was preferred. However, recent oyster culture trends have been towards deepwater production. The advantages of growing oysters off-bottom in deepwater includes the use of current technology, lower costs and greater productivity. Beaches previously used for oyster production are now often used primarily for clam culture (Anon. 1997).

The farmed production of clams in BC has been formally licensed only since 1991. Table 10b shows the volume and value of clam production in BC and Baynes Sound. The higher value of cultured clams in comparison to oysters is evident in the table, but the higher quality control associated with culture clams also gives them a higher market value than harvested wild clams (Heath 1997).

Bottom culture of oysters

Intertidal oyster culture generally occurs between 0.5 and 2.5 m above Chart datum. Techniques include both bottom (or beach) and near-bottom methods (Quayle 1988; BCSGA 1998).

Since the 1920's, the major species used for bottom culture in Baynes Sound has been the Pacific oyster (Gunn and Saxby 1982). The traditional method used in relatively protected bays is to distribute seed (juvenile oysters or spat), usually attached to pieces of oyster shell (called cultch), on the beach (Quayle 1969, 1988). At seeding, there are optimally from 8 to 15 spat per cultch shell, ranging in size from a few millimetres to more than a centimetre in shell length. After a period of growth, the larger clusters of oysters are manually divided ("cluster busting"). Harvesting by hand picking and placing oysters into onion sacks or cargo nets (for pick up at high tide by skiff) occurs from three to five years after planting. Intertidal tenures are also used by some oyster farmers for hardening or conditioning of oysters from suspended culture (e.g. rafts or longlines) for a period of a few months prior to marketing. Some beach sites with firm substrate may be accessed during low tide by light truck or wide-tired all-terrain vehicles (ATVs) to move seed or harvested product.

On tenures with seasonal wave exposure, coarse (19-25mm mesh) Vexar® fences (20-40 cm above and 0-10 cm below the substrate, held in place by steel re-bar pins) may be placed on the upper edge of (and sometimes around) oyster plots to reduce the loss of product from the plot area by wave action. Rock berms (see below) may also be used for this purpose.

Near-bottom oyster methods

Oyster seed is sometimes nursery-reared in mesh bags, trays or semi-rigid net bags on elevated shelves or racks (e.g. welded re-bar or steel frames) in the intertidal zone, especially in areas where there is a soft or muddy substrate. On firm gravel beaches, the trays or bags may be placed directly on the bottom and secured as necessary with re-bar pins or other anchoring methods. A typical sequence may involve reducing densities of cultch-less or "singles" seed as the oysters grow, using progressively larger-meshed bags or trays (BCSGA 1998). The enclosures, if properly closed, will generally provide protection from predators, such as crabs and starfish.

Intertidal culture of Manila clams

The experimental phase of Manila clam culture began in British Columbia in 1969 and continued until the early 1990's (Bourne 1989, Heath et al. 1992, IEC 1992), using methods developed on the Atlantic coast and in Washington State (Anderson et al. 1982, Toba et al. 1992, Mitchell 1995). These trials demonstrated that it was feasible to improve the production of Manila clams by a combination of seeding and use of protective netting (car cover or seine netting) and beach modification (e.g. berms, contouring, and stream channelisation) at suitable sites. Since 1990, commercial culture of Manila clams has been conducted on a relatively small area , mainly those areas that were tenured for oyster culture prior to September 1990 (Caine and Dickson 1992). Baynes Sound quickly became the leading growing area for Manila clams in BC, with about fifty licensed tenures covering about 280 ha, by 1996. Since 1998, more than half of the farmgate value of cultured shellfish produced in Baynes Sound has been farmed Manila clams (Table 10).

For successful commercial culture of Manila clams, the first step is to choose or modify, where appropriate, a site to obtain the desired physical characteristics for good growth, survival and harvestability of the crop. The most important physical factors are tidal level, substrate type, wave exposure, temperature and salinity. Biological factors that affect clam production are density, biomass, food availability, predation, competition, pests and disease. Pollution and marine biotoxins are factors that may affect the harvestability of clams.

Tenure modifications associated with clam culture

Farmers, after selecting a site, can influence substrate type, beach contour, wave exposure, predation levels, clam densities and competition, pests and disease.

Substrate type and modification

The ideal substrate for Manila clam growth and survival is a stable, loosely packed substrate consisting of gravel, sand, mud and shell (Miller 1982, Toba et al. 1992). Substrate stability is critical because Manila clams cannot survive in a constantly shifting substrate (Kurashige 1942). In unstable areas, the matrix of sediment fines that hold the gravel and sand together may wash away, leaving only an unsuitable, loose deposit of sand and gravel. Substrate stability can be enhanced by use of predator-exclusion netting and berms to lower wave energy.

If an intertidal shellfish tenure lacks adequate natural substrate to support Manila clams, there are methods for substrate modification (Toba et al. 1992, Mitchell 1995) that may be applied under appropriate circumstances, with permission from government agencies (BCAL, DFO). Substrate modification generally involves placing gravel or a combination of gravel and crushed oyster shell onto a soft (mud or mud-sand) or hard (packed cobble) beach area to create a substrate that approaches the ideal substrate for Manila clams (Thompson 1990, 1995; Mitchell 1995). In Baynes Sound, there has been no modification of substrate by gravel addition. This region has the most extensive intertidal flats with gravel/sand/mud substrates in British Columbia that are suitable for clam farming.

Wave exposure and berms

Despite their relative protection from wave action, many Baynes Sound beaches are periodically exposed to storm waves from the south-east or north-west that can shift substrate, clams or oysters. Vexar® fences are often used to hold oysters, but are relatively ineffective in stabilising substrate or preventing clam movements. Protective netting or car cover may assist in stabilising substrate, but waves may scour small Manila clams out of plots in the first few weeks or months after planting (Anderson et al. 1982). Low boulder berms are sometimes placed 50-100m seaward of the clam plots (at or near zero tide level) to protect them from storm damage (BCSGA 1998). Creation of such "improvements" requires approval within the tenure's Shellfish Development Plan by BC Assets and Lands.

Predation and Protective Netting

To reduce clam seed predation by a variety of predators, such as bottom fish, crabs, starfish and sea birds, the technique of placing panels of light-weight, 1.25 cm (0.5") mesh plastic netting (car cover) over seeded natural gravel substrates was developed in Washington (Glock and Chew 1979, Anderson et al. 1982). Some farmers also use old fish farm smoltpen netting to cover their plots. Studies comparing clam recovery in netted and unnetted (control) plots in Washington and BC have shown significantly higher recovery of Manila clams in netted plots (Anderson et al. 1982, Heath et al. 1992, IEC 1992). If protective netting is not used, the spreading of larger clam seed (21 mm shell length) does not necessarily result in better recoveries than use of the smaller seed (3-4 mm) commonly available from shellfish hatcheries (Anderson et al. 1982). Typical survival of 3-4mm seed with netting is 30-57% after two years, compared to 0 to 10% in unprotected plots (Anderson et al. 1982, Toba et al. 1992). BC clam growers generally estimate the mortality rate from 6-9 mm seed through to harvest ranges from 40-50% (BCSGA 1998) even with the use of protective netting.

Population Levels and Competition: Planting Clam Seed

As with other types of farming, appropriate seeding and inventory management on clam farms are critical to economic success. For Manila clam farming, the target initial stocking density is generally 330 to 660 clams m^{-2} or 30 to 60 clams ft^{-2} (Toba et al. 1992, BCSGA 1998). Higher densities (e.g. 800-900 clams m^{-2}), especially when the clams are reaching harvestable yields of 6-7 kg m^{-2}, can lead to reduced growth rates in clam plots, and possibly "stunting" effects, likely due to competition for food (Mitchell 1992). Since natural recruitment of clam seed into netted plots is variable, farmers spread hatchery seed to ensure a desired set. Natural sets, though, may sometimes augment hatchery seed inventories significantly, requiring regular inventory monitoring and management (e.g. tilling and thinning) to prevent over-crowding in clam plots (Toba et al. 1992).

When planting small seed clams, plots are usually prepared in advance. This may involve:

1) removal of wood debris and/or rocks that will interfere with farming techniques; contouring the intertidal; and creating berms and channelising streams that flow through the plots (the latter requires prior DFO approval); and
2) placing plastic netting over the plots (if predation, other than by moon snails, is considered a problem). Netting is typically installed as either car cover net panels usually 4-5m wide by 25-30 m long, with the perimeter having lead line woven through the edge and secured with plastic cable ties, or as smolt netpen panels approximately 15-30m x 15-30m. Panels (single or double layers) are fixed to the substrate by re-bar staples and/or rocks around the edges.

Planting, by sprinkling seed at a predetermined level within marked panel sections, is done on a rising tide on a relatively calm day (waves less than 15 cm high) in water 15-60 cm deep (Toba et al. 1992). When covered by calm water, Manila seed clams can dig into the substrate within minutes under calm conditions.

Maintaining Netted Plots

Netting typically lasts the three-four years of a crop cycle if properly maintained. However, damage to car cover is common (e.g. seam separation, tearing by debris or drift logs), and once the netting is damaged, predators can gain entry, resulting in dramatic loss. Miller (1982) reported that in situations where crabs entered through loose or damaged seams, clam numbers dropped from 550 m^{-2} to 165 m^{-2} over a three-month period. Thus, routine inspection and regular maintenance (e.g. stitching damaged seams) of nets are needed to avoid major losses of cultured clams.

Bio-fouling (macroalgae and mussel/barnacle growth on nets) may restrict water circulation and cause severe reduction in phytoplankton availability. This is most common from spring through fall. If the bio-fouling is significant (i.e. netting becomes clogged), then the fouling organisms must be removed manually. However, it has been suggested that, at some locations, the continual net upkeep may not be economically justifiable (T. Harper, Nanaimo, aquaculturist), as mussels may just reattach and currents may or may not wash the removed algae away.

Harvesting

Clam harvesting is currently done exclusively by hand raking. The netting, if used, is rolled back and the plot is systematically dug. Most harvesting is done by specialists who work year-round for the clam farmers; harvesting occurs at night from October to March because of the diel timing of low tides. Clams below market size (generally less than 35 mm) are left in the plots. When the final harvest is completed on a plot, the area is raked smooth, re-netted and planted with the next crop.

GEOGRAPHICAL AREA CURRENTLY UNDER CULTURE IN BAYNES SOUND

While the total Baynes Sound area currently under tenure for bivalve aquaculture is 538 ha, spread over 194 tenures (W. Heath, pers. comm., July 2001), this value is only meaningful in the context of the area that is currently naturally inhabited at significant densities by relevant bivalve species, and particularly manila clams. Clam species each have different preferred substrate requirements, tolerances to salinities and temperatures, and intertidal height ranges. We could find no summarised information on the total area, spatial patterns of occurrence, and abundance of manila clams in the intertidal zone in Baynes Sound. The habitat preferred by clams is not necessarily that of current leases, since most of these were initially established for oysters. It will only be some fraction of the total intertidal zone: about 1/3 of the intertidal zone is estimated to be in the intertidal height range preferred by manila clams, and of this, only some further fraction will have appropriate substrate characteristics and water conditions for manila clams.

Obtaining this information is important in calculating the ecological impact of bivalve culture. It is important to determine the percentage, e.g., 5, 25, 50, 75 or 95%, of manila clam habitat currently tenured, and the areas over which the different types of impacts associated with clam culture are being applied. Likewise, knowing the spatial pattern of tenures is important, as this can determine whether there are appropriate areas where other natural species may occur in abundance. A substantive series of contiguous tenures is likely to have a different ecological impact than a series of modest sized tenures with appropriately-sized uncultured areas between them, as has been found with urbanisation and agriculture (e.g. Yale Forest Forum 2000).

EXISTING TENURE EXPANSION PROCESS IN BAYNES SOUND

In November 1998, the Province announced the Shellfish Development Initiative, which included a procedure for expansion of existing shellfish tenures and a new application process for obtaining new shellfish tenures. Opportunities for limited tenure expansion were provided to growers that could demonstrate significant utilisation of their existing tenures for shellfish aquaculture.

An outline of the process for obtaining new shellfish tenures is provided in Figure 19. A major new feature of this process is the initial period of community input, including a Community Steering Committee and public meetings. Representation on Community Steering Committees is from a wide range of interests, including First Nations, the shellfish aquaculture industry, provincial agencies (MAFF, BCAL), local government, regional economic development agencies, environmental research groups and clam fishery management boards (Osborne 2000).

The role of the Community Steering Committee is to recommend (a) an acceptable rate of development for shellfish farming for the region (i.e. social acceptability); (b) suitable areas (i.e. capability and suitability for shellfish culture) for accepting new applications (suitability maps) and (c) community criteria for adjudicating tenure applications (i.e. criteria for overlapping applications or exceeding of allowable area). Seven steering committees were established; five of these committees have completed all their tasks. As a result, applications for new shellfish tenures have been accepted in the Powell River, Barkley and Quatsino regions. Nootka-Kyuquot will be opened for applications in the very near future. In Clayoquot Sound, discussions on the number of First Nation shellfish aquaculture reserves are underway. Once these discussions are complete, the area can be opened for applications.

Discussions to establish steering committees for Cortes Island, Quadra-Campbell River, Sechelt, Nanaimo and Southern Gulf Islands are ongoing.

The Comox Valley Shellfish Steering Committee was established in February 2000. The committee voted to hold its activities in abeyance after Denman Island Trustees on the committee advised that no area on the Island Trust area of Baynes Sound would be available without rezoning for shellfish aquaculture.

All applicants must follow the standard procedures for disposition of Crown Land (posting of Form 1, completion of a detailed Shellfish Development Plan that describes the proposed operation, including Schedules of seeding, production and improvements). Following acceptance and payment of a non-refundable administration fee of $500, the applications are referred to a list of agencies, including DFO (for fisheries, habitat and navigable waters concerns); WLAP; local governments (for zoning considerations); and First Nations (aboriginal rights and title issues). Publication requirements, community process, and referral process will determine if there are possible conflicts. Attempts at conflict resolution are made to address concerns before a land use and licensing decision is made. Successful applicants are offered a tenure, to be issued upon payment of an additional $4,500 fee. Figure 20 presents the existing and proposed aquaculture leases in Baynes Sound.

LITERATURE REVIEW OF ENVIRONMENTAL IMPACTS OF SHELLFISH AQUACULTURE

TENURE MODIFICATION IMPACTS ON THE INTERTIDAL ECOSYSTEM

We define disturbance as any physical modification of intertidal or shallow subtidal substrates that results from aquaculture practices (see Simenstad and Fresh 1995). Under this definition, this includes the addition of high densities of cultured animals to natural substrates and indigenous communities, altering sediment structure, modification of population characteristics of indigenous species that are considered deleterious to the efficient culture of the target species, and altering the natural hydrologic and sedimentary regimes. Only the impacts of intertidal bottom culture are considered here. The effects of commercial or recreational harvest impacts on natural bivalve populations have been excluded, even though they can cause extensive disturbance of intertidal communities as well.

Vexar® Fences, Berm Building and Beach Clearing

In comparison to near-bottom and off-bottom methods of culture, in situ bivalves in bottom culture seldom affect the pattern of water flow and sedimentation (Pillay 1992). However, as previously described, berms and vexar® fences are utilised in Baynes Sound for the stabilisation of sediment and retention of stock (Figure 21 and 22). In addition, beach clearing to remove cobble and boulder-sized sediment and driftwood is also practised to maintain ideal substrate conditions for bivalve culture. These modifications alter the natural patterns of waves and currents resulting in impacts on the natural patterns of erosion and sedimentation in the intertidal zone (Pillay 1992). To what degree these impacts have on the coastal ecosystem of Baynes Sound is not known.

Predator Exclusion Netting

One of the most extensive tenure modifications in the intertidal zone of Baynes Sound is the use of predator exclusion nets, which are utilised in Manila clam culture during the on-growing stage to protect stocks from predation by diving ducks, crabs, sea stars and snails. The netting is placed directly on the foreshore surface, and weighted down with lead lines that are attached by rebar (Figure 23-25). Either plastic netting or "car cover", which is made of polypropylene with a mesh size ranging from 10mm to 20mm, or to a less extent, old netting from smolt net pens are used. If car cover is used, more than one layer of netting may be laid over the substrate, especially during the early phases of culture when the clams are much smaller (Spencer et al. 1996).

Spencer et al. (1996, 1997, 1998) conducted a five-year study of Manila clam culture to assess potential physical and biological disturbances on the benthic community related to clam cultivation. Experimental plots, both with and without clams, were covered with netting, and were compared to control plots without netting. The use of 5 mm mesh netting for the first six months, and a larger mesh size of 10 mm for the remaining two years, had a continuous impact on the local hydrographic regime by reducing flow and increasing sedimentation (Spencer et al. 1996; 1997). Experimental plots treated with netting experienced up to four times the rate of sedimentation, resulting in the raising of netted beds by about 10 cm. The sediment under netted plots, with and without clams, also had higher levels of organic content and phaeopigment. The netting attracted epiphytes, which in turn attracted periwinkles; both contributed to the increase in organic content (Spencer et al. 1996; 1997). Alterations in the abundance of benthic infauna were also attributed to the use of netting via reduced flow, modified substrate conditions, and the exclusion of major predators. There was an increase in the number of species and density under netted plots, and a change in species composition towards domination by deposit feeding worms (Spencer et al. 1996; 1997). A smaller-scale study by Kaiser et al. (1996) reported similar results.

Simenstad et al. (1993) studied the use of predator exclusion netting on epibenthic assemblage structure in Puget Sound, to observe the potential impacts on prey resources of other commercially important juvenile fishes that rear in the intertidal zone during a critical period of their life history. Harpacticoid copepods were utilised as the indicator organism. The varying responses of species composition and density between plots indicated that site-specific factors such as initial grain size structure, tidal elevation, and beach geomorphology may play a larger contribution to epibenthic assemblage structure than was evident between netted and control plots. Similar to the findings of Spencer et al. (1996, 1997), changes to intertidal community structure were also attributed to reductions in mean sediment grain size, increased abundance of algae, and alterations in predation related to the presence of predator exclusion netting (Simenstad et al. 1993).

Bendell-Young et al. (2001) recently attempted to assess the impact of car-cover on intertidal structure and function in Baynes Sound by comparing basic components of species diversity (structure) and cycling of organic matter (function) among three beaches experiencing different farming/harvest intensities: a reference beach used only for recreational harvesting within a provincial park with no car-cover present; and, two commercially-leased beaches that were farmed but at different levels of harvest intensity and net coverage, i.e. partially covered and completely covered. Ecosystem structure was examined through measurement of species richness, abundance and distribution and basic community composition. Ecosystem function was evaluated by among-beach comparisons of surface sediment percent organic matter. Comparison of these indices indicated that intensive farming practices that included seeding and covering of the beach with car-cover decreased species richness and changed the community structure of the intertidal from one comprised of a balance of surface and subsurface species to one comprised primarily of bivalves (Figure 26). Car-cover also increased accumulations of surface sediment organic matter as compared to the reference beach, a finding previously noted by Spencer et al. (1996, 1997).

Predator Removal

In addition to the use of predator exclusion netting, the manual removal and killing of macro invertebrate predators found on lease areas is a common practice in intertidal bivalve aquaculture. Trapping programs can be utilised to limit crabs and sea stars from accessing the intertidal zone (Pillay 1990). In Martha's Vineyard, MA, one local area has a bounty system to monetarily reward fishermen for the removal of predators (Karney, 1995). In Baynes Sound, the invertebrate species subject to removal are Moonsnails, crabs (*Cancer productus, C. magister*), and sea stars *(Pisaster ochraceus, P. brevispinus*). This direct impact on the abundance of certain species of benthic macrofauna can affect the intertidal community structure through the alteration of predator/prey relationships. Caging experiments by Summerson and Peterson (1984) demonstrated that the removal of large, mobile epibenthic predators from unvegetated sandflats resulted in a substantial and significant increase in macrobenthic infauna.

Recent studies by Bendell-Young et al. (2001) and Bendell-Young and Ydenberg, (2001) also demonstrated that predator control has an effect on the abundance and distribution of bivalves (Figure 27 and 28). Three beaches of different shellfish harvest intensity (see above) were compared for species and abundance of bivalves. For the reference beach, non-native Manila and native littleneck are the dominant species, with abundances reaching up to 300 individuals $0.25m^{-2}$, but only at high tidal elevations (Figure 27 and 28). In contrast, on the netted plots, total number of bivalves were more evenly distributed along the intertidal (Figure 27), with Manilas dominating in one beach and Manilas and *Macoma spp*. dominating in the other beach

(Figure 28). That the netted beaches had a fairly even bivalve distribution over tidal elevation, with the Manilas dominating, was not unexpected given the practice of seeding with only Manilas and the removal of other indigenous clam species, specifically native littlenecks, by hand raking.

The high abundance of bivalves at higher tide levels on the reference beach in the absence of predator exclusion nets was somewhat counterintuitive and raises the question as to the actual role of predator exclusion netting in increasing bivalve yield. The location of bivalves on the reference beach is perhaps easier to explain in that unlike the farmed beaches where active predator control occurs, no such practice occurred on the reference beach. As a consequence there was a large Moonsnail population on the reference beach in contrast to the two farmed beaches where this predator was absent (L. Benedell-Young, pers. observation). Moonsnails require water in the substrate to move within the intertidal, and substrate desiccation occurs at higher tidal elevations. At the elevation where Moonsnails can no longer move within the intertidal, bivalves become more abundant. In the study, it was at approximately 2.5 m elevation. In the presence of predator exclusion netting, no such predation pressure on bivalve distribution occurred. It may thus be the removal of Moonsnails and not the presence of predator exclusion netting per se that was the important variable in these studies.

Beach Gravelling

Several studies on the impacts of beach gravelling to enhance hardshell clam habitat have taken place in Puget Sound, Washington. Gravelling either involves the placement of gravel alone, or a mixture of gravel and crushed oyster shell on mud and sand beaches. The addition of coarser sediment serves to increase predator protection and substrate stability, and creates interstitial space to enhance the settlement of juvenile clams in order to increase production (Thompson and Cooke 1991). Although as previously mentioned, gravelling has not taken place in Baynes Sound, aquaculture operators in BC can apply for permission for substrate modification. Permission was given to a farmer in Ladysmith Harbour to add pea gravel over a sandstone substrate to make a substrate for clam culture, but it was never acted on (Rob Russell, DFO, Nanaimo, pers. comm.). Gravelling was done on a clam lease in Nanoose Bay in 1993, and an assessment of the effectiveness of this gravelling project and that of a beach re-contouring project at a clam tenure in Barkley Sound was commissioned by BCMAFF (Mitchell 1995). The study concluded that substrate enhancement by beach contouring and by gravelling are both viable methods for increasing the productive capacity of BC clam tenures for Manila clam seed growth, survival and natural recruitment. This warrants the following review of gravelling impact studies.

Thom et al. (1994) studied the impact of gravelling at two study sites, one characterised by a fine sand and mudflat texture, and the other a broad sand flat. In general, gravelled plots were associated with an increase in secondary productivity, respiration, nutrient flux, and heterotrophy in comparison to control plots. However, there was no major difference between net productivity, and levels of dissolved oxygen and inorganic nitrogen concentrations. For both sand and mudflat sites, there were also significant increases in bivalve density and an increase in vegetation cover of *Ulva* sp. in gravelled plots, probably related to the increased nutrient flux associated with gravelling.

Two studies assessed the impact of beach gravelling on both abundance and diversity of epibenthic organisms. Simenstad et al. (1991) concentrated on gravelling impacts on species subject to predation by juvenile salmon, and found the abundance of harpacticoid copepods and gammarid amphipods was greater on plots of both sand and mudflats subject to gravelling relative to control plots. Thompson (1995) also found an increase in density of both gammarid amphipods and nemertean worms on gravelled plots, in addition to the presence of shore crabs not found in control plots. Conversely, there was a decrease in diversity and abundance of polychaete worm density, which may have been a short-term effect until the breakdown and accumulation of finer material in the substrate occurred. Overall, there were only minor differences in species diversity and abundance between gravelled and control plots. These were associated with changes in texture of gravelled sites and the increase in interstitial space created a more favourable environment for certain species (Thompson 1995).

In the above studies, beach gravelling was not observed to cause a net negative impact on epibenthic species diversity. However, these studies concluded that the enhancement of hardshell (steamer) clam habitat did have an effect on intertidal ecosystems, that the level of impact caused by alterations in substrate texture due to gravelling was related to degree of disturbance in relation to natural conditions (Thom et al. 1994; Simenstad and Fresh 1995).

Beach Tilling and Harvesting

During the 1–3 year harvest cycle of oysters, and the 2-4year harvest cycle of clams, husbandry practices may disturb the benthic environment on a regular basis. Beach tilling or raking associated with transplantation, redistribution or thinning, and harvest of oyster and clam beds directly impacts the intertidal zone. While mechanical harvesting of intertidal grown bivalves is practised in some countries, e.g., through the use of hydraulic dredges towed by boats and tractors (Hall and Harding 1997, Spencer et al. 1998), the use of such machinery has only been experimentally employed in BC (Adkins et al. 1983) and has never been operationally permitted. In Baynes Sound, all harvesting is performed manually by hand raking. Ecosystem impacts related to beach tilling and harvesting focussed on the potential impacts on intertidal vegetation. Although there is supposed to be no interaction between aquaculture leases and eelgrass, overlap of leases and eelgrass beds has occurred (Tamasi et al. 1997), and evidence of oyster on-growing amongst eelgrass has been observed (Figure 29).

Comparisons between mechanical harvesting and hand raking techniques have demonstrated that although the effects of hand raking are much less severe, it does impact the intertidal ecosystem (Peterson et al. 1987, Kaiser et al. in press). In experiments on both sand flat and seagrass bed environments, hand raking did not appear to have a direct, significant impact on the density and species composition of benthic macroinvertebrates in comparison to control plots (Peterson et al. 1987). However, hand raking in seagrass beds resulted in a 25% reduction in seagrass biomass, which subsequently underwent full recovery after one year. Peterson et al. (1987) concluded that through the direct impacts of hand raking on seagrass biomass, indirect changes in the benthic faunal community can occur. In contrast, Kaiser et al. (in press) did observe short-term changes in benthic species composition related to hand raking, but observed recovery occurred within 54 days of disturbance. Limits to disturbance by hand raking were attributed to the leaving of sediment in situ, thus not affecting all animals within the path of the rake (Kaiser et al. in press).

It should be noted that the wild fishery for clams also involves hand raking, and so all clam harvesting involves some ecological impact. On a modest scale, hand raking is unlikely to be too significant ecologically, as the intertidal zone is a dynamic one that is regularly impacted by wave action during storms. The scale and frequency of impacts may be important. Unfortunately, there is little published data that is relevant to either wild harvest or clam aquaculture on hand raking impacts. Bourne et al. (1998) investigated repeated digging effects on sublegal-sized manila clams, and found no significant difference in survival because of repeated digging with rakes. With this technique, the substrate is generally not overturned and juveniles are thus not usually buried under mounds of substrate. Another reason they identified for their lack of significance in survival rates of juveniles with different digging regimes (1,2 or 4 times per year for two years) was experimental design, as in hind-sight, they used large plots to minimise edge effects, but this decreased statistical precision due to fewer replicates.

Impacts from digging include clam removals, the killing and /or injuring of some unharvested clams, and increasing the exposure of others to either predators or adverse environmental conditions, such as desiccation, freezing, or possibly smothering. Smaller clams are likely to be most affected by the latter impact, but comprehensive studies are required to establish the nature and seasonal severity of impacts.

Channelisation of Estuaries and Deltas

Estuaries are important ecosystems and provide habitat to a rich diversity of organisms. Estuaries are transitional zones between fresh and salt water sharing characteristics of both environments. The key is the transition from fresh to salt water and the flood and ebb of tides, which changes the water chemistry, sediments, the micro-organisms and the plant and animal communities, such that the system functions in a different way from fresh or salt water habitats. Deltas are the morphological feature formed in estuaries where upland sediment is deposited in coastal areas by streams as they meet the lower energy marine environment. Some of the larger streams that flow into Baynes Sound form deltas, whose morphology is controlled by the supply of sediment from both upstream and longshore transport sources, and dominant tidal flows. As a result, estuaries and deltas are characterised by an unstable network of meandering tidal channels that are constantly changing. Through the relocation or addition of substrate to form fewer or a single channel(s), channelisation can be implemented to stabilise the physical estuarine environment. The effects of locally concentrating stream flow through artificially maintained channels can result in increased erosion and removal of vegetation, altering patterns of sedimentation, temperature, salinity, nutrients and oxygen levels (Bose et al. 1991). Over the long term, the restriction of the lateral movement by tidal channels will limit the downstream supply of these variables to parts of the estuary, while directing sediment farther out than normal. As a result, the overall size and shape of the delta will be altered.

In lease areas located at the mouths of some streams entering Baynes Sound, channelisation of estuaries is occurring that alters the temporal and spatial flow patterns in the intertidal zone (Figure 30-32). This allows the grower to increase the area that can be utilised for culture and reduces the risk of shellfish being washing away during freshets. To what extent these disturbances are occurring and the size of the impact in Baynes Sound is not presently known.

Terrestrial Vehicle and Boat Usage in the Intertidal Zone

Because tidal flats may not always be accessible by boat, terrestrial vehicles are sometimes used to access lease areas (Figure 33 and 34). DeGrave et al. (1998) studied the sediment and benthic macrofauna in vehicle access lanes at an intertidal oyster culture operation. In comparison to control sites, mid-tidal areas subjected to physical disturbance from moderate vehicle traffic experienced alteration in surficial sediment matrix through compaction and displacement, along with a higher abundance of epifaunal decapods at the expense of a reduction in small-bodied crustaceans and shallow, fragile burrowing bivalves. As well, accidental discharge of oil and gasoline from vehicles poses a potential contamination threat to fish and fish habitat in the intertidal zone. Lease areas serviced by boats also have the potential to be similarly impacted, and eelgrass beds can be damaged by propeller wash, the direct cutting action of propellers, and by boat hulls being dragging over vegetated bottoms (Short and Wyllie-Echeverria 1996).

Pesticides

There is no present use of pesticides in BC shellfish aquaculture operations (B. Kingzett, BC Shellfish Growers, pers. comm.) However, chemicals are used in finfish aquaculture to control sea lice (copepods), and their potential use in shellfish culture exists to address yield or quality problems that may be caused by crustaceans. Pesticides are used in bivalve culture in specific areas of coastal Washington, where the pesticide carbaryl (tradename, Sevin®) is used to control local populations of burrowing shrimp that in high densities can destabilise the substrate under oyster beds and result in oyster smothering (Simenstad and Fresh, 1995).

It can be argued that if the use of pesticides for this purpose is required, then the areas tenured are inappropriate for that type of bivalve culture. Even if not used at the outset of culture, managers should be aware of the potential demand for such substances if bivalve culture is approved in areas not particularly suited for profitable bivalve culture without the use of these chemicals.

ECOSYSTEM EFFECTS OF INTERTIDAL BOTTOM CULTURE

INTERTIDAL COMMUNITY RESPONSES TO AQUACULTURE DISTURBANCES

Positive environmental effects attributable to shellfish aquaculture include improvements to water quality by the removal of particulates from the water column by filter-feeders (Phillips et al. 1991). Furthermore, the requirement for good water quality for shellfish culture has lead to greater awareness of water quality issues and improvements in the quality of water flowing into Baynes Sound. Because of the closure of several shellfish growing areas due to faecal contamination in 1994, the Baynes Sound Round Table was formed to work towards reducing levels of non-point source pollution entering the Sound, resulting in a general improvement in water quality (Joughin and Lau 2001).

However, shellfish aquaculture does have the potential to negatively impact intertidal ecosystems in a variety of ways as noted earlier. To date, no studies have addressed the cumulative effect on ecosystems from bivalve culture. The following section attempts to identify the types of impacts that can directly effect intertidal productivity and community structure, and indirectly effect vegetation, fish and wildlife in Baynes Sound. It should be re-emphasised here that most actions by humans have an environmental impact. At issue here is not whether this should occur, as humans are also part of the natural ecosystem and have a right to extract resources to survive, but rather the nature, scale and areal extent of human impacts on the ecosystem. This is particularly important today because we now have the technology and physical capability as a species to effect tremendous change over relatively large areas in a relatively short time. The consequences of inadequately regulated intensive shrimp culture in tropical areas (Bhatta and Bhat 1998, Paez-Osuna et al. 1998, Miller et al. 1999, Flaherty et al. 2000) are an example of our ability to create a large adverse impact over a short time period.

Productivity

The sediment-water interface of aquatic ecosystems is an extremely important zone of nutrient (carbon, nitrogen and phosphorous) flux. In some cases, the sediments form a sink from which nutrients are slowly released. At other times, the sediments can be an important source of nutrients at critical times (Clavero et al. 2000, Yin and Harrison, 2000). This flux can determine amounts of primary productivity on which secondary productivity (i.e. bivalve yield) is based.

Shellfish culture may enhance primary production through an increased rate of nutrient cycling. The consumption of phytoplankton biomass and release of nutrients could increase the ecosystem's capacity for supporting additional primary production (Kaspar et al. 1985). However, intensive production of filter-feeding bivalves might result in a reduction in phytoplankton biomass that would reduce the food supply available to zooplankton, resulting in other alterations to the natural planktonic community (Weston, 1991). Thom et al. (1994) and Thompson (1995) indicated that graveling for enhanced clam production can significantly depress macroalgae cover, enhance chlorophyll-a concentrations, increase benthic respiration rates, and increase nutrient fluxes (particularly PO_4^{3-}, total inorganic N, NO_2^-, and NH_4^+); impacts, though, were quite variable and site-specific.

In addition, predator exclusion nets reduce flows and increase sedimentation and the accumulation of organic content (Spencer et al. 1996; Spencer et al. 1997; Bendell-Young et al. 2001). Exclusion netting provides a substrate for algae, mussels and other sessile species. How this alters the geochemical flux of nutrients of aquatic regions used for shellfish culture remains speculative and unproven. If it is enhanced, marine waters supporting mariculture might pose a threat to shellfish farms by possibly increasing the occurrences of undesirable phytoplankton blooms, particularly those of toxic species (red tides). If the normal flux of nutrients such as nitrogen was restricted at certain times, this could reduce primary productivity and thereby secondary productivity. Hence, from both an ecological as well as from the farmers' perspectives, it is important to consider the impacts of extensive use of intertidal culture practices on the basic geochemical cycling of the key nutrients, i.e., carbon, nitrogen and phosphorous. These impacts may also be incurred through alterations in intertidal hydrography and hence sedimentation due to the use of Vexar® fencing, building of berms, and beach clearing.

Community Structure

Types of aquaculture that provide increased topographic complexity (e.g., suspended culture) result in increased density and species diversity of wild fish in the vicinity of farms. Pile perch (*Rhacochilus vacca*), for example, typically occur in abundance in BC waters only around physical structure in the water column. Epifaunal and epiphytic growth on raft intertidal culture structures (references following refer to suspended culture, although elevated intertidal cultivation might somewhat have the same effect) are a potential food source that can attract other fish and wildlife such as crabs, demersal fishes and marine birds such as oystercatchers (Lopez-Jamar et al. 1984, Weston 1991). Alternatively, aquaculture in Baynes Sound could have potential negative impacts on wild populations by modifying gene pools because of cultured bivalve seed dispersal, increased transmission or transfer of diseases, introductions of species that might alter food webs, and competition for ecological niches (Weston 1991). Alterations in intertidal hydrodynamics through the building of berms, use of Vexar® fencing, beach clearing, and use of car cover netting could also have impacts on benthic recruitment processes (Eckman 1983). Furthermore, high densities of bivalves can reduce larval settlement and survival of other species (Kaiser et al. 1998), and decreases in macrofaunal abundance have been detected in intertidal areas under extensive culture (Castel et al. 1989).

Predator exclusion netting and the removal and destruction of predator species such as birds, snails, crabs, and sea stars can have both a direct and indirect impact on the intertidal community structure. Disturbances to natural patterns of intertidal hydrography by predator exclusion netting can also have indirect impacts on community structure. Both Castel et al. (1989) and Nugues et al. (1996) observed declines in water current velocity directly beneath intertidal oyster trestle culture sites. The associated increases in sedimentation and reductions in oxygen levels were attributed to significant declines in benthic macrofaunal abundance. In contrast, although Spencer et al. (1996) observed increased sedimentation at net-covered clam culture sites, they reported no significant alteration to the diversity of the benthic community. Simenstad and Fresh (1995) reviewed the impacts of predator exclusion netting on epibenthic meiofauna, and found the effects to be site-specific and likely dependent on the inherent levels of natural disturbance. Crustacean abundances, notably harpacticoid copepods and some cumaceans, were typically depressed in comparison to unnetted sites. However, at some netted sites, certain copepodite densities increased at certain times of the year (Simenstad et al. 1993). Similarly, Summerson and Peterson (1984) also observed a significant and substantial increase in benthic infauna related to the direct removal of mobile epibethic predators from unvegetated sand flats.

Bendell-Young et al. (2001) and Bendell-Young and Ydenberg (2001) demonstrated that one consequence of the removal and destruction/exclusion of predator species (e.g., snails, crabs, etc) was to shift the intertidal community from one dominated primarily by epibenthos species to that comprised primarily of clams (Figure 35). A shift to a system dominated by the cultured species is expected. Important ecological questions are thus: "What proportion of the natural ecosystem might be shifted to one of farmed bivalves without a significant disruption in natural ecosystem processes, and is fragmentation of the Baynes Sound ecosystem by aquaculture plots a concern with regards to important processes in the ecosystem?" These questions have not been addressed in the Northeast Pacific, and thus are the fundamental questions that should be addressed in an ecosystem assessment of the environmental impacts of intertidal bivalve culture. The impacts of both current levels of culture, and the proposed expansion on community structure and ecosystem functioning (e.g., nutrient cycling) are unknown and with available knowledge, cannot be easily predicted.

Evaluation of immediate responses by benthic communities to aquaculture substrate modifications such as beach graveling do not exist (Simenstad and Fresh 1995). Data that exist are comparisons of impacted sites with adjacent or nearby "reference" sites.

Simenstad and Fresh (1995) reviewed the literature and concluded that graveling beaches affected interstitial community structure. The main effect was the shifting of the benthic infauna from communities numerically dominated by glycerid, sabellid and nereid polychaetes to ones dominated by bivalves and nemerteans. For epibenthic meiofauna, effects were related to the extent of natural substrate replacement by gravel. If it was all replaced, biodiversity was depressed, but if there was not a total loss of sand and mud, an increase in habitat spatial complexity occurred, since both substrates types would then be present, that increased sediment diversity in the site as a whole.

Chronic low intensity, or infrequent intermediate intensity, intertidal substrate disturbances tend to be within the range of behavioural or ecological adaptability of intertidal species. Spatial distributions within most epibenthic intertidal populations are dynamic because of wave action and meteorological effects (reviewed by Simenstad and Fresh 1995). Meiofaunal species tend to havemultivoltine (i.e. more than two generations per year) turnover rates (Hicks and Coull 1983) that facilitate rapid recolonisation, making the spatial and temporal scales of processes that might affect repopulation particularly important. Hall and Harding (1997) postulated that non-harvested benthic communities, being adapted to periodic disturbance, are likely to recolonize harvested areas rapidly. However, recolonisation rates can vary depending on sediment stability and exposure to wave action and currents, and the scale and degree of disturbance. Disturbance impacts may be limited by adopting a farming cycle of seeding, harvesting and fallowing, depending on the amount of natural disturbance and timing of harvesting in relation to larval recruitment of target and non-target species (Kaiser et al. 1998). However, no studies have investigated these aspects in the context of the particular aquaculture practises currently being employed in Baynes Sound.

Changes in the composition of intertidal invertebrate communities can have an indirect affect on the growth, survival and utilisation of habitats by foraging species. This effect is especially significant if they are a "protected" or "endangered" species (WGEIM, 2000). This is particularly important in the Pacific Northeast where economically-important fishes feed preferentially on specific taxa of intertidal soft-substrate meiofauna and small macrofauna. These include chum, chinook and coho salmon (Groot and Margolis 1991), which all inhabit shallow nearshore habitats during parts of their lifecycles where they feed on epibenthic harpacticoid copepods, gammarid amphipods, cumaceans, and other species. Smelts, sandlances, some flat fish species and sticklebacks also heavily utilise these habitats, as do many sea birds such as sandpipers and Dunlin. The abundance of prey required for growth and reproduction of fish and birds, during at least parts of their life cycles, may also be limited as a result of aquaculture, as many of these only utilise prey species that are associated with specific microhabitats.

Eelgrass Habitat

Eelgrass beds are an important ecosystem component, and the secondary effects of reduced biomass are likely to have implications for fish (such as spawning herring, and juvenile salmonids) and subsequently for relevant foraging migratory birds. Intertidal eelgrass beds are located throughout Baynes Sound, and in some cases are located within shellfish aquaculture lease areas (Tamasi et al. 1997). There are currently no data on the impact of bivalve culture on eelgrass biomass in Baynes Sound. Studies from elsewhere, however, have demonstrated that declines in eelgrass abundance can be related to modifications caused by shellfish aquaculture practices (Peterson et al. 1987, Rumrill and Christy 1996, in Griffin 1997). Dredging, harrowing and levelling activities related to oyster bottom culture have been shown to impact eelgrass habitat by disrupting surface sediments and destroying shoots, leaves, roots and rhizomes. Effects may vary with the length of time the area has been cultured, but can persist for one (Peterson et al. 1987) or two years following farming (Waddell 1964, in Simenstad and Fresh 1995). Studies on the impacts of near-bottom shellfish culture relate declines in eelgrass abundance to shading, altered patterns of sedimentation and erosion, and direct physical disturbance during placement and harvest (Everett et al. 1995).

Juvenile Salmonids

Baynes Sound is an important area for juvenile salmonids to rear and acclimate to salt water. It is well documented that some species of juvenile salmon occupy estuaries and nearshore marine areas for up to three months before going to sea (Healey 1980, Levings 1994). In particular, these habitats are vital to the survival of chinook, chum and coho juveniles (Simenstad 1982), where they go through the smolting process. They can reside in these locations for up to several months. A survey carried out during 2000 in Baynes Sound, utilising beach and purse seines, documented large schools of chinook and chum smolts rearing close to shore during the months of July and August. By the end of August, these fish had grown significantly before migrating out of the area (Jenkins et al. 2001).

Juvenile salmon rely heavily on epibenthic organisms for food in both the estuaries and transition zones along the Pacific coast (Sibert 1979). Analysis of the diet of juvenile chinook in the transition zone around the Campbell River estuary found that numerically, epibenthic organisms comprised up to 96.7% of their diet (Kask et al. 1988). In the Nanaimo River estuary, juvenile chum grew at an average of ~6%/day and consumed mostly epibenthic harpacticoids, many of which are found in high densities in eelgrass and other vegetation (Healey 1979). In the Fraser estuary, over 80% of the total number of food organisms examined in the chum fry stomachs were harpacticoid copepods (Levings and Nishimura 1997).

Epibenthic and benthic organisms are specific to certain habitat types; sediment type and the presence or absence of vegetation such as eelgrass, *Fucus* sp., *Ulva* sp., and *Enteromorpha* sp. are important factors. For example, several species of harpacticoid copepods, that make up much of the diet of juvenile salmon, are only found in eelgrass beds and in association with other vegetation. In Baynes Sound, the beach culture of clams and oysters necessitates the removal of vegetation and substantially modifies the sediments prior to seeding the area with juvenile clams. The construction of berms and installation of predator exclusion nets further alienates these areas and may trap fish as the tide recedes. Habitat modification and the covering of the substrate with predator exclusion nets may thus adversely impact the production of harpacticoid copepods and other important epibenthic organisms, and hence adversely impact the successful feeding of salmon rearing in the area.

Herring Spawning

In Baynes Sound, a significant threat to Pacific herring is the loss or removal of macrophytes (eelgrass, algae) on which they spawn (D. Hay, DFO, pers.comm.). Pacific herring spawning is restricted to the nearshore or tidally active coastal areas of sheltered inlets, sounds and bays. Spawning occurs in the spring from the high tide zone to 20 m subtidal depth, generally within a 150 m wide strip. Eggs are laid primarily on intertidal and subtidal marine vegetation, but can also be deposited on substrate such as silt-free gravels to which the vegetation is attached (Haegele and Schweigert 1985). Aquaculture impacts on herring in Baynes Sound are of considerable concern given the high habitat sensitivity of the area (Hay and McCarter 2001).

Birds

The importance of the subject area for migratory birds, particularly the intertidal habitats, as described in the studies above, raises concerns about the effects of intertidal shellfish aquaculture on bird populations. Diving ducks and shorebirds are particularly vulnerable to potential deleterious effects of aquaculture operations. Below are potential actions by which aquaculture affects bird populations:

(i) Use of predator exclusion netting

The extent to which beach cover (either predator exclusion netting or dense oyster beds) reduces shorebird and seaduck access to the underlying substrates is not known. Protective netting only provides partial exclusion of diving ducks as the birds are able to, and do, excavate clams from under the edges of netting panels (Dave Mitchell, BC Shellfsh Growers, pers. comm). Even if species are able to access the substrate beneath, beach cover may increase the bird’s energetic costs of foraging, or increase the risk of their predation.

Beach cover may alter benthic invertebrate productivity beneath it. Bendell-Young et al. (2001 submitted) reported that species diversity and bivalve abundance is lower on farmed beaches with predator exclusion netting cover.

Washed-up netting may have a significant potential to entangle and kill migratory birds.

(ii) Disturbances to resident, overwinterers, and migrant birds by human activities

Many birds, and particularly those hunted in parts of their range, avoid close proximity to humans. Birds may habituate, move to nearby areas of the beach, or avoid areas of human activity altogether, and this can adversely affect the energetic demands of seaducks, shorebirds, and other migratory birds. The behavioural interactions, and their physiological consequences, between migratory birds and shellfish culture activities needs to be better understood. Because shorebirds generally exhibit high site fidelity, the potential exists for their exclusion from preferred foraging sites where they overlap with aquaculture sites. On the other hand, hundreds of western sandpipers have been observed resting on oyster rafts adjacent to tidal flats during high tide (W. Heath, pers. obs.).

(iii) Habitat alteration and displacement of traditional food sources

The removal by aquaculture growers of snails and other invertebrate resources that serve as food items for waterbirds may affect waterbird abundances and spatial distributions.

(iv) Loss of critical habitat

At present, there is a relative lack of effectively protected bird habitat for this region, and the critical requirements by wildlife are unknown. MELP submitted an application under the Land Act for designation of Baynes Sound as a Wildlife Management Area (WMA) (Clermont 1995); this WMA proposal, however, was rejected (Clermont, MELP, pers. comm.). Presently there are 92 ha of protected marine intertidal in the Baynes Sound/Courtenay River estuary area (Jamieson and Lessard 2000). Establishment of a provincial WMA with intertidal foreshore/estuary habitat at Coal Creek, Little Bay, Rosewall Creek, and Trent River to Millard Creek is being considered, but whether this is likely to occur, exactly how big it might be, and what habitat the WMA might contain are unknown (T. Clermont, MELP, pers. comm.).

Altered foreshore ecology is most likely to affect those birds feeding on benthic invertebrates in the intertidal zone, where the shellfishery, both wild and cultivated, is most active. Species of most concern include several seaduck species common to BC, including the white-winged scoter (*Melanitta fusca*), surf scoter (*Melanitta perspicillata*), harlequin (*Histrionicus histrioncus*), long-tailed duck *(Clangula hyemalis*) common goldeneye (*Bucephala clangula*) Barrow's goldeneye (*Bucephala islandica*) and bufflehead (*Bucephala albeola*). These ducks consume bivalves, snails, crustaceans such as crabs and shrimp, and a variety of other small benthic creatures (e.g., amphipods, isopods). A summary of diet information is given by Vermeer and Ydenberg (1989). The direct removal of potentially marketable clams by avian (and other) predators is without question of greatest immediate interest to wild harvesters and growers. Conversely, the extensive harvest of potentially consumable clams, and the exclusion of birds by nets and other methods, are potential threats to the health of the avian populations that winter in these waters.

Of particular interest are impacts on the scoters. Scoters are bivalve specialists (mussels and clams) that capture prey by diving to the bottom. They thus have access to intertidal areas only at high tide. Foraging, usually restricted to daytime hours, consists of alternating periods of diving and rest, as the bulky prey quickly fill the gizzard to capacity, and some digestion is needed before the stomach can be refilled. The low energy yield of the whole prey, much of which is shell, means that much of the day must be spent either capturing or processing prey. Most prey are encountered in underwater searches along the bottom, and under, in and around rubble and rocks. Mussels must be wrenched from their strong byssal thread attachments, and like some large crabs (cf. Zaklan and Ydenberg 1997), scoters dig clams from the bottom (Glude 1964). A wintering group of scoters continually churns and turns over sediments. Further, Lacroix (2001) showed that surf scoters were a keystone species that removed large quantities of mussels, which provided space for other species of intertidal invertebrates. The exclusion of scoters as predators by the use of exclusion netting may therefore reduce biological diversity in intertidal habitats.

Restricting the access of sea ducks to the substrate by use of exclusion netting benefits the aquaculture industry directly by reducing clam losses and indirectly by forcing them to prey upon surface-dwelling mussels, which are competitors for food eaten by clams. It may thus be that some bivalve predation by sea ducks is beneficial overall to intertidal clam culture, but the relative dietary importance of clams and mussels to sea ducks and how sea ducks are specifically affected by exclusion netting is not known.

CUMULATIVE EFFECTS ISSUES

In order to assess the cumulative effects of any environmental insult, there are numerous factors that must be considered. In order to determine whether an impact has taken place, before-farming baseline conditions must be known and compared with post-farming conditions, or the latter are compared to appropriate reference sites. Because of the dynamic nature of many intertidal areas, it is often unclear as to whether the extent of disturbance from any activity exceeds that to which biological communities might be normally experiencing and to which they are adapted. There must also be an understanding of the disturbances taking place. As pointed out by others (e.g. Sousa 1984, Simenstad and Fresh 1995), disturbances are not unidimensional. Scales include areal extent, intensity (magnitude), local and regional frequency, predictability, and rotation period. It is important to distinguish between the anthropogenic disturbances previously described in this paper, and natural disturbance regimes such as climatic cycles, storm events, and possible impacts of exotic species or outbreaks of disease (Simenstad and Fresh, 1995). There must also be an understanding of the threshold levels, responses, and recovery times of the environmental impact under consideration. The complex interaction of multiple species, habitats and disturbances on the indicator species also need to be understood. These may include not only direct impacts on the intertidal zone, but also indirect, secondary and synergistic effects. For example, anthropogenic factors from land use activities on the surrounding landscape that may contribute secondary impacts to the cumulative effects of intertidal aquaculture in Baynes Sound include:

- changes in water quality from terrestrial land use, increased nutrient loads from fertilisers and pesticide contamination from agriculture, increases in turbidity related to increases in erosion from forestry impacts;
- increased faecal coliform levels from both agriculture and residential septic systems, and also birds and marine mammals, especially sea lions which is a contamination concern in localised areas of the sound, e.g. haulouts in Fanny Bay and Mud Bay in spring during herring season; and

- changes in freshwater input through altered hydrologic regimes from dams and reservoirs, changes in runoff due to altered land cover by forestry and urban development (stormwater runoff) and so on.

ONGOING AND PROPOSED FUTURE RESEARCH

RELEVANT STUDIES AND INFORMATION SOURCES IN BAYNES SOUND

Various government agencies, NGOs, and the shellfish aquaculture industry are either mandated or have recognised the need for integrated resource management to minimise the impacts of human disturbance on marine ecosystems (LUCO 2000, *Oceans Act*). In 1995, the Baynes Sound Round Table on Water Quality (BSRT) was initiated after contamination of shellfish beaches in 1994 lead to widespread closures. The round table is made up of representatives from the shellfish industry, local governments, citizens' groups, non-profit organisations and government agencies, which worked to identify pollution sources and find ways to reduce them through information, education and action. Working towards this goal on behalf of BSRT, the Comox Valley Project Watershed Society (Project Watershed) has initiated a State of the Sound Geographic Information Systems (GIS) Project. The project has just completed Phase 1, collecting a number of inventories and digital data sets to be incorporated into a GIS to aid in the long-term management of Baynes Sound (Joughin and Lau 2001). On a more localised scale, Fisheries and Oceans Canada is working on the Courtenay River Estuary Management Plan (CREMP), to protect the endangered salmon stocks of the Courtenay/Puntledge watershed. Volume 3 of CREMP is an environmental resource inventory that presents the most recent documentation of plant, fish and wildlife descriptions for the estuary (ECL 2000). The Baynes Sound Round Table is taking responsibility for an integrated water quality monitoring program and the preparation and implementation of a co-ordinated environmental emergency response plan for episodic spills in the estuary, as part of CREMP. To improve access to relevant data regarding marine foreshore and estuary habitats in the Strait of Georgia, the DFO Marine Foreshore Fish Habitat Assessment Project produced a spatial database of references including information on Baynes Sound.

OTHER STUDIES ON ENVIRONMENTAL IMPACTS OF SHELLFISH AQUACULTURE

In 2000, the Aquaculture Association of Canada conducted an industry survey of aquaculture-related research and development priorities (AAC 2000). A greater understanding of the interaction between cultured shellfish and the natural environment was identified as a priority, including both wild populations and biofouling organisms. The need for monitoring protocols to measure environmental variables such as currents, oxygen, sedimentation, nutrients, and faecal wastes was identified for the long-term development of an approach towards carrying capacity issues.

Carrying capacity modelling of ecosystem impacts from aquaculture have been developed for finfish (e.g. Hargrave 1994) and shellfish aquaculture (e.g. Gangnery et al. 2001; Smaal et al. 2001), and there are currently three shellfish aquaculture carrying capacity modelling projects taking place on the Pacific coast. However, the Lemmens Inlet Test Study, the Okeover Inlet

Study, and the Productive Capacity Study of Gorge Harbour near Cortes Island are focussing on suspended oyster culture, and not intertidal bottom culture of shellfish at this time (W. Heath and S. Cross, pers.comm.).

CWS is implementing a 4-5 year study, commencing 2001, in Baynes Sound. This study will include weekly surveys in the Sound and in reference areas. Surveys will determine bird abundance, distribution, and seasonal patterns of use. A comparative analysis with previous survey studies will be undertaken. The study will map habitat types, aquaculture sites, habitat productivity, as well as historical changes. To assess the relationship between birds and habitat, radio telemetry will be used to help understand bird movements, time budgets, and habitat use. An important deliverable of this study will be to evaluate the culture industry's impacts, positive and/or negative, on migratory birds.

In addition, CWS, in conjunction with SFU, has submitted applications for research grant from NSERC and the Marine Ecosystem Health Program to evaluate effects of the shellfish industry on scoter populations. The overarching questions in the proposed research include:

(1) Are scoter populations limited by available space or food in winter, which will be reduced as a result of shellfish operations?
(2) What aspects of foraging ecology are potential mechanisms leading to population limitation?

The research approach is proposed to include assessment of scoter distribution and abundance, movements and foraging behaviour, trophic interactions of scoters and intertidal clams, scoter survival rates, and correlates of scoter distribution. The data will be critical for:

(1) Documenting any positive or negative effects of current levels of shellfish aquaculture on scoter populations;
(2) Predicting cumulative and regional effects of proposed industry expansion; and,
(3) Providing recommendations for shellfish industry activities that are most benign for bird populations.

KNOWLEDGE GAPS

McCann (2000) in a recent review on the "diversity-stability debate" concluded that biological diversity is positively related to ecosystem stability. The current scale (almost all of the harvestable bivalve habitat) of intertidal shellfish aquaculture practices, which purposely reduces species richness, can thus be expected to decrease stability of the natural intertidal ecosystem. Like other natural resource-based industries, economic yield depends on an ecosystem that can provide such services as nutrient cycling to maintain its productivity. The marine environment is not as closed as the terrestrial environment, since currents can bring in nutrients and plankton that originated elsewhere. Nevertheless, it has been shown elsewhere (e.g., mussel culture in Spanish rias) that intensive bivalve aquaculture can be conducted at such a large scale that the growth rates of individual cultured bivalves are reduced and that the economic viability of culture operations furthest away from the source of water exchange may be negatively affected.

COMPREHENSIVE FISHERIES AGREEMENT AMENDMENT

This Comprehensive Fisheries Agreement Amendment made:

BETWEEN:

HER MAJESTY THE QUEEN IN RIGHT OF CANADA as represented by the Minister of Fisheries and Oceans (hereinafter called "DFO")

OF THE FIRST PART

AND:

CHEMAINUS INDIAN BAND, also known as Chemainus First Nation (hereinafter called the "First Nation")

OF THE SECOND PART

WHEREAS on or about July 6, 2010, DFO and the First Nation entered into a Comprehensive Fisheries Agreement, hereinafter called the "Comprehensive Fisheries Agreement";

AND WHEREAS on or about February 7, 2011, the Parties were both interested in amending the Comprehensive Fisheries Agreement by decreasing DFO's contribution by $5,843.69 and increasing the First Nation's contribution by $5,843.69 by adding additional halibut quota to Appendix 1 to Schedule C-1 (Communal Commercial Licence(s) and/or Quotas);

AND WHEREAS the Parties are both interested in further amending the Comprehensive Fisheries Agreement by increasing DFO's contribution by $42,500.00, thereby increasing the Agreement from $93,319.81 to $135,819.81 for boat, motor and trimble unit;

NOW THEREFORE the Parties agree as follows:

Amendment

1(1) Subsection 5(c) of the Comprehensive Fisheries Agreement is hereby deleted and replaced with the following:

"5(c) Subject to subsections 5(b), and 5(d) to 5(f), DFO will, in Fiscal Year 2010-2011, provide a Contribution in the amount of up to ONE HUNDRED AND TWENTY-FOUR THOUSAND, EIGHT HUNDRED AND EIGHTY-SEVEN DOLLARS AND EIGHTY-EIGHT CENTS ($124,887.88) to the First Nation to help finance the Project. A Contribution may consist of money and other forms of assistance."

1(2) Subsection 1(a) of Schedule F-1 of the Comprehensive Fisheries Agreement is hereby deleted and replaced with the following:

"1(a) DFO will contribute to the First Nation up to ONE HUNDRED AND TWENTY-FOUR THOUSAND, EIGHT HUNDRED AND EIGHTY-SEVEN DOLLARS AND EIGHTY-EIGHT CENTS ($124,887.88) during the Fiscal Year 2010-2011 to be used exclusively for paying Eligible Costs. Any interest earned by the First Nation on the Contribution or any part of it will also be used exclusively for paying Eligible Costs."

1(3) Section 11 of Schedule F-1 of the Comprehensive Fisheries Agreement is hereby deleted and replaced with the following:

"11(a) The First Nation states that it has neither requested nor received any other financial assistance for the purposes of the Project for Fiscal Year 2010-2011. If the First Nation has requested or received any other financial assistance for the purposes of the Project for Fiscal Year 2010-2011, the First Nation must provide details and amounts of additional assistance in subsection 11(b).

11(b) The First Nation has requested, received, or will receive, the following financial assistance, in addition to that provided for in this Agreement:

$_______________from other federal departments_________________________
$_______________from the government of the province of_________________
$_______________from____________________ (regional or municipal government)
$_______________from____________________ (Crown corporation)
$_______________from____________________ (private sector organization)

$_______________(the total amount should be entered here)

11(c) The First Nation agrees to inform DFO promptly in writing of any additional financial assistance received, after the date on which this Agreement is signed, for the Project other than the financial assistance referred to in subsection 1(a) or 11(b).

11(d) If the First Nation is to receive, or receives, financial assistance from another funding source for the same item(s) that DFO contributes to for the Project, then DFO shall have the right to:

(i) reduce the Contribution by the amount of assistance for the same item(s); or

(ii) require payment of an amount equal to the assistance for the same item(s) if the Contribution has already been paid, and upon receipt of notice to repay under this section the First Nation agrees to repay the amount as a debt to DFO.

11(e) DFO supports partnering arrangements under which First Nations seek financial assistance from other funding sources. For greater certainty, subsection 11(d) does not apply where financial assistance from another funding source is for a different item(s) than items funded by DFO for the Project."

1(4) The "Estimated Expenditure" of "$84,519.81" specified for the subcategory "(a) Capacity Development (Development of Aquatic Resource Management Structure(s) and governance – includes organization strategic planning, administration and overall program management" under the category "1. Aquatic Resource Management and Stewardship" in Schedule G-1 of the Comprehensive Fisheries Agreement is hereby deleted and replaced with the following:

"$127,019.81"

1(5) The project description under the subcategory "(a) Capacity Development (Development of Aquatic Resource Management Structure(s) and governance – includes organization strategic planning, administration and overall program management" under the category "1. Aquatic Resource Management and Stewardship" in Schedule G-1 of the Comprehensive Fisheries Agreement is hereby amended by adding the following:

"(iii) <u>Boat and Motor $41,500.00 (PICFI)</u>

To acquire boat and motor

Motor, around 200 hp	$20,500
Boat, aluminium skiff 30 feet long	$21,000

The vessel will be used to complete the following activities:

- prawn and crab buoy count surveys,
- stock assessment surveys,
- stream monitoring,
- catch reporting,
- monitor and enforcement
- capacity for FSC harvest
- capacity on communal commercial harvest
- halibut, sable and salmon catch by gill net and long line
- drag sonar for herring surveys

Expected Results:
The boat provides the band and community with the capacity to improve collaborative management with DFO especially with regards to catch monitoring and reporting.

"(iv) Purchase of a Trimble Device $1,000.00 (PICFI)

The Trimble is a GPS/E log device that will assist the First Nation's fisheries staff to work in projects such as prawn buoy counts and habitat assessment. The First Nation will provide this stock assessment data to DFO.

Trimble unit GPS electronic log machine $1,000

Expected Results
Increased capacity and improved catch monitoring for fishery management purposes."

1(6) The "Estimated Expenditure" of "$93,319.81" specified for the heading "Total" in Schedule G-1 of the Comprehensive Fisheries Agreement is hereby deleted and replaced with the following:

"$135,819.81"

Notices and Representatives

2(1) Except as otherwise provided in this Comprehensive Fisheries Agreement Amendment, where any notice, request, information or other communication is required under this Comprehensive Fisheries Agreement Amendment, it will be in writing and delivered personally, by courier, regular mail, e-mail or facsimile and will be addressed to the Party at the address or number set out below:

To DFO:

Department of Fisheries and Oceans
Treaty and Aboriginal Policy Directorate, Room 1230
#200 – 401 Burrard Street
Vancouver, BC
V6C 3S4

Attention: Regional Manager
Aboriginal Fisheries Strategy

Telephone: (604) 666-8385
Facsimile: (604) 666-2336

To the First Nation:

Chemainus First Nation
12611 Trans Canada Highway
Ladysmith, BC
V9G 1M5

Attention: Chemainus First Nation Chief and Council Representative

Telephone: (250) 245-7155
Facsimile: (250) 245-3012

2(2) A notice, request, direction, information or other communication will be deemed to have been received the following business day if sent by courier, e-mail, facsimile or delivered in person, or five days after the posting if sent by regular mail.

2(3) A Party may change its representative, address or telephone or facsimile number by giving written notice of the change to the other Party.

Ratification

3(1) The First Nation warrants that the representative who executes this Comprehensive Fisheries Agreement Amendment on behalf of the First Nation has authority to bind the members of the First Nation.

3(2) The representative who executes this Comprehensive Fisheries Agreement Amendment on behalf of DFO has authority to enter into this Comprehensive Fisheries Agreement Amendment on behalf of, and to bind, DFO.

3(3) Execution of this Comprehensive Fisheries Agreement Amendment by the representative referred to in subsection 3(1) constitutes ratification of this Comprehensive Fisheries Agreement Amendment by the First Nation.

3(4) The First Nation will inform its members of the contents of this Comprehensive Fisheries Agreement Amendment and will provide members with a copy of this Comprehensive Fisheries Agreement Amendment upon request.

Continuance

4. The Comprehensive Fisheries Agreement as amended by this Comprehensive Fisheries Agreement Amendment shall continue in full force and effect.

IN WITNESS WHEREOF the Parties have executed this Comprehensive Fisheries Agreement Amendment under the hands of their proper officers duly authorized on their behalf this 25 day of March, 2011.

HER MAJESTY THE QUEEN IN RIGHT OF CANADA
as represented by the Minister of Fisheries and Oceans

MAR 24 2011

Witness

Susan Farlinger, Regional Director General
Pacific Region
Department of Fisheries and Oceans

CHEMAINUS FIRST NATION by its duly authorized representative

Witness

Chemainus First Nation and Council Representative

Certified Copy/Copie Certifiée MF

AFS2010-SYR-1007-2

BETWEEN:

HER MAJESTY THE QUEEN IN RIGHT OF CANADA as represented by the Minister of Fisheries and Oceans (DFO)

AND:

CHEMAINUS FIRST NATION (First Nation)

COMPREHENSIVE FISHERIES AGREEMENT AMENDMENT

SUPPLEMENT TO THE PRE-SEASON RETURN FORECASTS FOR FRASER RIVER SOCKEYE SALMON IN 2015

Context

Sockeye that spawn and rear in the Fraser watershed (i.e. Fraser Sockeye) exhibit two distinct life-history types: lake-type (Figure 1) and river-type (Figure 2). Most Fraser Sockeye are lake-type, including the Chilko stock, which is expected to contribute the largest proportion to the total Fraser Sockeye return in 2015 (35%). The predominant age class of lake-type Fraser Sockeye is four year olds. After spending their first two winters in freshwater (one winter as eggs in spawning gravel and one winter as fry in rearing lakes), lake-type Fraser Sockeye yearling-smolts migrate rapidly out of their rearing lakes, down the Fraser River, northward through the Strait of Georgia (SOG) and Johnstone Strait, and along the continental shelf, en-route to the Gulf of Alaska. They spend their final two winters in this ecosystem before returning to spawn (Figure 1).

River-type Sockeye spend a single winter in freshwater, and migrate downstream to the SOG as sub-yearling smolts shortly after emerging from their spawning gravel. Harrison Sockeye, the largest river-type stock in the Fraser watershed (this stock is expected to contribute 21% to total return in 2015), remains in the SOG for several months, after all lake-type Fraser Sockeye stocks have migrated out of this system, and subsequently migrate out into the northeast Pacific via the southern Juan de Fuca Strait route (Figure 2). This stock returns to spawn as three and four year olds.

For both life-history types, mechanisms influencing Fraser Sockeye survival are complex and poorly understood, due to the broad range of ecosystems they inhabit throughout their life-history. This increases uncertainty in the Fraser Sockeye forecasts. To improve our understanding of Fraser Sockeye survival mechanisms, starting in the 2014 forecast year (DFO 2014a), auxiliary information on the parental spawner generation through to the juvenile marine rearing environment is synthesized in a forecast supplement report (DFO 2014b). What was learned retrospectively from this first process is presented in Appendix 1 of the current paper.

To provide context for the 2015 forecast (DFO 2015), this year's Fraser Sockeye forecast supplement report focuses specifically on the 2011 brood year for lake-type stocks, and the 2011 and 2012 brood years for river-type stocks (i.e. Harrison Sockeye). This report synthesizes information on the adult migration conditions, escapement and spawner success, fry and their lake rearing conditions, smolt and juvenile migration, and ocean conditions. In addition, stock compositions of the 2011 escapements, 2013 downstream smolt migration, juvenile ocean migration, and 2015 return forecasts are compared to evaluate proportional changes in stock composition through time. The 2014 forecast supplement report (DFO 2014b) can be used, in combination with this report, to provide context for the five year olds returning in 2015 (DFO 2015).

This Science Response Report results from the Science Response Process of January 27-28, 2015 on the Supplement to pre-season abundance forecasts for Fraser River Sockeye Salmon returns in 2015.

Background

Returns

Total adult Fraser Sockeye returns have historically varied (Figure 3 A) due to the four-year pattern of abundances (cyclic dominance) exhibited by some of the larger stocks, and variability in annual survival (Figures 3 A & B) and exploitation. After reaching a peak in the early 1990s, returns decreased to a record low in 2009, due to declines in stock survivals (Figures 3A and B). In subsequent years, survival, and consequently returns, have increased. The 2010 and 2014 returns were particularly large, since this is the dominant cycle line for the Late Shuswap stock (i.e. Adams River Sockeye), and the combination of above average escapements relative to other cycle lines, and above average to average survivals contributed to these large returns.

For the 2015 return cycle (the current forecast year), Chilko and Late Shuswap have historically contributed the greatest proportion (30% and 26%, respectively) to the total return. The 2015 cycle has the second smallest average return of the four cycles of Fraser Sockeye, with an average annual return (1955-2011) of 5.2 million for all 19 forecasted stocks combined (excluding miscellaneous stocks).

Fraser Sockeye Survival

Total survival (returns-per-spawner) aggregated across all Fraser Sockeye stocks declined in the 1990s and culminated in the lowest survival on record in the 2009 return year. In subsequent years (2010 to 2014), survival was close to average (Figure 3 B). Individual stock survival trends, however, vary (Grant et al. 2011; Peterman & Dorner 2012). Most notably, Harrison Sockeye, a unique stock with a different age-structure and life-history compared to all other Fraser Sockeye stocks, have exhibited a large increase in survival in recent years (Grant et al. 2010; Grant et al. 2011).

Our understanding of what drives inter-annual changes in Fraser Sockeye survival is complicated by the broad range of ecosystems these stocks inhabit throughout their life-history. Most Fraser Sockeye stocks are lake-type Sockeye, which generally spend their first two winters in freshwater (egg through to smolt stage), followed by two winters (range of one to three winters) in the marine environment, before returning to their natal streams or lakes to spawn (Figure 1). These Sockeye migrate through a broad range of ecosystems during their first year of marine residence, moving rapidly northwards through the SOG (Preikshot et al. 2012), exiting this water body via the Johnstone Strait, migrating along the continental shelf, and finally moving off the shelf into the Gulf of Alaska in the winter months (Tucker et al. 2009). River-type Sockeye are less common in the Fraser watershed. The most abundant river-type Fraser Sockeye is the Harrison stock (Figure 2). Shortly after river-type Sockeye emerge from their spawning gravel as sub-yearling smolts they migrate to the ocean, and spend several months in the SOG, before migrating out into the northeast Pacific via the southern Juan de Fuca Strait. After two to three winters in the ocean they return as adults back to their spawning grounds as, respectively, three or four year old fish.

Considerable mortality occurs in the freshwater and marine ecosystems, as indicated by freshwater and marine survival data for Chilko River Sockeye (Figure 4 A & B). Chilko is the only Fraser Sockeye stock with a long and complete time series of smolt data (estimated at an enumeration weir located at the outlet of Chilko Lake), which can be used with escapement and return data to partition total survival into freshwater and ‘marine’ components (‘marine’ survival includes their migration downstream from the counting weir to the SOG). It is likely that a number of factors in both the freshwater and marine environments influence Fraser Sockeye survival, and these factors may vary between stocks and years.

Pre-Season Abundance Forecasts

The 2015 forecast ranges from 3,824,000 to 12,635,000 at the 25% to 75% probability levels. The 50% (median) forecast is 6,778,000 (DFO 2015). Four year olds comprise 78% of the total return forecast, which is lower than average (87%) due to the large brood year escapements contributing the five year olds returning in 2015, as compared to those contributing the four year olds for a number of stocks. In particular, Nadina (78%), Pitt (63%), Late Stuart (52%), Quesnel (56%), and Stellako (52%) contribute the highest percentages of five year olds to the total forecast. Chilko lake-type Sockeye and Harrison river-type Sockeye are expected to contribute the greatest proportions to the total forecast overall (respectively, 35% and 21%). The forecast for Chilko is dominated by four year olds (89% as a percentage of four plus five year olds) (DFO 2015).

Auxiliary data is presented in this report to provide context for the 2015 Fraser Sockeye forecasts. For lake-type Sockeye, data is presented from the 2011 parental spawner generation through to the juvenile marine rearing environment in 2013. Auxiliary information on the five year old returns of lake-type Fraser Sockeye in 2015 (brood year 2010) is presented in the Supplement to the pre-season return forecasts for Fraser River salmon in 2014 (DFO 2014b). For river-type Sockeye (i.e. Harrison), data from the 2011 and 2012 brood years through to the juvenile rearing environments in 2012 and 2013 are presented.

Analysis and Response

Lake-Type Stocks: Adult Migration and Spawning In 2011

Adult Migration Timing

- The arrival timing of most stocks to their spawning grounds was average, with the following exceptions: arrival timing to the Early Stuart spawning grounds was two to three weeks later than normal, and arrival timing of Summer Run stocks (including Chilko Sockeye) to their spawning grounds in 2011 was slightly delayed (approximately one week later than normal).

Adult Migration and Spawning Conditions

- Salmon migrating in temperatures above 18°C may show signs of decreased swimming performance (Eliason et al. 2011). Sustained temperatures above 20°C can lead to increased mortality, disease, and legacy effects on egg quality (Burt et al. 2011). Optimal spawning ground temperatures are between 10-12°C, while egg survival is reduced once values approach 15°C (Whitney et al. 2013). High discharge in the Fraser Canyon has been associated with migration delays (>7,000 cubic meter per second: cms) and can create a complete hydrological barrier to migration (> 9,000 cms), leading to increased risk of fish mortality and severe stress (Macdonald et al. 2012). Low river discharge on spawning grounds can affect spawning success (crowding due to less available spawning habitat) and egg survival (dewatering of redds). Alternatively, high river discharge events can cause bed movement, scouring, and egg mortality.
- In 2011, Fraser River discharge levels were over 8,000 cms from mid-June to mid-July, peaking near 10,000 cms at the end of June (Figures 5 A & B). The vast majority of Early Stuart, and portions of Early Summer migrants would likely have been affected by

high discharge levels (Figure 5 A), as signs of physiological stress are evident at flows above 7,000 cms, and Hell's Gate becomes a hydrological barrier to migration at flows above 9,000 cms. In conjunction with high flows, the early portion of the Early Stuart migration encountered temperatures below their physiological optimal (16 ^{o}C) (Figure 5 A), which could result in reduced swimming performance. In contrast, Chilko and other Summer stocks experienced moderate flows and temperatures in 2011 (Figure 5 B).

- According to observations by Fraser Sockeye stock assessment staff during the adult escapement enumeration projects, environmental conditions (water levels and temperatures) on the spawning grounds were considered favorable for spawning throughout the Fraser River watershed in 2011. Although high water events were noted at the tail end of the spawning period in the Upper Pitt, Chilliwack and Nahatlatch systems, these events are not expected to have significantly impacted egg-to-fry survival. It is important to note that environmental conditions are not assessed by field crews after the escapement enumeration projects have ended, so environmental events that occur between the end of these projects and the following spring could affect egg-to-fry survival but are not recorded.

Spawner Success: Egg Retention and Egg Viability

Escapement Enumeration Program Observations and Estimates

- Spawner success for a stock is calculated as the proportion of eggs spawned, based on spawning ground carcass surveys conducted during escapement enumeration. Spawner success is recorded as 0%, 50%, or 100% for each female carcass sampled, then averaged across all populations in a stock. Spawning success across all Fraser Sockeye populations was 80% in 2011, which is below the long term average of 89%.
- Pre-spawn mortality (PSM) is 100% minus the spawner success percentage. Very high levels of PSM were observed in several areas of the watershed, including the Nadina (57%), Quesnel (31%), Stellako (40%), Late Stuart (46%) and Late South Thompson (45%) systems.
- For Chilko Sockeye, the dominant stock in the 2015 forecast, pre-spawn mortality levels in the 2011 brood year throughout the duration of the die-off period in 2011 (82%) was below the long term average (1950-2010: 91%).
- Spawner success is incorporated into annual forecasts by using either effective female spawner (EFS) abundances (female escapement multiplied by spawner success) or smolt abundances as predictor variables.

Environmental Watch Program Observations and Estimates

- While spawning success provides a direct measure of eggs released on the spawning grounds, it does not provide a true measure of spawning success from the perspective of egg deposition or egg viability. A number of physiological metrics have been used to evaluate overall health of spawning fish. These can be used to determine the potential for successful redd construction and deposition of eggs into them by the spawners, and not simply their release of eggs. Similarly, direct estimates of egg and sperm quality are used to assess gamete viability of eggs that were deposited. For the few stocks with fry or smolt data such as Chilko, using these data as predictor variables can eliminate uncertainty in, respectively, egg-to-fry or egg-to-smolt survival. However, most stocks do not have fry or smolt data and, therefore, information on spawning success and egg viability from a physiological perspective can be used to qualitatively inform Fraser Sockeye freshwater survival.

- A suite of biological samples was collected from spawning Sockeye in 2011 to assess egg deposition and egg viability: physiology (ions & metabolites), steroids (to assess maturation & stress), condition (energy & lipids), and disease (RNA & histopathology) (Table 1). Ideally, a multivariate analysis of these variables would provide a holistic representation of fish condition. However, in the absence of such in-depth analyses there are some key surrogates of overall condition that can be used. For example, spawner glucose can represent an integrated measure of the ability to maintain metabolic homeostasis, while body fat content is an indicator of energy reserves. Healthy glucose levels are between 4-7 micromol-per-litre (mmol/L) and values above or below this range are considered abnormal and are linked to premature death of fish that have arrived on the spawning grounds but have not already begun spawning (Figure 6). However, the interpretation of any physiological variable, such as glucose or fat content, for fish on the spawning grounds is relative to their behavioral state (i.e. arrival/holding, paired/spawning, spent/moribund). For fish that are actively spawning, it is normal for glucose levels to rise well above 10 mmol/L, though these values will lead to rapid senescence. Normal fat content for fish arriving on the spawning grounds is between 2.5-4.0%. For fish that are actively spawning fat content can drop to just below 2%. If fish have not engaged in active spawning and are close to the 2% threshold it is unlikely they will successfully spawn.
- Returning adult sockeye were intercepted at various locations along their migration route in 2011 (Figure 6). Chilko, Late Shuswap, and Weaver lake-type Sockeye were the primary stocks targeted. Priorities and completion of lab analyses varies from year to year, but all samples are inventoried and stored for possible future analyses including analysis of energetic status, stress and pathogen status. In 2011, plasma glucose concentrations (an indicator of physiological stress) of in-river migrants were slightly above normal (8.0- 8.5 mmol/L) for Chilko and Shuswap, but at their spawning locations only Late Shuswap remained above normal (12.2 mmol/L) (Figure 6). Mean percent lipid (an indicator of condition) for all stocks at all locations was considered within the normal range. Gamete quality (egg survival to eyed stage) was average for Adams (Late Shuswap) (79%), good for Weaver (89%) and below average for Harrison (64%).

Lake-Type Stocks: Freshwater Rearing

Overview

- Fry (predominant age: 1_1) abundances have been assessed on a semi-regular basis (generally on dominant and subdominant cycle years) by DFO's Freshwater Lakes Division in Quesnel Lake and Lake Shuswap. Limnology has been sporadically assessed for Quesnel, Shuswap and Chilko Lakes.
- The stock contributing the greatest proportion to the 2015 forecast is Chilko Sockeye (35%). For this stock, smolt outmigration (predominant age: 2_2) abundances have been assessed consistently since 1949 by DFO's Stock Assessment Division.
- Smolt abundances for Cultus Sockeye, which contributes less than 1% to the total 2015 forecast, have been sporadically assessed since the 1920's. Fry abundances for this stock have been assessed in recent years only. Given the limited contribution of Cultus expected in the 2015 returns, detailed information on this stock is not provided.

Chilko Lake Limnology

- Limnological assessments of Chilko Lake were conducted between 1985 and 1993, and more recently between 2009 and 2012. A full suite of physical, chemical, and biological variables relevant to Sockeye Salmon rearing conditions were measured in these surveys, including, but not limited to, lake thermal structure, photosynthetic rates, and zooplankton species assemblage and biomass. Methods were similar to those used in Shuswap Lake and are generally described in Bradford et al. (2000) and Shortreed (2007).
- Chilko Lake was experimentally fertilized in the late-1980's and early-1990's to evaluate the enhancement of freshwater survival (see Bradford et al. (2000)). Though there was a long hiatus from limnological assessments conducted in Chilko Lake (1994-2008), recent data show that photosynthetic rates (PR) appear to have increased ~ 74% since the early-1990's (unfertilized years) to a new productivity state similar to that observed when over 100 tons of inorganic fertilizers were being applied annually (Selbie et al. 2010). This shift represents a rapid change in lake productivity for such a large system. Increased PR should be correlated with enhanced freshwater survival (Hume et al. 1996; Shortreed et al. 2000).

Chilko Sockeye Freshwater Survival and Fish Condition

- Chilko is the only stock for which a long time series (brood years 1949 to present) of smolt (predominant age: 2_2) abundance data have been collected. Smolt counts are assessed at an enumeration weir located at the outlet of Chilko Lake. Smolt data can then be combined with adult escapement and return data to provide a time series of freshwater (and marine) survival (Figure 4 A & B).
- The relationship between brood year effective female spawners (EFS) and resulting smolt abundance in Chilko Lake exhibits density-dependent freshwater survival at higher EFS spawner abundances, and has been modeled with both a Ricker (R^2<0.4) and Beverton-Holt (R^2<0.4) relationship (Figure 7 A).
- In 2011, the total escapement to the Chilko system was the second largest escapement on this cycle. This escapement fell within the range of updated photosynthetic rate (PR) model optimums for Chilko Lake (Figure 8 A), which suggests the potential for fry rearing limitation (i.e. food availability) provided fry densities were not limited by poor egg-to-fry survival. However, there are several pieces of evidence that indicate that fry rearing conditions were average for Chilko Sockeye in the 2011 brood year, including zooplankton biomass, freshwater survival, and smolt sizes (see subsequent bullets).
- Total zooplankton biomass in Chilko Lake over the growing season in 2012 followed trajectories observed in lower-escapement years, suggesting rearing limitation was likely modest.
- Freshwater survival in the 2011 brood year (97 smolts/EFS) was close to average (1950-2011 average: 117 smolts/EFS) (Figure 4 A; Figure 8 A). This lies in contrast with the suspected poor rearing conditions in the previous brood year (2010 brood year: 47 smolts/EFS freshwater survival), which likely resulted from high fry densities produced by the exceptional escapement of 1.2 million spawners in 2010, leading to high competition for food resources amongst the fry. For the 2011 brood year, the larger escapement and average freshwater survival resulted in smolt abundances (2013 smolt outmigration year: 44.2 million) that were above average (brood years 1950-2011: 19.9 million one year old smolts).

- Chilko Sockeye smolt nose-fork length assessed at the outlet of Chilko Lake at the enumeration weir in 2013 (85.3 mm) was close to the time series average (brood years 1952-2011: 83.2 mm). The average 2011 brood year smolt length was larger than the 2010 brood year average (77.4 mm). This evidence supports the notion that lake rearing conditions were average for the 2011 Chilko Sockeye brood. See subsequent Smolt Outmigration section.
- Condition analyses on Chilko smolts assessed at the outlet of Chilko Lake at the enumeration weir for brood years 2011 and 2010 are still being processed; these data were not available at the time of this report.

Quesnel Lake Limnology

- Limnological assessments of Quesnel Lake were conducted between 1985 and 1994, 2003, and more recently between 2004 and 2007. A full suite of physical, chemical, and biological variables relevant to Sockeye Salmon rearing conditions were measured in these surveys, including, but not limited to, lake thermal structure, photosynthetic rates, and zooplankton species assemblage and biomass. Methods were similar to those used in Shuswap Lake and are generally described in Bradford et al. (2000) and Shortreed (2007). Details were not provided for the current report.

Quesnel Sockeye Freshwater Survival and Fish Condition

- Quesnel is the only Fraser Sockeye stock that demonstrates evidence of delayed-density dependence (Peterman & Dorner 2012), likely caused by the influence of fry density on the lake ecosystem, which persists through to a subsequent year, consequently influencing fry productivity of that next year.
- Unlike most other Fraser Sockeye stocks, survival of Quesnel Sockeye has only improved in the most recent return year (2014); survival for most other stocks improved starting in the 2010 return year.
- Pelagic surveys of Sockeye fry in the Quesnel Lake system have been conducted since 1975, largely on the dominant and subdominant cycles. These surveys are conducted in the summer (August) and fall (October). Hydroacoustic estimates of fry abundance and distribution, coupled with biosamples (including length and weight) from mid-water trawls, provide density and biomass estimates of the Sockeye fry population. For complete methods, see MacLellan and Hume (2010).
- The relationship between EFS and resulting fall fry in Quesnel Lake exhibits density dependent freshwater survival at higher spawner abundances, and has been modeled with both a Ricker (R^2=0.6) and Beverton-Holt (R^2=0.3) relationship (Figure 7 B).
- Freshwater survival in the 2011 brood year (380 fall fry/EFS) was above average compared to all cycles (1976-2010 brood year: 189 fall fry/EFS), and given the low brood year escapement, the resulting fry abundance (6.4 million) was below average (1976-2010 average: 29.8 million).
- The lake-wide estimate of fall fry Sockeye (± 95% CI) was 6.4 ± 1.4 million fish. In terms of density this equated to 246 ± 54 fish/ha. Fry weighed 3.11 ± 0.23 g and were 65 ± 1.3 mm in nose-fork length. Condition metrics were not taken from fish collected in Quesnel Lake.
- Given the relatively small number of Sockeye fry in the lake in 2012, the Quesnel stock should not be expected to be a strong contributor to the 2015 returns (DFO 2015).

Shuswap Lake Limnology

- Limnological assessments of the Shuswap system (Shuswap and Mara lakes) were conducted in the years 1987-1993, 2011, and 2012. This sampling coverage includes rearing years (brood year+1) for dominant (1991, 2011), subdominant (1988, 1992, 2012) and weak cycles (1989, 1990, 1993). A full suite of physical, chemical, and biological variables relevant to Sockeye Salmon rearing conditions were measured in these surveys, including, but not limited to, lake thermal structure, photosynthetic rates, and zooplankton species assemblages and biomass. Methods for these surveys are generally described in Nidle and Shortreed (1996), Morton and Shortreed (1996) and Shortreed (2007).
- Macrozooplankton and *Daphnia* biomass (the latter is preferentially preyed upon by salmon fry and comprise 85-95% of the fall diet of age-0 Sockeye in Shuswap Lake) was higher in 2012 versus 2011 (2011 vs. 2010 brood years), given the much lower fry densities, and therefore lower density-dependent grazing pressure, in 2012.
- Freshwater survival (fry/EFS) in Shuswap Lake has declined post-1990, particularly on the subdominant cycle line. Though there was a long hiatus from conducting limnological assessments in Shuswap Lake (no assessments were conducted from 1994-2010), recent data show that photosynthetic rates (PR) increased ~ 45% between the early 1990's and 2011-2012. Increasing PR should be correlated with enhanced freshwater survival (Hume et al. 1996; Shortreed et al. 2000). However, increases in fry densities in the past decade (in several cases exceeding the lake's carrying capacity), and other stressors in Shuswap Lake (research in progress), should have resulted in density-dependent effects on food web structure and function, and thus reduced freshwater growth and survival.

Shuswap Sockeye Freshwater Survival and Fish Condition

- Pelagic surveys of Sockeye fry in the Shuswap Lake system (includes Shuswap & Mara Lakes) have been conducted since 1975, largely on the dominant and subdominant cycles. These surveys are conducted in the summer (August) and fall (October). Hydroacoustic estimates of fry abundance and distribution, coupled with biosamples (including length and weight) from mid-water trawls, provide density and biomass estimates of the Sockeye fry population. For complete methods, see MacLellan and Hume (2010).
- The relationship between brood year EFS and resulting fall-fry in the Shuswap Lake system exhibits density dependent freshwater survival at higher spawner abundances, and has been modeled with both a Ricker (R^2=0.8) and Beverton-Holt (R^2=0.6) relationship (Figure 7 C).
- The Early and Late Shuswap stocks both use the Shuswap and Mara Lake complex for rearing as fry. In 2011, the total escapement of Early and Late Shuswap stocks combined (74,000) was well below the spawner abundance that maximizes fry production for the lake system (S_{max}), as calculated from photosynthetic rate (PR) models (2.2 million, updated from Grant et al. 2011; see Hume et al. 1996 and Shortreed et al. 2000 for methods), or from stock-recruitment data (2.5 million) (Figure 8 B). Although compensation (increased growth and/or survival due to low densities) of fry would be expected in the 2011 brood year, freshwater survival (168 fall fry/EFS) was in fact well below the average across all cycles (380 fall fry/EFS) and below the cycle average (207 fall fry/EFS). This might be attributed to delayed-density-dependence from

the previous brood year escapement (2010), which was exceptionally large for the Shuswap system (DFO 2014a).

- In-lake estimates of Sockeye fry (± 95% CI) were 16.8 ± 3.5 million in August, and 11.2 ± 2.2 million in October. This translates into densities of 533 ± 112 fish/ha in August and 354 ± 68 fish/ha in October. While the absolute number of fry in the lake in 2012 was the lowest on record for the sub-dominant cycle (previous estimates ranged from 16.5 million (1995 BY) to 153.5 million (1987 BY)), the number of fry-per-EFS (154 fry/EFS) was within the historic range across all cycles (67 in 1995 BY to 422 in 1987 BY) (Figure 8 B).
- Summer fry weighed 2.24 ± 0.09 g and were 58 ± 0.7 mm in nose-fork length. Fall fry weighed 3.18 ± 0.12 g and were 67 ± 0.8 mm in nose-fork length. As in previous cycles, fry from the sub-dominant brood year (2011) were larger than those from the dominant brood (2010 brood year). This carried through to out-migrating smolts in 2013. Fry in 2012 (2011 brood year) had higher lipid proportions as summer fry through to smolts, than those in 2011 (2010 brood year). Morphologically, fish sampled in 2012 (2011 brood year) were more robust than those sampled in 2011 (2010 brood year), and were characterized by deeper bellies.
- Total zooplankton biomass was relatively abundant throughout the mid-to-late growing season, suggesting negligible rearing limitation in Shuswap Lake for the 2011 brood.
- Given the relatively small number of Sockeye fry in the lake in 2012, the Shuswap stocks are not be expected to be a strong contributor to the 2015 returns (DFO 2015).
- Smolts (predominant age: 2_2) in the Shuswap system from the 2010 and 2011 brood years (2012 and 2013 outmigration years) were sub-sampled to study the effects of density dependence on fish condition and survival. Sampling occurred on a weekly basis from early-May to mid-June at Little River, as smolts migrated out of the Shuswap system.
- The 2012 and 2013 samples indicate that peak migration occurs through mid-May, later than the Chilko and Cultus stocks (Figure 9 C). In 2013, a high proportion of smolts caught were two (3_3) year olds (~30%), based on length, although these were not observed in lake trawl surveys. This may indicate a possible return of age 5_3 adults to the Shuswap system in 2015. The average fat content of smolts leaving Shuswap Lake in 2013 was similar to fish leaving in 2012 (~2.8%).

Lake -Type Stocks: Smolt Outmigration

Smolt Outmigration Timing-Lake Outlet

- Three smolt assessment programs at the outlet of major rearing lakes were conducted in the 2013 outmigration year, including Cultus, Chilko, and Shuswap Lakes (Figure 9):
    - Cultus smolt assessments have been sporadically conducted from 1926 to present. The Cultus smolt 50% outmigration date in 2013 (2011 brood year) was April 20 (Figure 9 A).
    - Chilko smolt outmigration has been assessed consistently using a weir and counting system located at the outlet of Chilko Lake from 1951-present. The Chilko smolt 50% outmigration date (when 50% of the run had moved through the counting weir) in 2013 (2011 brood year) was April 29 (Figure 9 B).

- o Shuswap smolts have been opportunistically assessed, starting in 2012 to coincide with the exceptionally large run in the associated (2010) brood year, and also including 2013 (Figure 9 C). For this stock, sampling of smolts occurred weekly, and the 50% migration date in 2013 was in mid-May, later than Cultus and Chilko.

Smolt Outmigration Timing-Mission

- The Mission smolt project assesses smolt outmigration of virtually all stocks using mobile traps mounted to a vessel that operates in the Fraser River at Mission, B.C. (Figure 10). Only a few stocks entering the Fraser River downstream of Mission (e.g. upper Pitt River) are unavailable for capture at this location. During the spring and early summer (March 22-July 25) of 2013, combinations of three mobile traps were fished four days a week (M, T, Th, F) from 0600-1400 hours. This 2013 survey frequency differed from the survey frequency in 2012 of once every four days. A survey gap occurred between May 17 and June 1 due to vessel malfunction. As a result, estimates of stock proportions (for all stocks upstream of Mission) and outmigration timing (for later timed stocks) at Mission might not be accurate (Figure 11). The goal of this project was to evaluate the timing, size, abundance and stock composition of downstream migrating Sockeye smolts. Bio-samples were collected from a subset of the trapped Sockeye smolts. Bio-samples collected included fish length (nose-fork length), weight, adipose fin clip status, and tissue samples for genetic stock identification (GSI) and health assessments (analysis performed by other researchers).
- Stock proportion and outmigration timing at Mission is somewhat challenging to interpret in 2013, given the results of the 2012 assessment coupled with the assessment gap in the later component of the migration period in 2013. Stocks that migrate later, such as those from the Shuswap system (Figure 9), were likely not representatively sampled throughout their migration past Mission. This influences the relative abundance estimates for all trapped stocks. Additionally, this affects the estimated 50% outmigration date of any stock with significant numbers passing Mission between May 17 and June 1. The Chilko 50% outmigration date at Mission was May 5th (Figure 11) compared to April 30 in 2012 (see Figure 16 in DFO 2014b). For Chilko, similar to the supplement prepared for the 2014 forecast (DFO 2014), outmigration timing at the enumeration weir (Figure 9 B) was closely coupled with outmigration timing downstream at Mission (Figure 12 A), with a travel time of roughly 6 days.

Smolt Outmigration Conditions

- The effect of discharge on Sockeye smolt survival is unclear, for example higher discharge could increase smolt outmigration rates and increase water turbidity, both of which could reduce their exposure to predators in this ecosystem (McCormick et al. 1998).
- Peak freshet measured at Hope, B.C., on the Fraser mainstem occurred in mid-May in 2013 (Figure 12 B), largely after the peak outmigration of Fraser Sockeye smolts (late-April) (Figures 9 - 12). During Chilko smolt outmigration (April-May 2013; Figures 9A, 11, and 12 A), discharge in the lower Fraser River was slightly above average in April 2013, and above average in May 2013 (Figures 12 B), although the majority of Chilko smolt outmigration would have occurred prior to peak flows and temperatures (Figure 13). Discharge in the Chilcotin River, the first river system Chilko smolts migrate through en-route to the Fraser River, was also below average during Chilko smolt outmigration

(Figure 13). Depending on the outmigration timing of other stocks, there could be some overlap between higher flow and smolt outmigration from these other stocks.

- Temperatures in the Lower Fraser (measured at Hope, B.C.) were also largely average in 2013 for the majority of the smolt outmigration, although some stocks that out-migrate later, in early to mid-May, experienced above average temperatures (Figure 14).

Smolt Outmigration Sizes

- Smolt size is positively correlated with smolt-to-adult survival in Sockeye (Ricker 1962; Henderson and Cass 1991; Koenings et al. 1993; Bradford et al. 2000).
- Smolt length sampled at the outlet of Chilko Lake in the 2013 outmigration year (average nose-fork length: 85.3 mm) was greater than the 1954-2011 time series average (83.2 mm). The 2013 smolts were also larger than the previous outmigration year (2012) smolts, which exhibited below average nose-fork lengths (77.4 mm). The difference in average smolt length between 2013 and 2012 is likely attributed to density-dependent growth. Adult escapement (EFS) was much smaller in the 2011 brood year (2013 smolt outmigration year: 458,000 EFS) compared to the previous brood year in 2010 (2012 smolt outmigration year: 1.2 million), therefore density dependence likely restricted growth in the 2010 brood year.
- Smolt size sampled at the outlet of Shuswap Lake in the 2013 outmigration year (average nose-fork length: 80.7 ± 3.7 mm 95% CI; average weight: 4.6 ± 2.3 g 95% CI) was significantly larger (nose-fork length and weight both $p < 0.001$) than in the 2012 outmigration year (average length: 67.9 mm ± 0.7 mm 95% CI; average weight: 2.7 ± 0.1 g 95% CI). As expected, given differences in fry densities between the dominant (2012 smolt outmigration year) and subdominant (2013 smolt outmigration year) cycles, overall growth of Sockeye fry in Shuswap Lake occurred more quickly in the 2011 brood year (2013 outmigration year) than in the 2010 brood year (2012 outmigration year) when compared across on-shore, pelagic and smolt life stages.
- Sockeye smolt nose-fork lengths were also measured at Mission, B.C. in 2013, and were larger on average for most stocks compared to 2012 (Table 2; Figure 15). This difference can likely be attributed to density-dependent growth resulting from the exceptional escapements observed in a number of systems in the 2010 brood year (2012 outmigration year), particularly the Shuswap system and Chilko. Two exceptions were the Fraser-Summer (Stellako) and Quesnel-Summer (Horsefly/Mitchell) Sockeye stocks, where the average nose-fork lengths were larger in 2012 despite a much larger escapement in the 2010 brood year (2012 smolt outmigration year) (Table 2; Figure 15).
- Note that the Chilko smolts sampled in the Fraser River at Mission, B.C. in 2013 had a similar average nose-fork length to those sampled at the outlet of Chilko Lake. Given the limited time between their outmigration from Chilko Lake and their migration past Mission (approximately 6 days between the 50% migration dates; Figure 12 A), little growth would be expected.

Lake-Type Stocks: Juvenile Migration in the Strait of Georgia

Background

- Most juvenile Fraser Sockeye spend four to six weeks rearing and growing in the Strait of Georgia (SOG) prior to moving north through Johnstone Strait (Preikshot et al. 2012). Trawl surveys have been conducted in the SOG since 1998 (with one missed early summer assessment in 2003) to assess juvenile salmon abundances. These surveys have been consistently conducted between late-June to early-July and again between September to early-October. The surveys follow a standard track line that is fished over a nine to ten day period (Beamish et al. 2000; Sweeting et al. 2003) (Figure 16).

- In 2013, an additional trawl survey was conducted during the first ten days of June, specifically to target juvenile Sockeye during their peak abundance in the SOG. This early June survey followed the standard track line fished during the annual surveys (Figure 16). In addition, sets were conducted in the Discovery Island region during this survey. The purse seine surveys conducted in May and June 2010 to 2012 (Figure 16; Neville et al. 2013) were not replicated in 2013. However, results from these earlier purse seine surveys are used as a reference to compare the distribution of juveniles between years. Information collected during all marine surveys included catch-per-unit-effort (CPUE), length/weight, diet, stock composition, scales and otoliths, and tissues for fish health, genomic and energetic studies.

Juvenile Migration Timing

- Although the annual (1998-present) trawl surveys conducted in late-June/early-July target Coho Salmon, all salmon species are collected. Given the late timing of these surveys, however, only about 10% of juvenile Sockeye Salmon remain in the SOG during this period. For a single year in 2008, Thompson et al. (2012) reported that the stock structure present during the survey conducted was roughly representative of the expected stock composition based on brood year escapements in the 2006 brood year. However, based on last year's results from the Mission smolt outmigration project and the temporally expanded SOG Program, there is evidence of differences in outmigration timing amongst Fraser Sockeye stocks (DFO 2014b). Further, the 2013 early June surveys (conducted annually starting in 2010) indicated that Fraser Sockeye juvenile migration through the SOG was earlier than in previous years (see subsequent bullets) (Figure 18). Therefore, relative abundance (CPUE) from this annual survey could change depending on the dominant stock(s) migrating through the SOG and inter-stock and inter-annual variation in outmigration timing (Figure 17).
- The CPUE of juvenile Sockeye Salmon in the standard trawl survey in late June/early July of 2013 was the lowest (CPUE 4.7 fish/hr) observed for the particular cycle year since the survey was initiated in 1998, however, see previous and subsequent bullets for interpretation (Figure 17). The few Sockeye Salmon that were captured in the survey were in the central and northern portions of the SOG and the Gulf Islands, typical of the distribution generally observed during this time period (Figure 18 B). The timing of the survey in 2013 was consistent with the previous survey on this cycle line in 2009, however the catches in 2009 were 11 times greater (CPUE 53.0 fish/hr) than in 2013 (Figure 17). Brood year escapements were three times larger for the 2013 juvenile outmigration (2011 brood year EFS: 1.2 million EFS) than for the 2009 juvenile outmigration (2007 brood year: 400,000 EFS), therefore, assuming survival was similar, a larger Fraser Sockeye juvenile CPUE would be expected in the SOG in 2013 compared to 2009. On the 2013 cycle, there was one other brood year (2003; EFS: 1 million) that had a similar low CPUE (in the SOG during their 2005 juvenile outmigration 9.4 fish/hr) compared to 2013 (4.7 fish/hr). However, the 2005 survey was conducted even later than usual for this sampling program, commencing in the middle of July and, therefore, a larger percentage of the Fraser Sockeye juveniles likely would have left the SOG by this time (Preikshot et al. 2012).

- In 2013, an earlier timed trawl survey (June 1-11, 2013) was conducted, in addition to the standard annual survey described in the previous paragraph (Figure 18 A). During this earlier trawl survey (Figure 16), the CPUE for the standard survey area in the SOG was 59.0 fish/hr. The largest catches of juvenile Sockeye Salmon during this period were within the Discovery Islands (June 3, Area 6, CPUE 942.6 fish/hr) (Figure 18 A). When compared to similarly timed surveys conducted from 2010 to 2012, the migration of the juveniles out of the SOG in 2013 may have been earlier (June 3) than observed in 2010-2012 (June 10, see subsequent bullet).
- There are no comparable data on this cycle for the early June trawl surveys. However, juvenile salmon distribution can be compared with recent late-May/early-June surveys conducted on other cycle years. The catch distribution of juvenile Sockeye Salmon from the trawl survey (June 1-10, 2010) and from purse seine surveys (late-May/early-June 2010 to 2012) indicated that the migration of the majority of Sockeye Salmon out of the SOG occurred in early-June. Neville et al. (2013) reported that between 2010 and 2012, very few Sockeye Salmon were observed leaving the SOG before the beginning of June, with virtually no juvenile Sockeye Salmon captured in the northern SOG (Discovery Islands; Figure 16, Area 6) during the last week of May. The few Sockeye Salmon that were captured from the Discovery Islands region in these earlier surveys were B.C. mainland stocks and were not from the Fraser River. Similar to estimates by Preikshot et al. (2012), peak Fraser Sockeye abundance for the 2010 to 2012 years was estimated during early-June (June 10).
- It is not known if this variation in Fraser Sockeye juvenile timing observed between 2013 and the 2010-2012 years is specific to the stocks dominating the 2013 cycle line, is due to environmental conditions in 2013, or can be attributed to other factors. It is important to note that this shift in timing did not occur in 2014, when the distribution of juveniles was consistent with observations in 2010-2012.
- The proportions of empty stomachs in both trawl surveys in 2013 were average (27%), therefore suggesting that conditions were not out of the normal range observed in the SOG.

Juvenile Sizes in the Strait of Georgia

- Juveniles caught in the early June trawl survey were an average (± standard error) nose-to-fork length of 106.2 ± 13.9 mm (Figure 19). The average length of the juveniles captured in the standard survey in late June-early July was 123.4 ± 12.0mm (Figure 19), and was the largest observed in the 15 year time series. In 2013, the largest fish observed in the surveys were in the regions adjacent to and south of Texada Island (Figure 16, Area 3 and 4). The smallest fish were the juveniles captured within the Discovery Islands (Area 6). This is in contrast to 2010-2012 when the largest fish were captured in the Discovery Islands (Area 6), northern SOG (Area 5) and Gulf Island (Area 2) regions and the smallest fish were captured just off the mouth of the Fraser River (Area 1). The mechanisms underlying these size differences in the different areas of the SOG are currently unclear.

River-Type Stocks: Adult Migration and Spawning In 2011 and 2012

Adult Migration and Spawning

- In 2011, Harrison Sockeye (contributing four year olds to 2015 returns) were reported to be in poor condition on the spawning grounds with several en-route mortalities reported in the near terminal areas. This may be due to the exceptional escapement observed in this system in this brood year (387,100 effective female spawners). Spawning success at Harrison was 91% in 2011 (long-term average: 99%). Physical conditions (water levels and temperatures) on the spawning grounds were favorable throughout this stock's spawning period.

- In 2012, Harrison Sockeye (contributing three year olds to 2015 returns) were reported to be in good condition on the spawning grounds with a spawner success of 99%. Escapement in this year was much lower than the previous brood year at 32,900 effective female spawners.

River-Type Stocks: Sub-Yearling Smolt Outmigration

Fry Outmigration Conditions

- Since this stock does not rear in freshwater but migrates to the ocean as sub-yearling smolts (age: 1_1) shortly after they emerge from the gravel, there is no rearing lake sampling for this stock, and given their size and outmigration timing (Birtwell et al. 1987), no Mission smolt sampling of this stock.
- Harrison Sockeye migrate out later than most Fraser Sockeye stocks as subyearling smolts (Birtwell et al. 1987), rather than as yearling smolts, and would have experienced slightly above average to slightly below average discharge levels in 2013 (four year olds returning in 2015) (Figure 12 B).

River-Type Stocks: Juvenile Migration in the Strait of Georgia

Juvenile Migration Timing

- Harrison River Sockeye Salmon enter the SOG in late June/early July (later than river-type Fraser Sockeye) and are typically captured in Howe Sound during that time period. In September, Harrison River Sockeye are the dominant stock of Sockeye Salmon captured in the SOG and Howe Sound regions (Beamish et al. 2012). Since Harrison Sockeye return as three and four year old fish, the Harrison River Sockeye Salmon that will return in 2015 will include juveniles that entered the ocean in both 2012 (brood year escapement of 400,000) and 2013 (brood year escapement of 33,000). There is considerable inter-annual variability in Harrison Sockeye age of maturity, although on average they return at older ages (greater proportion of four year olds relative to three year olds) in years when Pink Salmon are also spawning in the Harrison system (Grant et al. 2010).
- The catch (CPUE) of juvenile Sockeye Salmon in the SOG in September 2012 and 2013 was below average for the survey time series (Figure 20). In both 2012 and 2013 during this month, the largest catches of Sockeye Salmon were in Howe Sound (73% and 70% respectively) rather than the SOG. These fish are not included in the CPUE (Figure 18) as this region is not part of the standard survey track line. We cannot compare the catch in Howe Sound between years, as the effort in this region varies. Although Beamish et al (2012) demonstrate that typically by September the majority of Harrison Sockeye have moved into the SOG, the 2013 results may suggest that the timing of movement in 2012 and 2013 into the general SOG region was later than typically observed and, therefore, our September CPUE may be an underestimate for these years. Overall, there appeared to be a shift in distribution of juvenile Harrison River Sockeye Salmon in 2012 and 2013, with the majority of the fish observed in September occurring in the Howe Sound region.

Therefore, although the CPUE's observed in the standard survey were some of the lowest on record this may be an underestimate of true abundance, as the fish in Howe Sound are not included in the estimates.

- In 2012, the average length of juvenile Sockeye Salmon captured from all regions was 113.3 mm and the distribution was bimodal (Figure 19). Using DNA analysis, Beamish et al. (2012) demonstrated that in years of bimodal distribution Harrison River Sockeye comprise the lower mode of the distribution. In 2012, this lower mode represents about 85% of the total catch. The average length of the lower mode was 103.4 mm; the smallest fish in the time series. Overall, the average length was the fifth smallest average size observed between 1998 and 2013. In 2013, the average length of juvenile Sockeye Salmon was 131.1 mm, or slightly above the long term average (Figure 19).

Stock Proportions (Escapements in 2011 to Juveniles in 2013)

- Fraser Sockeye stock proportions were calculated for the 2011 escapement, and assessed in the various mixed stock sampling components: 2013 Fraser Sockeye smolt outmigration at Mission (sample size: 1,409 fish), 2013 juveniles in the SOG (sample size: 295 fish) (Figure 21; Table 3) and 2013 juveniles in the Queen Charlotte Sound (sample size: 15 fish). Due to the small abundances of other stocks in the various sampling components, strict interpretation of percentages is not possible, particularly in light of the sampling gap that occurred in the latter part of the sampling period for the Mission smolt project in 2013. As a result of the gap in sampling, estimates of stock proportions from the Mission project are likely biased high for early migrating stocks like Cultus and Chilko, and biased low for later migrating stocks like Shuswap (Figures 9, 11 and 21). Note that Harrison Sockeye are not included in this comparison, despite their relatively large predicted contribution to the 2015 returns, as they have a unique life history (DFO 2015).
- Queen Charlotte Sound samples of Fraser Sockeye juveniles, collected by DFO's High Seas Salmon Program were excluded from Figure 21 and Table 3 due to the extremely low sample size (*n*=15). Note, however, that Chilko comprised 33% of this sample, along with Late Shuswap (33%), and all Early Summer stocks combined (33%). See documentation of this project in previous publications (Tucker et al. 2009; Trudel et al. 2011; Beacham et al. 2015) and the 2014 Fraser Sockeye supplement report (DFO 2014 b).
- The dominant stock in all sampling components, excluding Queen Charlotte Sound, was Chilko. The contribution of this stock to the total escapement or forecast, or total sample size for the Mission and SOG surveys is as follows: escapement (62%), Mission (55%), SOG (60%), and four year old forecast (60%).
- The Shuswap stocks (both the early and later timed groups combined) were present in all sampling components: escapement (10%), Mission (3%), SOG (12%), and four year old forecast (17%). Note, again, the Mission percentages might be biased low due to the gap later in this sampling program.
- Birkenhead, a stock that exhibited anomalously low survival in the 2010 brood year relative to all other stocks, also appeared in similar proportions across all sampling components in 2013: escapement (13%), Mission (<1%), SOG (4%), and four year old forecast (7%). This might indicate that the anomalously poor survival observed in the 2014 return (predominantly 2010 brood year) did not affect the 2011 brood year.

- Weaver was one exception, this stock has a similar four year old forecast (274,000 at the 50% probability level) to Birkenhead (236,000) yet it did not appear in any of the sampling components (Mission, SOG)
- Other Summer Run stocks that were detected in all sampling components included Quesnel (on average 5% in all samples) and Stellako (on average 6% in all samples).

Strait of Georgia Coho

- Coho that enter the SOG remain and rear in the Strait through September. Beamish et al. (2010) demonstrated that the CPUE of Coho Salmon in the September SOG trawl survey is an index of Coho returns for the following year. In 2013, the trawl catch of Coho Salmon was the largest on record suggesting good returns of Coho to the SOG in 2014, and indicating that conditions within the Strait were favorable for juvenile salmon that entered the ocean in 2013 (Figure 22).

Fraser Sockeye Jack Returns in 2014

- Jack (age: 3_2) recruits can be used to provide some indication of the return of four year old recruits (age: 4_2) in the subsequent year. Jacks that returned in 2014 came from the same brood year as the four year old recruits that will return in 2015 and, therefore, will have experienced the same conditions during early growth and development in both the freshwater and marine environment, but return one year earlier (e.g. jacks from the 2011 brood year return in 2014 and four year olds return in 2015).
- For the 2015 forecast, a sibling jack (age 3_2) to four year old (4_2) model, based on $\log_e$ transformed variables, was used to predict the four year old returns in 2015 (Figure 23)
- Chilko had sufficient jack (3_2) recruit data from the 2014 preliminary returns to use a sibling model (Figure 23). Jack recruits in 2014 (2.4 million) are preliminary estimates only, and were generated from near-final escapements, preliminary return age proportions, and preliminary information on exploitation rates (55%). The jack-sibling model predicted a four year old return of 1.2 million in 2015 at the 50% probability level (range: 721,000 to 2.1 million at the 25% to 75% probability levels), which was half the abundance predicted by the official forecast (50% probability level 2.4 million; range: 1.6 to 3.8 million at the 25% to 75% probability level) (DFO 2015).
- Although uncertain, jack data from 2014 do indicate a lower return for Chilko than generated by the official forecast, which predicted that Chilko would contribute the largest proportion to the 2015 returns (DFO 2015), at 35%.

Ocean Conditions

Background

Ocean conditions affect the survival of Fraser Sockeye during their entire marine life-history phase (typically two years out of their four years of life). Specifically, marine conditions in nearshore and shelf waters influence the survival and growth of juvenile salmon when they first enter the ocean and migrate north along the continental shelf, and conditions in the Gulf of Alaska influence the juveniles as they mature to adults and return to coastal and fresh waters to spawn. Historically, high survival of various species of salmon that migrate along the west coast of Vancouver Island has been associated with cooler water temperatures and higher abundance of lipid-rich zooplankton, among other processes (Mackas et al. 2007). In the SOG, higher survival of various species of salmon has been associated with (among other processes) cooler water temperatures and larger abundances of zooplankton (Beamish et al. 2010; Araujo et al. 2013). DFO annually reviews observations of ocean conditions in its State of the Pacific Ocean workshops and publications. The highlights below are summarised from the State of the Ocean reports for 2013 (Perry 2014), when Fraser Sockeye entered the ocean and migrated north along the B.C. coast as juveniles, and 2014, when these fish were feeding and maturing into adults in the central Gulf of Alaska. Note that the information for 2014 is preliminary, pending the DFO State of the Ocean meeting scheduled for March 2015.

Highlights

Overall, physical ocean conditions were in transition in 2013: cooler temperatures dominated the first half of the year, with conditions becoming warmer during the second half of the year. Biological responses, however, were muted, likely because of time lags between physical and biological systems. In the Gulf of Alaska, cooler temperatures prevailed early in 2013, but warmed in the fall and became very warm at the end of 2013 and into 2014. This produced very strong vertical stratification in the central Gulf of Alaska during summer-fall 2013, which is believed to have reduced the mixing of deep nutrients into the upper layers, leading to observations of reduced chlorophyll in the NE Pacific in spring 2014 (Whitney 2015). Along the outer B.C. coast, the first half of 2013 was generally cooler than the 30-year (1981-2010) average, but the second half of 2013 was warmer. On an annual basis, the zooplankton composition along the west coast of Vancouver Island had above normal biomass of large lipid-rich copepods, which are generally favourable for growth of juvenile salmon. On a seasonal basis, however, there was a larger biomass of warm water, typically lipid-poor, zooplankton in summer and fall of 2013 than earlier in the year. In the SOG, the timing of the spring phytoplankton bloom returned to earlier blooms (end of March) after a series of late blooms (mid-April) from 2007 to 2012 (Figure 24).

The very warm conditions in the Gulf of Alaska that started towards the end of 2013 persisted through 2014, continued to strengthen (Figure 25), and shifted eastward towards the B.C. coast, so that by September 2014 this warm water occurred close to the continental shelf break of B.C.. Very warm sea surface temperatures occurred along the outer B.C. coast, especially in autumn 2014, when record high temperatures were measured at several locations (Figure 26). The biological consequences of these warm temperatures along the B.C. coast and continental shelf are in the process of being analysed. As of 23 January 2015, there is only a moderate (50-60%) likelihood of El Niño conditions in the NE Pacific in the first half of 2015 (NOAA 2015).

Assuming that Fraser Sockeye migrated north along the B.C. coast during summer 2013 as juveniles, then out into the central Gulf of Alaska in Fall 2013 where they were located through all of 2014, they would likely have been exposed to the following ocean conditions. In the SOG in April-May 2013 they would have experienced normal to slightly above normal water temperatures (with "normal" defined as conditions during 1981-2010), and normal timing of the spring plankton bloom (late March; based on 1981-2010) compared with the late blooms (mid to late April) that had occurred from 2007 to 2012. Along the northern shelf of B.C. during summer 2013, the migrating juveniles would have encountered slightly cooler than normal temperatures up to the end of August, then warmer than normal temperatures in September (Figure 26). Once in the central Gulf of Alaska, however, these Fraser Sockeye would have encountered warmer than normal conditions in Fall 2013, followed by much warmer than normal temperatures (at times 4 °C above normal) through most of 2014. These high temperatures are speculated to have influenced the food web (more lipid-poor zooplankton) and possibly introduced unusual predators (such as various warm water tuna and squid species) into the Gulf of Alaska and Canadian continental shelf areas.

Conclusions

Key Conclusions

To provide support for the official 2015 Fraser Sockeye forecast, supplemental data on Fraser Sockeye condition, survival, and relative abundances were presented for the parental spawners in 2011 through to the 2014 jack returns, including ocean conditions during their ocean residence (2013 to present). This synthesis of existing data represents a starting point for reducing uncertainty in Fraser Sockeye forecasts, through improving our understanding of inter-annual variability of survival in these stocks. A learning component to the 2014 forecast supplement, following the returns in 2014 (Appendix 1), is being built upon in the current paper. The key stocks contributing the highest percentages to the forecasted total returns in 2015 are the lake-type Chilko stock (35% of the total forecast at the 50% probability level) and the river-type Harrison stock (21% of the total forecast at the 50% probability level). Both of these stocks are in the Summer Run timing group.

Information that indicated average conditions for Fraser Sockeye survival during their life-history from 2011 adult spawners through to 2015 returns:

- Relatively good upstream migration conditions for dominant stocks in 2011;
- Above average lake productivity for assessed stocks (Chilko, Late Shuswap);
- Larger smolt and juvenile sizes in 2013 for most assessed stocks (Chilko; Shuswap; Gates);
- Average proportion of empty stomachs in juveniles in the Strait of Georgia (no red flags with regards to empty stomachs, as was observed in the 2007 ocean entry year (Thomson et al. 2012);
- Stock percentages in the Mission smolt project and SOG juvenile surveys in 2015 indicate that Chilko dominated stock proportions, which reflects this stock's contribution to the brood year EFS in 2011 and, consequently, the 2015 forecast;
- High CPUE of Coho Salmon in the Strait of Georgia in 2013.

Other pieces of information that provide possibly poor signals for Fraser Sockeye returns in 2015:

- Anomalously warm ocean conditions commenced in the 2013 ocean entry year of most stocks returning in 2015. These conditions have persisted through to present (May 2015), which is immediately prior to the return of Fraser Sockeye in 2015. This warm water coincided with low nutrient, and consequently, low chlorophyll concentrations in surface waters, and shifts in coastal zooplankton communities to warmer water species with lower lipid content (and, therefore, poorer food quality for fish). Warmer ocean conditions are typically linked to poorer salmonid survival, although direct linkages to Fraser Sockeye survival remain currently unclear.
- The sibling jack model forecast for Chilko suggests that this return will be half the size of the official forecast; Chilko contributes the largest proportion to the total 2015 forecast at the 50% probability level (DFO 2015).
- For lake-type Fraser Sockeye stocks, CPUE assessed in the SOG surveys was below average, although this assessment period is late for Fraser Sockeye migration timing and, further, there were indications that outmigration was earlier than normal in 2013.

- Harrison Sockeye CPUE in 2012 and 2013 was also low, despite the exceptional escapements in the 2011 brood year, which might indicate poorer returns than expected for this stock in 2015 as well. However, the largest catches of these fish occurred in Howe Sounds outside of the standard study area, and therefore, were excluded from the CPUE, which may reflect an underestimate of true abundance.

Lake-Type Stocks Summary

- On their return to the spawning grounds in 2011 (the parental generation that will produce the four year old returns in 2015), Early Stuart and Early Summer migrants experienced higher discharge in the Fraser mainstem (>8,000 cms), which can create a hydrological barrier to fish passage in the Fraser Canyon. Early Stuart migrants also experienced low temperatures, below their optimum (16°C). Migration conditions for the dominant Chilko and Harrison stocks were considered benign. Spawner success was slightly depressed for a number of smaller stocks, although this was accounted for in the 2015 forecast variables. Physiological metrics of adult Fraser Sockeye health were generally close to normal in the 2011 returns, though this information is not currently accounted for in the official forecasts.
- Chilko escapements in the 2011 brood year were within the range of spawners at maximum production (Smax), although data on zooplankton biomass, freshwater survival, and smolt sizes, indicate that the rearing capacity was average in this brood year. Late Shuswap escapements in the 2011 brood year were well below the Smax, and compensation (increased survival) would therefore be expected. However, freshwater survival in this brood year (168 fall fry/EFS) was well below the all cycle average (380 fall fry/EFS), and the cycle average (207 fall fry/EFS). This might be attributed to delayed density dependence from the previous brood year escapement for the Shuswap system, which was exceptionally large (3.1 million). Primary productivity (as measured in photosynthetic rates) in Chilko and Shuswap Lakes has increased in recent years (although major sampling gaps exist between the beginning and current sampling periods).
- Smolt outmigration conditions (discharge and temperature) were largely average for Fraser Sockeye in the Fraser River in 2013.
- Smolt size is positively correlated with smolt-to-adult survival in Sockeye Salmon (Ricker 1962; Henderson and Cass 1991; Koenings et al. 1993; Bradford et al. 2001). Smolt sizes were above average in 2013 for most assessed stocks, including Chilko and Shuswap stocks assessed at the outlet of their rearing lakes, and at Mission. Quesnel was one exception, where average fork length at Mission was slightly smaller in 2013 compared to 2012. Similarly, the average size of juveniles caught in the SOG was larger in 2013 compared to the time series (1998-2012), and was in fact the largest on record.
- The 50% smolt outmigration date for Chilko in 2013 at the outlet of Chilko Lake was April 29^{th}. Late Shuswap outmigration timing at the outlet of the Shuswap Lake system in Little River was mid-May. Although the Mission smolt project operated in 2013, a gap in the sampling program resulted in challenges interpreting migration timing for later outmigrating stocks such as Shuswap stocks. The Chilko outmigration timing at Mission was approximately May 5^{th} (50% date), which was roughly a week after they migrated out of Chilko Lake.
- Fraser Sockeye CPUE in the Strait of Georgia was amongst the lowest on record, based on the standard annual late-June/early-July sampling program (1998-2013) which is

thought to include 10% of the Fraser Sockeye juveniles during their SOG residence. However, given inter-annual and intra-stock differences in smolt outmigration timing (DFO 2014b), and also given evidence that juvenile migration through the SOG was later than normal based on earlier timed surveys (late-May/early-June) that were initiated in recent years, this CPUE might not be comparable across all years.

- The average proportion of empty stomachs sampled in both trawl surveys in 2013 was similar (27%) to what is typically observed and would therefore suggest that conditions were not out of the normal range in the SOG.

River Type Stocks (Harrison Sockeye) Summary

- Harrison Sockeye in 2015 will come from the 2011 and 2012 brood years, returning respectively as, four and three year olds. The four year old brood year escapement was 400,000 and the three year old brood year escapement was 33,000. Despite the large difference in brood year escapements, CPUE for Harrison was particularly low in the 2012 and 2013 SOG September surveys (<15) for both years. These results contrast with the 2011 survey year, which was also associated with a high brood year escapement of 300,000 in 2010, and resulted in exceptional returns in 2014 of greater than one million Sockeye. The CPUE in this 2011 survey year was much higher (~60) than the two subsequent years (2012 and 2013) relevant to the 2015 returns. Although a large proportion of Harrison Sockeye were assessed in Howe Sound, this area is not part of the standard survey area, and therefore, is excluded from the CPUE.

All Stocks

- Coho CPUE in the annual SOG surveys was above average in 2013.
- Jack abundance in Chilko in 2014 indicates a return that is half the size of the official forecast at the 50% probability level. This could be a signal of poor ocean survival for stocks in 2015, although the jack relationship is uncertain.
- Relative proportions of stocks in all sampling components (escapements, Mission smolts, SOG juveniles, and 2015 forecasts) were dominated by Chilko Sockeye (on average comprising 60% of the total escapement/forecast or sample). Shuswap stocks were also present in all sampling components (on average 10%), as well as Quesnel (5%) and Stellako (6%). Birkenhead also contributed a consistent percentage (6%) despite the anomalously poor survival of this stock in the previous brood year. The only stock that dropped out of the sampling components outside of the escapement and forecasts was Weaver.
- Ocean conditions in the second half of 2013, when Fraser Sockeye juveniles that will return as four year olds in 2015 first entered the ocean, coincided with a warming pattern. The warming in the northeast Pacific has persisted to the timing of this report (April 2015), and is considered anomalously warm (referred to as the 'warm blob' by oceanographers). The warm water has contributed to increased vertical stratification, decreased nutrient inputs and lower chlorophyll in the surface waters. Further, a shift to warm water copepods has coincided with this warming pattern in the northeast Pacific waters. It is unclear how this major shift in ocean conditions will influence Fraser Sockeye survival, however, it does introduce considerable additional uncertainty into the 2015 forecast, given that these conditions have not previously been observed.

Table 1. Adult Fraser Sockeye sample sizes for blood physiology, disease and fish condition in the 2011 migration year in three sampling locations (marine, in-river, and on the spawning grounds). See corresponding Figure 6.

Location		**Blood Physiology**	**Disease**		**Condition**
		Stress, Metabolism, Osmoregulatory	RNA	Histology	Lipid Metrics
Marine	Johnstone St.	30	30	30	30
	Port Renfrew	60	60	30	60
In-River	Whonnock	24	24	24	24
	Chilliwack	31	31	31	20
	Harrison	88	88	88	88
Spawning	Adams	20	20	20	-
	Chilko	20	20	20	-
	Harrison	40	40	40	-
	Weaver	40	40	40	40
TOTAL		**354**	**354**	**324**	**374**

Table 2. Average nose-fork length of Sockeye smolts sampled at the Mission, B.C. by year for select stocks. See corresponding Figure 15.

Year	**Fraser-S (Stellako)**	**Quesnel-S (Horsefly/ Mitchell)**	**Chilko-ES (Lake spawners**	**Chilko-S (River spawners)**	**Shuswap-L (Adams/ Low & Mid Shuswap)**	**Anderson-ES (Gates)**
2012	91.9 ± 9.4 mm (*n*=130)	84.1 ± 6.7 mm (*n*=301)	74.4 ± 6.1 mm (*n*=64)	76.8 ± 6.8 mm (*n*=233)	71.8 ± 6.5 mm (*n*=968)	77.9 ± 4.1 mm (*n*=71)
2013	88.0 ± 9.0 mm (*n*=90)	79.9 ± 4.8 mm (*n*=166)	86.8 ± 12.1 mm (*n*=98)	85.5 ± 9.1 mm (*n*=543)	86.9 ± 8.6 mm (*n*=32)	97.4 ± 5.4 mm (*n*=140)

Table 3. Stock composition (relative percentages) in the various sampling components: 2011 brood year escapement; 2013 smolt outmigration at Mission, B.C.; 2013 Strait of Georgia surveys; and 2015 four year old return forecasts. See corresponding Figure 21. Note: Harrison river-type Sockeye are not assessed given their differential migration timing from lake-type stocks.

Stock Name	**Effective Female Spawners (2011)**	**Mission Smolts (March 22 - May 16 and June 2 - July 25 2013) *n*=1,409**	**Strait of Georgia Juveniles (June 1-11, 2013) *n*=295**	**Four Year Old Return Forecasts (2015)**
Chilko	62%	49%	60%	60%
Shuswap (Early & Late)	10%	3%	12%	17%
Weaver	3%	0%	0%	8%
Birkenhead	13%	<1%	4%	7%
Stellako	4%	7%	6%	5%
Quesnel	2%	12%	6%	5%
Gates	4%	10%	1%	4%
Pitt	4%	0%	4%	1%
North Thompson	2%	10%	4%	1%

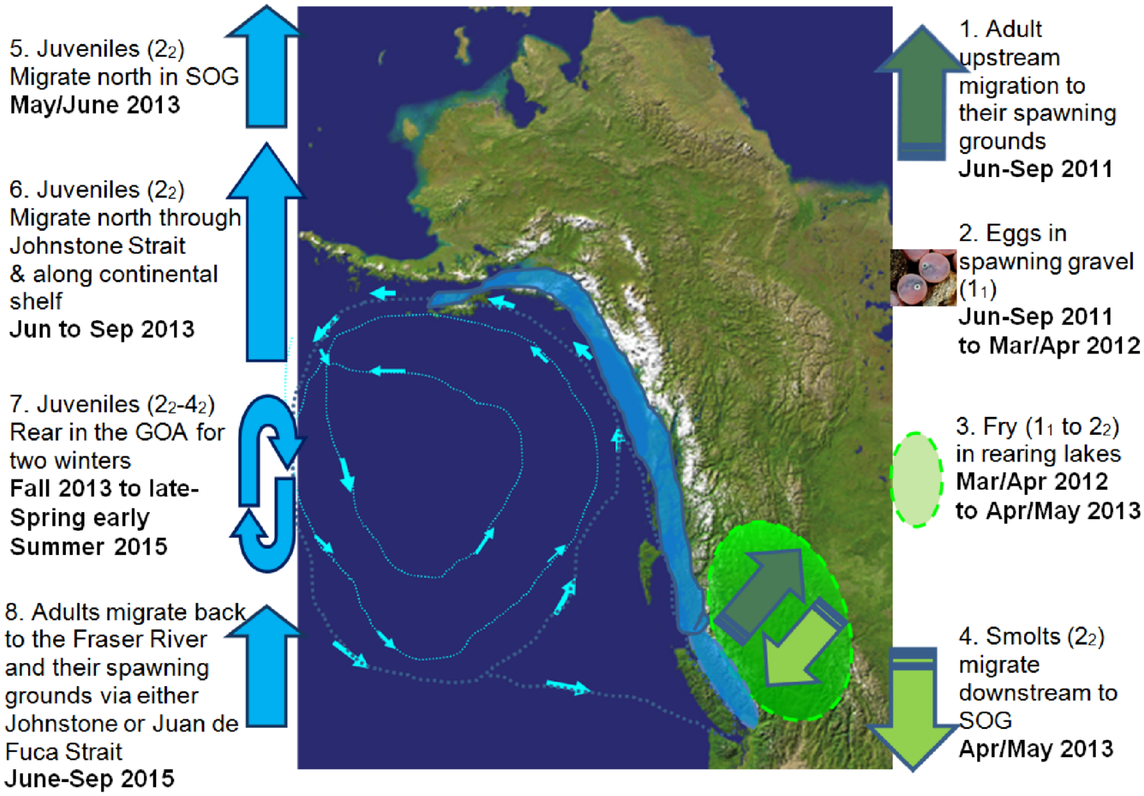


Figure 1. Lake-type Fraser Sockeye life-history for individuals that will return to spawn in 2015 as four year olds. Most Fraser Sockeye return as 4_2 fish (Gilbert-Rich ageing convention), where the total age is indicated by the '4' (that includes the freshwater and marine stages) and the winters spent in freshwater are indicated by the subscript '2'. The 4_2 Fraser Sockeye expected to return in 2015 will come from spawners that spawned in 2011, and will have spent their first two winters in freshwater (one winter as eggs in the gravel and one winter as fry in their rearing lakes) and their last two winters in the marine environment. After their second winter in freshwater (2013), these fish migrated downstream through the Fraser River and entered the Strait of Georgia (SOG). From here they migrated north, through the Johnstone Strait and along the continental shelf out into the northeast Pacific. They spent two winters (2013 & 2014) in the Gulf of Alaska and will return back to their spawning grounds in the late-summer/fall of 2015.

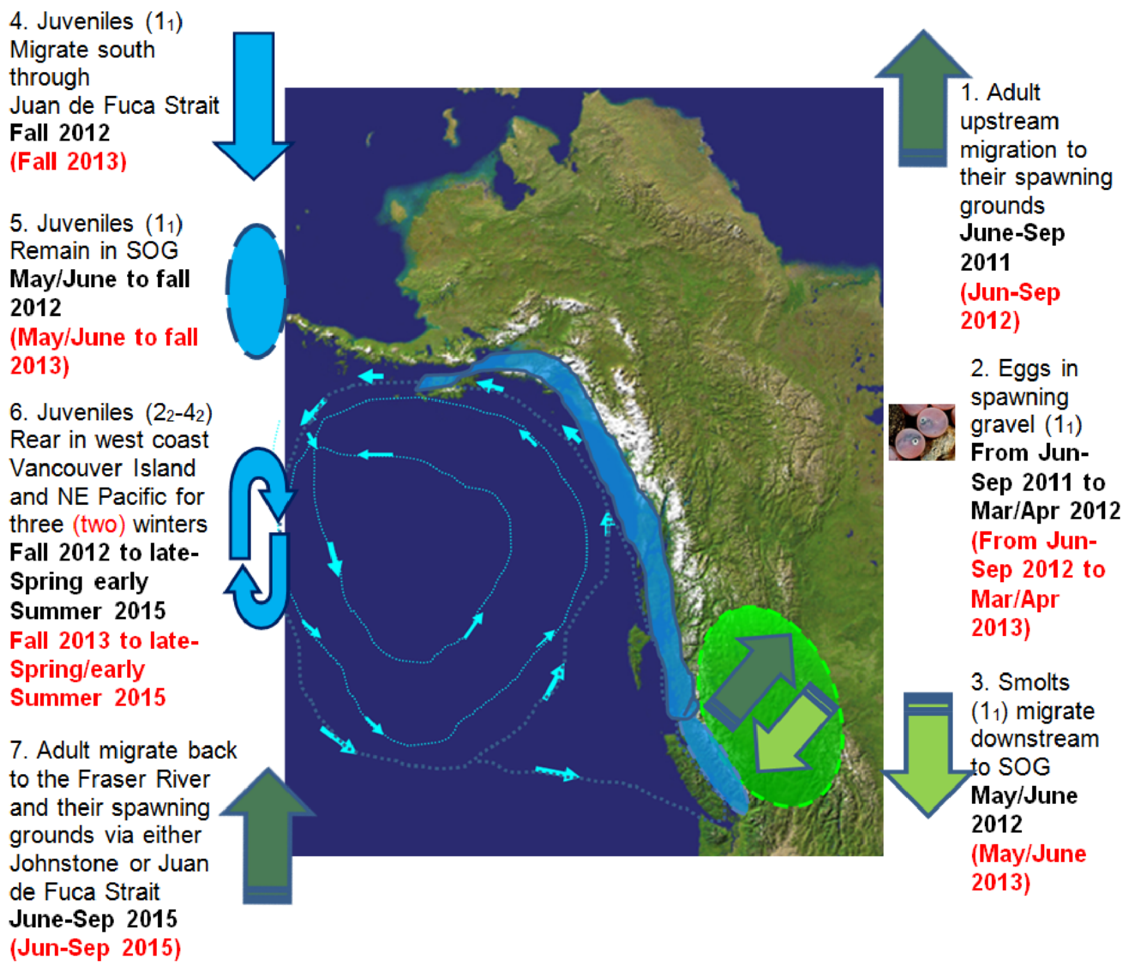


*Figure 2. River-Type Fraser Sockeye (specifically Harrison Sockeye) life-history for individuals that will return to spawn in 2015 as three (red text) and **four year olds (black text)**. River-Type Fraser Sockeye return as 4_1 or 3_1 fish (Gilbert-Rich ageing convention), where the total age is indicated by the '4' (or '3') and the freshwater residence years are indicated by the subscript '1'. River-Type Fraser Sockeye returning in 2015 will have come from spawners that spawned in 2011 (or 2012 for 3_1 fish), and will have spent one winter in freshwater (as eggs in their spawning gravel) then migrated about a month later than river-type stocks downstream to the Strait of Georgia (SOG) in 2012 (or 2013 for 3_1 fish). They migrated south out of the SOG (they remain in the Strait of Georgia longer than other stocks, leaving in the fall of 2012) through the Juan de Fuca Strait to rear along the west coast of Vancouver Island and in the north east Pacific. After three winters (or two for 3_1 fish) in the marine environment they will return back to their spawning grounds in the late-summer of 2015.*

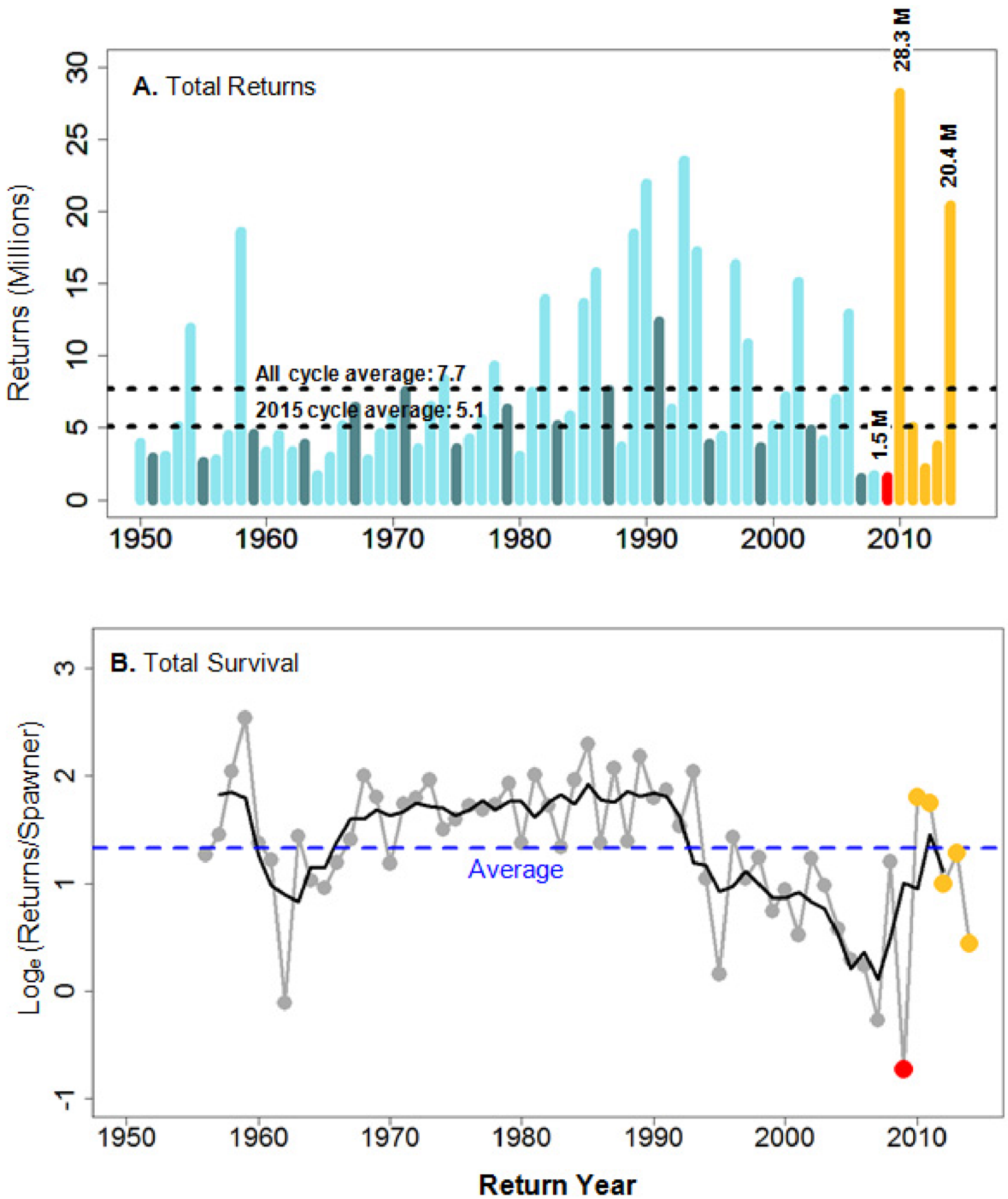


*Figure 3 **A**. Total Fraser Sockeye annual returns (dark blue vertical bars for the 2015 cycle and light blue vertical bars for the three other cycles). Recent returns from 2012 to 2014 are preliminary. **B**. Total Fraser Sockeye survival (log_e(returns/total spawner)) up to the 2014 return year. The light grey filled circles and lines present annual survival and the black line presents the smoothed four year running average. For both figures, the dashed line is the time series average. The red vertical bar in Figure A (or filled circles in B) represents the 2009 returns (low survival), and the yellow vertical bars in Figure A (or filled circles in B) represent the 2010 to 2014 returns (average survival for the Fraser Sockeye aggregate).*

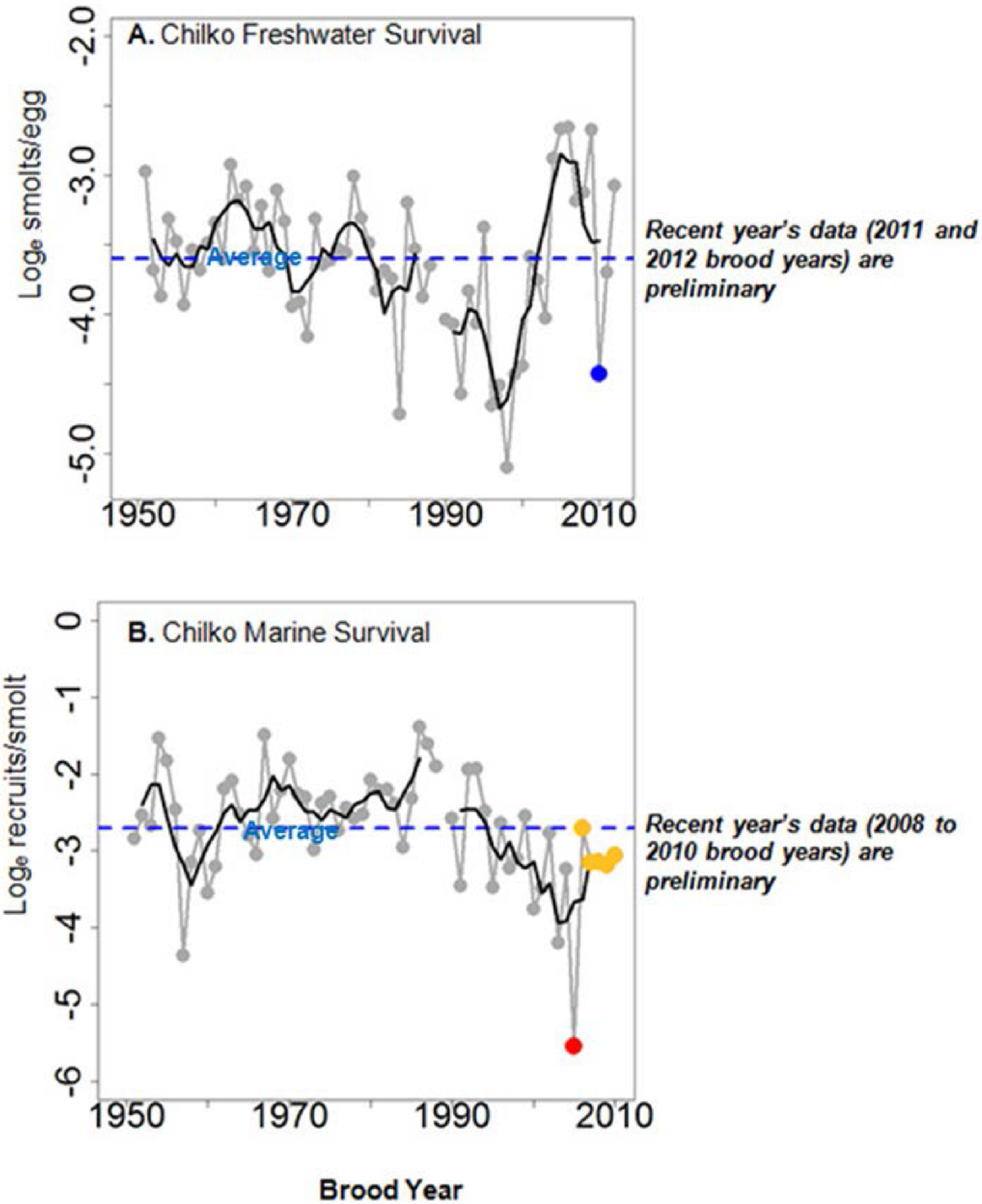


*Figure 4. Chilko River Sockeye **A**. annual freshwater ($\log_e$ smolts-per-egg) survival (filled grey circles and lines) with the 2010 brood year survival indicated by the blue filled circle and **B**. annual marine ($\log_e$ recruit-per-smolt) survival (filled grey circles and lines) with the 2005 brood year survival indicated by the red filled circle. The black line in both figures represents the smoothed four-year running average survival. The dashed blue lines indicate average survival.*

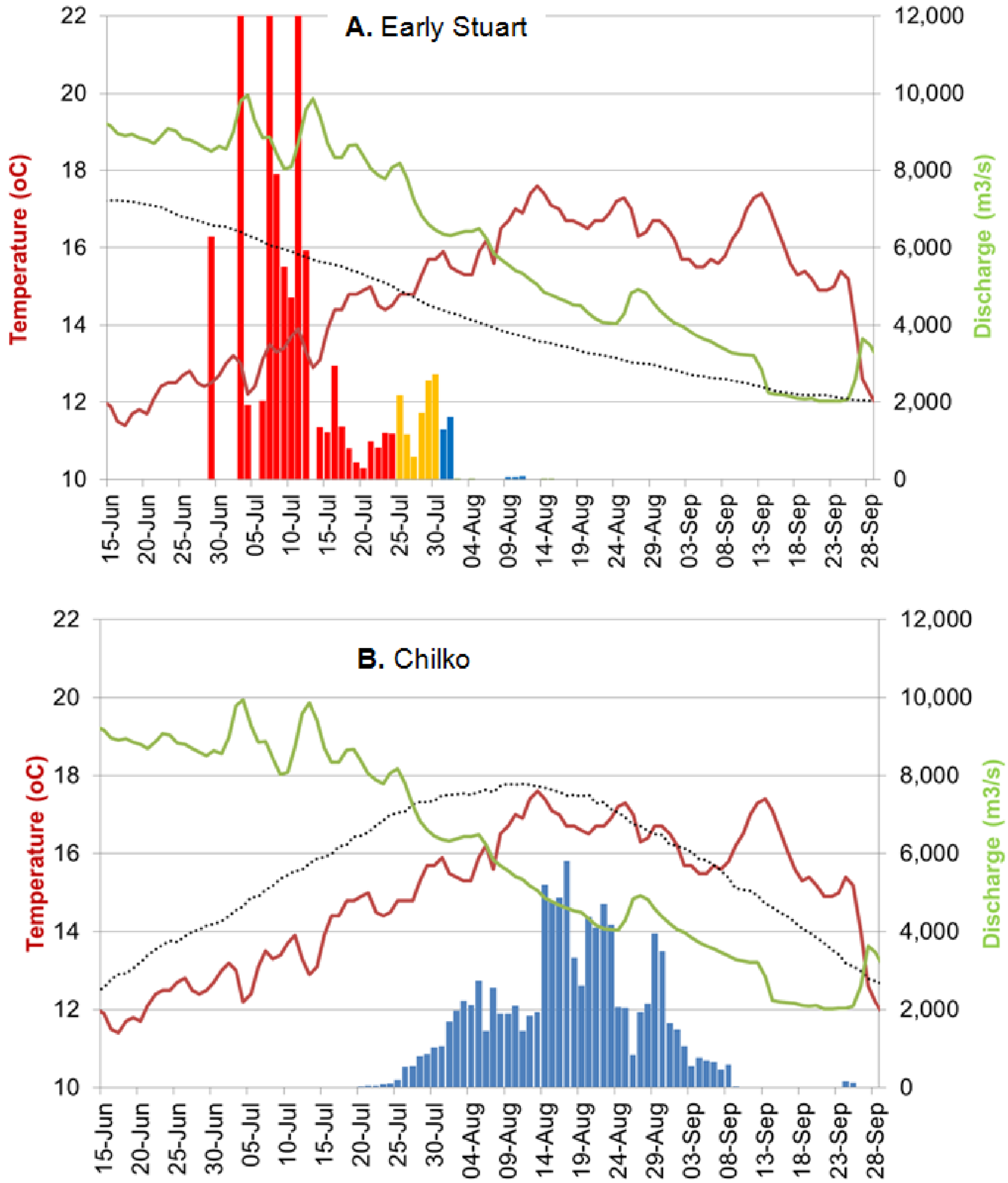


Figure 5. Migration conditions in 2011 (red line: temperature; green line: discharge; black dashed line: historical average temperatures 1941-2009) for ***A.*** *Early Stuart (low temperature and high discharge conditions) and* ***B.*** *Chilko Sockeye stocks (benign temperature and discharge conditions). The vertical coloured bars represent relative abundance of migrating salmon for each of these stocks; bars coloured blue represent the portion of the run that experienced benign temperature and discharge conditions (water temperatures between 14°C and 16°C and discharge below 6,000 m^3/s); red coloured bars represent the portion of the run that experienced conditions thought to negatively influence upstream migration and survival to the spawning grounds (water temperatures above 20°C and discharge above 8,000 m^3/s); amber coloured bars represent the portion of the run that experienced conditions thought to moderately influence upstream migration and survival to the spawning grounds (water temperatures between 18°C and 20°C and discharge between 6,000 m^3/s and 8,000 m^3/s).*

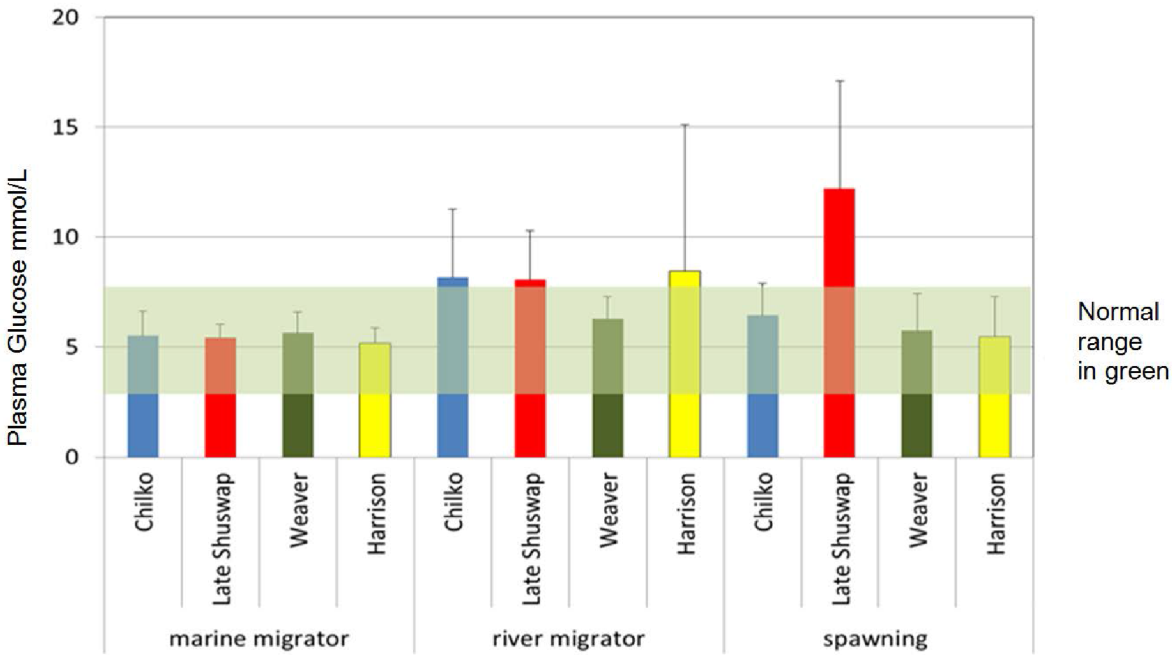


Figure 6. Fraser Sockeye plasma glucose results assessed for 2011 returning adults in three different sampling locations (marine, Fraser River, and spawning grounds) for four key stocks (Chilko: blue bars; Late Shuswap: red bars; Weaver: green bars; Harrison: yellow bars). The normal range is represented by the green shaded area, coloured bars below or above this range are outside the normal range. See corresponding Table 1.

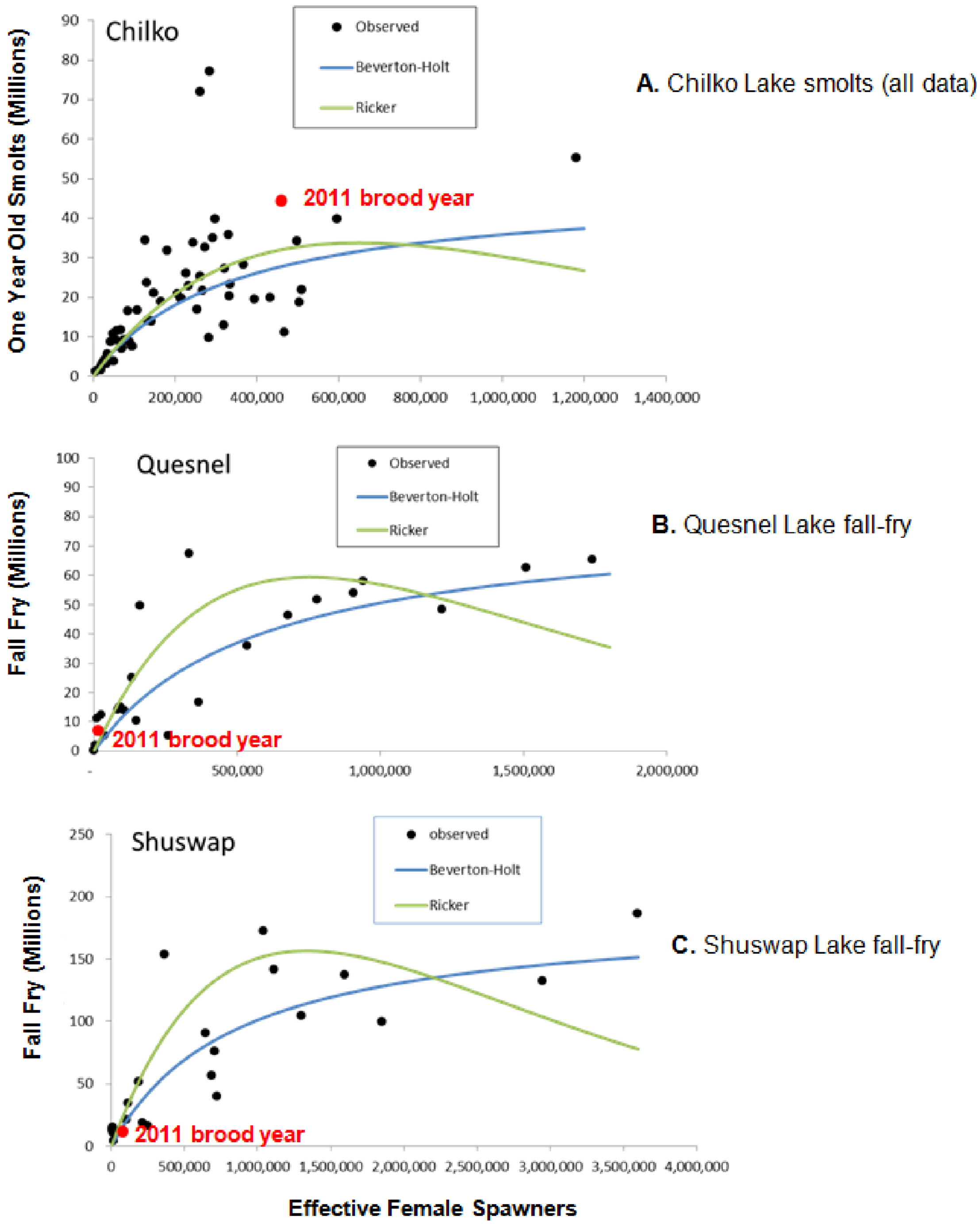


Figure 7 ***A.*** *Smolts-per-effective female spawner in Chilko Lake for all years (brood years 1949-2010, excluding 1989).* ***B.*** *Fall fry-per-effective female spawner in Quesnel Lake (brood years 1974 to 2011 non-inclusive).* ***C.*** *Fall fry-per-effective female spawner in Shuswap Lake (brood years 1974 to 2011). In each figure the 2011 brood year value is indicated by a red filled circle and text. Ricker (green line) and Beverton-Holt (blue line) models are fit through each of these time series'.*

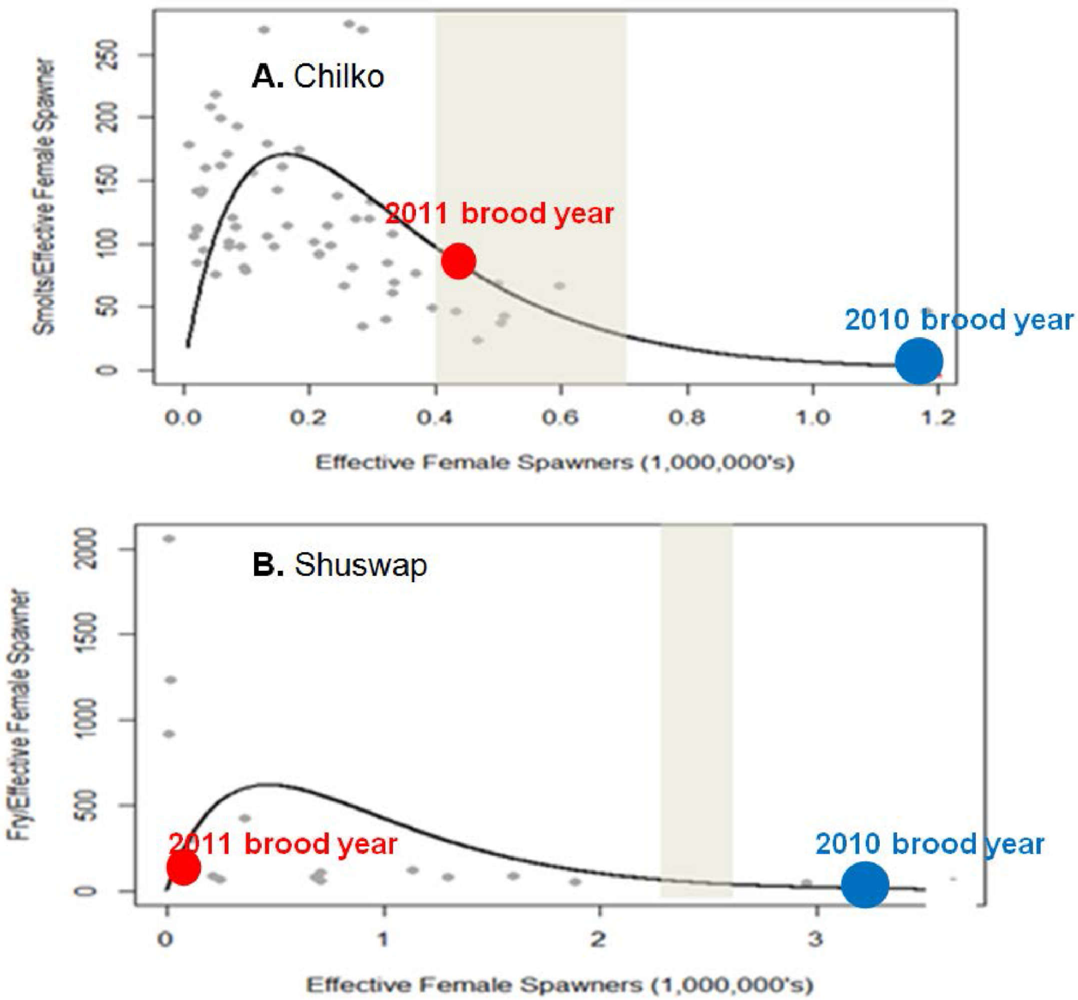


*Figure 8. Early freshwater survival (Chilko: smolt-per-effective female spawner; Shuswap: fall-fry-per-effective female spawner) versus effective female spawners, with a Ricker model fit through the data set. The range of spawners at maximum production (Smax) estimated from photosynthetic rate models and stock-recruitment data are represented by the shaded grey areas on each plot. Large red filled circles represent the 2011 brood year escapements and associated freshwater survivals (blue filled circles represent the 2010 brood year escapements) for **A.** Chilko (smolt/EFS: 96; EFS: 457,000) and **B.** Shuswap (early- and late-run stocks) (fry/EFS: 150; EFS: 74,000).*

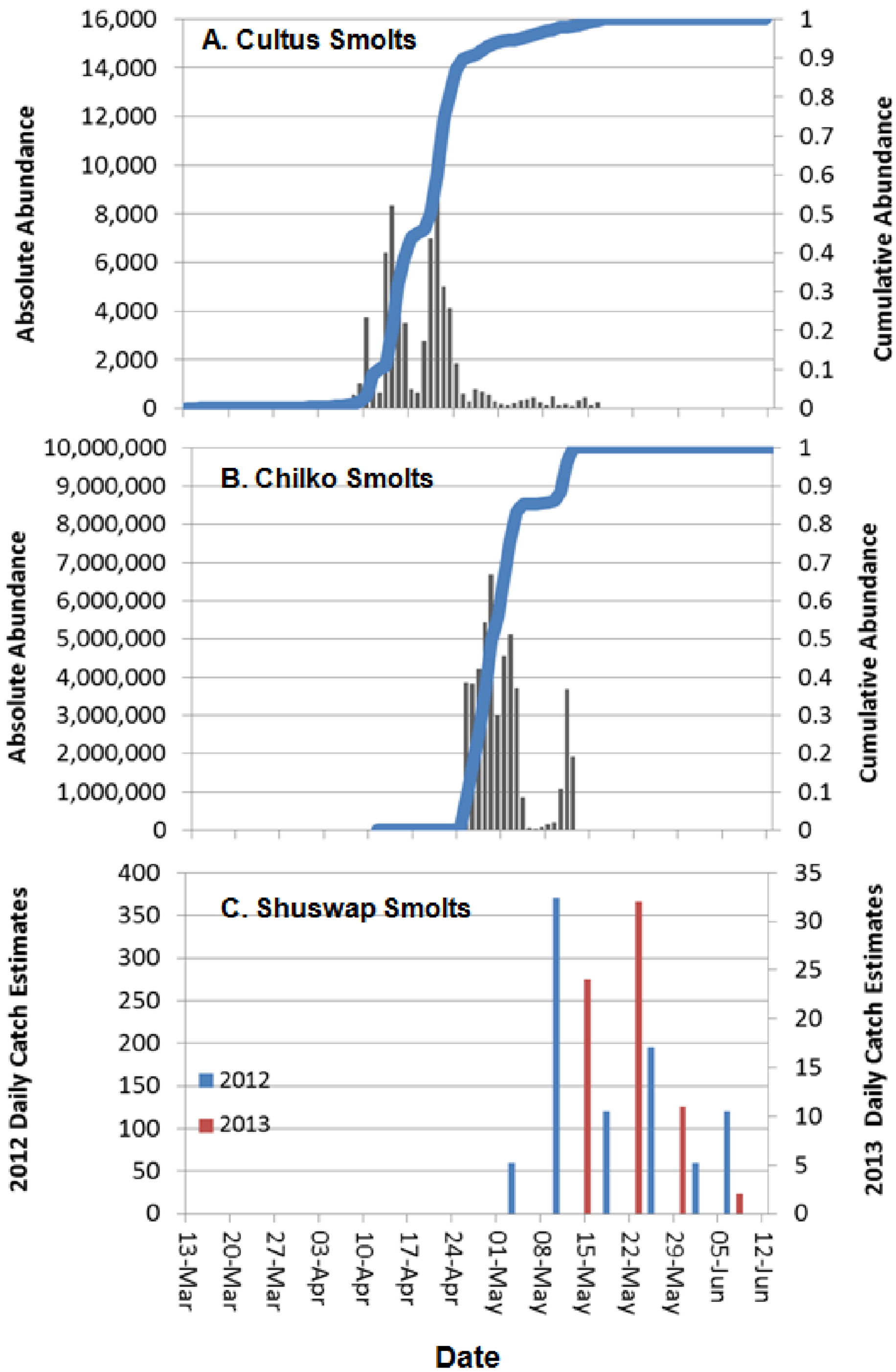


*Figure 9. Smolt outmigration timing at lake outlets for **A.** Cultus; **B.** Chilko; and **C.** Shuswap stocks in the 2013 outmigration year. The vertical bars for Cultus and Chilko are the absolute abundances and the blue lines these stocks are the cumulative smolt abundances over the smolt out-migration period. The 50% outmigration date for Cultus is April 20th, for Chilko is April 29th, and for Shuswap is mid-May. Note: smolt sampling for Cultus and Chilko are, respectively, fence and weir counts conducted throughout the migration period, while Shuswap smolt sampling was based on weekly sampling only and is not part of an annual assessment program.*

Figure 10. Aerial image of the Mission juvenile project located in the Fraser mainstem at Mission, B.C. The white rectangle outlines the study area and the dashed arrows indicate the direction of Fraser River flow.

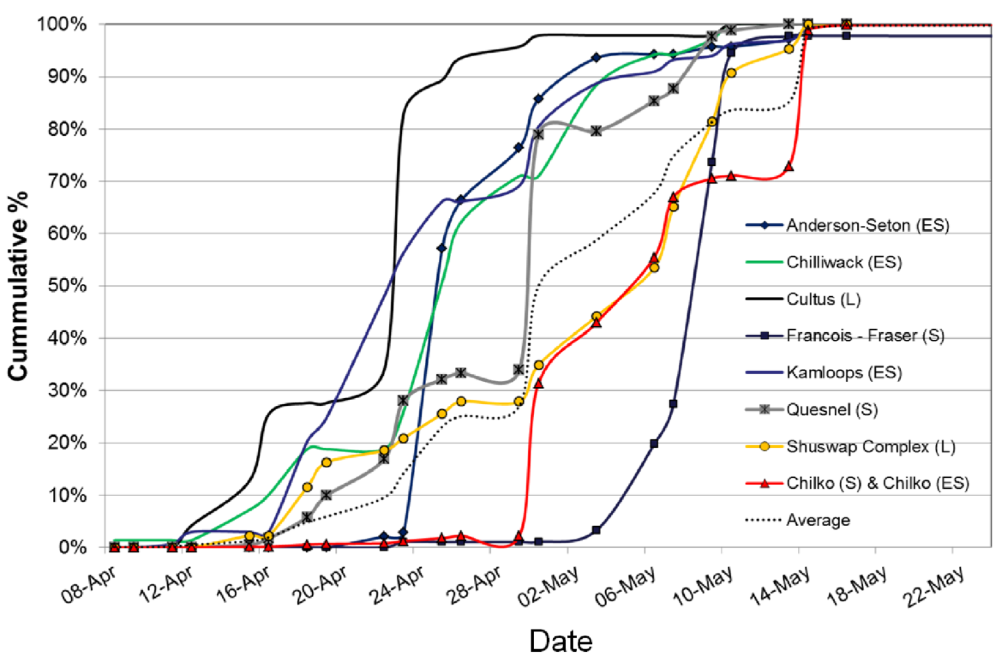


Figure 11. Sockeye smolt outmigration timing for select stocks at Mission, B.C. from March 22 to July 25, 2013. There was a gap in operations between May 17 and June 1 due to a vessel breakdown, therefore, stock composition has to be interpreted with caution. The combined 50% migration date for all stocks presented was April 30 (dotted line), with the Chilko 50% migration date being May 5th(red line).

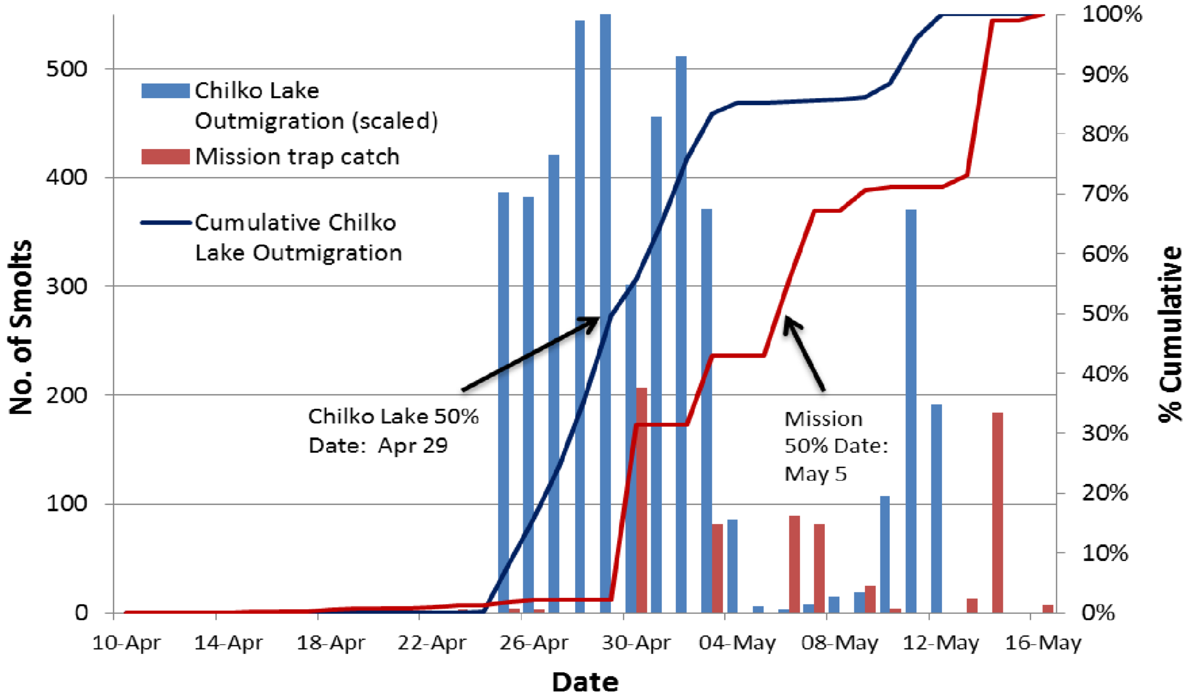


Figure 12 A. Chilko Lake outmigration abundance estimates (scaled) and Chilko trap catches at Mission with the corresponding percent cumulative abundance for each. There was a six day difference between the 50% cumulative migration date at the Chilko Lake outlet (April 29) and that at Mission (May 5) in 2013.

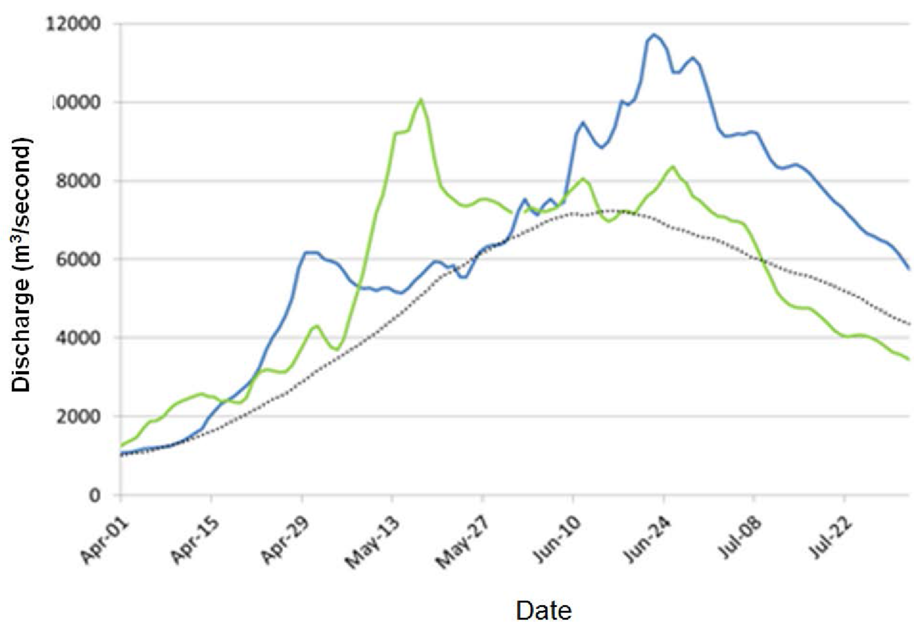


Figure 12 B. During the Fraser Sockeye smolt outmigration period, Fraser River discharge levels at Hope, B.C., in 2012 (blue line) and 2013 (green line) ranged from average to above average (1912-2009 average: dashed line).

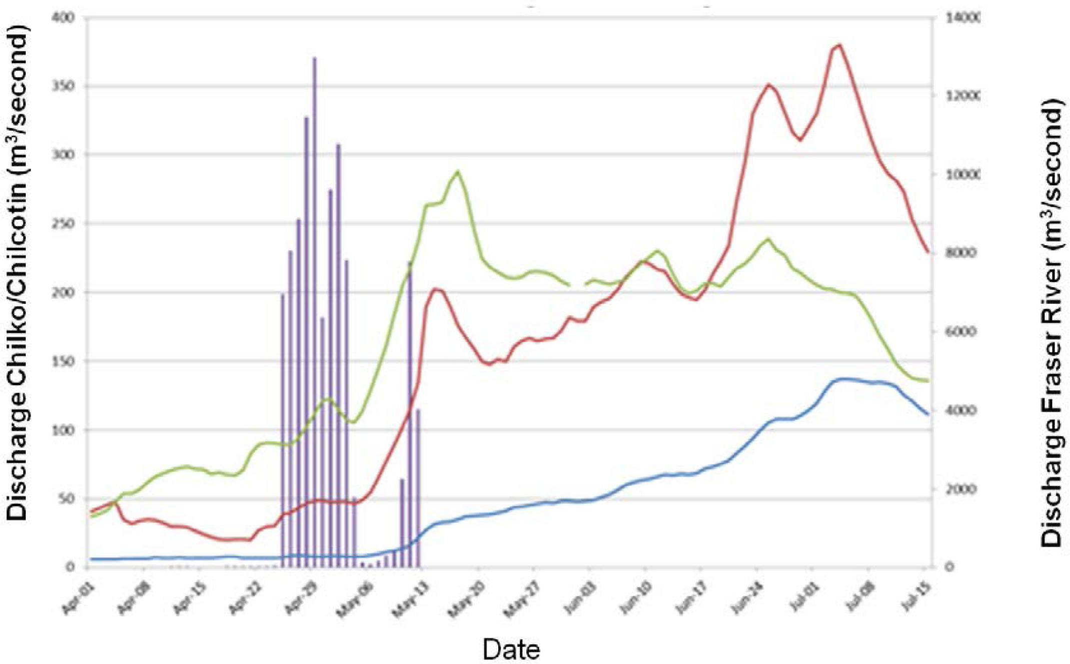


Figure 13. Discharge levels for the Chilko River (blue line), Chilcotin River (red line) and Fraser River at Hope (green line) compared to the relative abundance of Chilko smolts during their outmigration from Chilko Lake (purple vertical bars).

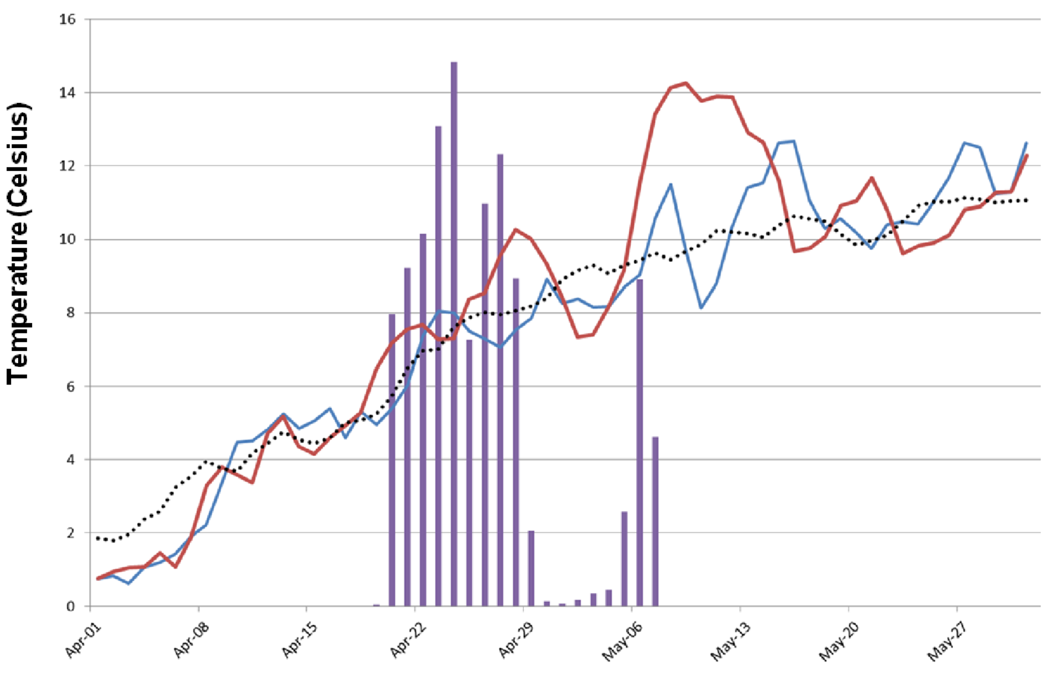


Figure 14. River temperature conditions at the Chilko Lake outlet for the 2012 (blue line) and 2013 (red line) outmigration years compared to the relative abundance of Chilko smolts during their outmigration from Chilko Lake (purple vertical bars). Average temperatures are indicated by the dotted line.

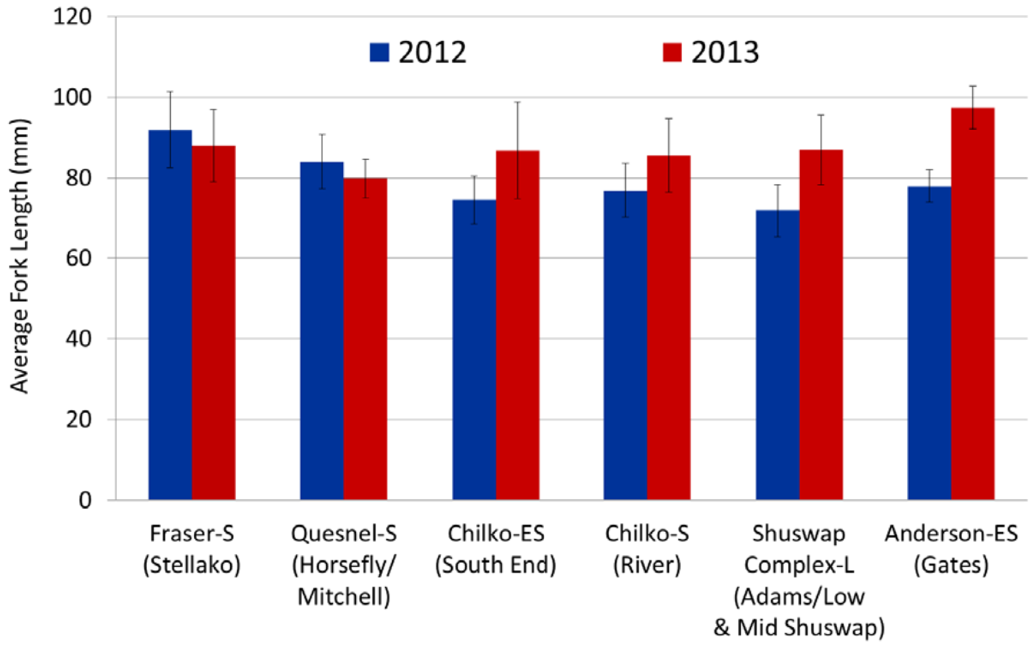


Figure 15. Average Sockeye smolt fork length at Mission for stocks with n>30 in both 2012 (blue bars) and 2013 (red bars). For each of the six conservation units in this figure the following applies: S: Summer Run timing group; ES: Early Summer Run timing group; L: Late Run timing group. See corresponding Table 2.

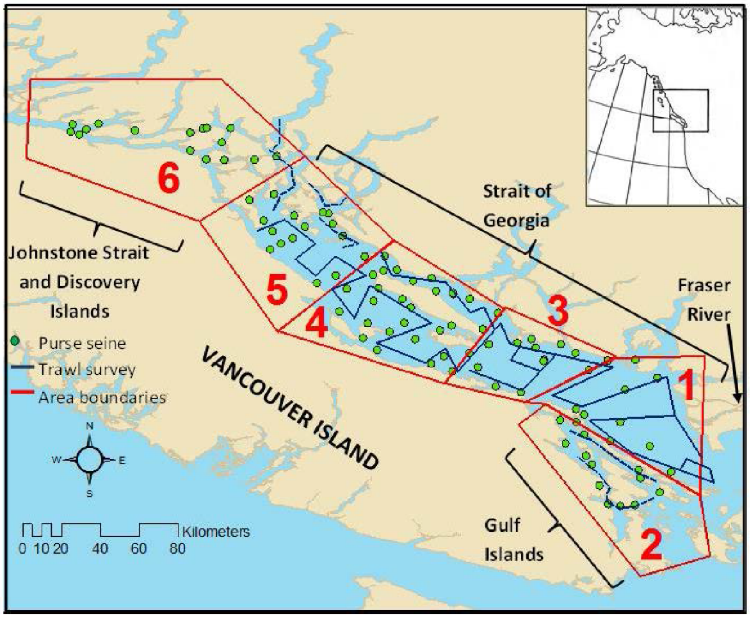


Figure 16. Location of the trawl survey standard track line (solid blue line) conducted annually (1998-2013, excluding 2003) in late-June/early July. In recent years, 2010-2013, additional survey periods (early-June and September) also follow these survey track lines. Dashed blue lines in Areas 5 and 6 are sampled during the trawl survey but are not included in inter-annual comparisons (Figure 15). The purse seine surveys conducted in the SOG and Discovery Islands in 2010-2012 are identified by green dots. The areas represented by red polygons are used for spatial catch comparisons. Areas 1, 3, 4, and 5 are the Strait of Georgia, Area 2 is the Gulf Islands, and Area 6 is the Discovery Islands.

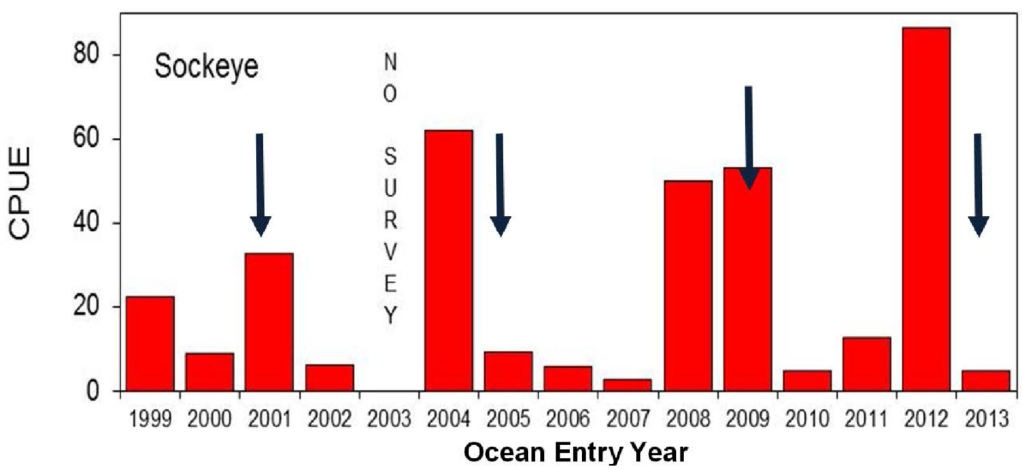
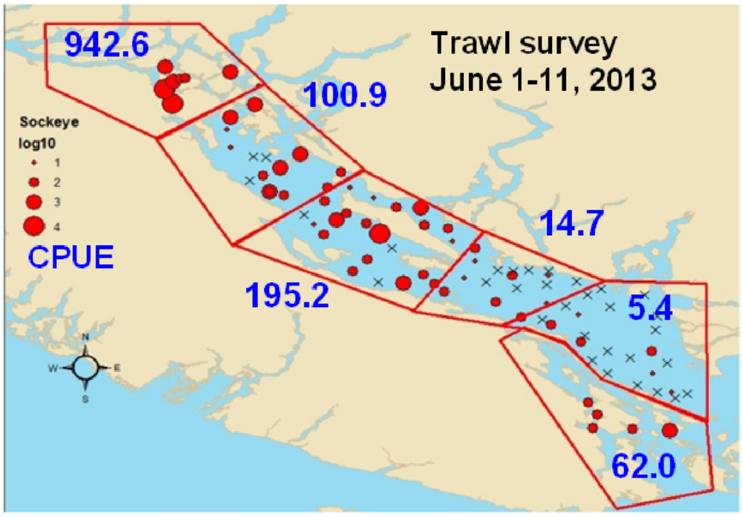
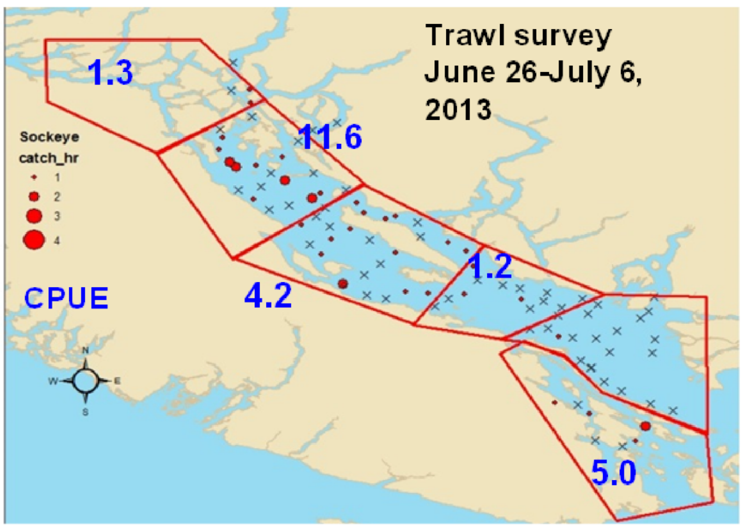


Figure 17. Catch-per-unit effort (CPUE) of juvenile Sockeye Salmon in the annual late June- early July survey from 1998 to 2013 (CPUE data is comparable starting in 1999). Arrows indicate the 2013 cycle years. See Figure 18 B relative to A for densities of Sockeye juveniles during this standard trawl survey timing; note: this standard survey period typically only captures ~10% of the total juvenile Fraser Sockeye outmigration and there were some indications that migration through the SOG in 2013 was early.



A. Additional trawl survey conducted in early June (1-11, 2013) to specifically capture a greater proportion of the juvenile Fraser Sockeye migration



B. Standard timing of annual surveys (1998-2013): the target species is Coho Salmon, although all salmon species are sampled. Roughly 10% of the Fraser Sockeye run is likely assessed during this sampling period.

*Figure 18. The distribution of juvenile Sockeye Salmon in **A.** June 1-11, 2013 and **B.** June 26-July 6, 2013 trawl surveys. The number in each polygon is the catch-per-hour for sets conducted with headrope (rope along the upper edge of the net) depth of 0 or 15 m in that region. The X's on both maps indicate sets where no Sockeye Salmon were caught.*

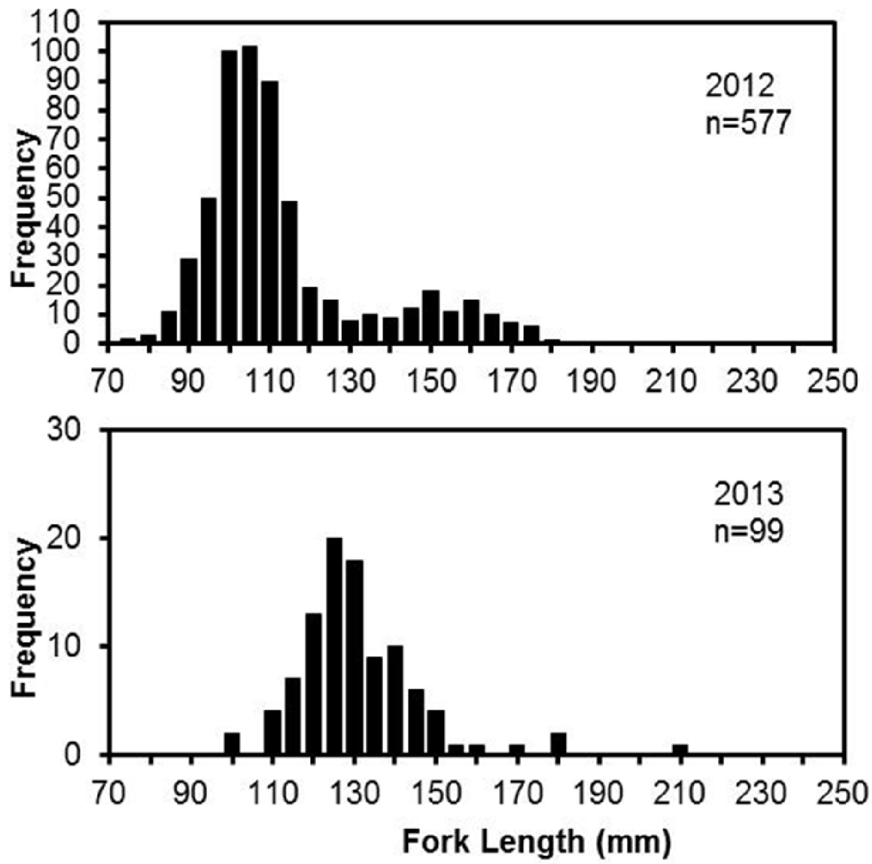


Figure 19. The length frequency of juvenile Sockeye Salmon captured in the Strait of Georgia and Howe Sound in 2012 and 2013.

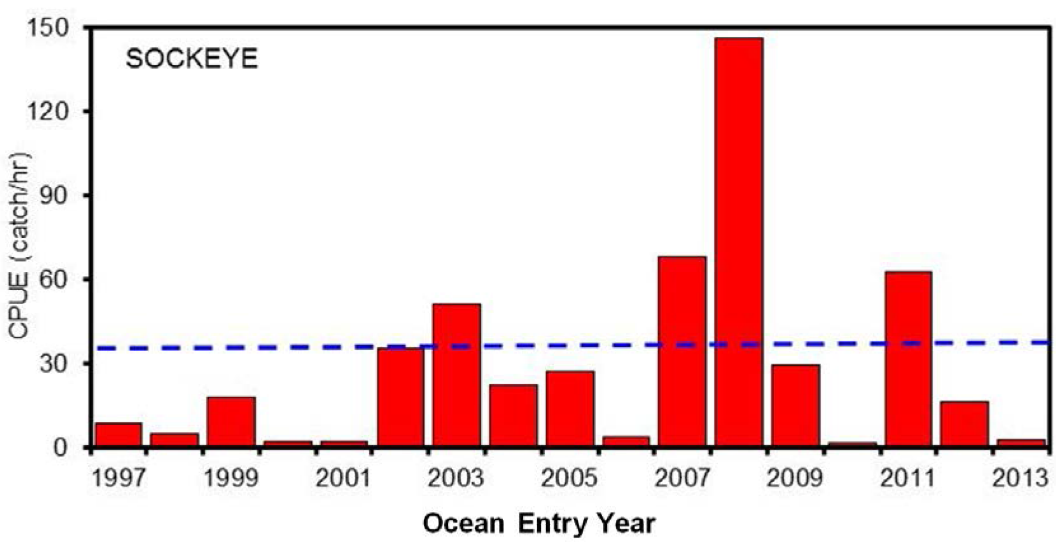


Figure 20. The CPUE of Sockeye Salmon, largely comprised of the Harrison Sockeye stock, in the September trawl survey in the Strait of Georgia. Juveniles captured in 2012 and 2013 could return as four and three year olds in 2015.

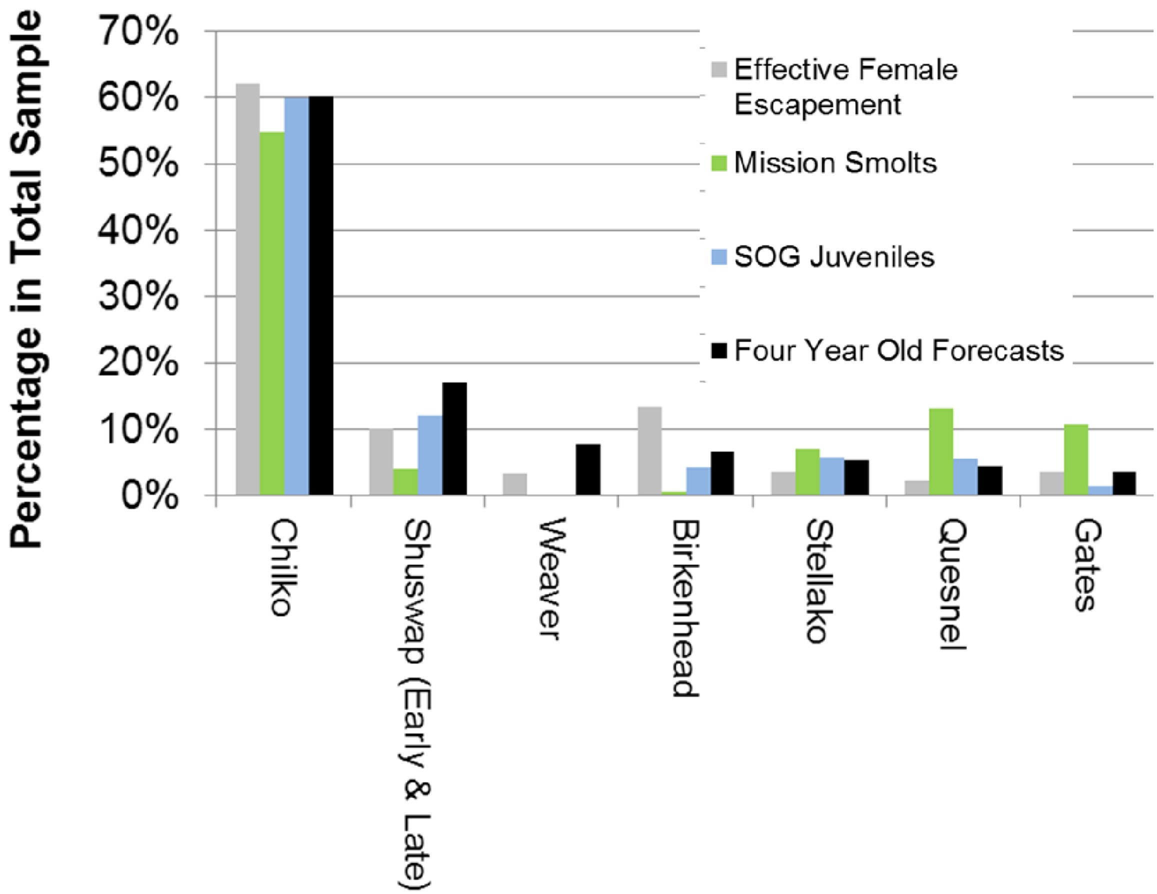


Figure 21. Stock composition (percentages) in the various Fraser Sockeye sampling components: 2011 escapements (effective female escapement), 2013 smolt outmigration at Mission, Strait of Georgia juvenile sampling (SOG juveniles sampled in the June 1-June 11 period), and the official four year old forecasts at the 50% probability level (DFO 2015). Note: because Mission sampling was disrupted from May 16 to June 1, percentages of early migrating stocks (e.g. Chilko, Stellako, Quesnel) may be biased high, and later migrating stocks (e.g. Shuswap) biased low. See corresponding Table 3.

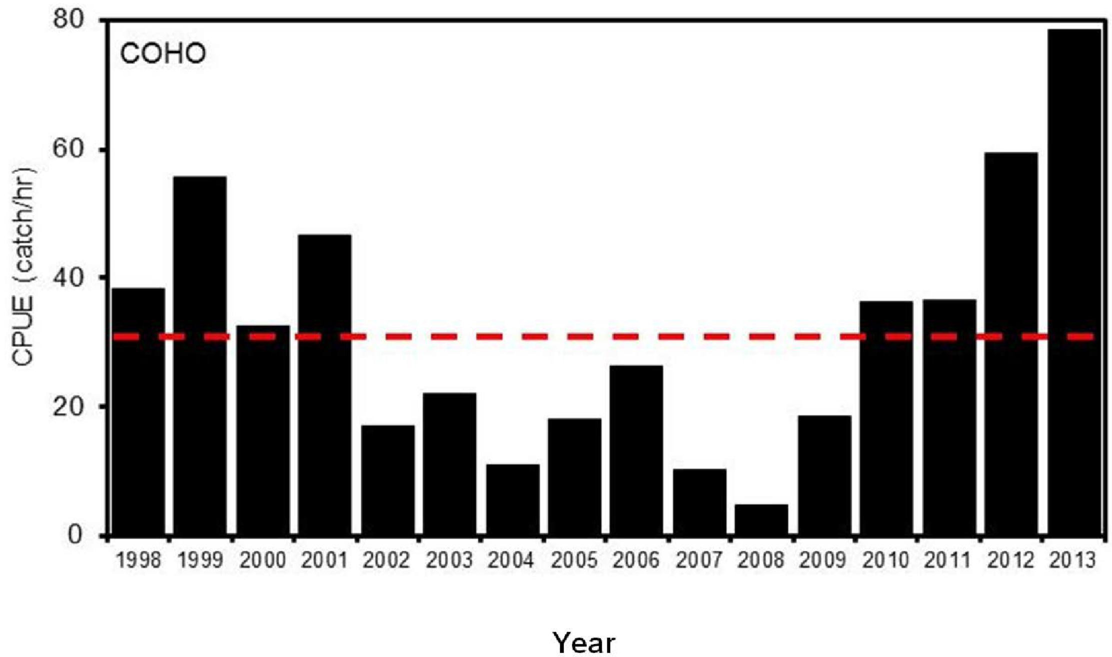


Figure 22. The catch-per-hour (CPUE) of Coho Salmon on the standard track line in the SOG in September 1998-2013.

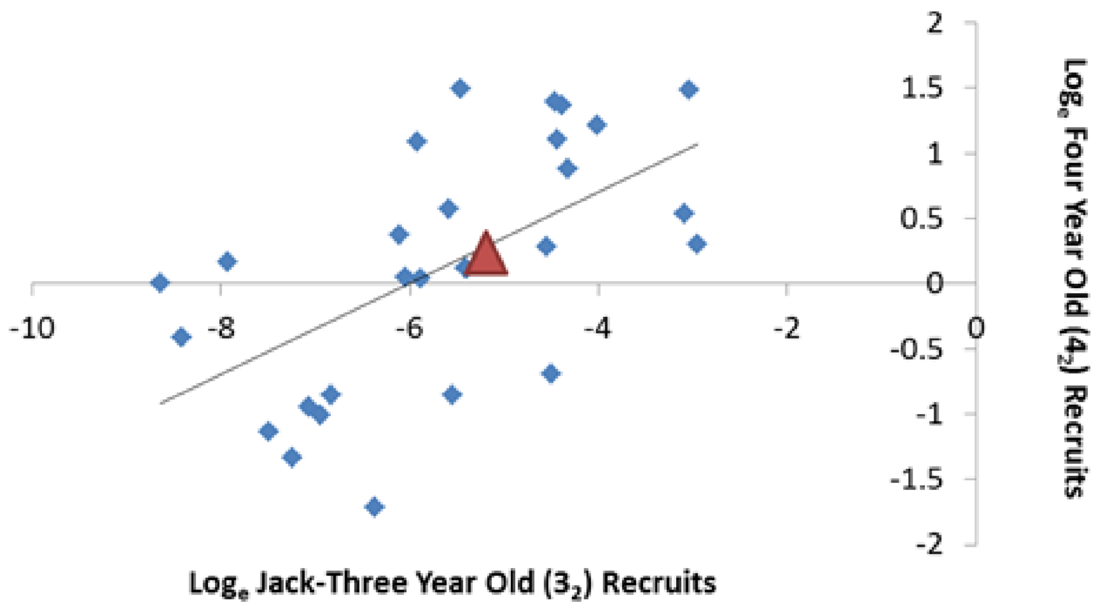


Figure 23. Chilko Sockeye sibling model: four year old (4_2) versus jack (3_2) recruits with model equation and R^2 indicated. The 2014 jack returns used to predict 2015 four year old returns for Chilko are indicated by the red triangle. At the 50% probability level (median) forecast, the four year old sibling model forecast using 2015 jack data as a predictor variable is 1.2 million, compared to the official forecast of 2.4 million (DFO 2015).

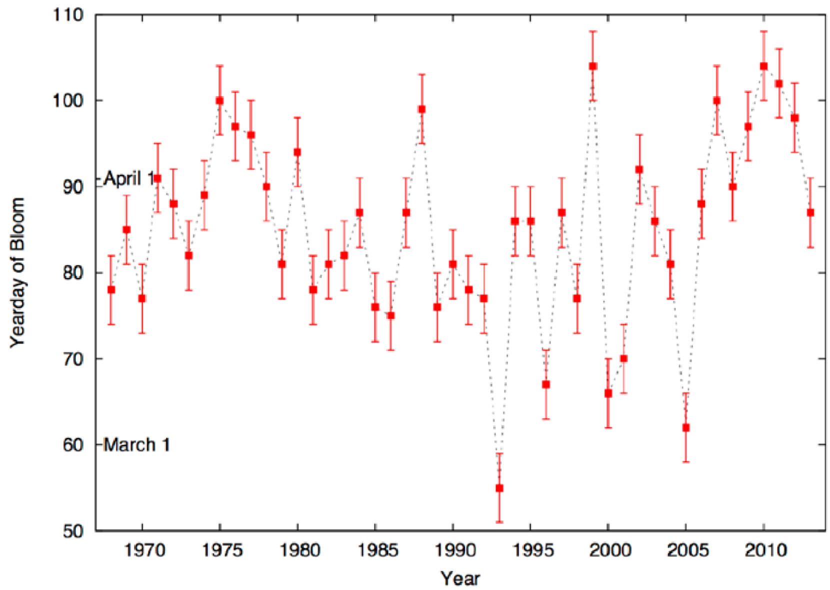


Figure 24. Model-based analysis of the timing of the spring phytoplankton bloom in the Strait of Georgia. Note the predicted shift to an earlier bloom in 2013 (Allen et al. 2014. Can. Tech. Rep. Fish. Aquat. Sci. 3102: 97).

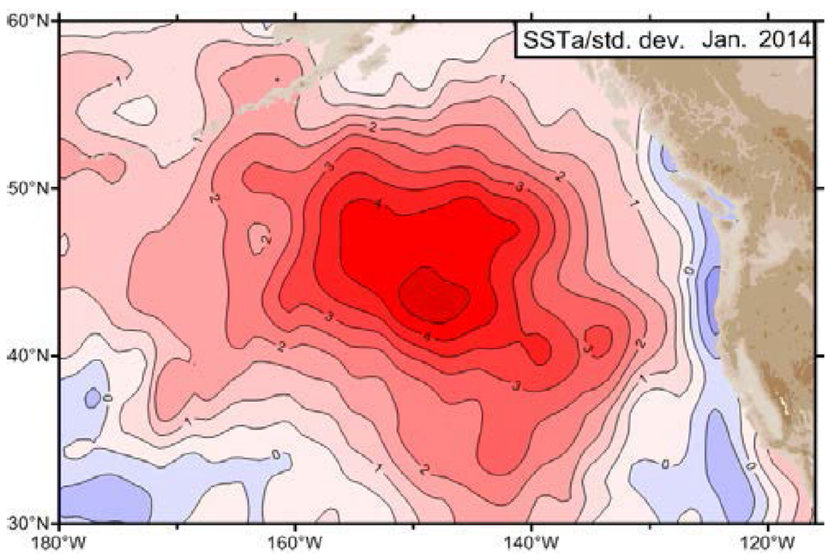
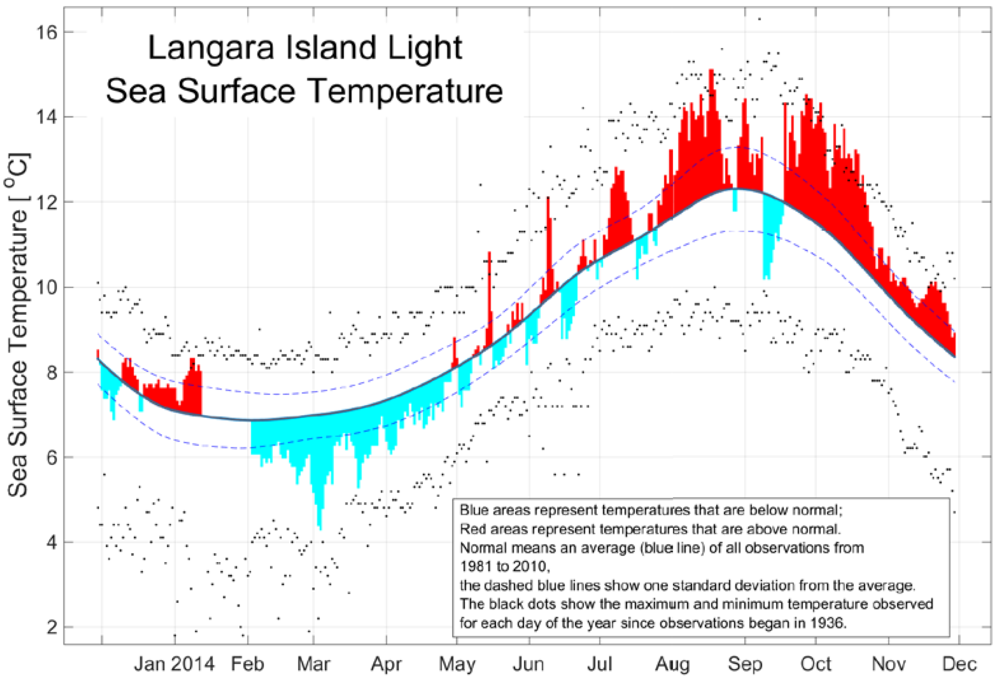


Figure 25. Spatial pattern of sea surface temperature anomalies in January 2014 (i.e. January 2014 compared with conditions in January 1981-2013). Maximum difference is over 4°C, which is considered very large (H. Freeland. 2014. Can. Tech. Rep. Fish. Aquat. Sci. 3102: 23).



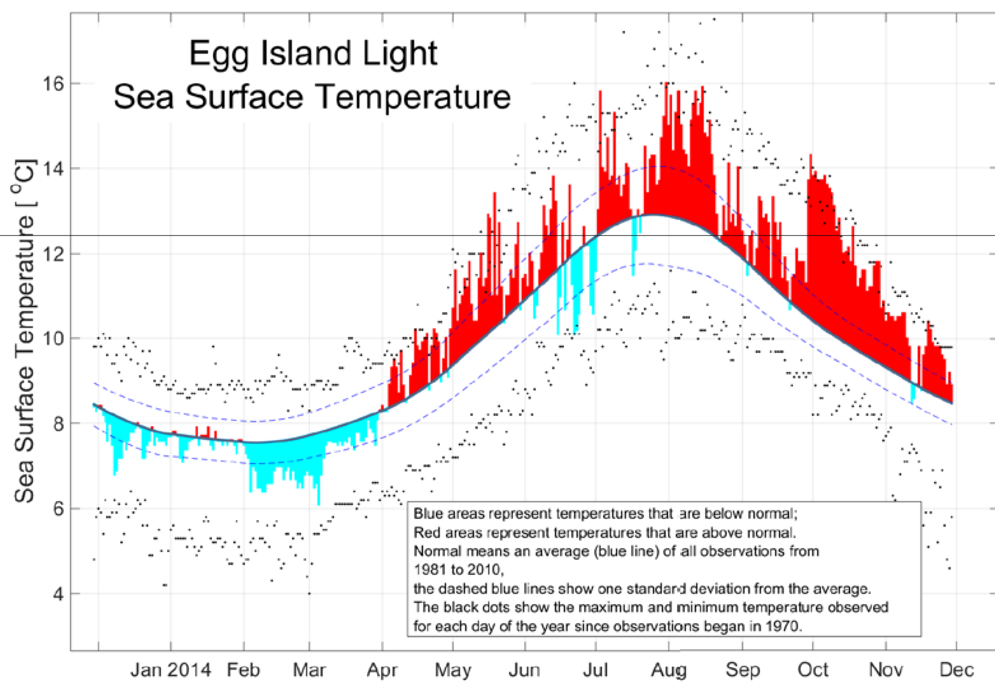


Figure 26. Sea surface temperatures for Egg Island (central coast) and Langara Island (Dixon Entrance) lighthouse stations, 2014. Cool temperatures prevailed from February to May, but warm temperatures are evident from May to December, especially in the autumn. Some record daily high temperatures were observed in Oct-Nov 2014 (P. Chandler, in preparation for DFO State of the Ocean workshop, March 2015).

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Sources of information

Araujo, A.H., Holt, C., Curtis, J.M.R., Perry, R.I., Irvine, J.R., and Michielsens, C.G.J. 2013. Building an ecosystem model using mismatched and fragmented data: a probabilistic network of early marine survival for Coho salmon *Oncorhynchus kisutch* in the Strait of Georgia. Prog. Ocean. **115**: 41–52.

Beacham, T.D., Beamish, R.J., Candy, J.R., Wallace, C., Tucker, S., Moss, J.H., and Trudel, M. 2015. Stock-specific size of juvenile Sockeye Salmon in British Columbia waters and the Gulf of Alaska. Trans. Am. Fish. Soc. **143**: 876–889.

Beamish, R., Neville, C., and Sweeting, R. 2012. An early marine life history strategy for Fraser River Sockeye Salmon. N. Pac. Anadr. Fish. Comm. Tech. Rep. **1423**: pp. 23.

Beamish, R.J., McCaughran, D., King, J.R., Sweeting, R.M., and McFarlane, G.A. 2000. Estimating the abundance of juvenile coho salmon in the Strait of Georgia by means of surface trawls. N. Am. J. Fish. Manag. **20**: 369–375.

Beamish, R.J., Sweeting, R.M., Lange, K.L., Noakes, D.J., Preikshot, D., and Neville, C.M. 2010. Early marine survival of coho salmon in the Strait of Georgia declines to very low levels. Mar. Coast. Fish. Dyn. Manag. Ecosyst. Sci. **2**: 424–439.

Birtwell, I.K., Nassichuk, M.D., and Buene, H. 1987. Underyearling sockeye salmon (*Oncorhynchus nerka*) in the estuarty of the Fraser River. Can. Spec. Publ. Fish. Aquat. Sci. **96**: 25–35.

Bradford, M.J., Pyper, B.J., and Shortreed, K.S. 2000. Biological responses of sockeye salmon to the fertilization of Chilko Lake, a large lake in the interior of British Columbia. N. Am. J. Fish. Manag. **20**: 661–671.

Burt, J.M., Hinch, S.G., and Patterson, D.A. 2011. The importance of parentage in assessing temperature effects on fish early life history: a review of the experimental literature. Rev. Fish Biol. Fish. **21**: 377–406.

DFO. 2014a. Pre-season run size forecasts for Fraser River Sockeye (*Oncorhynchus nerka*) Salmon in 2014. DFO Can. Sci. Advis. Sec. Sci. Resp. 2014/040. (Accessed May 12, 2015)

DFO. 2014b. Supplement to the pre-season return forecasts for Fraser River Sockeye Salmon in 2014. DFO Can. Sci. Advis. Sec. Sci. Resp. 2014/041. (Accessed May 12, 2015)

DFO. 2015. Pre-season run size forecasts for Fraser River Sockeye (*Oncorhynchus nerka*) and Pink (*O. gorbuscha*) salmon in 2015. DFO Can. Sci. Advis. Sec. Sci. Resp. 2015/014. (Accessed May 12, 2015)

Eliason, E.J., Clark, T.D., Hague, M.J., Hanson, L.M., Gallagher, Z.S., Jeffries, K.M., Gale, M.K., Patterson, D.A., Hinch, S.G., and Farrell, A.P. 2011. Differences in thermal tolerance among sockeye salmon populations. Science. **332 (6025)**: 109–112.

Grant, S.C.H., MacDonald, B.L., Cone, T.E., Holt, C.A., Cass, A., Porszt, E.J., Hume, J.M.B., and Pon, L.B. 2011. Evaluation of uncertainty in Fraser Sockeye (*Oncorhynchus nerka*) Wild Salmon Policy status using abundance and trends in abundance metrics. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/087. viii + 183 p. (Accessed May 12, 2015)

Grant, S.C.H., Michielsens, C.G.J., Porszt, E.J., and Cass, A.J. 2010. Pre-season run size forecasts for Fraser River sockeye salmon (*Oncohrynchus nerka*) in 2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/042. vi + 125 p. (Accessed May 12, 2015)

Henderson, M.A., and Cass, A.J. 1991. Effect of smolt size on smolt-to-adult survival for Chilko Lake sockeye salmon (*Oncorhynchus nerka*). Can. J. Fish. Aquat. Sci. **48**: 988–994.

Hume, J.M.B., Shortreed, K.S., and Morton, K.F. 1996. Juvenile sockeye rearing capacity of three lakes in the Fraser River system. Can. J. Fish. Aquat. Sci. **53**: 719–733.

Koenings, J.P., Geiger, H.J., and Hasbrouck, J.J. 1993. Smolt-to-adult survival patterns of Sockeye salmon (*Oncorhynchus nerka*): effects of smolt length and geographic latitude when entering the sea. Can. J. Fish. Aquat. Sci. **50**: 600–611.

Macdonald, J.S., Morrison, J., and Patterson, D.A. 2012. The efficacy of reservoir flow regulation for cooling migration temperature for sockeye salmon in the Nechako River watershed of British Columbia. N. Am. J. Fish. Manag. **32**: 415–427.

Mackas, D.L., Batten, S., and Trudel, M. 2007. Effects on zooplankton of a warmer ocean: recent evidence from the Northeast Pacific. Prog. Ocean. **75**: 223–252.

MacLellan, S.G., and Hume, J.M. 2010. An evaluation of methods used by the freshwater ecosystems section for pelagic fish surveys of sockeye rearing lakes in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. **2886**: 68 pp.

McCormick, S.D., Hansen, L.P., Quinn, T.P., and Saunders, R.L. 1998. Movement, migration, and smolting of Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. **55**: 77–92.

Morton, K.F., Shortreed, K.S. 1996. Results from a seven-year limnological study of Shuswap Lake. Part II. Zooplankton. Can. Data. Rep. Fish. Aquat. Sci. **1005**: pp. iii + 132.

Neville, C.M., Trudel, M., Beamish, R.J., and Johnson, S.C. 2013. The early marine distribution and juvenile sockeye salmon produced from the extreme low return in 2009 and the extreme high return in 2010. N. Pac. Anadr. Fish. Comm. Tech. Rep. **9**: 65–68.

Nidle, B.H., and Shortreed, K.S. 1996. Results from a seven-year limnological study of Shuswap Lake. Part I. Physics, chemistry, bacteria, and phytoplankton. Can. Data. Rep. Fish. Aquat. Sci. **1005**: 132 pp.

NOAA. (n.d.). ENSO: Recent evolution, current status and predications. (Accessed May 12, 2015)

Perry, R.I. 2013. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2013. Can. Tech. Rep. Fish. Aquat. Sci.: v + 136 pp.

Peterman, R.M., and Dorner, B. 2012. A widespread decrease in productivity of sockeye salmon (*Oncorhynchus nerka*) populations in western North America. Can. J. Fish. Aquat. Sci. **69**: 1255–1260.

Preikshot, D., Beamish, R.J., Sweeting, R.M., Neville, C.M., and Beacham, T.D. 2012. The residence time of juvenile Fraser River sockeye salmon in the Strait of Georgia. Mar. Coast. Fish. Dyn. Manag. Ecosyst. Sci. **4**: 438–449.

Ricker, W.E. 1962. Comparison of ocean growth and mortality of sockeye salmon during their last two years. J. Fish. Res. Board Can. **19**: 531–560.

Selbie, D.T., Bradford, M.J., Hague, M.J., Hume, J.M.B., MacIsaac, E.A., and D.A.P. 2010. Are freshwater habitat conditions in the Fraser River watershed an important contributor to the Fraser Sockeye situation? *In* Synthesis of Evidence from a Workshop on the Decline of Fraser River Sockeye: June 15-17 2010. *Edited by* R.M. Peterman and D. Marmorek. pp. 79–82.

Shortreed, K.S. 2007. Limnology of Cultus Lake, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. **2753**: vi + 85 pp.

Shortreed, K.S., Hume, J.M., and Stockner, J.G. 2000. Using photosynthetic rates to estimate the juvenile sockeye salmon rearing capacity of British Columbia lakes. *In* Sustainable Fisheries Management: Pacific Salmon. *Edited by* E.E. Knudsen, C.R. Steward, D.D. MacDonald, J.E. Williams, and D.W. Reiser. CRC Press LLC, Boca Raton, New York. pp. 505–521.

Sweeting, R.M., Beamish, R.J., Noakes, D.J., and Neville, C.M. 2003. Replacement of wild coho salmon by hatchery-reared coho salmon in the Strait of Georgia over the past three decades. N. Am. J. Fish. Manag. **23**: 492–502.

Thomson, R.E., Beamish, R.J., Beacham, T.D., Trudel, M., Whitfield, P.H., and Hourston, R. a. S. 2012. Anomalous ocean conditions may explain the recent extreme variability in Fraser River sockeye salmon production. Mar. Coast. Fish. Dyn. Manag. Ecosyst. Sci. **4**: 415–437.

Trudel, M., Moss, J.H., Tucker, S., Candy, J.R., and Beacham, T.D. 2011. Stock-specific distribution of juvenile sockeye salmon in the Eastern Gulf of Alaska. N. Pac. Anadr. Fish. Comm. Tech. Rep. No. 1353. 11 pp.

Tucker, S., Trudel, M., Welch, D.W., Candy, J.R., Morris, J.F.T., Thiess, M.E., Wallace, C., Teel, D.J., Crawford, W., Farley, E. V., and Beacham, T.D. 2009. Seasonal stock-specific migrations of juvenile sockeye salmon along the west coast of North America: Implications for growth. Trans. Am. Fish. Soc. **138**: 1458–1480.

Whitney, C.K., Hinch, S.G., and Patterson, D.A. 2013. Provenance matters: thermal reaction norms for embryo survival among sockeye salmon *Oncorhynchus nerka* populations. J. Fish Biol. **82**: 1159–1176.

Whitney, F.A. 2015. Anomalous winter winds decrease 2014 transition zone productivity in the NE Pacific. Geophys. Res. Lett. **42**: 428–431.

Appendix 1

Learning Component to the Previous Year's (2014) Forecast Supplement Process

- The CSAS Fraser Sockeye forecast supplement process occurred for the first time concurrently with the 2014 forecast (DFO 2014b). In this forecast the Shuswap complex, and Chilko stocks, were expected to contribute the greatest proportion to the 2014 return (DFO 2014a). The preliminary return estimates in 2014 largely reflect average survival for most stocks, although Early Shuswap stocks exhibited slightly below average survival, and Birkenhead Sockeye exhibited extremely poor survival.
- The following information, documented in the 2014 supplement (DFO 2014b), provided some indication that the returns to the Early Shuswap in 2014 may be lower than expected. For early Shuswap stocks, forecasts were particularly uncertain, given that brood year escapements were exceptionally high and forecast models were being extrapolated beyond their observed stock-recruitment range. Therefore, the low returns observed for the early Shuswap stocks in 2014 improve our understanding of the various carrying capacities within this system. Carrying capacity in this case likely represents spawning ground capacity, as the Shuswap stocks all share the Shuswap Lake system as a juvenile rearing area, and Shuswap Late did not exhibit below average survival, unlike the Early Summer stocks. Additionally, a rain on snow event in the Seymour system may have decreased egg-to-fry survival of this stock. Sibling-jack model forecasts were lower for Scotch and Seymour relative to the official forecasts, also possibly indicated that survival could be lower for these stocks in the 2010 brood year. Relative stock proportions at Mission and Queen Charlotte Sound were slightly lower for Early Shuswap stocks. Spawner success based on physiological metrics was flagged as being poor particularly for Scotch Creek (Early-Shuswap) Sockeye, although egg viability assessments indicated minimal issues with this factor.
- In the Birkenhead system, a major landslide that occurred in September 2010 was not documented in the 2014 Fraser Sockeye forecast supplement (DFO 2014b). Although the specific mechanism linking this landslide to the exceptional poor survival observed in this system is not clear, it is possible that increased turbidity in the lake during smolt outmigration may have contributed to this low survival.
- For the other key stocks (Late Shuswap and Chilko), a number of pieces of information did not suggest any significant departures in survival from that indicated by the official forecasts:
    - Upstream migration conditions in 2010 were generally considered average for the dominant stocks (Chilko and Late Shuswap).
    - Given the exceptional escapements observed in Late Shuswap and Chilko in the 2010 brood year, which were above the calculated Smax for these stocks based on stock-recruitment data and photosynthetic (PR) model results, compensation (lower survival) was expected, and was observed in juvenile data. Further, large escapements in these key systems (Chilko and Shuswap) led to smaller fish sizes in the smolt and juvenile (ocean) stages compared to average. Growth of Shuswap Lake Sockeye was slower in the 2010 brood year, compared to 2011 (the only two years this was evaluated). Fat content was also low during the downstream migration of Shuswap smolts, both at the outlet of Shuswap Lake and at Mission. Fat content in Chilko Sockeye indicated that a portion of the run was not in healthy condition, and gamete viability was low compared to other

stocks. There was strong density-dependent zooplankton grazing pressure by the high fry abundances in both the Chilko and Shuswap systems (lower zooplankton biomass in 2011 compared to 2012).

- Official forecasts directly included freshwater compensation by using smolt data (Chilko and Cultus Sockeye) as a predictor variable in models
- Other key stocks in the 2014 forecast included Shuswap stocks (Scotch, Seymour, and Late Shuswap), which relied on escapement based predictor variables. The official forecasts were compared to those estimated with fry based predictor variables (DFO 2014a), which indicated that these model forms largely corroborated one another.
- Jack-sibling model forecasts for Chilko and Late Shuswap corroborated the official forecasts, providing no indication of departures in survival from that indicated by the official forecasts (DFO 2014a).
- Stock proportions in all sampling components (Mission smolts, Strait of Georgia juveniles, Queen Charlotte Sound juveniles) largely reflected the key stocks in the 2011 brood year escapements (and, therefore, the 2014 forecasts): Late Shuswap, Early Shuswap, Chilko, Quesnel and Stellako.

- For all stocks, SOG conditions were not flagged as anomalous:
  - Coho in the SOG in 2012 was the highest in 14 years of assessments
  - Herring CPUE in the SOG in 2012, also did not provide any unusual signals (high or low) for survival of Fraser Sockeye juveniles in 2012.
  - Ocean conditions were cool and salinity was below average in the 2012 ocean entry year, which suggests good ocean conditions for salmonids, although linkages to Fraser Sockeye are not quantitatively correlated.
  - In their final winter in the ocean (2013), Fraser Sockeye from the 2011 brood year experienced above average temperatures, although there is some evidence that warmer conditions in their final year have been linked to better Fraser Sockeye survival.
- Smolt outmigration timing:
  - During the 2012 outmigration, there were two clear outmigration periods. The first group to migrate out at Mission were Summer Run stocks such as Chilko, Stellako and Quesnel, with an average 50% outmigration date of April 24. These were followed by Shuswap stocks (early and late timed), with a 50% outmigration date of May 17 (see Figure 16 C in DFO 2014b).
  - In the SOG there were three juvenile Sockeye sampling periods (May 19-June 1; June 11-25; June 20-July 2), and relative stock proportions changed significantly between these periods to reflect the same pattern seen in their outmigration at Mission. Specifically, Summer Run stocks were observed in the earlier sampling periods, dropping off in the later periods, with the opposite occurring for Shuswap stocks (relative proportions increase with time).

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