THE SOUTHERN OCEAN SALMON PROJECT

PHASES I & II

Compiled by

Colin E. Nash, Ph. D.
ICLARM Project Manager

This Appendix to the Technical Project Document for the Southern Ocean Salmon Project contains reports of the Preplanning Phase (Phase I) and the completed part of the Planning Year (Phase II).

Hawaii

October 1976

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SUMMARY RECOMMENDATIONS

The summary of specific recommendations for the development of Phase III of the Southern Ocean Salmon Project, following discussions of Phase I and Phase II activities to date, was tabled as follows:

- The Southern Ocean Salmon Project was a national project of the Government of Chile, and it should be operated under Chilean direction with the full technical support of the International Center for Living Aquatic Resources Management (ICLARM) and the members of the Task Force.

- The Division Proteccion Pesquera (SAG) was to be the nominated counterpart agency of the Government of Chile. The Government had issued a directive that the Division was responsible for all salmonoid projects in the country through the development stages. This was acceptable to the Director of the Instituto Fomento Pesquero, who had initially opened the way for the project with invitations to Chile.

- ICLARM was to be the executing agency for the project and would nominate a Project Manager from its staff.

- The continuous assistance of the Armada de Chile and the Fuerza Aerea de Chile was of vital importance for the success of the project.

- The floating hatchery concept, while physically possible and potentially desirable for the southern region, and sites were available, was to be temporarily shelved. The Magallanes region presented logistical problems for hatchery operations and management which could only be overcome by massive financing and/or a major reliance on the Armada de Chile. This was not to be recommended during an initial development phase but could be reconsidered to reinforce the seeding once the first returns were demonstrated.

- Access to the hatchery at all times was an essential requirement. This would reduce the need for a community being developed at the hatchery site, and would also make the project self-sufficient for day-to-day operations.

- The most suitable location observed during the course of the visits by Task Force members was in the headwaters of the Rio Serrano and Ultima Esperanza system. The hatchery located in this area would always be accessible and would enable the biological evaluation of the site to begin immediately.

- The final decision for a hatchery located on the Salto Chico in the Torres de Paine National Park would depend on final engineering and biological tests. The quality of the water for the hatchery and access to the site by road were all added advantages to the main criterion of delivery of water under pressure.

- The size of the hatchery would be based on an annual production of 100,000 lbs. of smolts (about 10 million eggs). The production would involve incubation and rearing of a number of Pacific salmonoid species. Note, they vary greatly in weight at the desired time of release and in their ability to return to the hatchery areas to spawn when adults.

- The hatchery was to have the capability for heating water to assist incubation and rearing of fry.

- The feed for the smolts was to be developed and processed within the country using local resources.

- The project was to pay considerable attention to the environmental impacts of releasing salmon in the region.

- The project was to begin to work sooner for details of the trapping gear for returning adults. This was a present major concern of the Japanese.

- It was important to integrate the project with that of the Japanese-supported project at Aysen. The two projects should work toward the most efficient use of available sources of salmon eggs; the formulation and supply of feed for smolts; the development of nursery facilities for holding smolts to condition them to remain in the fjords of Chile; bio-oceanographic data exchange for release of smolts; and technical training. Both projects would benefit from a joint exchange of resources and data, and the Southern Ocean project would be greatly accelerated.

- It was important that the project cooperate with other international and national agencies and projects; for example, the Scientific Committee on Antarctic Research, the Scientific Committee on Ocean Research, the United Nations Development Programme, and the Food and Agricultural Organization of the United Nations.

CHAPTER I

INTRODUCTION

Salmon, properly introduced into the waters of the Southern Ocean, can provide a useful focus for a new approach to a rational, international system of fishery management.

By the introduction of carefully selected salmon stocks from an appropriate land base, Antarctic waters can be seeded with highly valued, easily harvested pelagic species capable of sustaining a major new fishery. Such a fishery, created where none now exists, will be free of many of the entrenched interests and precedents that have inhibited rational management in the Northern Hemisphere.

The land base most suitable for launching salmon into the Southern Ocean is the southernmost extremity of Chile (Figure 1). Projecting further south than any other continental land mass, except ice-covered Antarctica, it is a region of channels and fjords into which flows an abundance of clear, fresh water from the snowfields and glaciers of the Cordillera Darwin.

Other possible land bases might be developed in New Zealand, Argentina, the Falkland Islands, and the Kerguelen Islands of the Indian Ocean. These, however, do not have the same geographic advantages for salmon as southern Chile, and the logistics for maintaining facilities for large-scale fish culture in the two small island groups would be particularly difficult.

The key to the successful migration of salmon from southern Chile into the Southern Ocean will be the careful seeding of appropriate stocks at a position below the divergence of the West Wind Drift (Figure 2). This westerly current strikes the coast of Chile continuously, but the divergence moves between Latitudes 35-45° South with seasons. Seaward migrating salmon, released south of Latitude 46° South, would be carried into the cold, highly productive water around the Antarctic Convergence. Some experimental introductions are presently being attempted further north, but the migrants are likely to be carried by the Humboldt Current into warmer waters unsuitable for them.

The selection of sites for rearing and conditioning salmon in Chile must be made with great care to ensure that the selected stocks will have the best possible chances for reaching oceanic feeding grounds in prime condition; also, for returning successfully to the places where they were released after maturing at sea. The fresh water needed for hatching eggs and rearing fry at the sites must be of the highest purity, vary minimally in temperature and flow, be situated as close to seawater as possible, and preferably, have a sufficient head behind it to flow by gravity through the incubating and rearing systems.

The entire operation, from selecting an appropriate site to designing facilities and planning for their construction, operation, and management, will demand input from experts in all phases of salmon rearing and management.

The preliminary program was planned in two phases. Phase I (now complete and described in this document) consisted of a Preplanning Visit to Chile to discuss the proposal and obtain the support of the responsible agencies and to make some regional surveys for sites.

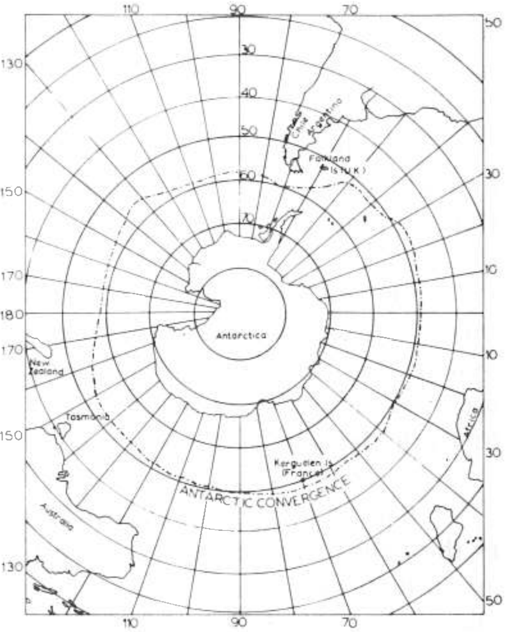


Figure 1. The Antarctic Convergence.

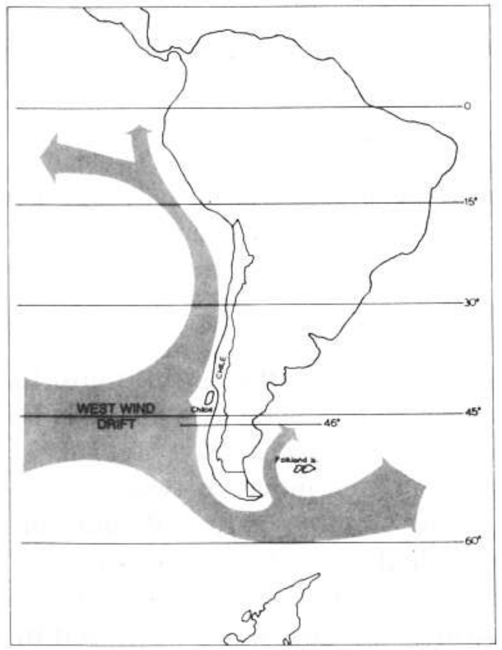


Figure 2. The coastal currents of Chile.

Phase II consisted of a Planning Year in which experts and the necessary financial support were provided to assist the Chilean agencies to narrow down the areas for site selection.

At the end of the Planning Year, a Technical Project Document Phase III was developed and presented to the authorities in Chile for submission to appropriate international funding agencies.

This document is an Appendix to the Technical Project Document Phase III and is a report of the activities under Phase I and Phase II.

CHAPTER II

PHASE I - A REGIONAL SURVEY - THE MAGALLANES PROVINCE

by

C. E. Nash and T. Joyner

For the convenience of the project, the Chilean province of Magallanes was divided into three logistic areas (Figure 3).

Area I consisted of all but the southwest coast of the Peninsula Brunswick, the northeast half of the Isla Riesco, and the mainland north of Seno Otway and Seno Skyring, extending to the Argentine border.

Area II contained three systems of inland waterways: the Canal Bustos; the Golfo Almirante Montt and its tributary sounds and channels as far as the Paso Kirke that leads to the Seno Union and the open sea; and the chain of lakes fed by the glaciers of the Torres de Paine that drain through the Rio Serrano into the Seno Ultima Esperanza, an arm of the Golfo Almirante Montt.

Area III consisted of the outer islands and channels along the windward (western and southern) slopes of the Cordillera Darwin.

Areas I and II are accessible by land over an adequate system of graded, but mostly unpaved, roads. The city of Punta Arenas (population 70, 000) is the logistic base for Area I. Puerto Natales, a town of about 4, 000 persons, serves Area II. Punta Arenas has a major commercial airport and harbor and dock facilities capable of handling the largest ships. Puerto Natales is served by an airstrip that is used primarily by military aircraft, a deepwater pier in town, and another several kilometers to the north at Puerto Bories from which it is possible to load and unload small freighters of up to 8 meters draft. There is a scheduled bus service to Punta Arenas.

Services for Area III depend exclusively on sea transport, with the Navy (Armada de Chile) the only agency having a really significant logistic capability. The Navy provides hydrographic and lighthouse maintenance services and supplies a network of bases and shore stations in the area.

General surveys of the areas

In September 1975, a preliminary evaluation was made by Nash and Joyner of the availability in Areas I and II of fresh water suitable for supplying a salmon hatchery. All but one (the Rio Grande of the Isla Riesco) of the sites visited were reached by road. An aerial survey over the Rio Grande was made in a military aircraft.

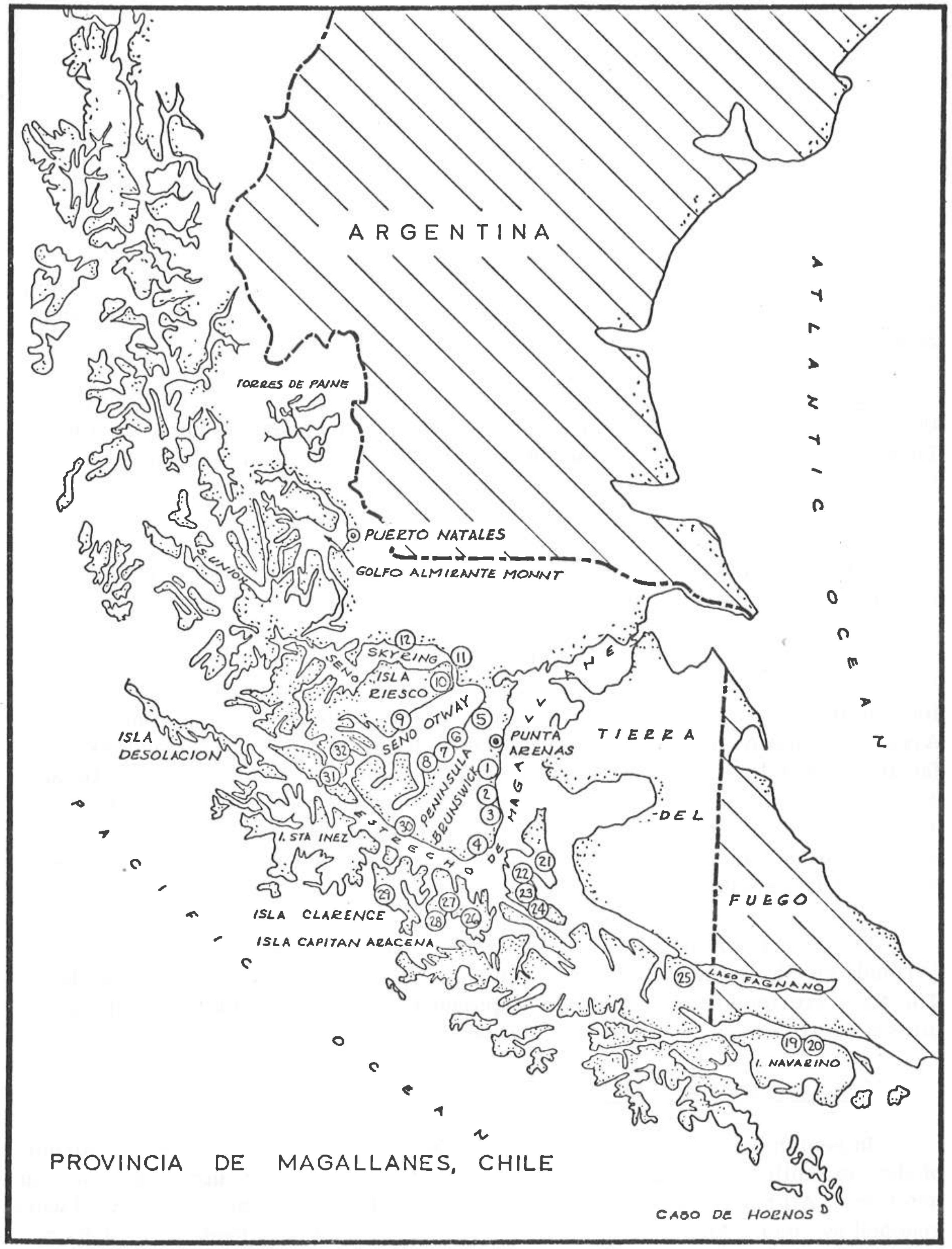


Figure 3. Southern Chile: The Magallanes Region.

Area I (See Figure 3: Sites #1-12)

(a) East shore of Peninsula Brunswick, draining into the Estrecho de Magallanes:

Site #1. Rio Tres Pescados
2. Rio Santa Maria
3. Rio Aguafresca
4. Rio San Juan

These streams all flowed through flat, peaty valleys and were red with the characteristic color of bog water. The temperature in the streams ranged from 2° to 3.5° C, and the saltwater into which they flowed (measured at the beach nearby but away from the plume of fresh water) was 7° C. All but the Rio San Juan 60 km south of Punta Arenas had insignificant flow. The flow of the Rio San Juan was judged to be about 20 m^3/sec, and the bed contained clean gravel.

(b) Northwest shore of Peninsula Brunswick, draining into the Seno Otway:

Site #5. Rio de los Patos
6. Rio Grande
7. Rio el Canelo
8. Rio la Caleta

These were small streams flowing through flat, peaty valleys. The color was red. The Rio la Caleta flowed at a rate of about 10-20 m^3/sec (estimate), and has a bed of clean gravel. The temperature was 3.5° C in the river, and 5° C along the shore of the Seno Otway.

(c) Southeast shore of Isla Riesco, draining into the Seno Otway:

Site # 9. Rio Grande (overflight)
10. Rio Valenzuela

The Rio Valenzuela was a small, turbid stream, said by local ranchers to dry up in the summer. The Rio Grande appeared from the air to be very fast and turbid. Bridges were washed out in its lower valley, indicating severe flooding.

(d) Mainland - north shore of Seno Skyring and east shore of Canal Fitz Roy:

Site #11. Rio Verde
12. Rio Perez

These are small streams of about 3 m^3/sec or less (estimate) with significant seasonal variations in flow. The color was red, and the temperature (5^o C) matched that of the salt water into which they flowed.

The larger streams and adjacent salt waters of Area I all contain populations of sea-run rainbow and brown trout according to the local sport fishing authority.

Area II (See Figure 4: Sites #13-18)

In the system of lakes at the base of the snow-covered peaks of the Torres del Paine, a National Park, three lakes connected in a descending chain serve as settling basins for sediment carried from the mountains by melting snow. The waters of these three lakes are crystal clear. The difference in elevation between them is greater than the seasonal variations in their levels so that there is ample head to maintain vigorous flow over the falls connecting them. The highest of these lakes, Lago Nordenskjold, drains over the falls named Salto Grande into Lago Pehoe. The latter drains over the Salto Chico into the Rio Paine and on into the Lago del Toro. The outlet of the latter is the Rio Serrano, which before it drains into the Seno Ultima Esperanza, is joined by the milky white Rio Grey that comes out of Lago Grey, lying at the foot of the giant Balmaceda glacier.

A small valley, possibly the bed of a tributary in earlier times when the level of the lakes was higher, enters the valley of the Salto Grande at a shallow angle near the base of the falls. A National Park Service ranger station is located at the junction of the two valleys. A water pipe comes down the dry valley after crossing a small rise from the outlet to Lago Nordenskjold to supply the ranger station. There would be ample room in the small valley for a hatchery and a system of descending raceways and rearing ponds fed by gravity from Lago Nordenskjold. The temperature of the water at the outlet of Lago Nordenskjold was 6.5^o C.

The drop from Lago Pehoe into the Rio Paine over the Salto Chico is about 10 to 15 meters, and alongside the falls is a small turbine generator. There is a sport fishery for trout in Lago del Toro and in the Rio Serrano. There are no falls in the Rio Serrano and sportsmen negotiate it in small boats while fishing for sea-run trout. Above the Lago del Toro, the falls of the Salto Chico prevent the passage of trout into the upper lakes. Plans have been developed for a fish ladder alongside the turbine well.

Although there is no area of flat ground near the base of the Salto Chico that would be large enough for a hatchery and a system of above-ground rearing ponds, piling could be driven into the shallow, shelving beach for a platform supporting a hatchery building and a system of finger piers to which floating rearing tanks and raceways could be moored. Water could be drawn from above the Salto Chico to

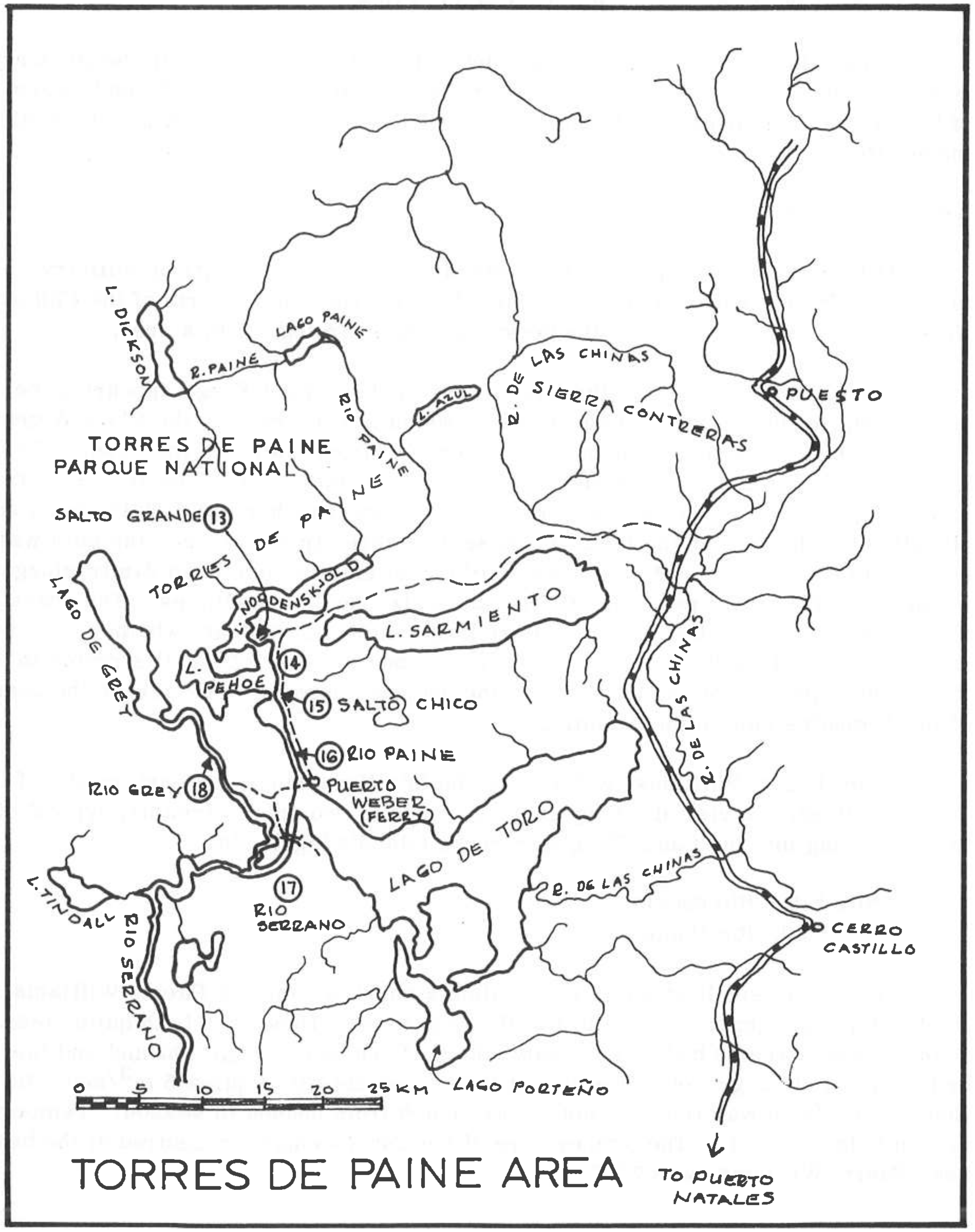


Figure 4. Torres de Paine National Park, illustrating the sites surveyed.

flow by gravity through the system. Lakes Nordenskjold and Pehoe are within the boundaries of the Parque Nacional Torres del Paine.

In the Rio Serrano, between Lago del Toro and the junction with the Rio Grey, is a 10 kilometer stretch of clear water paved with clean gravel. The undersides of boulders picked at random from the river bed showed ample evidence of aquatic insect life.

Area III (See Figure 3: Sites #19-32)

Although most of this area is accessible only by sea, a flight by military aircraft to Puerto Williams and the study of the hydrographic charts of the Chilean Navy gave us some insight into the geography and hydrology of this area.

North of the Cordillera, the Isla Grande de Tierra del Fuego appears to be semi-arid, rolling country. Lago Fagnano which is traversed by the Chile-Argentine border is the largest and most impressive body of fresh water on the island. From the air, it appeared to be deep and clear, much resembling Lake Chelan in the State of Washington. U. S. Air Force Operational Navigation Chart ONC T-18 shows an elevation for the lake of 459 feet. Because of severe air turbulence, the pilot was not able to fly over the outlet, Rio Azopardo, that empties into Seno Almirantazgo, a long arm of the sea branching off from the Estrecho de Magallanes. The charts show this river to be about 10 kilometers long, but do not indicate whether or not there are falls along it. Except for this river and a number of small streams in the northern part of the island, most of the drainage appears to be across the pampas of the Argentine side to the Atlantic.

From Puerto Williams, which is on the Isla Navarino at the eastern end of the Canal Beagle, a visit (by Navy car) was made to two small streams, typical of those draining into the Canal Beagle from the Island's highlands:

Site #19. Rio Robalo
20. Rio Uquica

These very small streams were within a short distance of Puerto Williams; the Rio Uquica 2 km east, the Rio Robalo 5 km west. They were both quite clear. Both of these streams had a red, peaty color. Each had a single channel and the beds were of clean gravel. The flow of these streams (Rio Uquica 5 m^3/sec, Rio Robalo 2 m^3/sec) was reported not to vary much from season to season. Temperature of both was 4^o C. The temperature of the Canal Beagle, measured at the beach near Puerto Williams, was 7^o C.

On the return flight to Punta Arenas from Puerto Williams the plane flew over the Rio Fox on the Isla Dawson. Because of a nearby naval station it had been seen and recommended as suitable for fish. The river flowed through semi-arid lowlands and low hills. Its channel was braided and it looked very turbid. This flight completed the limited reconnaissance of Area III.

Examination of the excellent hydrographic charts of the Chilean Navy, however, revealed that along the southern and western slopes of the Cordilleras, there are many cascades descending into the myriad channels. A notable example is the Gran Cascade at Bahia Wodsworth on Isla Desolacion at the western exit of the Estrecho de Magallanes. The chart shows the outlet of a small lake dropping 260 meters over a distance of 450 meters to the bay.

During the surveys of Area III with the Armada de Chile in Phase II, the following sites were detailed and can be located on Figure 3:

Site # 21. Rio Fox, Isla Dawson
22. Seno Owen, Isla Dawson
23. Seno Brenton, Isla Dawson
24. Lago Lientur, Isla Dawson
25. Rio Azopardo, Seno Almirantazgo
26. Lago Algo, Seno Mercurio
27. Lago Mercurio, Seno Mercurio
28. Lago Engano, Canal Engano
29. Lago Julio, Canal Barbara
30. Rio San Bernabe and Caleta San Miguel, Estrecho de Magallanes
31. Lago Botella, Canal Jeronimo
32. Fiordo Sullivan, Seno Otway

Figures 5-10 illustrate key locations described in Area II.

Figure 5. Lago Nordenskjold below the Torres de Paine.

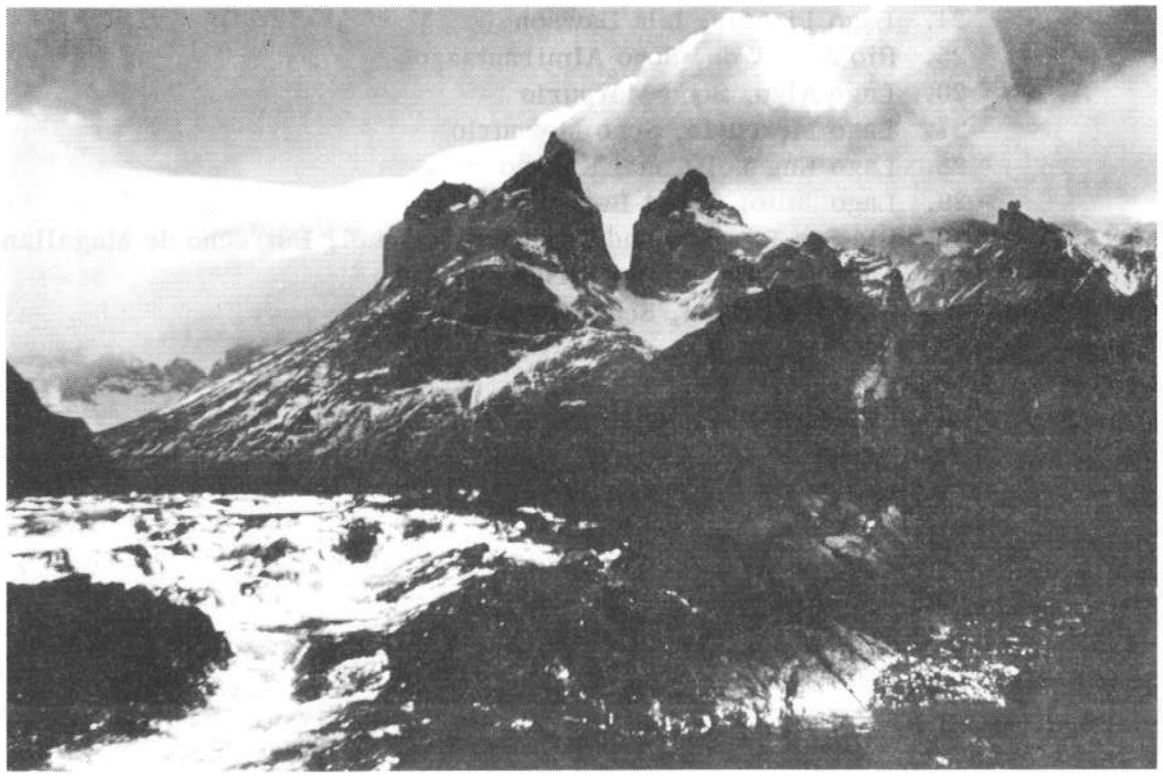


Figure 6. The rapids at Lago Nordenskjold above the Salto Grande.

Figure 7. The Salto Grande.

Figure 8. The rapids below Salto Grande entering Lago Pehoe (buildings belong to Corporation Nacional Forestal, Departamento de Parques Nacionales).

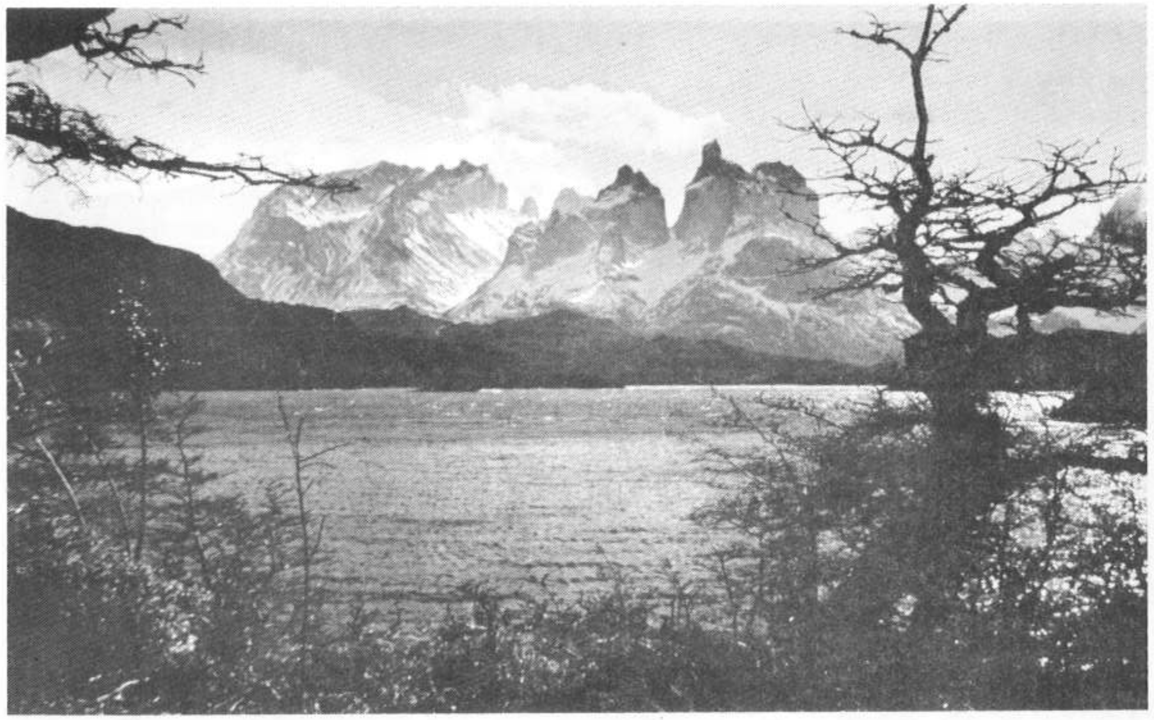


Figure 9. Lago Pehoe and the Cordillera Paine.

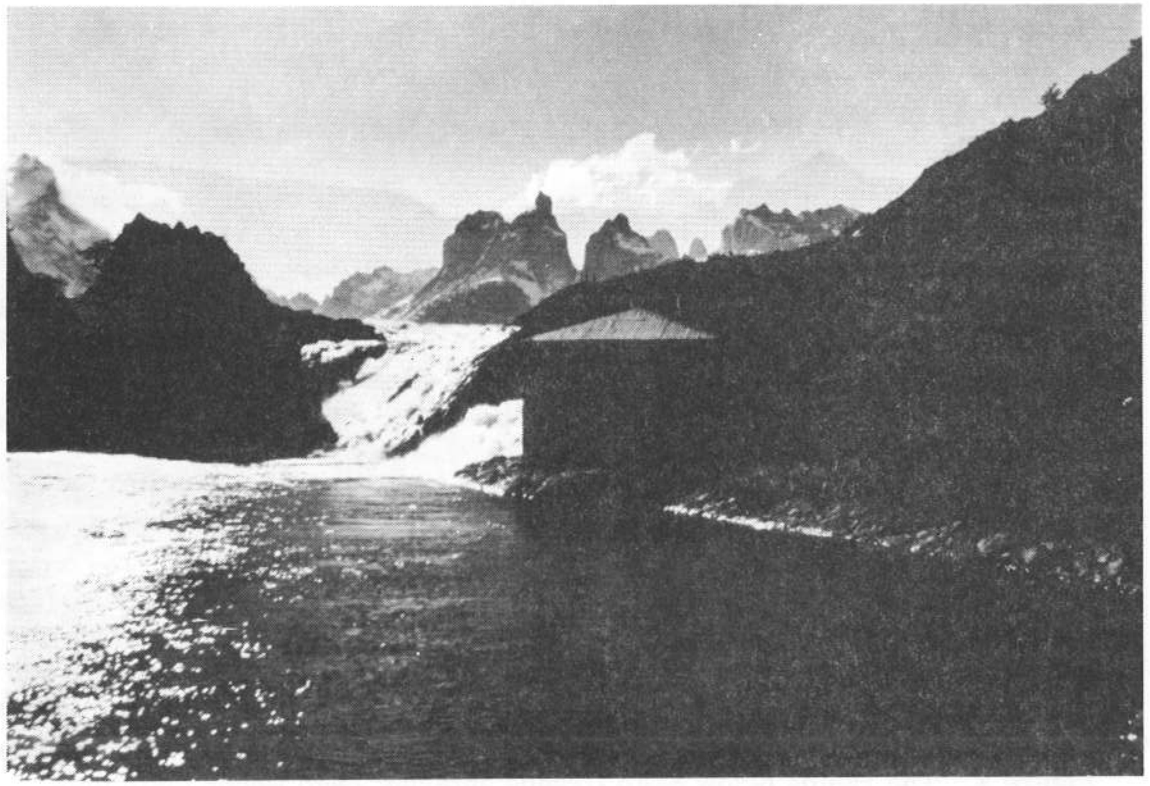


Figure 10. Salto Chico between Lago Pehoe and the Rio Paine (building houses turbo-generator).

CHAPTER III

SUMMARY ASSESSMENT OF PHASE I

The three-week overview of the pertinent geographical and human resources in Chile for a serious effort to seed the Southern Ocean with salmon suggested that with imaginative, flexible planning and careful coordination, a phased development program should have excellent prospects for success. The reasons for thinking so were as follows:

1. The agencies and institutions in Chile through which such a program would be coordinated have thoroughly studied and discussed among themselves the concept as presented in Joyner's 1973 and 1974 publications and 1975 Pacific Science Congress address, and concurred that (a) the reasoning underlying the idea was sound; and (b) it would be a highly desirable focus for fishery development in the far south of Chile.

2. On the staff of the Chilean agencies and institutions, the combined technical and organizational competence appropriate for the task was at a very high level.

3. The geographical resources of Chile's far south appeared to be superbly suited to the proposal if carefully chosen.

4. The project appealed to the national pride of the Chileans contacted, who seemed eager to use it as a demonstration of Chile's strong desire to make a major contribution to the betterment of international living resources management.

Although, as stated above, the prospects for the proposed program were most favorable, it would be remiss not to point out that what was proposed could not be based simply on the direct transfer of North American or Japanese salmon-rearing technology to the far south of Chile. While the climatology, hydrology, and oceanography of the area seemed particularly benign for salmon, the logistics of supporting human activity in the areas most favorable for salmon would be extraordinarily challenging. Designing, installing, supplying, and maintaining salmon-rearing systems in these areas would demand both imagination and ingenuity. While the basic principles for the rearing of salmon would have to be preserved in these facilities, new designs stressing flexibility, mobility, and minimal maintenance would have to be developed. It was already obvious that mobile structures would have to be essential components of systems to stand up to the logistic and physical demands of that remote and stormy environment. The design of such structures constituted one of the most exciting challenges in living marine resource development today.

It was summarized from this first visit that a mobile floating hatchery, strategically located and protected by the islands in Area III and supplied with fresh water from a nearby waterfall, might be the best way to get the smolts as far south as possible at the time of release. A floating hatchery would be an innovative but demanding approach.

One of the priorities proposed for the early part of Phase II was a combined Task Force/Chilean experts/Armada de Chile survey of the outer islands in Area III to determine if such a site was available.

The following chapter contains the reports of this survey.

CHAPTER IV

REPORTS BY THE TASK FORCE

Report 1:	Colin E. Nash and Timothy Joyner
Report 2:	Guy N. Rothwell
Report 3:	Ronald D. Mayo
Report 4:	John B. Spencer
Report 5:	Harry Senn
Report 6:	Conrad V. W. Mahnken
Report 7:	Paul K. Bienfang

REPORT OF

Colin E. Nash, Ph.D.
The Oceanic Institute

and

Timothy Joyner, Ph.D.
International Aquaculture Consultancy

A three-week, intensive review of possible salmon-rearing sites in Magallanes was undertaken by two teams of experts selected from the Project Task Force. The Armada de Chile provided ships and full support for the mission. The mission objectives were: (1) to identify sites in the channels zone where salmon might be successfully reared and released; and (2) to assess the biological, engineering, logistic, and psycho-social factors upon which rational choices of sites for rearing and planting salmon in the zone could be based.

The two teams were organized as follows:

Team I

T. Joyner (oceanographer), International Aquaculture Consultancy, Seattle
C.V.W. Mahnken (oceanographer), National Marine Fisheries Service, Seattle
P.K. Bienfang (biologist), The Oceanic Institute, Hawaii
G.N. Rothwell (engineer), The Oceanic Institute, Hawaii
A. Herrera C., Capitan de Corbeta, Armada de Chile

Team II

C.E. Nash (biologist), Director of Research, The Oceanic Institute, Hawaii
R.D. Mayo (engineer), Kramer Chin and Mayo, Inc., Seattle
J.B. Spencer (engineer), International Aquaculture Consultancy, Isle of Man, U.K.
H.G. Senn (biologist), Director, Division of Hatcheries, Washington Department of Fisheries
G.N. Rothwell (engineer), The Oceanic Institute, Hawaii
G. Celedon C. (fisheries engineer), Instituto de Fomento Pesquero, Punta Arenas, Chile
P. Aguilera M. (fisheries engineer), Division de Pesca y Caza, SAG, Coyhaique, Chile

Mission Operations, April 1976

April 4 Team I departs from Hawaii and Seattle

April 5 Santiago, Chile. Contacts: Capitan de Navio F. Garcia-Huidobro, Operaciones Estado Mayor General, Armada de Chile; Teniente Ivan

Petrowitsch F., Director, Division de Pesca y Caza, Servicio Agricola y Ganadero; Arturo Reid S., Jefe, Div. Inv. y Fomento, Instituto de Fomento Pesquero.

April 6 Punta Arenas. Contacts: Contra Almirante Raul Lopez, Comandante-en-Jefe, III[a] Zona Naval, Armada de Chile; Capitan de Navio Luis Bravo Bravo, Op. Est. Mayor, III[a] Zona Naval; Capitan de Corbeta Alfonso Herrera Correa, Comandante, P.P. Lientur; Ing. Guido Celedon C., Jefe, Zona Austral, Instituto de Fomento Pesquero.

April 7 Team I sailed from Punta Arenas on P.P. Lientur, Capitan de Corbeta A. Herrera C. commanding.

April 8-18 Team I field investigations (landforms, hydrography, hydrology, and water quality) of 15 prospective rearing and planting sites:

- Isla Dawson - Lago Fox, Rio Fox
- Seno Owen
- Seno Brenton, Pto. Coisel
- Unnamed lake system adjacent to Seno Brenton (Lago Lientur)
- Same lake system from Canal Gabriel, Bahia Isla (Lago Lientur)
- Seno Almirantazgo, Rio Azopardo
- Unnamed lake system, east arm, Seno Mercurio
- *Unnamed lake system, north arm, Seno Mercurio (Lago Algo)
- Unnamed lake system, Canal Engano
- *Unnamed lake system, Canal Barbara, Isla Julio (Lago Julio)
- Bahia Smyth, Canal Barbara
- Bahia Fortescue, Estrecho de Magallanes
- *Rio San Bernabe, Caleta San Miguel, Bahia Cordes, Estrecho de Magallanes
- *Lago Botella, Fiordo Condor, Canal Jeronimo
- Fiordo Sullivan, Seno Otway

*Sites selected for detailed investigation by Team II.

April 17 Team II arrived in Punta Arenas.

April 18 Debriefing of Team I.

April 19-25 Team II field investigations. P.P. Elicura, Capitan de Corbeta Carlos Silva, commanding.

April 19-26 Joyner, Mahnken, and Bienfang return to Santiago. Discussions and planning for followup studies by Chilean cooperators. Contacts: Universidad de Chile: Profs. Ureta, Pincheira, and Vila, Dpto. de Biologia, Sede Santiago; Instituto de Biologia Marina, Monte Mar: Tarsicio Antezana J., specialist in zooplankton of southern Chile; Piscicultura Rio Blanco (Div. Pesca y Caza, SAG): inspection of fish feed processing facilities.

April 26-27 Debriefing of Team II in Santiago. Joyner and Nash summarize mission for IFOP and SAG executives.

April 28 Joyner and Nash brief Almirante Jose Toribio Merino, Comandante-en-Jefe de la Armada de Chile, member of the Junta de Gobierno, and Vice President of Chile. Meetings with Capitan de Navio Raul Herrera A., Director of the Instituto Hidrografico de la Armada, and Capitan de Navio (ret.) Roberto Kelly V., Ministro Director of the Oficina de Planificacion Nacional (ODEPLAN).

Preliminary Results

Debriefing of the two teams revealed a general consensus that from the biological standpoint, at almost all of the sites visited on this mission and at one previously visited by Joyner and Nash in September 1975, it would be feasible to produce healthy salmon fry, ready to migrate to sea. As a consequence, the economic, logistic, and psycho-social aspects connected with building and operating the proposed system will be the primary factors in the final decision on a rearing site.

Appropriate expertise is readily available in Chile for conducting the proposed year-long followup studies of the climatology, hydrology, hydrography, and ecology in the vicinity of the site(s) finally chosen. The University of Chile in Santiago, the Instituto de Biologia Marina in Monte Mar, IFOP, and the Div. de Pesca y Caza of SAG are able and willing to undertake selected aspects of these studies, provided that the modest funding necessary to support the field operations can be provided.

The meetings with Admiral Merino and Captain Kelly indicate strong interest and support for the project at the highest levels of government.

REPORT OF

Guy N. Rothwell
The Oceanic Institute

INTRODUCTION

This report mainly covers observations made during the first of two cruises in the vicinity of the Magellan Strait along with comments on the second cruise, two overland trips on the Brunswick Peninsula, interviews with civilians and naval persons in Punta Arenas, and some reflections. It is divided into five parts:

1. Cruise #1. PP Lientur, Alfonso Herrera commanding, April 7-17. Survey party: Tim Joyner, Conrad Mahnken, Paul Bienfang, and Guy Rothwell. Main purpose: to scan the islands south of the Magellan Strait for suitable hatchery sites. Figure 1 shows the locations of the sites visited.

2. Cruise #2. LSM Elicura, Carlos Silva commanding, April 20-24. Survey party: Colin Nash, John Spencer, Ron Mayo, Harry Senn, Guido Celedon, Pablo Aguillera, and Guy Rothwell. Main purpose: to re-examine the four sites recommended by the first party.

3. Visits overland to rivers on the Brunswick Peninsula, April 18, 19, and 25. Various members of the group. Main purpose: to examine these rivers as hatchery sites.

4. Interviews with naval personnel and with a civilian contractor, and a tour of ASMAR Punta Arenas, April 26. Main purpose: to ascertain the capabilities, standards, methods, and costs for construction in the Punta Arenas area.

5. Some reflections on all the above, by the undersigned. Main purpose: to provide an independent view of some aspects of the project for use by its managers.

I. CRUISE #1: PP LIENTUR

This ship is a former U.S. Navy vessel, known as an ATA. About 150 ft. in length, it was used as an auxiliary seagoing tug. It was built in New Orleans in 1943 during World War II and purchased by Chile soon after the war. The Lientur now has responsibility for maintaining all navigation aids in the Magallanes Province. A comment on the Armada de Chile: virtually all the original equipment is still aboard and in working condition. The original engines are in good condition after 33 years.

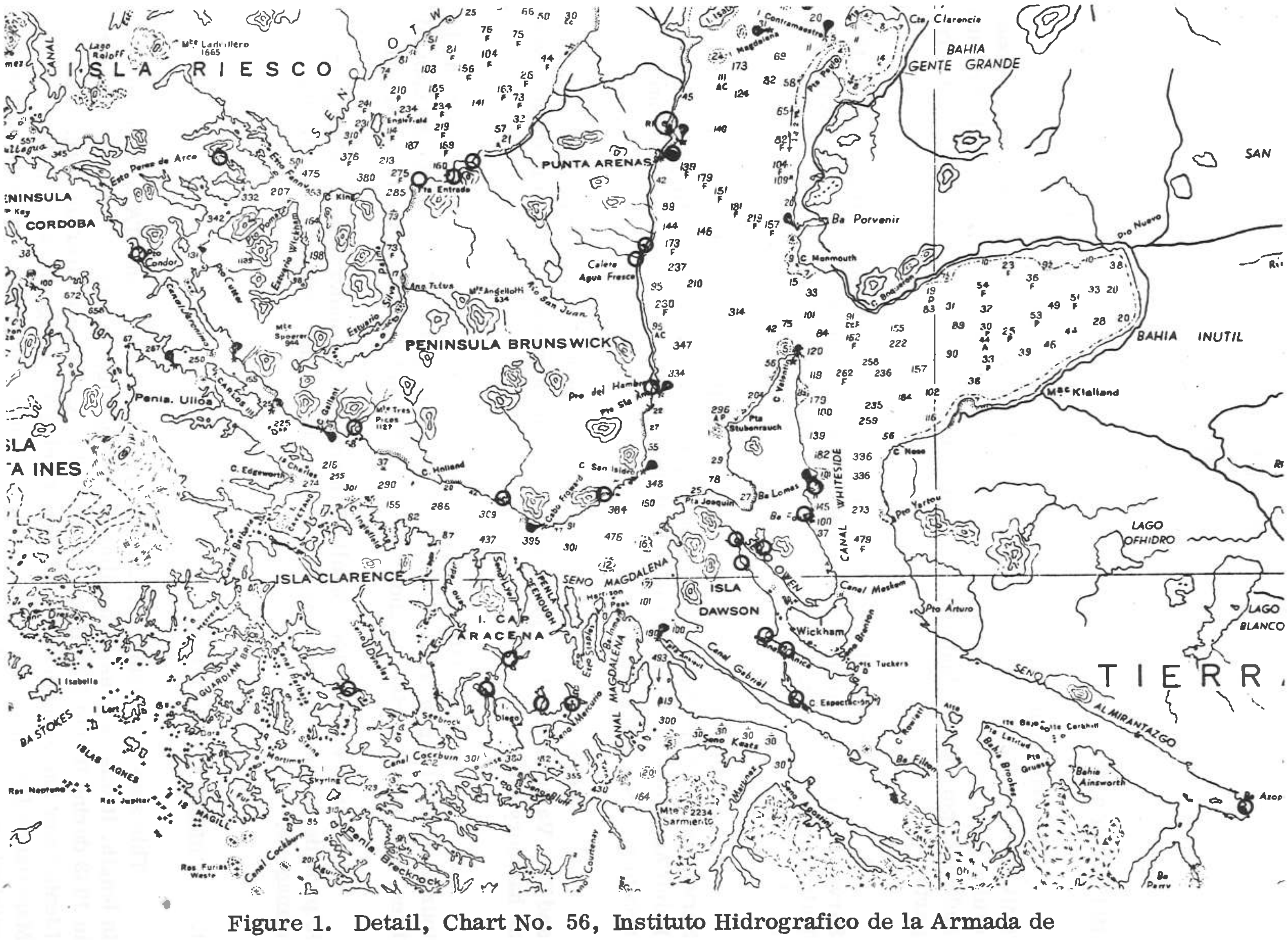


Figure 1. Detail, Chart No. 56, Instituto Hidrografico de la Armada de Chile. Scale 1:260,000. Central portion. (O = sites visited)

We cleared Punta Arenas on a clear, sunny morning of light winds and no sea to speak of. Throughout both cruises we were treated to mild weather, sunny most of the time, otherwise with rain or snow flurries, and occasional fresh winds. Never was the sea uncomfortable. April is early fall in the south. Either we were exceptionally lucky or the weather in that province is not as bad as reported. Of course, we were not in a small sailboat.

The ship crossed the Strait to the southeast. We saw cormorants, boobies, and one large and one small seal. First stop was the navy base at Isla Dawson, where a new concrete pier capable of at least one ton per square foot is still being fitted with its fender system. We were told that the temperature extremes here are 26° and minus 10° Celsius.

Site 1: Lago Fox. We all went by navy truck to Lago Fox, a shallow lake about 1/2 km long, three miles from the harbor. Lake water was clear, the borders of the lake being black saturated loam. Elevation of the lake is 60 to 70 m. Water temperature was 8.5°C, pH 6.6. The exit streambed was barely damp, with grass growing in it, reflecting the dry weather and the fact that the lake is catchment for no more than 5 or 6 times its own area.

Site 2: Bahia Fox. On April 8 we hiked across the peninsula south of the navy base to Bahia Fox to investigate a river there which we had been told contains brown trout. Bahia Fox is a small estuary about 1/2 km wide and 1 km long, fed by a river with two forks and draining a watershed several tens of square km in extent. Flow at the mouth was estimated at 2 to 3 m^3/sec. We found a wide gravel beach rich in organic material, saw herons feeding in the shallow water, but saw no shellfish or small fish. The right fork of the Rio Fox, about 1 mile from the Bahia, had low riffles, water the color of tea, with pH 5.6, temperature 5.5°C; very clear, no suspended fines; gravel bottom. The left fork had about 2/3 the flow volume of the right fork, a lighter color, and pH 5.0. These streams are very beautiful, just like the trout streams in the Pacific Northwest. On the right fork a local horseman and his dog came by and told us there are trout here. The Rio Fox is in a broad (3 to 5 km) valley with gentle slopes, with a few trees lining the streams. Cattle are grazed here over much of its lower watershed. See Figure 2.

Later in the day we cruised down the east side of Isla Dawson, turning west into Seno Brenton, a passage leading south of Isla Wickham into the Owens Sound. To the south we saw Mt. Sarmiento and other nearby peaks, clear and snow covered, beautiful as any alpine peak. To the southeast, a long view down the Almirantazgo Sound, a corridor between tall cliffs with icy mountains in the distance. Later, porpoises played around the bow, five of them, very fat and husky, with white bellies, dark grey backs, no beaks like our bottlenose. The Lientur was doing 11 kt; these porpoises easily do 15. Along the way, the skipper ordered the longboat over the side with a crew and two scuba divers, who were

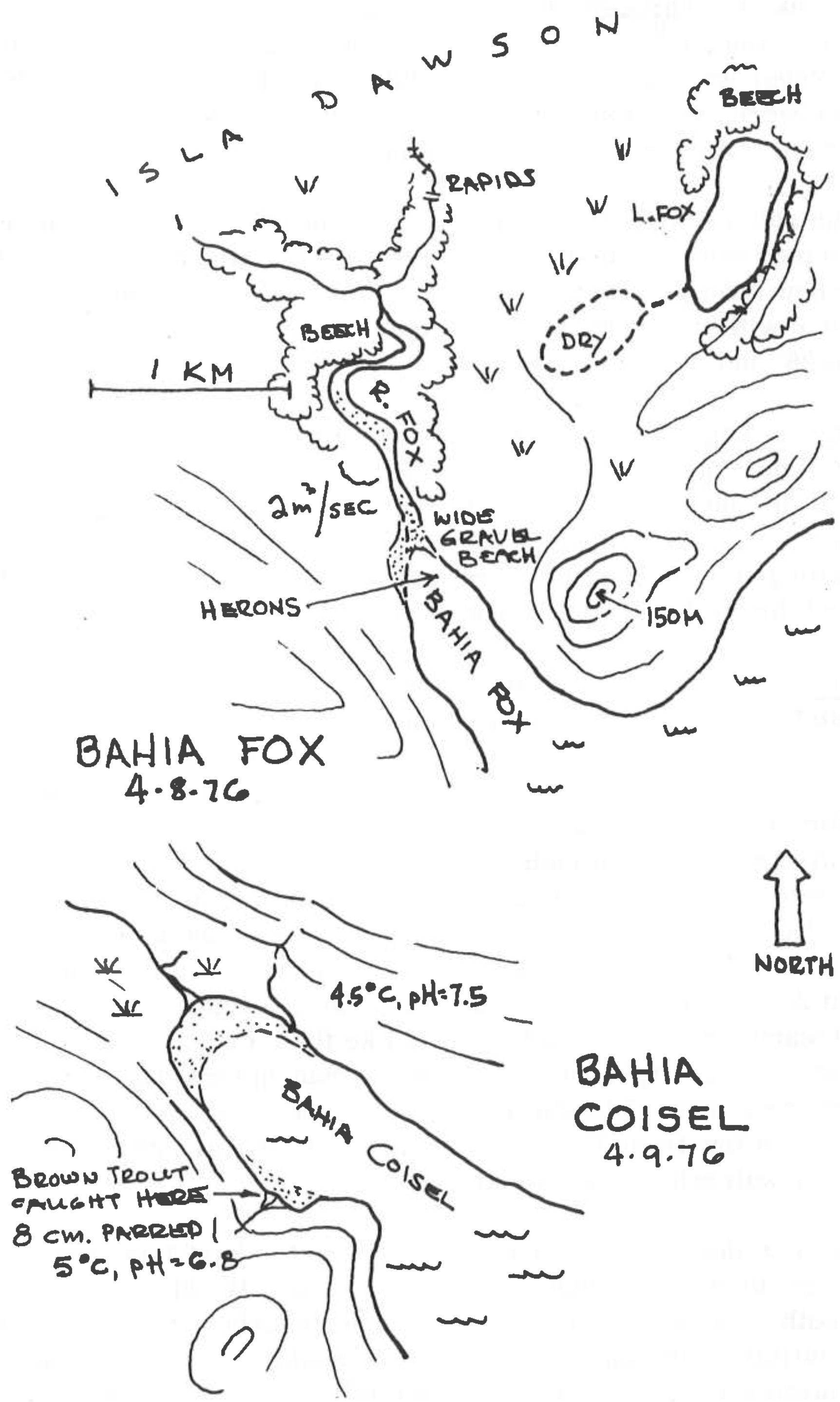


Figure 2. Isla Dawson. Lago Fox and Bahia Fox, top; Bahia Coisel, below.

going to catch dinner. We picked them up hours later, after dark, the boat loaded with chorgas and centolla crabs, the crew with Pisco and good spirits.

Site 3: Owens Sound. During the afternoon of April 8, we explored the head of Owens Sound (see Figure 3). The head of the bay proved to be unreachable after Tim, Paul, and Connie stepped overboard in hip boots in 1 m water a hundred meters from the beach, only to find that it got deeper in all directions. We saw a quite respectable stream crossing a wide, flat mud/gravel beach at the mouth of a broad valley with flat floor; boggy, probably. On the north shore of the sound, the charts show Lago Don Bosco, part of a system of small lakes that apparently drains into Bahia Lomas on the west side of Isla Dawson. Climbing to this lake, we found a bog/muskeg, but no lake. Here the going was as difficult as we found anywhere. A small stream flows here, the color of coca cola. Across the south shore we found a small, tea-colored stream issuing into the mud flat, with riffles just above in the thick foliage. Temperature was 7°C, pH was 5.6, and the flow was about 1 cfs.

Site 4: Bahia Coisel. On the morning of April 9, we were ashore by 8:30 at Bahia Coisel, a small, well sheltered bay at the head of Seno Brenton. It is quite similar to the head of Seno Owens, but here a landing is readily found on

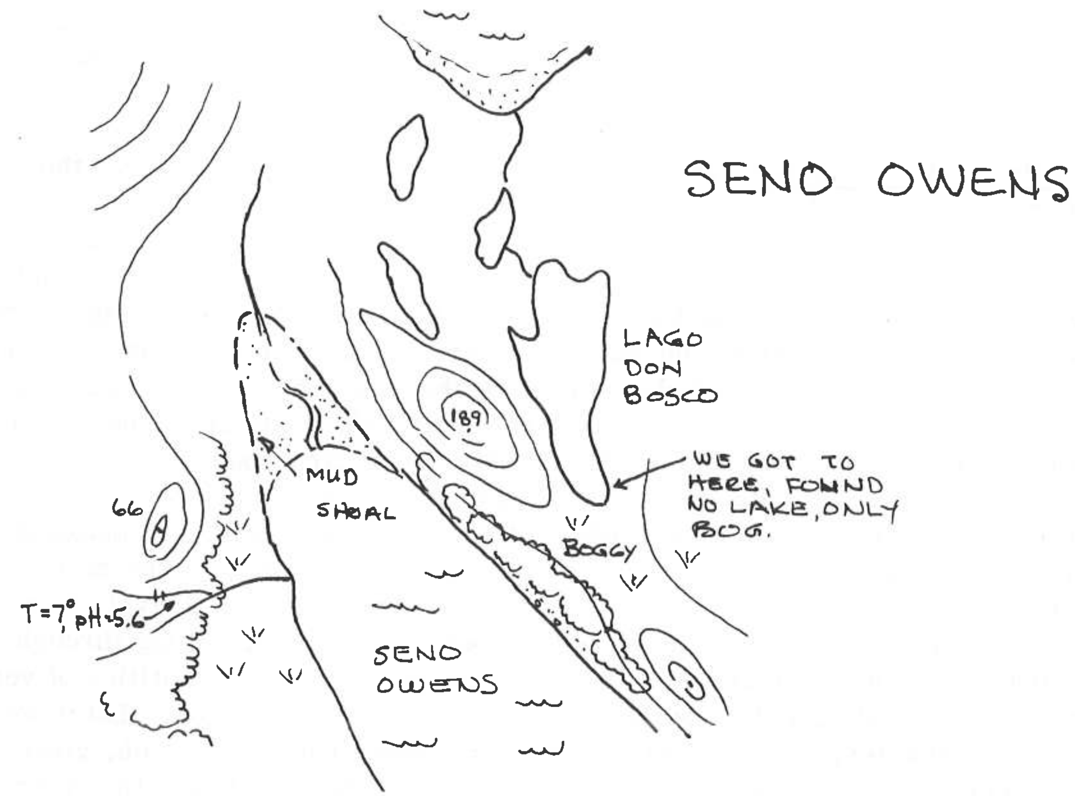


Figure 3. Sites at head of Seno Owens.

the north shore about 1 km from the head of the bay. It was low tide, and the beach was mixed mud and cobbles. A dense forest, choked with underbrush, occupies the top of the beach. A stream of at least 5 m^3/sec. flow entered the head of the bay across a clean flat gravel beach with occasional logs and large pieces of driftwood. A road could easily be cut through the forest above the beach on the north side of the bay, to connect the landing to the valley floor. The shape of the valley--broad flat bottom, rounded hills at the sides, snow on peaks at the head of the valley--suggests a flat gradient for the river around 1 m/km, and no prospect of gravity flow from the main stream. The forest floor has several feet of organic matter. The bench through which the present stream cuts does not seem to be muskeg. The flood plain meets the mountain slope directly at the valley sides. A brook enters the main stream from the right about 1/2 km from its mouth. Although the flow is small, 50 to 75 ft. of head is easily obtained. More such brooks occurred nearby. A hatchery could be built here, serviced by the road mentioned above. Numerous small streams would have to pass under the road. This is a beautiful bay, with rich littoral life. There is plenty of good water, and the bay might be a good nursery. The main disadvantages are: not much head available on the main stream; expensive road and landing or limited to landing craft. An abandoned fishing camp near the spot where we landed indicates the bay has fish in it. Later, on the south side of the bay, we landed on a wide muddy beach and discovered in a small stream which issues out of the trees a fat young brown trout about 8 cm long, still parred. Stream temperature is 5°C, pH is 6.8. By noon it was extreme low tide. Debris marks indicate that the tide range in this bay is more than 2 meters.

Site 5: Rio Flamingo. During the afternoon of April 9, we entered the north end of what we will later call the Lientur system (see Figure 4). (Here, and in several other places, we did not find names on the charts, so we assigned working names.) We entered between little islands of stacked-up granite, and found a narrow gut partly choked with kelp, with high wooded hills on either side, and a 3-knot current. Inside, the water is clear, brackish and shallow. Several times we grounded lightly, landed on a mudflat that would not support our weight, then at last started on foot up a wide, flat valley with the gentlest of slopes, all the while in water shin-deep and flowing briskly, or on firm mud flats. The valley is several km wide, with low hills near the river on the left, or east side, and a broad, low boggy area to the right. Beyond, on both sides, are peaks of several hundred meters, none of which showed much if any snow. The middle of the river where water is flowing now at or after low tide is clean gravel, 1 to 4 cm in size and rounded. We did not stir up any mud while marching through it. In the lower part of the river, near the entrance, we saw large quantities of very fat mussels and a stunningly beautiful flock of bright pink flamingos. Later we found two tributaries, Rio Uno and Rio Dos, with about 1 m^3/sec. each, good gravel, temperature 7° and 6°C, and pH 6.9 and 6.7. Beyond these, the river broadens to contain a series of muskeg islands one or two hundred meters across

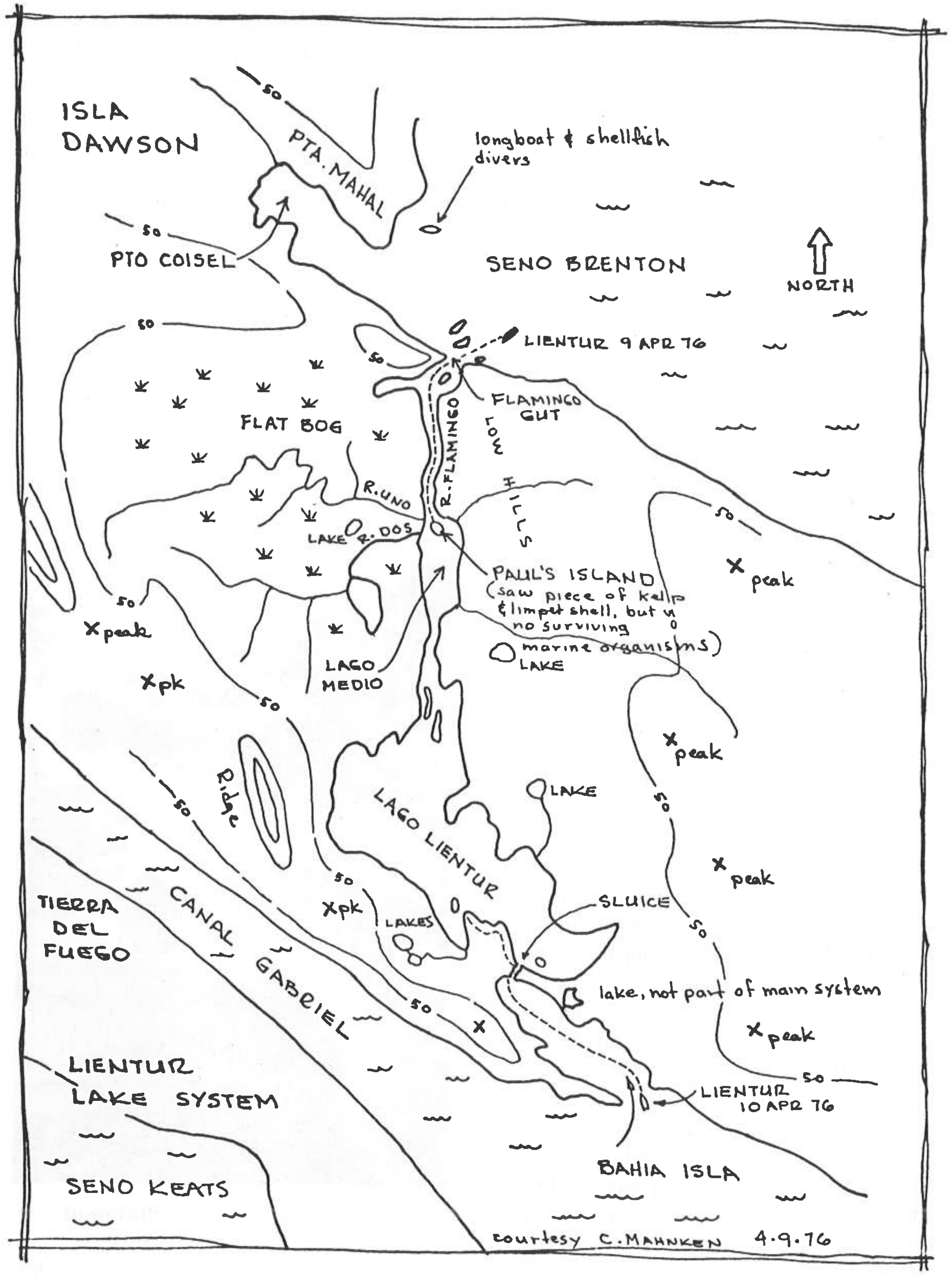


Figure 4. Sketch map of Lientur system.

and about 1.5 meters thick. They have dwarf beech trees at least 25 years old. Here we discovered a dead (recently drowned) nutria, an empty limpet shell, and a piece of kelp, but no evidence of living marine forms. It seems that tidal water comes at least to here. The first island we named for Paul. Beyond Paul's island, we saw the river still flowing north, but slowly, about 3 cm/sec. We had reached a lake. The water was clear, but a dark tea color. We measured a flowrate of 1.8 m^3/sec. We returned northward down the river to the ship, which proceeded down Seno Brenton, around Cape Espectacion and into Canal Gabriel, dropping anchor at Bahia Isla at the south end of the Lientur system.

Site 6: Bahia Isla and Lago Lientur. The following morning, April 10, was overcast, rainy and cold. We got away early from the ship in the whaleboat and rode through the mist into the Bahia Isla, 1 km long and half as wide. The head of the bay presents a rocky clifflike shoreline 3 to 5 m high, with steep, thickly tree-covered slopes above. We got a strong feeling of tropical jungle. Approaching the back of the bay we noted decreasing salinity, and found a natural cut or sluice in the rock wall, 10 m wide, out of which came tumbling a substantial stream, better than 5 m^3/sec. (see Figure 5). We moored the whaleboat and clambered ashore. The sluice is about 100 m long, comprising a pool with a low riffle (0.2 m) at its inlet and another (0.8 m) at its outlet, for a total drop of about a meter. Above the sluice is a large lake, at least 5 km long and 2 wide. At this exit the salinity is 7.0 ‰. The lake is obviously tidal in that it receives some seawater at high tide. We proceeded to some high bluffs south of the lake. From this vantage point the entire north end of the lake could be observed. This system of lakes and streams lies in a linear depression trending northwest/southeast, entirely across the southern part of Dawson Island, between two ranges of low mountains. Rain runoff apparently exits from both ends of the system. It is interesting to speculate whether Lake Lientur could be rendered fresh by providing a dam and a gate at the sluice, preventing entry of seawater, but allowing fresh water to leave. It would also be possible to allow the lake to rise a few meters so that all

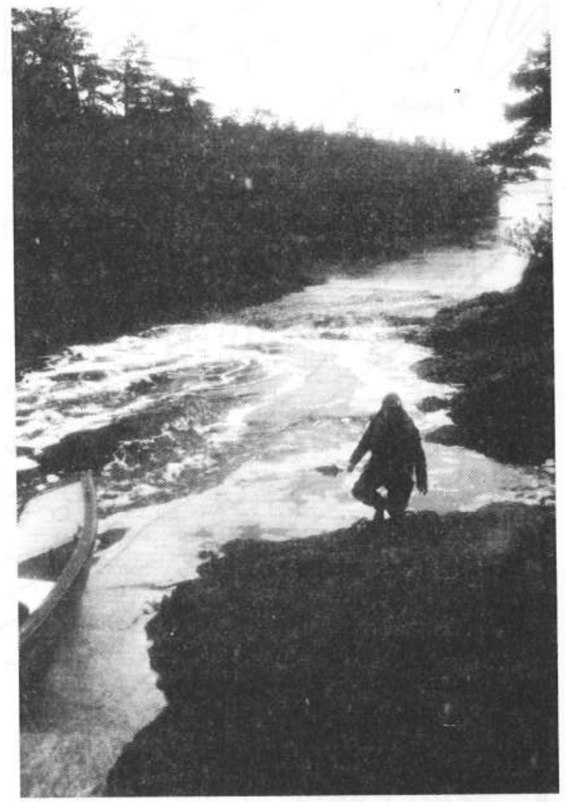


Figure 5. Bahia Isla. Sluice at south end of Lago Lientur; light snowfall. Note narrow cut through rock wall, middle distance.

water exits to the north except that tapped off at the southern end for use by a hatchery. The safety of such a proposal depends on the extreme penetration of seawater into the system from the north, as well as the possibility that the lake is underlain by saltwater at present. Certainly, building the required structures at the south end would be relatively easy. A site of limited extent is available for a hatchery immediately adjacent to the sluice, where a flat area of approximately 3 acres is located. The answer to these questions will have to await sampling of the lake and running levels through the system. It appears to be an excellent potential resource for the future.

Site 7: Seno Almirantazgo. On the morning of April 11, we were at the southeast end of Seno Almirantazgo, a 50-mile-long sound that penetrates deep into the interior of Tierra del Fuego. The sound lies on the course of the prevailing west winds. We went ashore in wind and rain, grounding momentarily on the bar at the river mouth, backing off into the surf and then scrambling ashore with some difficulty through the framework of an old wooden trestle on the south side of the bay (see Figure 6). This trestle was erected long ago in an unsuccessful attempt to find quiet deep water to tie up a cargo vessel. The river delta is mainly fine grey crystalline sand, shaped by the river, the surf, and the wind

Figure 6. Seno Almirantazgo. Joyner, Bienfang, and Herrera ashore with wet feet. Whaleboat is aground. Note cliffs on north side of sound.

into a series of offshore bars, a steep, high-energy beach, a region of dunes, and behind a complex of ponds and slews. The river had an estimated flow of 25 m^3/sec. of crystal clear, colorless water. The seaward margin of this delta has been extensively reworked in recent times, but the major portion, comprising at least a square mile, is stable at an elevation of about 25 feet in front of the steep-sided rocky gorge from which Rio Azopardo flows (see Figure 7). There is an estancia here that has been in the timber business as evidenced by at least two ruined sawmills and is now into cattle and sheep raising. A young boy who lives in the settlement there answered our questions with an unfailing "yes," but was otherwise a good guide. There is a road on the charts that goes up into Argentina, but we did not see it, nor did we see any serviceable vehicles. There is no shelter for a ship or boat within miles in westerly weather, contrary to the presence of the trestle. In addition, the marked wind-training of the trees shows an average velocity probably above 20 knots. In all, it is an inhospitable place. However, there are two arguments for it: first, there is plenty of excellent water; and second, people have been continuously living there, if sometimes precariously, for a long time. A second, much smaller stream drops down out of a short valley (2 to 5 km) with steep sides and upper slopes covered with snow. This stream has good gravel, is crystal clear, and has a flow of about 3 m^3/sec. It crosses the beach near its south end, next to the existing settlement. This stream alone would provide sufficient water for a hatchery, with plenty of head. It is very cold and the small apparent size and steep pitch of its watershed may mean that it is intermittent.

On April 12 we entered the complex of fjords and channels in Isla Capitan Aracena that open to the south onto the Cockburn Channel. This maze of waterways contains Isla Aguada, Seno Mercurio, Canal Engano, and Lago Algo.

Site 8: Bahia Algo. This is a system of small lakes above the head of the narrow, deep, well protected fjord which extends northward 10 km to the center of Isla Capitan Aracena from the Cockburn Channel (see Figures 8, 9, and 10). At the head of the fjord is a brackish forebay about a mile long, with a narrow entrance, capable of handling a vessel the size of the Lientur, but still practical to contain and harvest a large returning salmon run. Surface salinity in the forebay was zero to three parts per thousand. A lake of about 15 hectares extent and 18 m elevation drains into the forebay through a narrow rocky cleft between two heavily wooded knolls 70 to 80 m high. On April 12 the stream was discharging over 3 m^3/sec. of clear water with a slight red tint. Within the cleft is a free-falling waterfall 5 m high. Where the lake drains into the top of the cleft, a dam could easily be placed to give an extra one or two meters of storage, and for a penstock header. This location could support a low-head hydroelectric generator if water is consistently available. Fronting on the forebay immediately west of the stream mouth is a flat rocky area of 5 acres or more, covered to a depth of 2 m by a muskeg carpet consisting of mosses and small trees, standing an average 3 m above the bay surface. A landing wharf could be readily

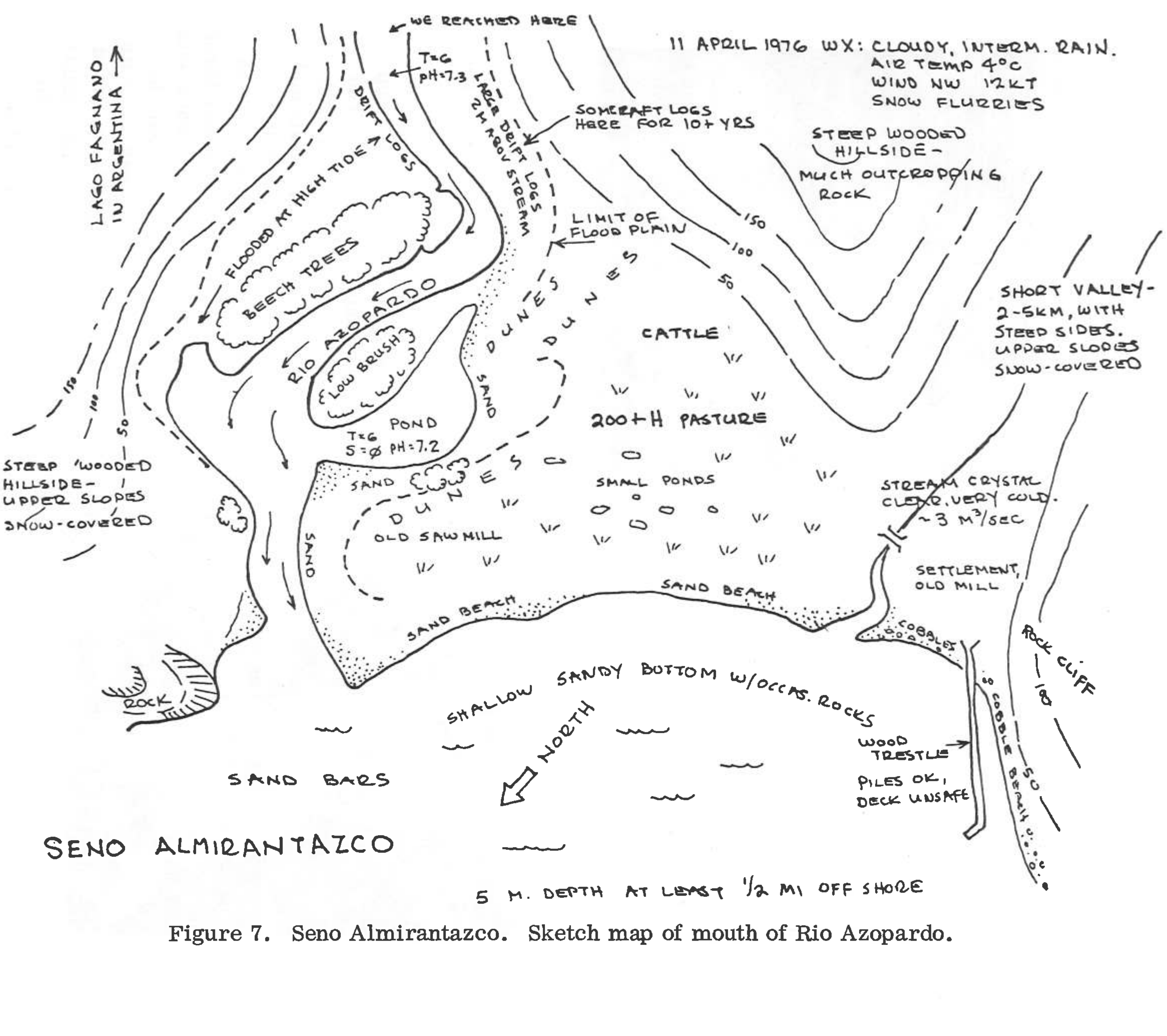


Figure 7. Seno Almirantazco. Sketch map of mouth of Rio Azopardo.

supported on columns to allow bringing a vessel of 100 tons or so alongside the site. Here, as in the other possible hatchery sites on Aracena, Clarence, or Riesco, where muskeg is the rule, it would pay to import a portable rock crusher and to provide a pad of compacted gravel one or two meters thick as sub-base for the hatchery, tank, or raceway floor slabs, since there is no existing soil to speak of. The west arm of Bahia Algo is straight, narrow, and deep. It backs into high hills with snowy mountains above. It is completely protected from all but strong southeast winds. Surface water in the arm was slightly red, salinity was 3.0 ‰. At the head of the arm is a mud delta

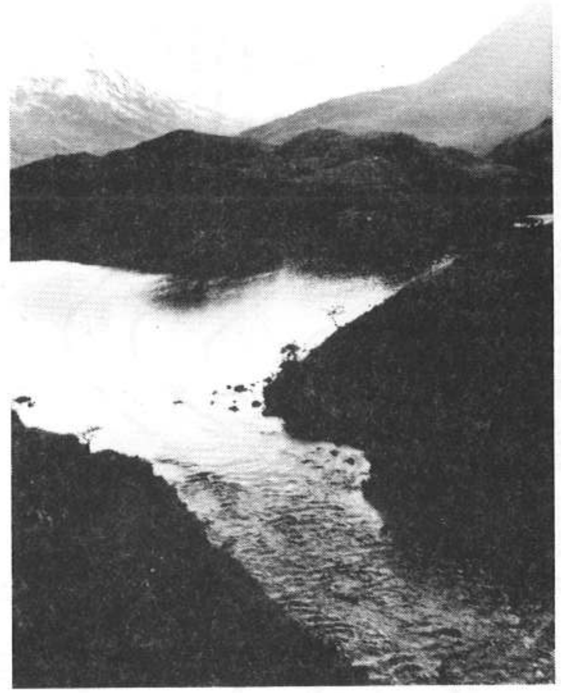


Figure 8. Lago Algo. View of lake and exit stream.

Figure 9. Lago Algo. View of exit stream from above; estuary in background. This is difficult country on foot.

about 50 m wide, crossed by a small stream flowing about 0.3 m^3/sec. The sides of the arm are steep and heavily wooded, above short steep beaches of mud and cobbles. The mouth of the valley is 150 m wide between precipitous rock walls and contains a beautiful, lush rain forest. The stream's flow gradient is 50 to 100 m per km, for we could see three branches high in the valley, each with its waterfall. A hatchery could be built here beside the stream near its mouth, with water piped from one of the waterfalls, and a landing similar to the one described above for the north arm. However, a spot more isolated in the dead of winter can scarcely be imagined.

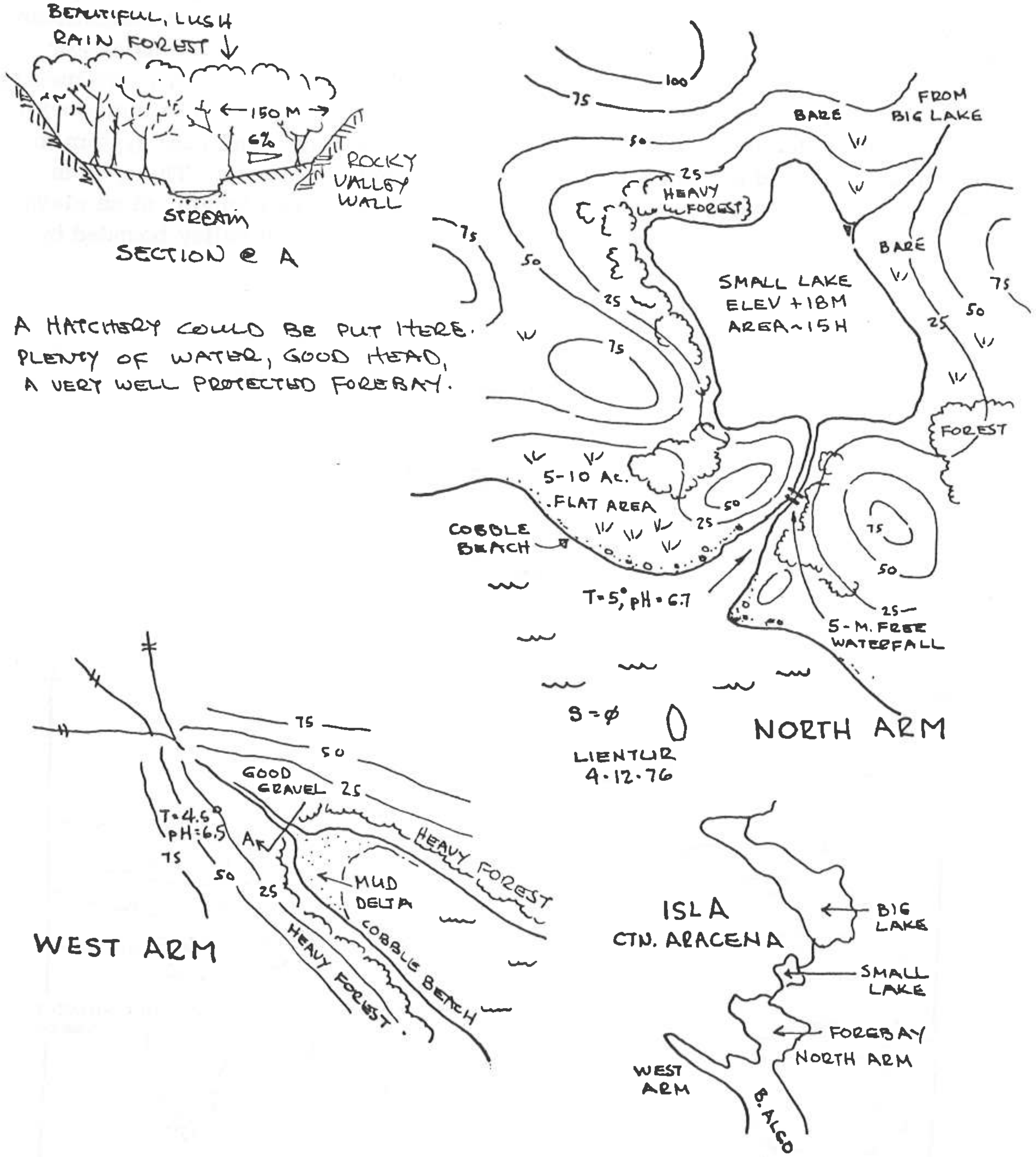


Figure 10. Sketch map of Lago Algo.

Site 9: Canal Engano. On the afternoon of April 12, we entered the lagoon at the north end of Canal Engano (see Figures 11 and 12). It is aptly named. Engano means hoax, or lure. The north entrance of the canal is an insignificant opening in the west wall of the blind sound, which grandly lures the navigator south into a dead end. The lagoon is shallow, in places no more than two meters, crystal clear, and heavily populated with kelp in the shallows. It is dotted with small islands and navigable only by vessels up to 50 tons. The lake system to the north was found not to drain into the main sound to the east. The system comprises two moderate-sized lakes, about 3 km in overall length, at an elevation of 20 to 25 m above sea level, lying in a saucer-shaped valley bounded by

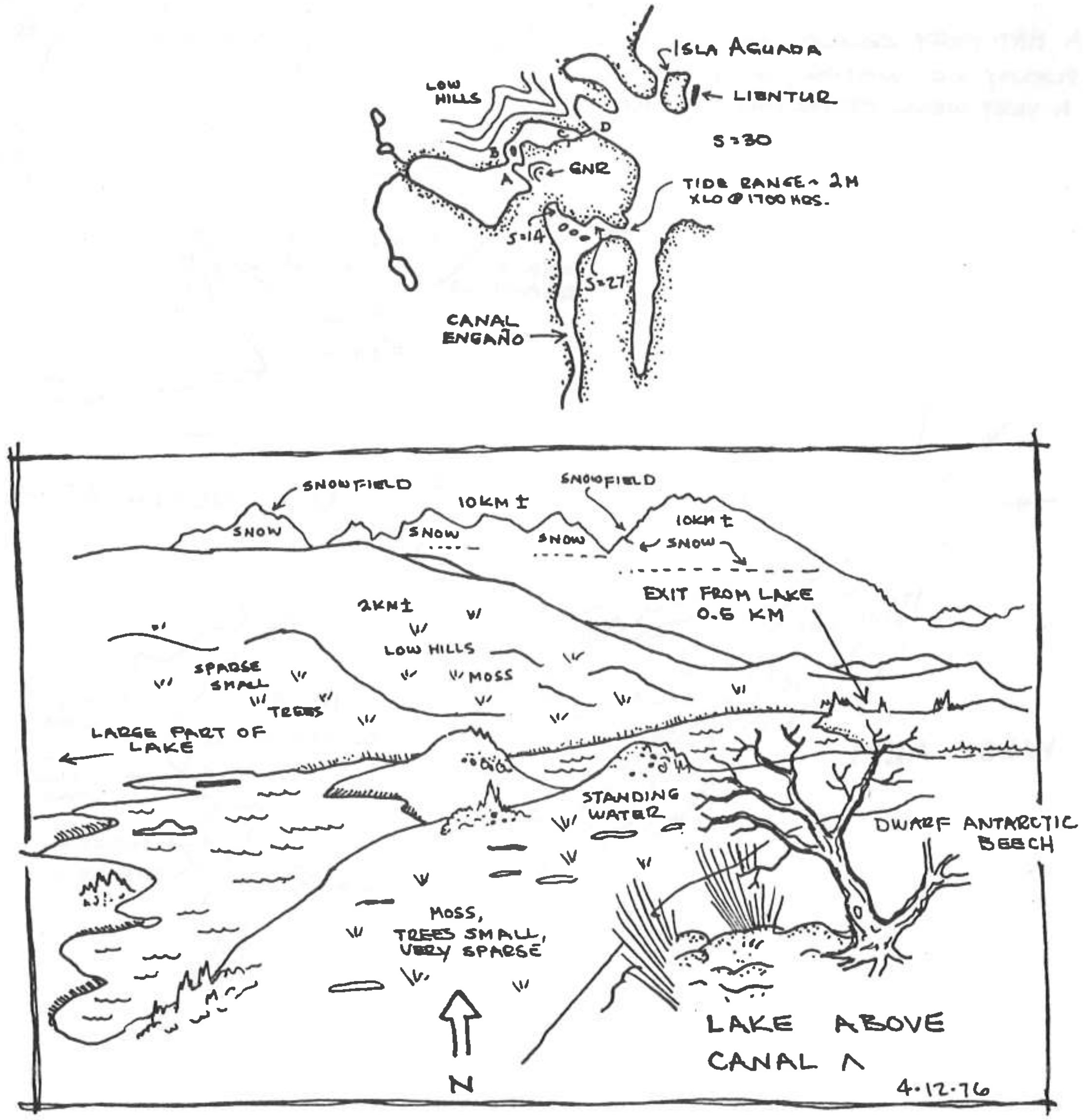


Figure 11. Sketch map of Canal Engano.

Figure 12. Canal Engano lagoon; party returning to whaleboat.

rolling hills and opening out to the east. The entire valley seems barren and windswept, with muskeg everywhere, sparse grass, rock outcrops, and a few small trees. At first glance it has the look of being heavily grazed. Walking over this landscape was fairly easy, compared with Bahia Algo. Temperature of both lakes was 7.5° to 8° C, pH was 6.2 and 6.4. Outflow, measured at the top of the exit stream, was 2+ m^3/sec. The outflowing water was clear, a definite red color. Benthic algae were plentiful; three types were seen. No fish or insects were observed. By late afternoon temperature at the mouth of the exit stream was 6.0° C, pH 6.4. Air temperature was 2.0° C. This system was hard to evaluate. Water was plentiful and at a more acceptable temperature than other sites. Gravity head on the exit stream was more than adequate and water quality seemed acceptable. Navigation into Canal Engano would appear difficult except for smaller craft, however, and the mouth of the exit stream (see Figure 13) did not present a good building site, the ground being rocky and nowhere level. Perhaps a floating hatchery would be reasonable here. The surrounding waters, and the lakes themselves, appeared unproductive. In the end, the place did not impress anybody very much.

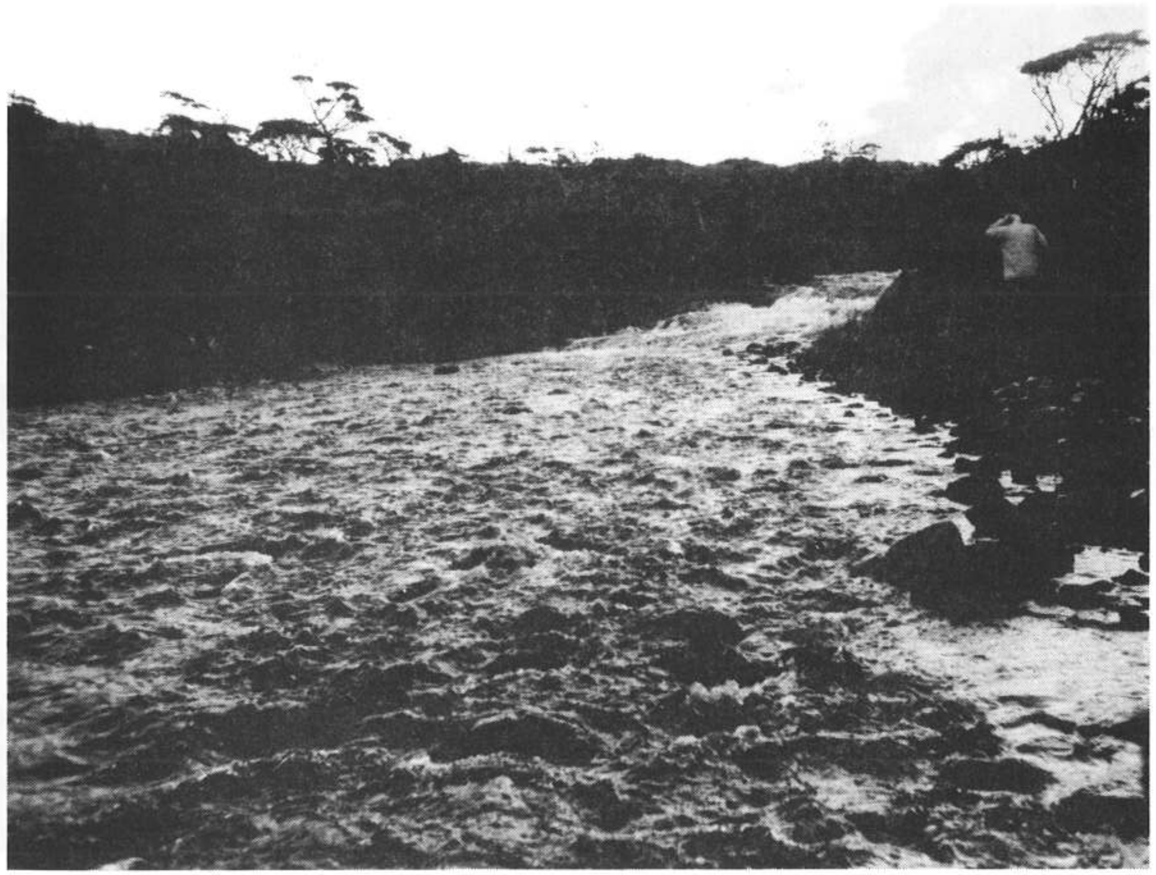


Figure 13. Canal Engano exit stream.

Site 10: Seno Mercurio (Figure 14). This is the easternmost of the three branches of the Isla Aracena waterway. It consists of a well protected bay three miles long, a lagoon 3/4 mile long connected to the bay through a shallow (2m), narrow passage, and a low-lying lake of about one square mile. The lake is shallow, no more than a meter deep near the south end. Temperature was 8.6°C, pH 5.5, the color dark, clear red. At the time of our visit, the exit stream was discharging about 2 m^3/sec. No beaches were visible suggesting that lake level was high. The temperature was remarkable, considering that the upper slopes of the surrounding mountains were snow covered. The water quality indications, difficulty of access, and apparent shallowness of the lake rendered this system uninteresting for further study. This completes the sites on Isla Capitan Aracena.

Site 11: Bahia Julio (Figure 15). Bahia Julio, 30 miles west of Seno Mercurio, on Isla Clarence, has a lake system somewhat similar to Algo. An inlet 1 km wide and 3 km long opens to the west, offering a safe quiet anchorage, except in strong west wind. A small, confined lagoon opens on the inlet at mid length. The lagoon, 800 m long and 400 m wide, showed a slight color, and zero

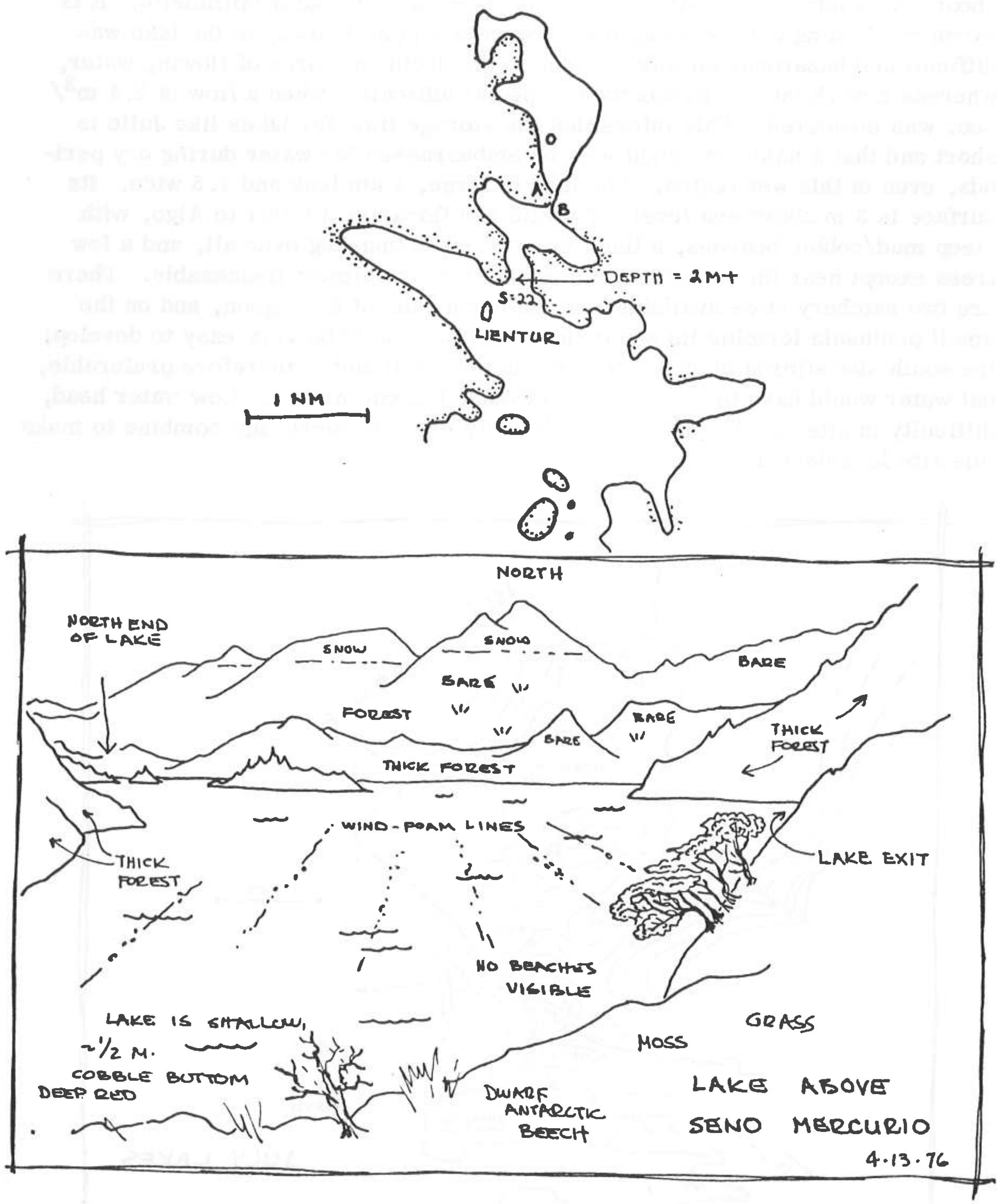


Figure 14. Sketch map of Seno Mercurio and view of lake.

salinity. A substantial stream drains into the lake above, down a rocky course about 500 m long. Our estimate of 10 m^3/sec. was probably optimistic. It is worth mentioning that crossing this stream at a point halfway to the lake was difficult and hazardous on April 14 due to the depth and force of flowing water, whereas a week later it presented no special difficulty, when a flow of 2.4 m^3/sec. was measured. This infers that the storage time for lakes like Julio is short and that a hatchery might well be embarrassed for water during dry periods, even in this wet region. The lake is large, 4 km long and 1.5 wide. Its surface is 3 m above sea level. Terrain and flora are similar to Algo, with steep mud/cobble beaches, a thick layer of moss/muskeg over all, and a few trees except near the water's edge, where they are almost impassable. There are two hatchery sites available: on the north bank of the lagoon, and on the small peninsula forming its south side. Neither would be very easy to develop; the south site affords direct access to landing craft and is therefore preferable, but water would have to be conducted at least 1/2 km farther. Low water head, difficulty in site development, and relatively exposed anchorage combine to make this site less desirable than Algo.

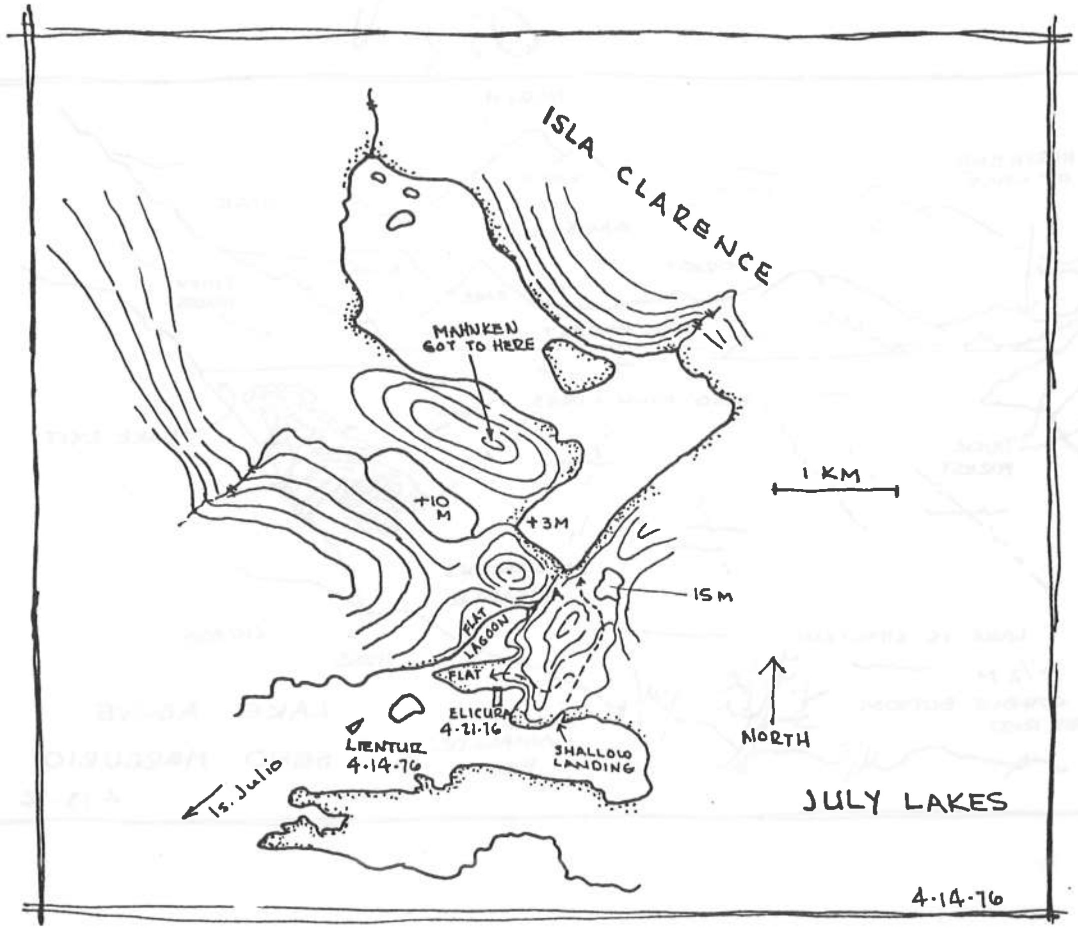


Figure 15. Sketch map of Bahia Julio.

Site 12: Bahia Cordes. Bahia Cordes (Figure 16) is located on the Strait of Magellan in the southwest part of the Brunswick Peninsula. It consists of a 4 km long landlocked bay, Caleta San Miguel (Figures 17 and 18) fed by Rio San Bernabe (Figure 19), and a nearby group of lakes which are hydraulically independent, having their exit on the open coastline southeast of the Caleta San Miguel. This area is very interesting. River flow is substantial, estimated at 7 m^3/sec. It flows out of a high valley, crossing the 50 m contour about 5 km from its mouth, then over a series of small falls and riffles, where flow is fast and the river bed is filled with boulders, gravel, and tree trunks. For the last kilometer, it flows through a boggy, moss/muskeg flood plain onto a broad, flat beach of mud and sand. There is no road up the valley. A wood cutter who runs a small sawmill (Figure 20) on the caleta told us he has not seen the rapids, although he has logged here for years. He said also that the caleta freezes

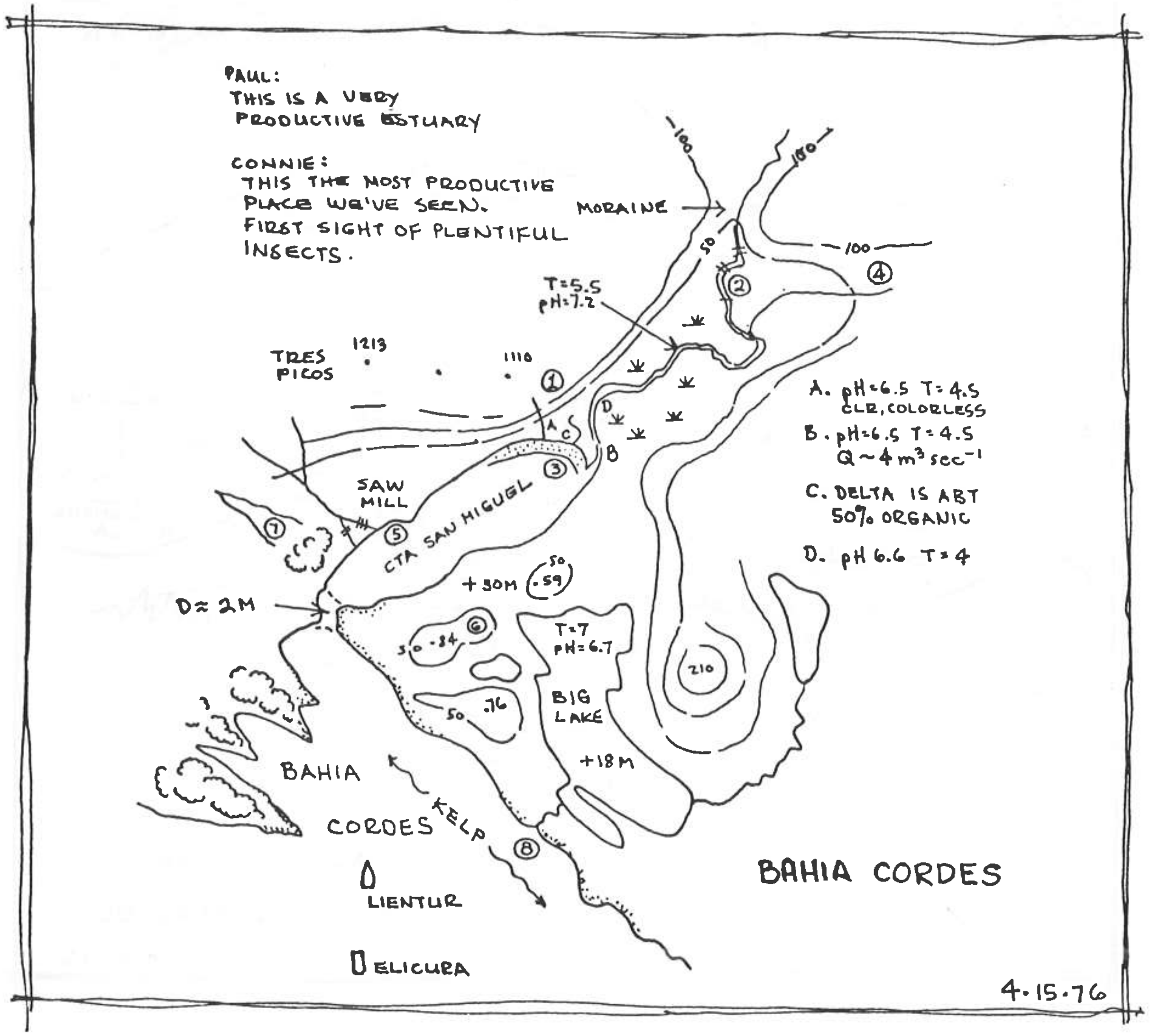


Figure 16. Sketch map of Bahia Cordes.

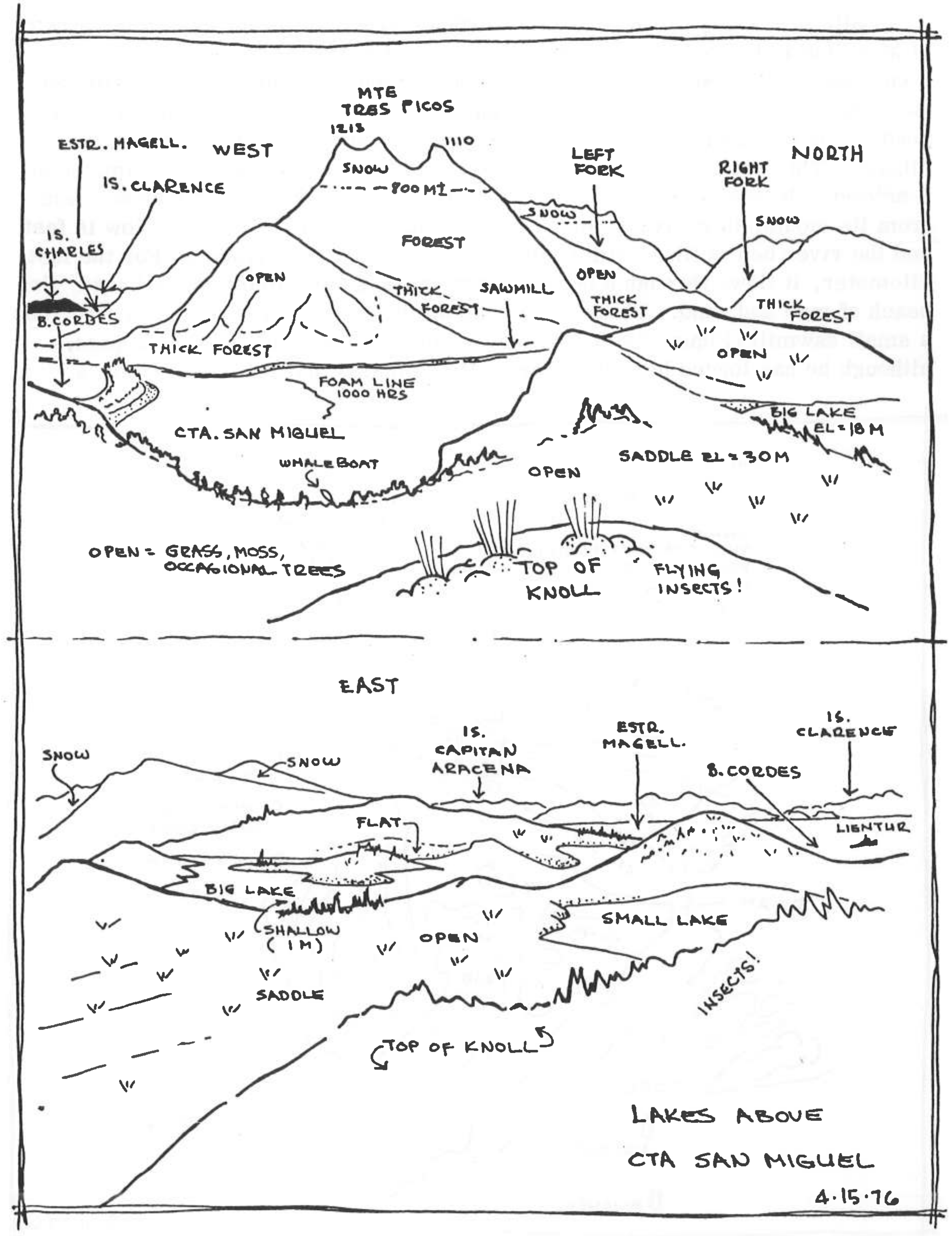


Figure 17. Bahia Cordes; view of Caleta San Miguel and lake system.

Figure 18. Caleta San Miguel; mussel fisherman in middle distance, mountains on Isla Santa Inez, background.

Figure 19. Rio Bernabe. Note impassable condition of bank.

occasionally (2 cm) for a few days, that the caleta gets strong north winds in winter, that snow stands a foot deep at his sawmill for short periods, and that robelo come in occasionally. We observed his aged partner removing a one-pound brown trout from his net near the head of the caleta. The valley slopes have heavy dark green forest up to 500 m, beech for another 200 m, then bare, and snow above 800 m. Near the sawmill the mountain side has recently suffered a massive avalanche which completely removed a large stand of very big trees. This appears to be a very productive estuary, evidenced by a large crop of mussels being harvested near the caleta mouth, abundant fish fry in the shallows at the river mouth, the brown trout, plentiful insects, and the vigorous and abundant kelp beds in the outer bay. River temperature and pH average 4.5° C and 6.6, while in the lakes, which stand 20 m above sea level, temperature is 7° C and pH 6.7. A great deal seems to be going on here, but it is hard to see how it can be developed. The entrance to the caleta is too shallow for any but small craft, no easy site for a hatchery presents itself, and the lakes drain directly to the open coast. Except for the possibility that plant-out will appear feasible here as part of the current program, this locality seems to be a resource for the far future.

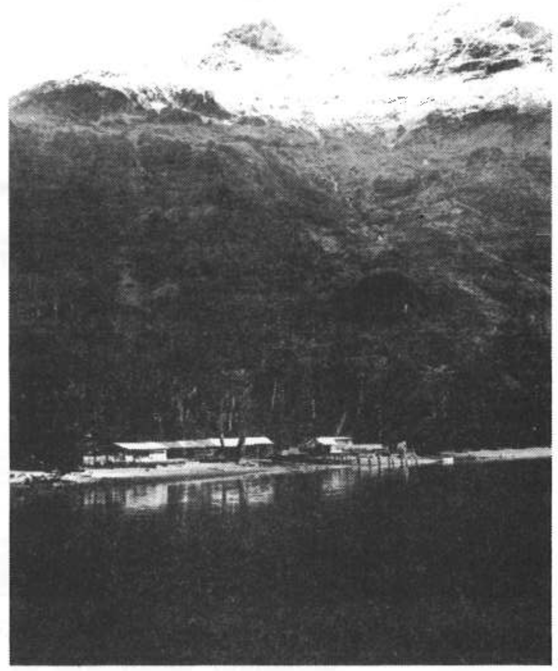


Figure 20. Bahia Cordes. Sawmill, Monte Tres Picos.

Two sites were examined in Isla Riesco, on the Canal Jeronimo: Lago de la Botella and Fiordo Sullivan (Figure 21).

Site 13: Estero Condor and Lago de la Botella. This system consists of the Estero Condor, a fjordlike estuary 6 km long and 2 km wide, providing excellent anchorage for even large ships, and the Lago de la Botella, 4 km long and 1 km wide, at an elevation 3 m above sea level. The lake drains into the fjord through a fast-flowing stream (Figure 22) we estimated at 10 m^3/sec., again probably optimistic. This is a large lake, with steep-gradient streams feeding it. Snow was seen on the higher slopes. The lake could easily be dammed at the exit to provide for storage and some additional head. Two meters does not seem to be too much to accomplish. The banks of this stream are of mild slope, allowing a road from the mouth to the lake exit. A hatchery

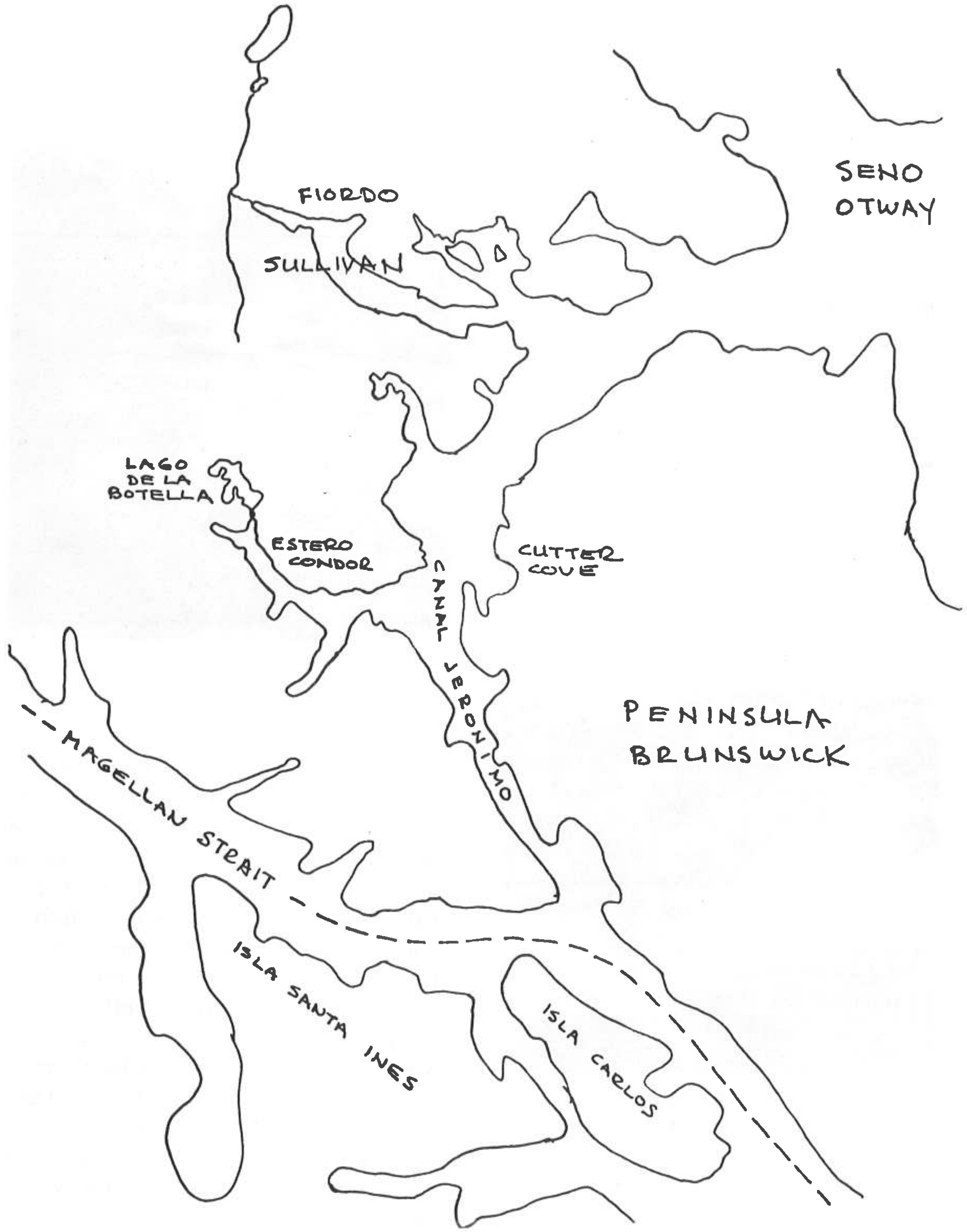


Figure 21. Lago de la Botella, Fiordo Sullivan, and vicinity.

could be placed on either side of the stream (Figures 23, 24, and 25). The west side is probably the best, either by use of a temporary floating structure which could be floated into the small cove and flooded to rest on sleepers, or by conventional construction on the cove bank. Water quality here is exceptional, at least in relation to previous sites: average water temperature is 7.5° C, pH is 6.8 to 7.1. The high pH can be explained by the presence of rapidly weathering alkaline rock, but the temperature is not so easy to compare with other sites, where it is

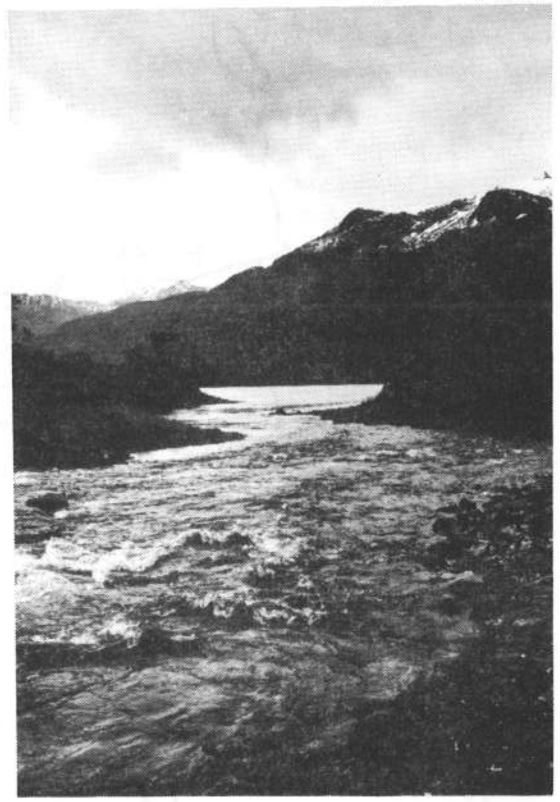


Figure 22. Lago de la Botella exit stream, 14 April 1976.

Figure 23. Lago de la Botella. View from preferred hatchery site; small cove at left, stream mouth in background. Nash and Mayo, foreground.

uniformly 2.5 to 3° C colder. Also, with the low head, it would be worthwhile measuring the salinity of bottom water in the lake. This site is about 10 miles by water from the Cutter Cove copper mine which is staffed and operated by the Chilean Government. It is accessible by water through Otway Sound as well as by Canal Gabriel and the Magellan Strait. Construction of a hatchery would be relatively easy here. The main disadvantages of this site are the low head, which can be improved, and the need for water access, which cannot.

Figure 24. View across Lago de la Botella.

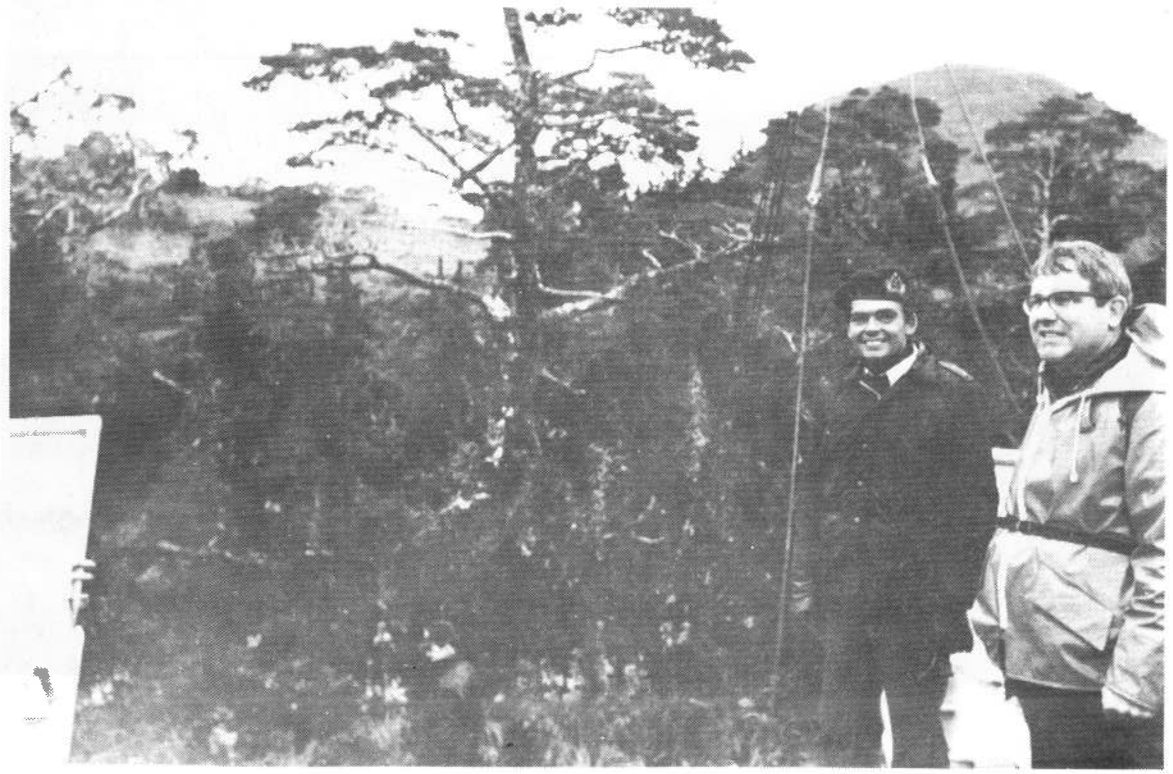


Figure 25. Lago de la Botella; bow of Elicura nosing into the trees at hatchery site. Carlos Silva and Ron Mayo.

Site 14: Fiordo Sullivan. This locality was of interest because of the nature of its topography. The system is shaped like a T, the stem (Figure 26) being the river delta and the fjord, and the crossbar (Figure 27) a valley whose low point occurs at a break in the valley wall so that the two rivers flow directly toward each other. The delta region is very similar to the Rio Bernabe at Bahia Cordes, with a meandering stream cutting through banks of marsh and muskeg choked with trees and underbrush. Building a road into this valley would be possible but difficult. In the north limb of the crossbar is a series of lakes which appear to be accessible to migrating salmon. The river has substantial flow and may be useful for plant-out. Measurements were taken of the river water. It looked clear and colorless. This system will not be useful for hatchery operations.

Figure 26. Fiordo Sullivan; stem of the T, fiord, and river delta.

Figure 27. Fiordo Sullivan. On the crossbar; Herrera, Mahnken, and Joyner 120 m above valley floor. Large lake hidden in mist, background.

II. CRUISE #2: LSM ELICURA

LSM Elicura was built in Chile, as a sister ship to a U.S. Navy LSM which had been acquired by the Armada de Chile some years before. The Elicura's main duty is in cargo handling around the Magallanes Province. Because of the problem of constant maintenance of the hull plating on the U.S.-built ship, the Elicura's plating is heavier and is reinforced. This reduced the ship's payload by some 150 tons, a fair trade for a tight hull in an assignment which routinely puts the ship on the beach hundreds of times a year in any weather.

My assignment during the second cruise was to act as guide to the second survey party and the ship's company in touring the four sites previously selected. Furthermore, the observations of the members of the second party are fully described in their own reports. This section will therefore make only general observations.

Site 8: Bahia Algo. This locality looked less formidable as a possible construction site on the second visit. Temperature and pH measured 5° C and 6.8; water flow was visibly less. My notes show that on second look, I favored the east side of the stream mouth as a hatchery site.

Site 11: Bahia Julio. On the other hand, this site looked much less interesting than before. Whereas nothing about the place appeared radically different, my impression was that there just is not enough merit to come all the way out here. Perhaps I was influenced by the wild look in Pablo Aguillera's eyes when he understood that we had actually proposed Julio as a candidate site.

Site 12: Bahia Cordes. This is still a beautiful place, with a great deal going on. It is continuously inhabited, it is fished, and it is accessible from Punta Arenas. I believe this site should receive some serious consideration for some auxiliary use in the program, particularly if it does not have to be manned continuously.

Site 12: Lago de la Botella. On second look, the outstanding problem with this site is its lack of head. If resort is not made to pumping, the hatchery design will be distorted by its need to be practically underwater in order to receive adequate flow. In later consideration, Botella should be compared only with other sites with similar low head.

III. RIVERS ON THE BRUNSWICK PENINSULA

South side: Rio Aguafresca, Rio San Juan, Rio San Nicolas.
North side: Rio Grande, Rio el Canelo, Rio la Caleta.

All six rivers are topographically similar in that they flow with flat gradient for some kilometers across a coastal plain of low relief and issue into the sea on an open coastline. None has associated lakes, except far in the interior. All are strongly colored, but otherwise their water quality seems acceptable. Except for Rio San Nicolas, all are accessible overland. The road down the south coast as far as Rio San Juan is well traveled, all-weather, gravel surfaced, and maintained. For any construction contemplated on this section of coastline, all materials and equipment can go by truck. This is not true of the road down the northwest coast to Rio la Caleta. This road is poorly (maybe privately) maintained, narrow in places, and limited in capacity. The bridge over Rio Grande (Figure 28) will safely support no more than about 10 tons, whereas that over the Rio Canelo (Figure 29) appears to be worthless. In April, the river level is low, permitting use of a ford near this bridge. At other seasons, the ford may be impassable. Several short bridges over narrow streams have also limited capacity; replacement or reinforcement to handle heavy trucks would represent a substantial cost.

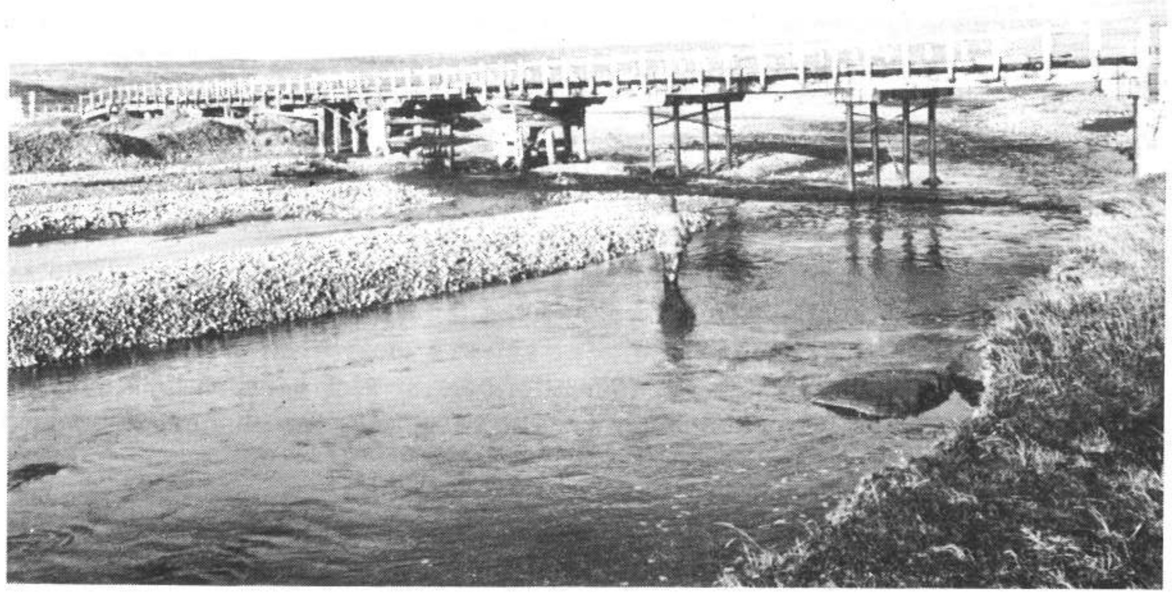


Figure 28. Brunswick Peninsula; Rio Grande bridge. Note repairs.

Figure 29. Brunswick Peninsula; Rio el Canelo bridge.

IV. ASMAR PUNTA ARENAS, CIVILIAN CONTRACTORS

The procedure suggested by Captain Quinones, a tender based on preliminary documents furnished by the owner, is a typical one encountered in Europe, South America, and elsewhere. The main problem will be misunderstanding of intent. For this reason, preliminary documents should be more than ordinarily complete, and liberal use should be made of shop drawings during construction. A full-time resident representative of the project will be required, with authority to approve changes and substitutions.

There is some question of competition between the ASMAR and private contractors. This should be resolved, as well as the question whether the project should act as its own prime contractor or select a local firm (or the ASMAR?) for that role. In view of the large amount of coordination between local efforts and imported (owner-furnished) equipment and supplies, the former seems best.

The three largest general contractors in Punta Arenas are:

1. "JUPEMAR," Juan Pedro Martines. Timber, concrete, and steel construction.

2. Hadley & Compania. Carlos Almeida Justianovitch. General building construction.

3. Carlos McIntire Dagnino, Contractor and Civil Engineer. Has earth-moving equipment. This is the firm we talked to, in the person of Adolpho Rojo Fajardo.

We saw some pretty abominable concrete work in the town. Most of the poor stuff looked fairly old. Prefab metal buildings abound, as does wood construction. The ASMAR has a metal foundry, mechanical and engine shops, a superb diesel shop, a small but well equipped steel fabrication shop able to handle (i.e., bend) up to 3/8 plate by 8' wide, and a shipway for 500-ton vessels. They work equally well with English and metric dimensions, but shop drawings must be in Spanish. The place looks competent, well run, and reasonably busy. It has none of the rag-tag look so common elsewhere in South America. John Spencer's report of our interviews with Quinones and Rojo Fajardo is excellent.

V. REFLECTIONS

The floating hatchery notion does not seem to have survived intact. Instead, two related notions make sense now. The first of these is the barge as transportation, especially for a remote site, but applicable anywhere that water access is easy. Prefabrication and dockside checkout of mechanical units, tanks, parts of buildings, or even entire buildings in Punta Arenas, and delivery by barge, is probably the best choice for economy and reliability because of savings in field mobilization, reduction in number of trades at the site, and the like. The second notion is that structures which are going to be in or near the water in use, such as wharves, raceways, holding tanks, etc., might be incorporated into the barge design so that once the barge has arrived, it can be set on the bottom and turned to its new use. Both of these notions support the goal of portability, without making a portable hatchery design the necessary or obvious choice.

Above all, the choice of a portable hatchery, with its aura of easy recovery from an erroneous site selection, should not form an excuse, either for inadequate study of site conditions or for designing a hatchery before we know where it will be located.

We have already seen, in the case of water color as indicator of water quality for example, that superficial similarity between sites in North and South America does not necessarily mean identity of detail. It may be dangerous to rely solely on such similarities to support a choice of site, species, or method in this project.

In the face of our almost total ignorance of the food web into which we plan to introduce young salmon, it is tempting to say, "It'll take years to get where we know as much about the South as we do about the North, which isn't all that much. So let us bring the salmon and let them show us." This seems somehow wrong, because a few measurements are a whole hunk better than none.

We are all agreed, but I will say it again: We had better have compelling reasons to pick a hatchery location off the mainland.

REPORT OF

Ronald D. Mayo
Kramer Chin and Mayo, Inc.

This report takes the form of a diary on the trip and on the conclusions reached along the way. In general it is chronological but the commentary has the benefit of hindsight, as the text was dictated at the completion of the trip.

April 14, 1976

Left Seattle.

April 15, 1976

Arrived in Santiago at 4:00 p.m. Stayed at the Conquistador Hotel. With me was Harry Senn who traveled from Washington with me. At the hotel we met Colin Nash and John Spencer.

April 16, 1976

Left Santiago at 8:30 a.m., arrived in Punta Arenas 2:30 p.m. Stayed in the Hotel Cabo de Hornos. Met by Guido Celedon.

April 17, 1976

The first site selection team returned on the Lientur from their initial 10-day trip. We met and discussed, in a preliminary way, their findings.

In the afternoon most of the combined site selection teams drove south from Punta Arenas to three separate rivers: Aguafresca, Rio San Juan, and one other. Temperatures on these rivers varied between 5 1/2° to 7° C and pH from 7 to 7.2. The color in all the rivers was a tea color but generally clear. The gradient of the rivers was relatively flat, but construction sites were definitely available. The question of gravity flow to hatchery sites was not resolved.

April 18, 1976

We took the opportunity to walk around Punta Arenas and watch the Easter Military Parade. As military parades go, it was distinctly efficient.

April 19, 1976

Boarded the Chilean Navy Ship, Elicura, to begin the site selection trip. Cruised through the night to the first site as selected by the initial site selection team.

Break in Chronological Narrative

The following is a statement of mission for this facility that served as a basis for my viewing of these sites:

Primary Mission

1. Receive eyed eggs (at proper stage of development), hatch and rear to proper size at proper time.

2. Meet fish release goals at this site and others so as best to ensure a return.

3. Capture adequate numbers of returning adults and spawn successfully.

4. Eye eggs and incubate to hatch.

5. Provide an adequate living and working environment for the staff.

Secondary Mission

1. Collect and summarize site marine and freshwater data as appropriate to primary mission.

2. Search out new planting sites.

3. Optimize production (beyond initial goal) using initial facilities and site opportunities.

4. Support studies of expanded potential (new hatching and rearing units) for the salmon introduction scheme.

Tertiary Mission

1. Support marine biology studies not directly related to salmon.

2. Support other types of scientific study.

3. Provide a human environment to encourage acceptance of long-term staff assignments.

April 20, 1976

Went ashore at first site, Bahia Algo (approximately 71°20' west by 54° 15' south). This site features a lake system (upper lake and lower lake) which flows into a small well protected bay. Flow measurements were made by sectioning the river, measuring the depth at one-meter intervals, and estimating the velocity using a stopwatch and a twig floating at the surface.

The width of the stream at the measurement point was 8.5 meters, average depth approximately 1/2 meter. The estimated quantity of flow was 1.3 meters/second. This assumes that the average velocity was 75% of the surface velocity.

The lower lake was approximately 17 meters (by hand-level) above the saltwater of the bay. The distance was approximately 450 meters. At a point approximately 200 meters from the bay, the stream has a free-discharging waterfall 5 meters high. The rest of the drop was evenly distributed over the length of the stream. The lower lake was approximately 1 1/2 kilometers in diameter. We were not able to reach the upper lake.

The Captain was able to land the ship both to the east and west of the river mouth outlet. He expressed some preference for the west landing.

Suitable hatchery sites are available on both sides of the stream. Foundation conditions consisted of approximately 5 feet of moss under which could be found approximately 9 miles of rock. Construction could probably best be accomplished using a bulldozer to remove the moss and leveling the site with beach gravel and rock.

In moss taken from the bottom of the stream, small insects could be found generally resembling gemarous. On the beach were limpet-like shellfish up to 1 1/2" in diameter and large barnacles typically 4" long. I understand that the barnacles are relative old (12 years ±). This was confirmed several days later when we had them for lunch.

In my view, the site was well suited for the construction of a hatchery facility with the serious reservations of logistics and personnel problems arising from the isolation of the site. The relationship of the lake to the site would suggest that hydroelectric power could be generated, although the quantity would be small and probably not worth the investment as compared to other power sources.

<u>April 21, 1976</u>

This morning we went ashore at a site described as Julio (72° west, 54° 15' south). Bahia Julio was initially reported as possibly being fresh water, as it has a small entrance (and from the initial measurements). At the time of our visit this was not true. We attempted to go up the river to the lake immediately above the stream, but this was not possible. We climbed the mountain and viewed the lake. It was several kilometers across in each direction and approximately 3 meters above the saltwater bay.

We measured the flow by sectioning the river, but tests indicated that there was saltwater intrusion at our point of measurement. After some analysis we estimated that the freshwater stream was approximately 1/2 meter deep with an average surface velocity of .57 meters/second. Based on that, the width of 11 meters and the assumption that the average velocity was 70% of the surface velocity, we arrived at an estimate of 2.5 cubic meters/second for the freshwater flow.

No attempt was made to land the ship outside of the bay and Captain Silva was reluctant to even consider entering the bay.

While it might be possible to tap the freshwater supply by gravity, we could see no appropriate hatchery site. The slopes on either side of the bay are exceedingly steep and (like Bahia Algo) covered with a thick moss which overlays the rock. In my view the site is not especially well suited for a hatchery, both because of its location and the character of its topography.

We left Bahia Julio and went north, stopping to check the glacier on Santa Inez and proceeding through Shag Pass to Bahia Fortescue where we anchored for the evening. While this was not a primary site, we went ashore. I visited the river on the east side of the bay, estimating the flow at 1 meter per second. There were signs of clearing and human activity near the river. In my view this site has modest potential for a hatchery, although no detailed analysis was made. The topography is suitable, the landing ship could probably beach without problems, and it is near a well traveled shipping lane, the Straits of Magellan.

Incidentally, it is said that Magellan slit the throats of two mutineers there; however, the bay was peaceful during our visit.

<u>April 22, 1976</u>

At Bahia Cordes, I went ashore with Spencer and Nash at the outlet of the small lake west of the entrance of Cordes. We measured the temperature at 6.5° C, the width 4.8 meters, and the depth approximately 4/10 meters. We estimated a flow of .54 cubic meters/second using a factor of 75%.

Accompanied by a number of dolphin, we then went into the entrance of Cordes Bay. The bay is approximately 3 miles long with a small sawmill on the west side (we saw other signs of human habitation including fences and shacks on the beach between the stream and the entrance to the bay). As we started north into the bay, the wind rose considerably and by the time we had reached the halfway point, we were in a solid spray and waves a meter high. The sailor operating the motor turned ashore suddenly and we then became aware for the first time that the boat had a foot of water in it and was in serious danger of sinking. As we had no life jackets and nothing but the sailor's shoe to bail with, we encouraged him to reach shore as quickly as possible. We went ashore, bailed the boat out, and considered starting up the bay again. Our purpose for going up the bay was to visit the main river and meet the other party. The sailor informed us he had little gas and we could choose between reaching the river or reaching the ship. We chose to proceed back toward the ship, stopping to profile the ridge between the bay and the lake. The distance from the lake to the bay was approximately 370 meters. The high point of the ridge was 100 meters from the lake. The top of the ridge was 9.5 meters above the lake and 29.2 meters above the bay.

We returned to the ship without sighting the other party. At one point while we were waiting for them, wind gusts locally called williwaws were throwing spray 50 feet in the air from the surface of the bay. On our return to the ship, we asked the Captain to fuel the boat again and send it for the other party in case they were in trouble. He did so. The two boats returned 1 1/2 hours later without special problems. We determined thereafter that boats would not leave the ship without life jackets.

We then proceeded west through the Straits to Jeronimo Canal and anchored for the night at Bahia Henry. Although the cargo lights were on, there was no visual indication of life in the waters of Bahia Henry.

April 23, 1976

The following morning we proceeded to Bahia Condor. The area of our interest is a very well sheltered bay into which drains a large lake called Bottela. The lake is approximately 2 meters above what appears to be the high water in the bay. The water was as clear as any we had seen and on measurement had an approximate flow of 2.3 cubic meters/second. The width of the stream at the outlet from the lake was 16 meters, the average depth approximately 6/10 of a meter, and the deepest point .94 of a meter (2 centimeters above the top of my wading boots). The temperature by thermometer was 6.5° C and by direct emersion somewhat colder; pH was 6.8.

Sailing documents which were consulted suggested that the river flow stopped on occasion, but consultation with people familiar with the lake (at Cutter's Cove) contradicted this.

There were some indications of saltwater intrusion with the presence of clam shells on the bottom of the lake. This could not be confirmed and, if a problem, could possibly be prevented by a low dam. The potential hatchery site is rock overlaid with several feet of moss. This site is accessible both from the Straits of Magellan and from Seno Otway, thus reducing some of the logistics problems. It is approximately 10 miles from the Cutter's Cove copper mine.

In my view this is the best of the sites we visited. The Captain landed the ship to demonstrate the possibility of bringing equipment ashore. Gravity flow could be developed and water quality looked good.

We left Botella and visited the copper mine at Cutter Cove. The Captain had some difficulty making the landing although a site has been prepared. Problems arose primarily because of the heavy currents and the orientation of the site.

We discussed the area with the manager and several others. When the mine is operating, it employs 200 men who work for $2.00 (U.S.) for an 8-hour workday from which they must pay $.30 for food and housing. The mine is a tunnel mine with approximately 6,500 meters developed. The mine has a diesel generator system with about a 14,000 kilowatt capacity; it has an extensive mechanical shop and operates a passenger boat to transport the miners about once a week. The trip to Punta Arenas via Otway Sound is approximately 5 hours on the boat and one hour in a car. There are only several families at the mine. The miners work on a 23-day-on and 6-day-off work cycle.

April 24, 1976

We anchored off Rio San Nicholas; because of heavy winds, there was some uncertainty whether or not we would be able to go ashore. After some discussion, Captain Silva, Guy Rothwell, and I left the ship in the ship's gig. When we got inshore, it was calm and we were able to cross a small bar into the river mouth without problems. We proceeded approximately 2 miles up the river which has a mild gradient and is typically 20 meters wide. The river is in a well established channel and has the appearance not unlike one might expect of a steelhead stream in the lower reaches of Washington. The river was somewhat tea-like in color, temperature about 7° C, and pH near 7.0.

At this point our motor quit and we rowed to the mouth of the river. We went ashore briefly and talked to a fisherman who has a small cabin near the mouth of the river. He said he often catches salmon (we think he means brown trout) in his beach seine.

After unsuccessful attempts to get a boat from the ship, we rowed out to it.

The river is much like other rivers on the Brunswick Peninsula. It would probably make a fair salmon stream and possibly even a good hatchery site. However, anchorage is difficult and exposed and the possibility of obtaining gravity flow of water is low. We then returned to Punta Arenas.

April 25, 1976

We drove to three rivers: Rio Grande, Rio Canelo, and Rio Caleta on the Otway Sound.

The farthest of these, Rio Caleta, is 90 kilometers from Punta Arenas and could almost certainly support a hatchery site, although the road to it is difficult.

In general description of all of the rivers of the plains of the Brunswick Peninsula, it can be said that hatchery development would be possible although the development of gravity flow for water supplies might be difficult. All of these rivers cross high-energy beaches and access to the saltwater would be difficult.

April 26, 1976

We met with various Navy personnel to discuss construction and the capability of the shipyard at Punta Arenas. We also met with a representative of the McIntyre Construction Company of whom we could request both surveys and detailed design services.

Various judgments we made during the trip relative to construction and logistics were generally verified in these discussions.

We returned to Santiago in the evening and the next day met with Chilean government personnel for general discussion of the trip. Returned to Seattle April 27.

Miscellaneous Notes - Not Chronological

1. In discussions at the shipyard, it was suggested that we use 440/110 volts 60 cycle as a basic power criteria. Further, it was suggested that the equipment that would give the best results in terms of service could probably come from the Caterpillar Company (Cummings as an alternate).

2. The hatchery at Coyhaique has houses that are 72 square meters in size. The manager indicated that this is quite inadequate, especially when there are children and they have no other place to play out of the weather.

3. The shipyard can build the large barge hatchery on its existing construction ways. (This is the Alaskan Barge 170' long, 50' wide, and producing 50,000,000 fry.)

4. Cummings is a good alternate to Caterpillar.

5. In proposing construction of the barge, American Bureau of Shipping Classifications should be specified in order for the structure of the barges to be insured.

6. While in the past, liquified natural gas has been cheap in the south of Chile, it can now be delivered to the international market. For that reason, its price will be little different than other energy sources such as diesel and bunker oil. It was suggested to us that since the Navy is a major user of fuel in this area and since they almost exclusively use diesel, our facilities should be based on diesel.

7. In order to establish a better understanding of temperature variations in this area, it would be desirable to have monthly readings of water temperatures of those rivers accessible by car from Punta Arenas. These recordings should include a brief description of the weather during the preceding several days.

8. In discussing the requirements of a service boat for an isolated hatchery, Captain Silva suggested the following as appropriate to isolated sites such as Algo: a diesel-powered boat approximately 25 meters long, 120 tons in size with radar, radio, and a magnetic compass. It would require a pilot, a mechanic, and a sailor to operate it. This is probably not unlike the boat we saw at the copper mine at Cutter Cove.

9. Captain Silva indicated three private ships similar to his LSM that would be available for use. They are the Rio Cisles, the Melinka, and the Akade.

10. The following water sample analysis was requested of the group who are making the samples:

a. Required Metals

Iron	Mercury
Manganese	Cadmium
Zinc	Copper
Lead	Chromium

Analysis after sample is passed through a glass filter.

b. Other

Total Organic Nitrogen (TKN)
Fluoride
Total dissolved solids
Salinity
Total solids

11. Attached are copies of several items which may be of interest.

First is a copy of a label from a can of simulated salmon bought in Punta Arenas, our competition on the local market. It costs between 45¢ and 60¢ a can.

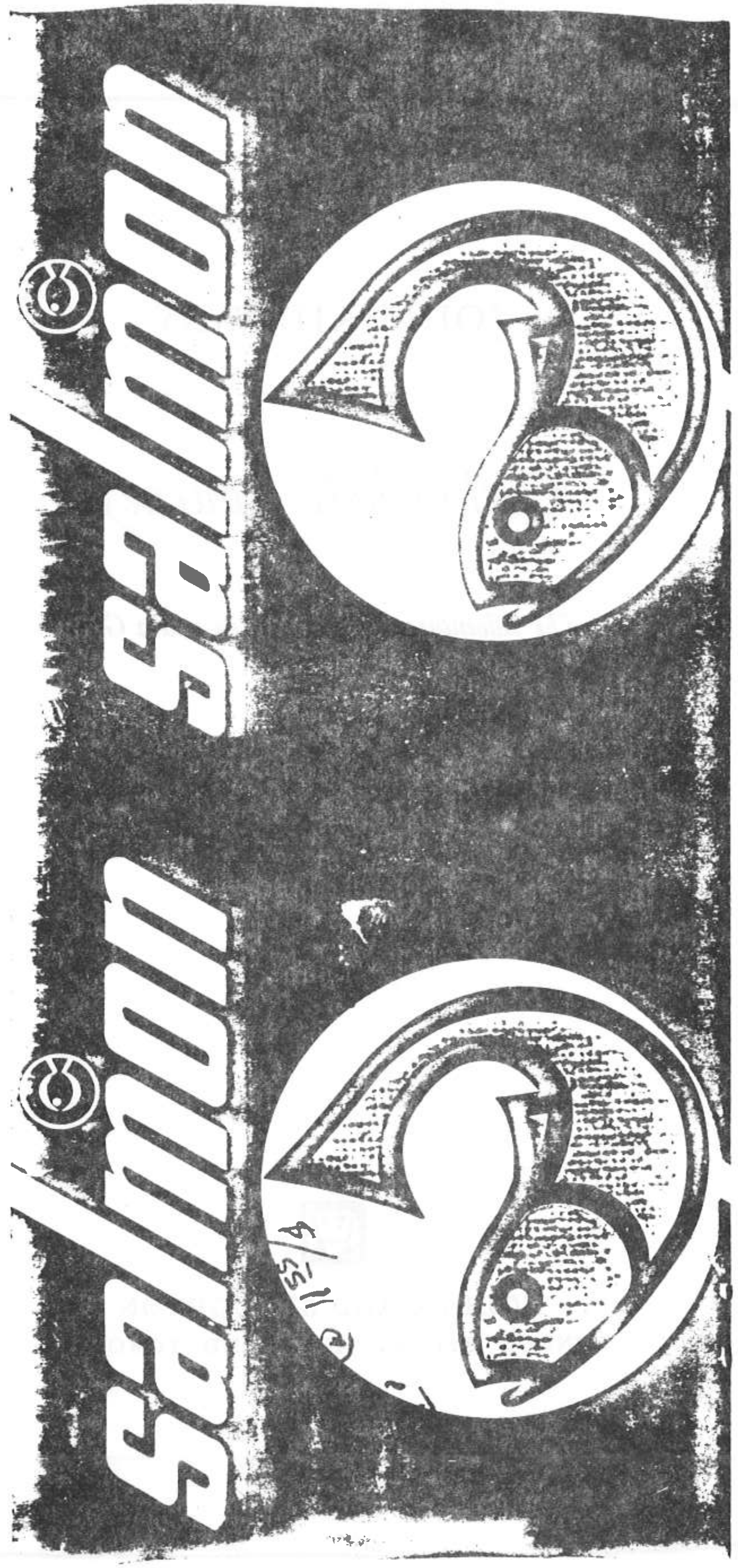
Next is the flyleaf from the Ridgeway book that you may want to read. Following that is a map of his route.

Finally, there is information on temperatures on the Taiya River in Alaska near Skagway and a lake near Seward, Alaska.

12. Type of Facility. Several options were considered, including a barge (similar to Figure 1) or a fixed facility (as defined in Figure 2).

Size. The facility is based on the following production goals:

Species	Release Number	Percent Return	Number Return	Eggs/ Female	No. Adults Needed to Produce Eggs	Surplus
Chum	8,000,000	1	80,000	2,000	12,000	68,000
Pink	1,000,000	1	10,000	2,000	1,500	8,500
Coho	660,000	5	33,300	3,000	660	32,600
Chinook	330,000	2	6,600	4,000	250	6,350


salmon
salmon

JOHN RIDGWAY

Cockleshell Journey

The Adventures of Three Men and a Girl

HODDER AND STOUGHTON
LONDON SYDNEY AUCKLAND TORONTO


ESTANCIA SKYRING
1st BASE
Rio Perez
Rio Pinto
SENO SKYRING
ISLA UNICORNIO
DIADEM MTS
PUNTA LAURA
ISLA LARGA
PUNTA DEL NORTE
MT OLVIDADO
ISLA RUCAS
PORTAGE PASO DEL INDIOS
CERRO ATALAYA
MONTE INACCESSIBLE
ISLA CHANDLER
THE NARROWS
CANAL GAJARDO
2nd BASE
ROUTE UP GLACIER
ICE-FALL
HILL 1189
3rd BASE
LAGO MUNOZ GAMERO
CAMPO NEVADO ICE-CAP
TIDE RALE
PORTALUPPI CAMP
CANAL ALMIRANTE MARTINEZ
BAHIA BEAUFORT
MAGELLAN STRAITS
Kilometres
Miles
SOUTH AMERICA
ARGENTINA
CHILE
70°W
50°S

Taiya River, Alaska

The Taiya River has a drainage basin area of 179 square miles (464 km^2). The length of the river from the gage to the basin divide is approximately 16 miles (26 km) and its channel slope is approximately 190 feet per mile (36 m/km). The mean basin elevation is estimated to be between 4,000 and 4,500 feet (1,220 and 1,370 m). Precipitation in the Taiya River Basin has not been recorded but based on unit runoff, it exceeds that in the Skagway River Basin.

The Taiya River has a mean annual flow of 1,074 ft^3/s (30 m^3/s). Mean monthly flows are based upon gaging station records gathered since October 1969. The highest recorded discharge was 10,100 ft^3/s (286 m^3s), August 6, 1972. However, the flood of September 1967 was estimated to have exceeded 25,000 ft^3/s (708 m^3/s). A minimum flow of 20 ft^3/s (0.57 m^3/s) occurred January 15 and 16, 1972. The Taiya River exhibits large diurnal fluctuations due to glacial melt in the basin.

The Taiya River has two major tributaries, the Nourse River and West Creek. Several smaller streams, including Nelson Creek, also flow into the Taiya River.

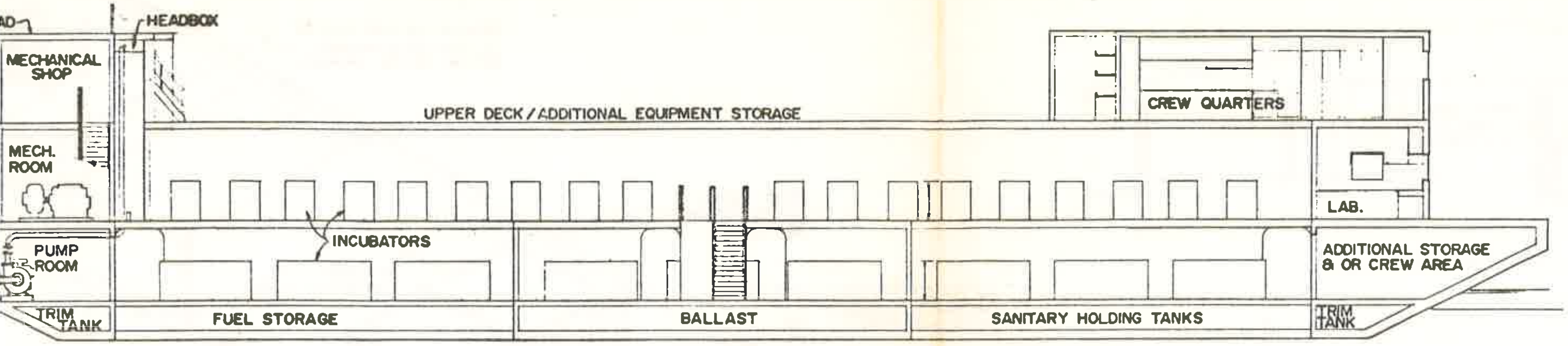
Glaciers in the basin include Saussure and Irene. Saussure Glacier is on the southeast side of Mount Hoffman near the headwaters of the Taiya River, while Irene Glacier is farther downstream, on the north side of Mount Yeatman.

The only lake in the basin is an unnamed one in the Nourse River drainage at a point where the river changes course from south to southeast.

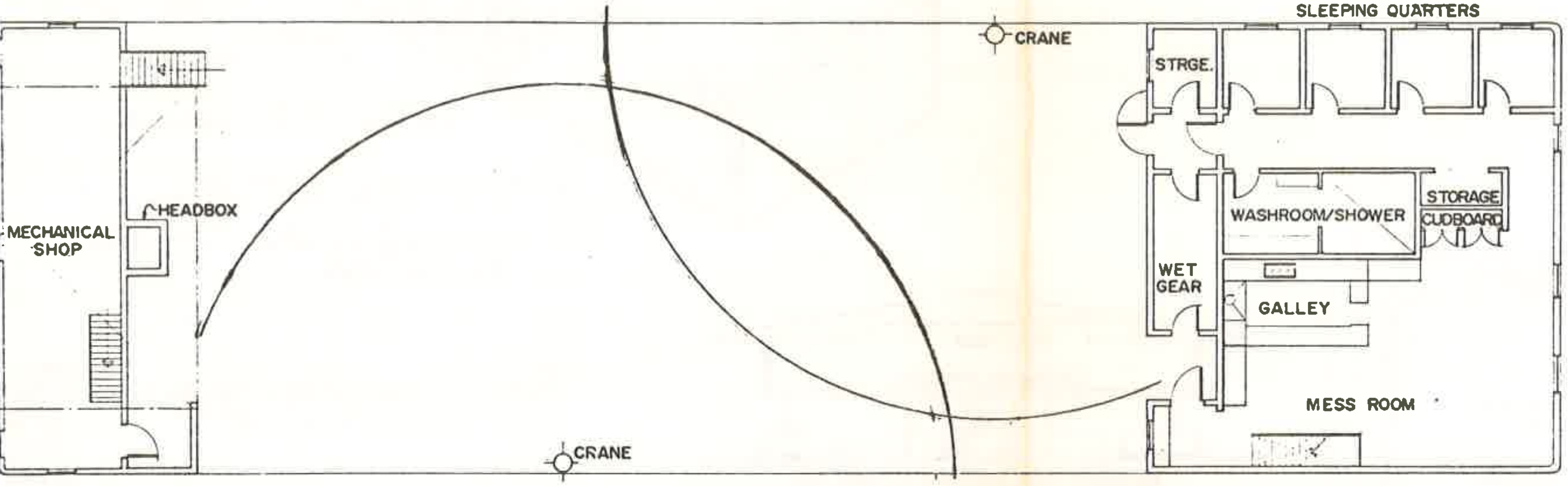
Water quality samples have been collected at various discharges. Like the Skagway River, water from the Taiya River is of excellent chemical quality with concentrations of dissolved constituents far below those maximums recommended by the U.S. Public Health Service (1962).

Because it is also fed by glacial melt, suspended sediment loads (glacial flour) increase during the summer months, when runoff is the heaviest. A few sediment samples have been collected at various discharges in the Taiya River.

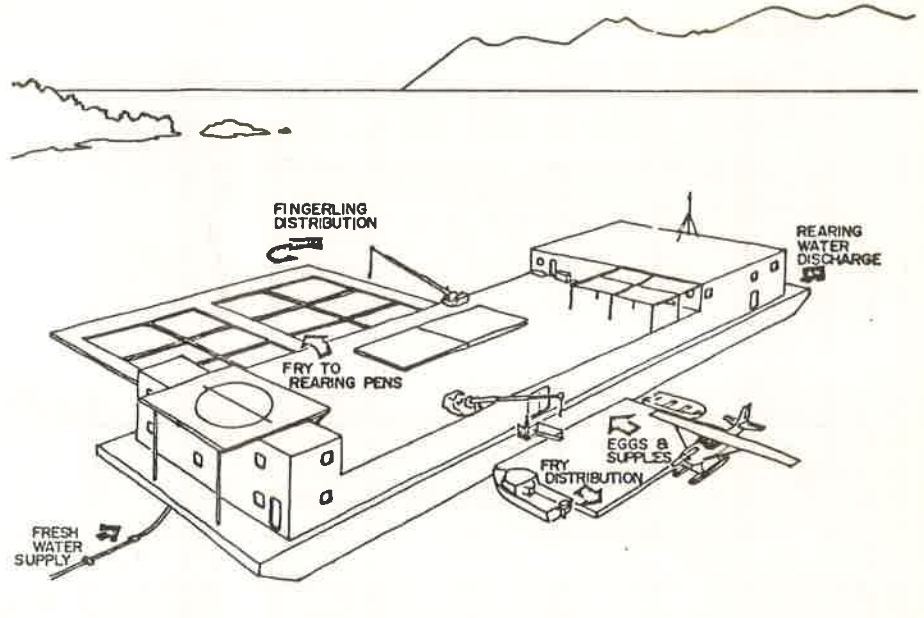
Water temperature data has been collected since June 1971 and is shown in Table 1. Due to recorder malfunction during the winter months, data is available for only part of the 1972 water year, while the 1973 water year data is nearly complete.



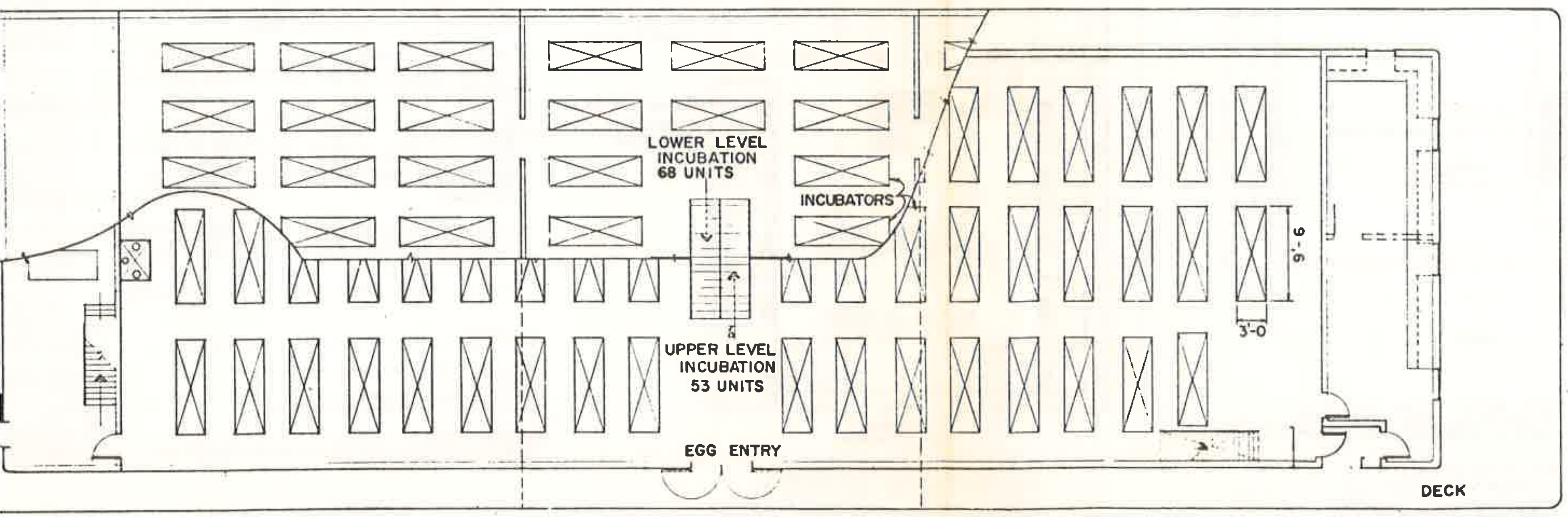
SECTION



UPPER DECK

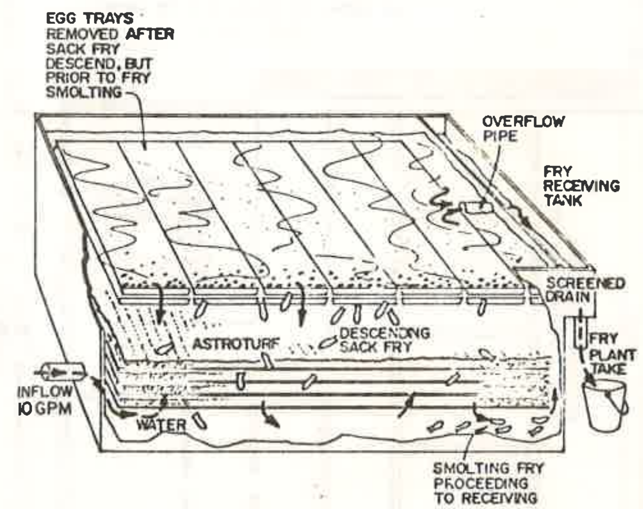


INCUBATION BARGE



INCUBATION CUTAWAY

SCALE 16'



CROSS SECTION INCUBATION UNIT

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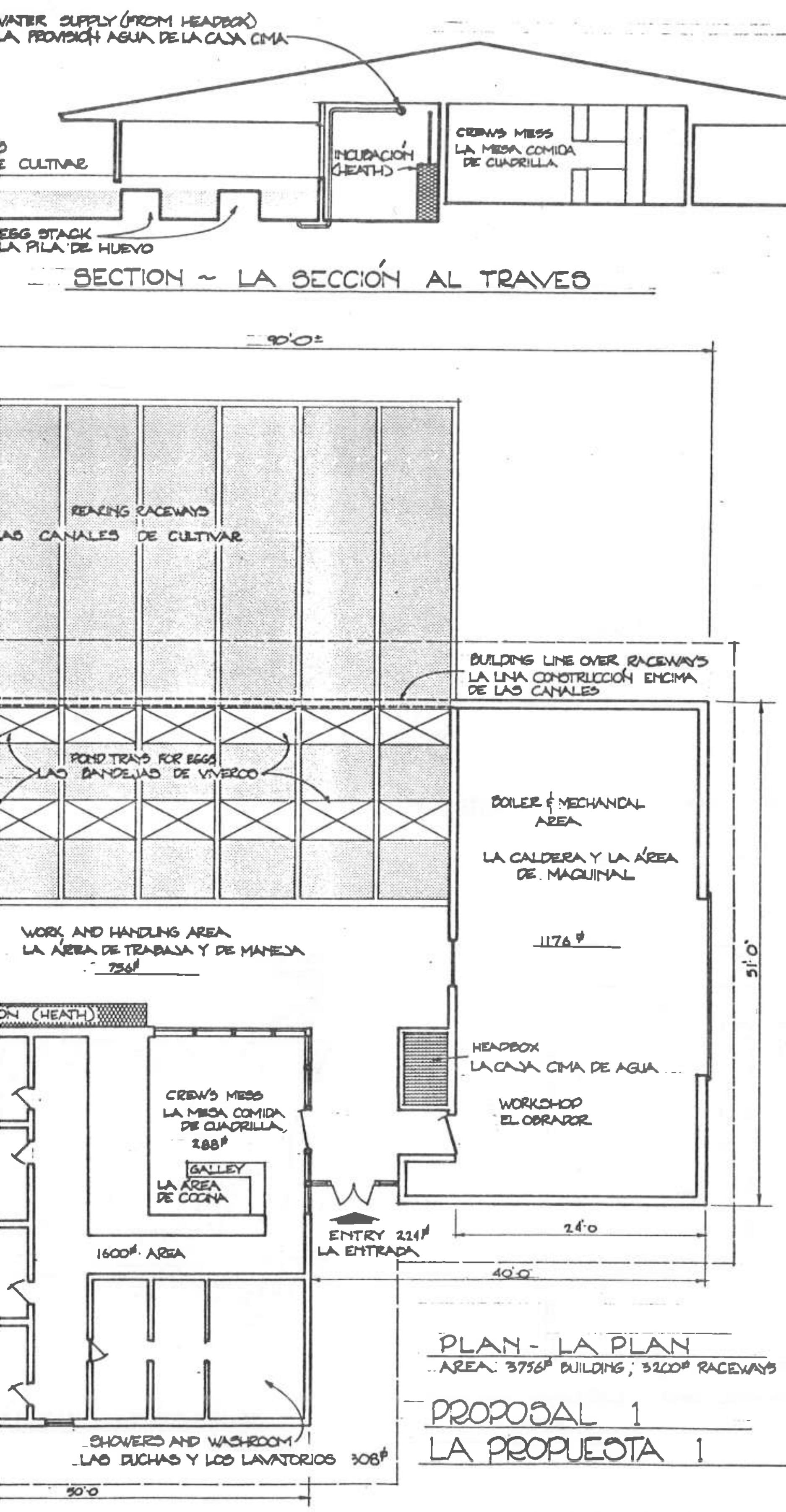
STATISTICS LENGTH : 170' WEIGHT : 1,000 TONS PRODUCTION : 50 MILLION FRY
WIDTH : 50' FLOW : 1,200 gpm/120 INCUBATION UNITS-10GPM/UNIT

CONCEPT DRAWINGS
SALMON EGG INCUBATION BARGE

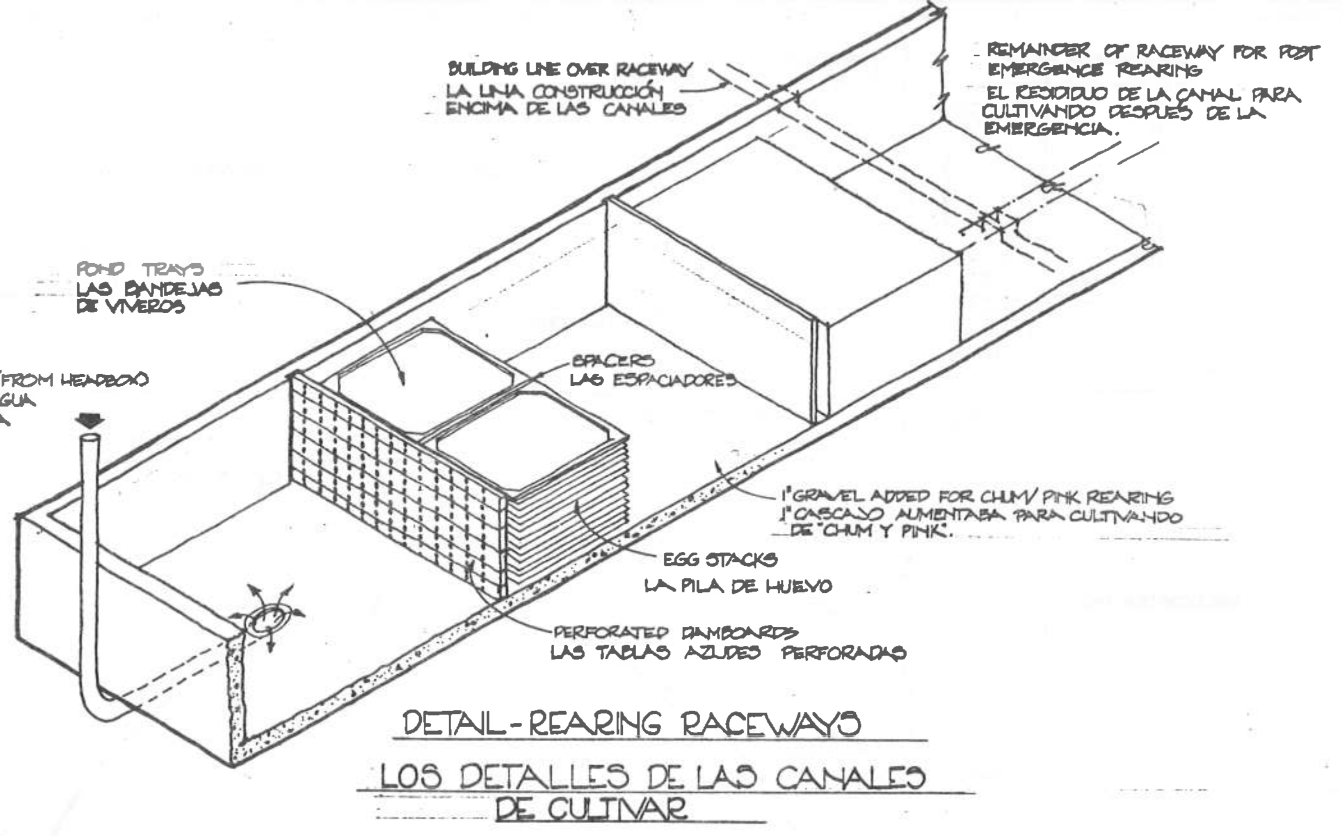
Figure 1



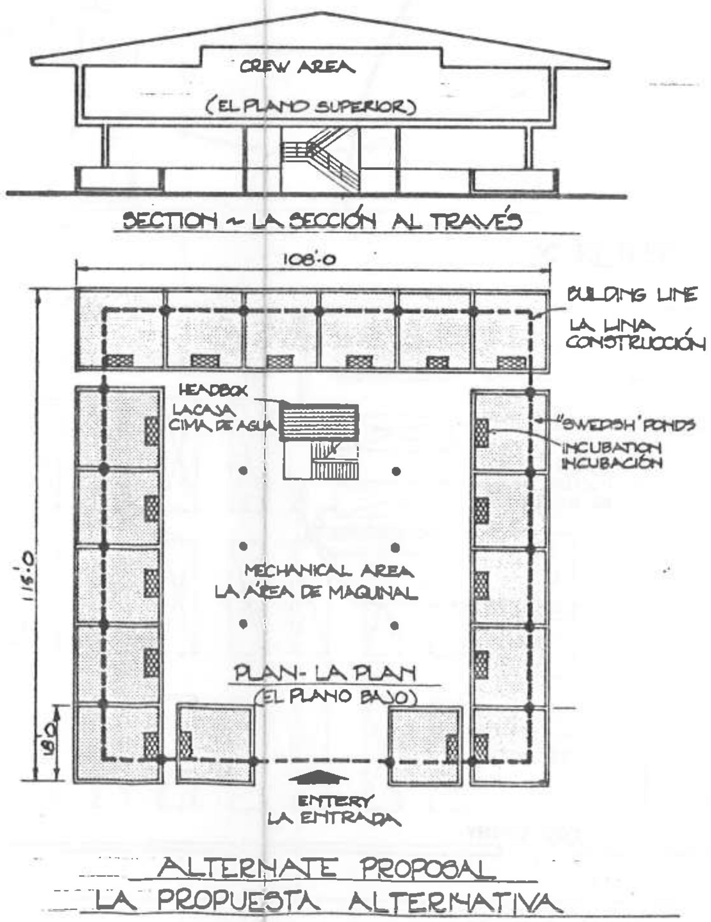
SECTION ~ LA SECCIÓN AL TRAVES

PLAN - LA PLAN
AREA 3756# BUILDING; 3200# RACEWAYS

PROPOSAL 1
LA PROPUESTA 1



DETAIL - REARING RACEWAYS
LOS DETALLES DE LAS CANALES DE CULTIVAR



SECTION ~ LA SECCIÓN AL TRAVÉS

PLAN - LA PLAN
(EL PLANO BAJO)

ALTERNATE PROPOSAL
LA PROPUESTA ALTERNATIVA

RACEWAYS

1. Raceways used for rearing Coho/Chinook following Pink/Chum emergence and emigration. Flows based on incubation at 1.5 GPM/10,000 Eggs = 240 GPM/Raceway. Flows based on rearing at temp = 7°C at peak (Spring) = 225 GPM/Raceway.
2. Trays are of wood or plastic framed with net screening.
3. A continuous cross sectional flow is critical to good survival rates.

MECHANICAL SYSTEMS

Assumptions

a. Water is supplied by gravity and does not need disinfection or filtration.
b. Water for eg trays or raceways not heated.
c. Water for Heath incubators = 200 GPM (757 L/Min) raised 10°F (5.6°F). It is assumed that this requirement for heated water will last four months and that there will be no other requirement before or after this.
d. Building will be heated for eight months per year.

Equipment

a. Boiler - 2, 30 Boiler horsepower 80% efficient and heat exchange (1,004,370 BTU/hr = 1.06 x 10^9 Joules/hr). Heat exchanges to be automatically controlled for proper heat output. Either boiler can take the entire hatchery heat requirement.
b. Generator - 3, 50 Kilowatt units, one to be running, one to be alternate, one to be for repair. Each unit can take entire load of hatchery. Cooling radiators to be outside building.
c. Aerators - fixed in headbox to deaerate water after heating.

Fuel Storage

Boiler, 30,000 gallon, entire four month requirement.

Generator, 20,000 gallon, six month requirement.

CONSTRUCTION

Building any available materials.
Raceways, concrete or fiberglass (probably precast).

ALTERNATE PROPOSAL

The alternate proposal would utilize the EHOS "Swedish pond" which would be assembled on site.

LAS CANALES

1. Las canales usaban de cultivar Coho/Chinook siguiente la salida y emigracion de Pink/Chum. Las torrentes basadas en la incubación a 1.5 GPM/10,000 huevos = 240 GPM/la canal. Las torrentes basadas en cultivando a la temperatura = 7°C a la cima (primavera) = 225 GPM/la canal.
2. Las bandejas son de madera o plástico fabricados con el red mampara.
3. Una torrente continuó seccionario contrario está critico a la buena proporción supervivencia.

LA SISTEMA MECHANICO

Las asunciónes

a. El agua está suplido por la gravedad y no necesita la desinfección o la filtración.
b. El agua para las bandejas de huevos o las canales no estan calentados.
c. El agua para las incubadoras Heath = 200 GPM (757 L/Min) levantado 10°F (5.6°F). Está asumido que este requisito para el agua calentado continuaró para cuatro meses y que no estarán otros requisitos antes de or después de este.
d. El edificio levantará para ocho meses para año.

El equipo

a. La caldera - 2, 30 la caldera caballo de fuerza 80% eficiente y el cambio calor (1,004,370 BTU/hr = 1.06 x 10^9 Joules/hr). Los cambios calores estar gobierno automático para la particular capacidad calor. Cada una caldera puede tomar todo el requisito calor de la incubación.
b. El generador - 3, 50 las unidades kilovatios, una estar corriendo, una estar alternativa, una estar para reparar. Cada unidad puede tomar la carga entera de la incubación. Las radiadores atemperantes estar externo del edificio.
c. Los aparatos para la aeraciónes - fijados en la caja cima para deventilar el agua después de levantando.

El almacenaje de combustible

La caldera, 30,000 galones, el cuatro mes requisito entero.

El generador, 20,000 galones, el seis mes requisito.

LA CONSTRUCCIÓN

El edificio-cualquieras materiales aprovechables.
Las canales-concretos o fibreglas (probablemente pre-amoldar).

LA PROPOSICIÓN ALTERNATIVA

La proposición alternativa utilizában el EHOS "Swedish pond" que había congregado en el sitio.

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CONCEPT DRAWING - MULTI-SPECIES INCUBATION & REARING FACILITY

EL DIBUJO CONCEPTO - LAS MULTICLASES LA INCUBACION Y LA FACILIDAD DE CULTIVAR

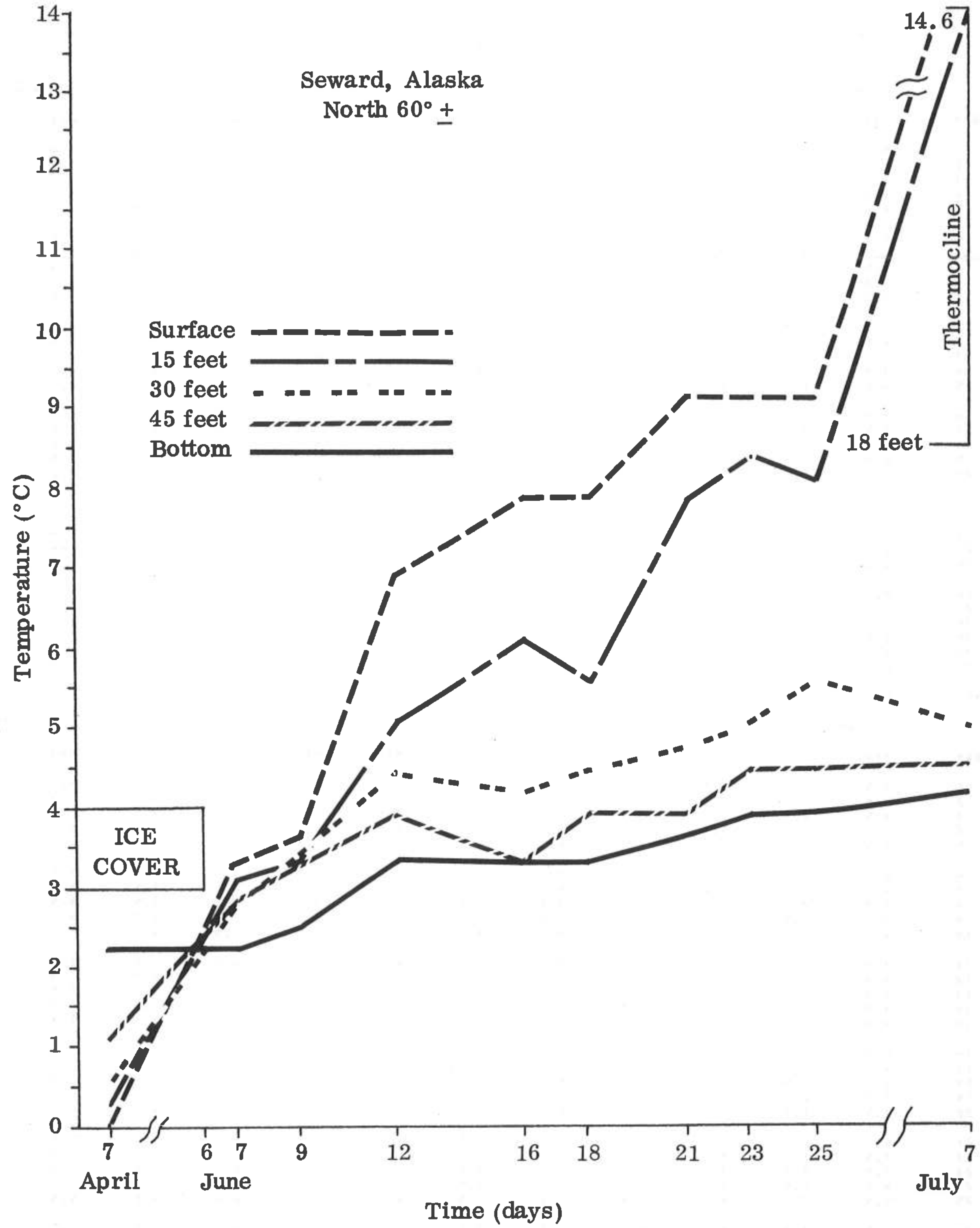
Figure 2

Table 1

TEMPERATURE (DEG. C) OF WATER, WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973

DAY	OCTOBER MAX	OCTOBER MIN	NOVEMBER MAX	NOVEMBER MIN	DECEMBER MAX	DECEMBER MIN	JANUARY MAX	JANUARY MIN	FEBRUARY MAX	FEBRUARY MIN	MARCH MAX	MARCH MIN
1	5.5	3.5	2.5	1.5	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0
2	3.5	3.0	2.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.5	2.5	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
4	3.5	2.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0
5	4.0	2.5	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0
6	5.0	3.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
7	5.0	3.5	1.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
8	3.5	3.0	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
9	3.0	2.0	2.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
10	2.0	0.5	2.5	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0
11	3.5	2.0	2.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
12	4.5	3.5	2.5	2.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.5
13	2.5	0.5	2.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
14	3.0	1.5	2.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
15	4.0	2.5	3.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
16	4.5	4.0	3.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	---
17	3.5	3.0	2.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	---
18	4.0	3.5	1.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	---
19	4.0	1.5	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	---
20	2.0	0.5	1.5	0.0	0.0	0.0	0.5	0.0	0.5	0.5	0.0	---
21	2.0	0.0	2.5	1.0	0.0	0.0	0.5	0.0	0.5	0.5	---	---
22	3.5	1.5	2.5	1.5	---	---	0.5	0.0	0.5	0.0	---	---
23	3.0	0.0	2.0	1.5	---	---	0.5	0.0	0.5	0.0	---	---
24	3.0	0.5	2.0	1.5	---	---	0.0	0.0	0.0	---	---	---
25	3.5	1.0	2.0	1.0	---	---	0.5	0.0	0.0	---	1.0	---
26	2.0	1.0	2.0	1.0	---	---	0.5	0.0	0.0	0.0	1.0	0.5
27	2.0	0.5	1.0	0.0	---	---	0.0	0.0	0.0	0.0	2.0	0.5
28	1.0	0.0	1.0	0.0	0.5	0.5	0.5	0.0	0.0	0.0	2.0	0.5
29	1.5	0.5	1.5	0.5	0.5	0.0	0.0	0.0	---	---	2.5	1.0
30	3.0	1.5	0.5	0.0	0.5	0.5	0.5	0.0	---	---	3.5	1.0
31	2.5	2.0	---	---	0.5	0.5	0.5	0.0	---	---	3.0	---
MONTH	5.5	0.5	3.0	0.0	0.5	0.0	0.5	0.0	0.5	0.0	3.5	---

DAY	APRIL MAX	APRIL MIN	MAY MAX	MAY MIN	JUNE MAX	JUNE MIN	JULY MAX	JULY MIN	AUGUST MAX	AUGUST MIN	SEPTEMBER MAX	SEPTEMBER MIN
1	3.5	1.0	5.5	2.0	8.5	2.0	7.0	3.5	6.5	3.0	6.0	4.0
2	2.0	0.5	6.5	2.0	6.0	4.5	7.5	3.5	5.5	3.0	5.5	4.0
3	3.5	1.5	7.0	1.5	7.0	3.5	7.5	3.5	4.5	2.5	7.5	4.5
4	4.5	1.0	5.5	1.5	7.0	3.5	8.0	3.5	6.0	2.5	6.5	4.0
5	4.5	0.5	6.5	2.0	6.5	4.0	6.0	3.5	5.5	2.5	6.5	4.5
6	4.5	0.5	8.0	2.0	8.5	3.5	7.0	3.5	5.0	2.5	6.5	4.5
7	4.5	0.5	6.5	2.5	8.0	4.0	4.5	3.5	4.5	3.5	5.5	4.0
8	3.0	2.0	6.5	3.0	7.0	3.5	5.5	3.5	4.0	2.5	5.5	4.0
9	3.5	1.5	7.0	2.0	7.5	4.0	5.5	3.5	7.0	4.0	6.0	5.0
10	4.5	1.0	7.5	3.0	8.5	4.0	7.0	3.5	6.0	4.0	7.5	4.5
11	5.5	0.5	7.5	2.5	9.0	3.0	4.5	3.5	6.0	4.0	8.0	---
12	6.5	1.0	6.5	2.0	7.0	6.5	5.5	3.5	6.0	4.0	7.5	3.5
13	6.0	1.0	7.5	3.0	4.5	3.5	6.0	3.0	5.5	4.0	7.5	---
14	5.5	1.0	9.5	3.0	5.5	3.0	6.0	3.0	6.5	4.0	7.0	3.0
15	4.0	1.5	6.0	2.5	7.5	3.0	6.0	3.5	7.0	4.0	7.5	3.0
16	6.0	0.5	6.0	1.5	7.5	3.0	7.5	3.5	7.0	4.0	7.0	---
17	4.0	0.5	5.0	2.0	8.0	4.0	7.0	3.0	8.5	4.0	7.0	---
18	4.5	1.5	4.5	2.0	5.5	4.0	5.5	4.0	7.5	---	7.0	2.5
19	7.0	2.0	7.5	2.5	7.5	3.5	6.5	3.0	8.5	4.0	6.5	2.5
20	3.5	1.5	5.5	3.0	8.0	4.0	6.0	3.5	8.5	4.0	6.5	---
21	4.5	1.0	8.0	2.0	5.0	3.5	4.5	3.5	8.0	4.0	5.5	4.5
22	7.5	1.5	8.0	3.0	7.5	3.5	5.5	3.5	6.0	4.0	6.0	4.0
23	7.0	0.5	7.5	2.0	5.0	3.5	5.5	3.0	6.0	4.0	6.0	---
24	6.0	2.5	7.0	4.0	7.0	4.0	4.5	3.0	6.0	4.0	6.0	3.0
25	5.5	2.0	8.0	3.5	7.5	3.5	6.0	3.0	6.0	4.0	5.5	4.0
26	4.5	2.0	8.5	2.5	7.5	3.5	5.5	3.5	6.5	4.0	5.5	4.0
27	4.5	1.5	7.0	3.0	7.0	3.5	7.0	3.5	6.0	4.5	6.0	4.0
28	4.5	1.0	8.5	3.5	7.0	3.5	6.0	3.5	6.0	4.0	6.5	4.5
29	5.5	2.0	7.5	3.0	6.5	4.0	5.5	3.5	6.5	4.0	6.0	---
30	4.5	3.0	8.5	3.5	7.0	3.5	5.0	3.0	7.5	4.5	5.0	---
31	---	---	9.5	3.5	---	---	6.0	2.5	7.0	4.0	---	---
MONTH	7.5	0.5	9.5	1.5	9.0	2.0	8.0	2.5	8.5	2.5	8.0	---



BEAR LAKE WATER TEMPERATURES (°C) PER 15-FOOT DEPTH INTERVALS, APRIL 7 TO JULY 7, 1972

REPORT OF

John B. Spencer
International Aquaculture Consultancy

1. INTRODUCTION

In the brochure prepared for ICLARM in March 1976 by Drs. Nash, Joyner, and Mayo, the goals of a program whose initial aim is to increase production of fish from the Southern Ocean by controlled introduction of salmon stocks into the channels of Southern Chile are defined.

The strategy for attainment of the program goals are set out as phased sub-projects to be conducted in the years 1975-1986. The Phase I preplanning investigations were completed in 1975 and documented under the aegis of Seeding the Southern Ocean with Salmon publications prepared by the first two abovenamed authors in their capacities as Project Coordinator and Project Director. Now, at the commencement of Phase II of the program, the important task of searching out an optimum salmon hatchery site has begun. This report is reflective of one aspect of that search.

In the period April 6-17, 1976, a primary site-selection team comprising T. Joyner, P.K. Bienfang, C.V.W. Mahnken, and G.N. Rothwell undertook to investigate potentially suitable areas of the South Patagonian peninsula and Estrecho de Magallanes. Their efforts were facilitated by close cooperation with representatives of Chile's Servicio Agricola y Ganadero, the Instituto de Fomento Pesquero and, in its seaborne aspect, by the Chilean Navy ship "Lientur".

From a large number of sites viewed, a preliminary "shortlist" of preferred sites was drawn up. These then became the focus of detailed evaluation in the period April 17-27 by a followup site-selection review team: Messrs. C.E. Nash, P. Aguilera M., G. Celedon C., R.D. Mayo, H.G. Senn, and J.B. Spencer. (G.N. Rothwell performed a valuable liaison function, serving on both primary and review teams.) This party's seaborne search was carried out aboard the Chilean Navy's LSM "Elicura", commanded by Captain Carlos Silva, in the period April 19-24. Overland surveys of potentially useful river sites on the Brunswick Peninsula south and west of Punta Arenas were carried out April 17 and 25.

In addition to the site surveys, during the period April 17-27, discussion group meetings and interviews with Chilean Navy agencies, civil engineering contractors, and equipment suppliers were held. All are reported chronologically in Section 2 of this report. Those parts dealing with the site surveys attempt to record physical characteristics and data observed while making analyses and conclusions about their fitness as hatchery sites.

Section 3 aims at an overview and analysis of factors germane to selection of a hatchery site in undeveloped and remote regions. It expresses this engineer/author's feelings about the sites visited, the support needed and available, and the probable problems to be overcome. In short, it tries to transcend the biological aspects of successful hatchery operations and focuses attention on the human and engineering resources which will bear on the prospects for success or failure of the project. Finally, it draws certain conclusions and makes some tentative recommendations for the charting of future policy.

As brief appendixes to the report, some illustrative cartographic and meteorological data have been included, together with a list of photographic slide material taken at the several sites visited.

2. CHRONOLOGICAL REPORT

2.1 Saturday, April 17--Brunswick Peninsula, south of Punta Arenas

Overland survey of two river sites; see reports by others. The author, smitten by a 24-hour alimentary tract infection, was unable to participate.

2.2 Sunday, April 18: Punta Arenas, Hotel Cabo de Hornos

No site surveys were carried out this day but in an afternoon debriefing meeting, members of Dr. Joyner's primary site-selection team gave a most useful review of the many sites they had visited April 6-17. Suggested criteria to be used by the second site-selection review team in evaluating four "preferred" sites were established. The four sites in question were:

1. Rio 'Algo' (an unnamed, hence 'something', river between Senos Prat and Mercurio on Canal Cockburn)

2. Rio Julio (by Caleta Julio) on Canal Barbara

3. Bahia Cordes on Estrecho de Magallanes

4. Lago la Botella and Lago Titus, on Estero Condor of Estrecho de Magallanes.

It was agreed at the meeting that if time permitted, secondary subordinate sites should be viewed. In fact, two such sites were added at Bahia Fortescue and Bahia San Nicola. It was further agreed that to facilitate more detailed data gathering at the selected sites than had been practical for the first party, the second should have benefit of Guy Rothwell's services in a bridging or liaison capacity. In the event, his prior knowledge of the sites visited proved invaluable, particularly since different Chilean Navy vessels and different captains and crews were used by the two parties.

It was also agreed that in addition to physical site data relating to stream flow rates, water temperature, salinity, and pH, there would be merit in taking bottled samples of water at each site. Subsequently, replicated analyses of these samples for chemical and metallic content would be carried out in both Chilean and U.S. laboratory facilities.

2.3 Monday, April 19: Punta Arenas and at sea on Estrecho de Magallanes

After a morning spent getting equipped and organized for its tour of sea duty, the second party went aboard the Chilean Navy LSM "Elicura" in the early afternoon. "Elicura's" Captain Carlos Silva put to sea at 1500 hours and proceeded southward via Seno Magdalena for the balance of the day, sailing toward her first site objective, the site called "Algo".

2.4 Tuesday, April 20: Site 1 - Rio Algo on Canal Cockburn, south of Estrecho de Magallanes and between Seno Prat and Seno Mercurio, Lat. 54° 20'S, Long. 71° 30'W.

Observations

"Elicura" moored offshore at Algo at approximately 0730 hours and survey parties went ashore in the small aluminum dinghy made available by G. Celedon (IFOP) and a clinker-built ship's longboat. While the parties were ashore, Captain Silva demonstrated the feasibility of beaching a shallow-draft LSM-type vessel on a beach to the right, facing the shore, not only of Rio Algo but also of a tongue of land perhaps some 2 hectares in area. Here, a shelving beach facilitates bringing equipment and material ashore for site development.

Later, in the afternoon, Elicura sought out a second anchorage, this time well to the left side of Algo's confluence. Here advantage lay in shelter secured behind a chain of small islands; disadvantage lay in the fact that while Elicura could beach her ramp quite readily, the shoreline was boulder strewn and gave way abruptly to a bank rarely less than 2 meters high. The bank was broken by 10-12 small feeder streams; flows were low, of the order of 0.33-0.5 cfs, and temperatures $\sim$5° C. Existence of this bank and the fact that its top was scrub, shrub, and tree covered could make the landing of equipment and materials more difficult here. Its irregularity and tendency to climb fairly steeply close in to the shoreline suggests that its development as a hatchery site might prove expensive.

The beaches on either side of Algo revealed a great abundance of mussels and large barnacles along the exposed shoreline. Large crabs were seen in the deep water from Elicura's deck. However, few birds were seen in the area.

Ashore, the survey parties abandoned efforts to make their way up the River Algo's course, but struck inland on a course roughly paralleling the left bank (facing upstream). The terrain made overland progress difficult. Rough, irregular terrain; soft springy tundra; shrubs, brush, and stunted and dying trees made an ascent to the first (and smaller) of two lakes shown on the chart at the head of Algo difficult. Once there, a data gathering-base was established at the exit stream from the lower lake and some observations made by Messrs. Mayo, Senn, and the author. The lower lake was judged to be approximately 800 meters across to the point at which a stream from the upper lake entered it. The distance from the point of exit of the stream from the lower lake to its confluence with the sea was estimated to be 400-500 meters.

Attempts at fishing the small lower lake went unrewarded. There was almost total absence of bird life in the area. Benthic organisms were found under rocks at the edge of the lake and in the exit stream.

Submerged mosses (suggestive of fluctuating water flow through the various seasons of the year) also yielded freshwater shrimp-like amphipods and a very few insect larvae similar in type to the Mayfly.

Approximately 120 meters downstream from the lake data-gathering base there is a waterfall some 1.5 meters high; a further 180 meters or so downstream a second fall perhaps 5 meters high was found.

Measurements of stream velocity and depths across a single profile just below the lake indicate a stream flow of approximately 1.25 cubic meters per second (M^3/sec) (45 cfs). Stream temperature was approximately 6° C and its bed uneven and covered with rock rather than gravel.

Analysis and Conclusions

Given that results of tests of water samples from this site prove satisfactory, stream temperatures and flows appear sufficiently suited to the operation of a hatchery to consider conducting a program for year-round measurement of all relevant parameters.

The fact that Elicura could go close inshore at two locations to both right and left of Algo's confluence suggests that offloading of materials and supplies and such earth-moving and construction equipment as would be necessary for construction of a hatchery, raceways, and personnel support facilities would be feasible.

The terrain on the left of Algo's confluence, while unlimited essentially in its shoreline length, had some depth limitations. Furthermore, it appeared to the author to be so rough and undulating as to present considerable, though not insuperable, construction problems. Existence of the 2-meter-high bank might inhibit offloading and site development here.

A preferred hatchery site seemed at first evaluation to be the 2-hectare flattish tongue of ground on the right bank of the stream looking upstream. This land area could readily accommodate a hatchery geared to the 10-20 million egg and smolt production envisaged for this project; its configuration would also lend itself to construction of an integrated raceway, adult holding, juvenile rearing, and wild-stock trap complex of facilities. Its physical relationship to the stream and the 5-meter-high falls would ensure adequate water supply under gravity-fed conditions.

The tongue of land is probably large enough to permit construction of personnel quarters and support facilities adjacent to the hatchery complex. Alternatively, if expediency decreed, homesites could readily be found along the adjacent bayshore to the left or right of the hatchery tongue.

Assuming that biological factors at the Algo site are suited to a salmon hatchery operation here, then physical conditions at the site would not preclude its development in engineering terms and at reasonable cost. However, the logistics of developing, supplying, and servicing this site would, in the author's opinion, require that it be relegated to a very low position of priority. Furthermore, the sense of isolation at the site would probably render it difficult to contract the services of suitably qualified and adequately motivated personnel to operate the hatchery successfully on a year-round basis. This thesis is common to most of the sites visited by Elicura and is developed in Section 3.2.2.

2.5 Wednesday, April 21: Site 2 - Rio Julio (by Caleta Julio) on Canal Barbara, south of Estrecho de Magallanes, Lat. 54° 12'S, Long. 72° W.

Elicura weighed anchor and departed Rio Algo at approximately 1500 hours on April 20. She sailed through Canal Cockburn to Canal Barbara and made a sheltered anchorage in an island lee by 1930 hours. The following morning, April 21, Elicura's journey resumed at approximately 0600 hours and by 0700 hours she had reached her second objective, an anchorage at Site 2, Rio Julio.

Observations

Two survey parties went ashore around 0830 hours again using the 14-foot aluminum IFOP dinghy and the smaller of two ship's longboats. While the survey parties were ashore, Elicura's Captain Silva took soundings through the long narrow approach lagoon at whose upper end there entered a good-sized stream which was fed from an inland freshwater lake.

The approach lagoon was some 800 meters long and perhaps 400 meters at its widest point; its entrance was very narrow but by Captain Silva's reckoning proved to be not less than 7 meters deep. Messrs. Nash, Mayo, Celedon, Senn, and Spencer, finding the streambed irregular and difficult to traverse and hampered by the water depth and rate of flow, struck inland and overland to make for the head lake, perhaps some 800 meters distant. Underfoot conditions were extremely difficult. The lagoon frontage comprised nearly everywhere a rocky beach only a meter or so in depth beyond which a low scrub and tundra-covered bank 1-3 meters high confronted the would-be explorers. The ground rose steadily and in places extremely sharply so that ingress became more a matter of climbing than of walking.

From an elevated position some 500 meters inland and still some 300 meters from the inland freshwater lake, the members of the survey party made observations and formulated some opinions about this site. It was generally agreed that this was extremely difficult terrain to contemplate driving any sort of road system through. The lake was estimated to be of the order 1, 000 meters long by 800 meters wide. There was a notable absence of bird life in its vicinity.

Returning to the lagoon shore, some physical data were collected at the stream's confluence with the finger-like access lagoon. Here, the stream was identified to have an upper (0.3 meters deep) layer of fresh water flowing at an estimated 2.4 M^3/sec (72 cfs). Under this layer, salinity was measured at 28 ppt.

As mentioned earlier, access to the upper (freshwater) regions of the stream was difficult but in its lower reaches, the water appeared clear and no great quantities of gravel were observable in its rock-strewn bed.

In the subliteral levels of the lagoon adjacent to the stream, there was no evidence of marine life in any observable form and mussels, clams, and barnacles were notably absent.

Analysis and Conclusions

As at Site 1, water temperature and flow appear adequate for the purpose of our intended hatchery scheme, given that water sample analyses also prove favorable.

However, from an engineering standpoint, the logistics and economics of site development promise to be considerably less attractive than at Site 1, Algo. Other factors such as the absence of avian and marine life may not augur well at this site.

An even greater sense of confinement and remoteness might well be shared by hatchery operating crews and their families. In the author's opinion, one would need to be a desperate masochist to select Julio for this project's purposes. However, if the decision to operate a hatchery at this location were to be made, the difficulty and cost of developing the site conventionally would, in the author's view, justify considering adoption of the floating hatchery concept here.

<u>April 21 - Secondary mission to Bahia Fortescue</u>

After weighing anchor and departing Caleta Julio, Elicura sailed through Canal Barbara and made anchorage in the early evening at Bahia Fortescue.

Here, while Elicura stood well offshore, the landing of a survey party in the aluminum dinghy was rendered easy by shelving beaches of fine sand and no rock. An abundance of seashells littered these beaches which flank a small stream across whose entrance a sandbar presented a hazard to all but shallow-draft dinghies at all states of tidewater.

The stream itself has a rocky base and could be navigated by small boats only for a matter of 80-100 meters or so. Fairly dense thickets flank the stream; above the 80-meter point, fallen trees and overhanging branches made further ingress difficult even on foot. Water depths in excess of 1 meter discouraged this mode of penetration. There was no indication that the stream was flowing from ground whose elevation would lend itself to a gravity-flow hatchery system. The site was accordingly classified as having inadequate potential for the project's purposes and no plans for a followup survey and data-gathering visit the following day were made.

With some slight difficulty, the sandbar across the mouth of this first stream was negotiated and a subsidiary survey mission launched with a skeleton survey party to investigate the potential of a second stream which enters the marine lagoon at its extremity some 1,200 meters distant. Although well into the center of the lagoon channel, the fortuitous presence of some wading birds gave clear indication that the lagoon was shallowing rapidly. Accordingly, since the evening light was also failing rapidly, the attempt to visit the second stream was aborted and once aboard Elicura, agreement was reached that this stream site also could hardly justify a followup visit for data gathering on the following morning.

2.6 <u>Thursday, April 22: Site 3 - Bahia Cordes</u> on Estrecho de Magallanes, Lat. 53° 43'S, Long. 71° 57'W.

First light on April 22 saw Elicura anchored and survey parties ready to evaluate sites in this region. From Elicura's mooring well offshore, two survey parties set off in the early morning hours to fulfill their mission. A party comprising Messrs. Rothwell, Celedon, Aguilera, and Senn took the aluminum dinghy and headed straight for the sandbar entrance from Bahia Cordes to the long finger-like marine lagoon whose feeder stream at its remote extremity formed the major focus of this site. The second party, Messrs. Nash, Mayo, and Spencer, undertook a secondary mission to investigate a small stream which flowed into Bahia Cordes 1,200-1,500 meters east of the entrance to the lagoon. The smaller of the two ship's dinghies was used for this mission. An Elicura crewman served as helmsman.

Observations

Bahia Cordes has extensive kelp beds. There was much evidence of marine life; shellfish, dolphins, and sea birds were present in large numbers. In general, the beach at Cordes shelved gently but was rocky and difficult to negotiate, even in a small boat. However, the rocky areas were interspersed with sandy stretches paralleling the shore and in evidence for the first time at any site so far visited were signs of human habitation. At the point where the stream entered the bay, on the left bank facing upstream, stood a small shelter which showed recent signs of occupancy. Human and canine footprints of recent origin were also in evidence in the sand.

The stream water suffered a peaty discoloration, being the color of weak tea. Rocks lifted from the streambed revealed a number of life forms--snails, worms, etc.--but in small numbers. Measurements and physical data taken at the stream site showed: water temperature 6.5° C; flow rate approximately 0.54 M^3/sec (~18 cfs). Water samples taken for subsequent analyses were in bottles numbered P1664, P1056, P1850, and 174.

The Elicura helmsman returned for the small shore party in approximately one hour's time at 0830 hours and proceeded west along the bay shore toward the entrance to the finger lagoon. While there was some indication of shallowing water at the bar entrance to the lake, a crude depth check carried out using the boat's oar was unable to find bottom. Depth soundings from the chart of this area (see Appendix I) revealed water depths along the lake shore varying from 9 to 23 meters. The center channel is assumed even deeper.

Before the head end of the lake was reached, stiffening breezes and lopping waves resulted in danger of the boat being swamped. Accordingly, the party had to put ashore to bail out the boat and reappraise its plans.

Conditions on the lake remained squally; rain was falling and a series of williwaws shipped waves and spume to an extent which discretion decreed should call off any further attempt to reach the head end of the lake. In any case, the helmsman queried whether the outboard motor gas tank was sufficiently full to accomplish the mission and return to the Elicura.

Accordingly, a secondary mission was agreed upon to traverse the saddle midway down the lake on the right-hand shore (looking to the head) and establish data for a small lake alongside the main one and some 400 meters from it.

The anterior lake had a mucky bottom, registered a temperature of 6.5° C, and hand level sights taken from the saddle ridge showed it to be some 100 meters from the ridge and approximately 9.50 meters below it. Traverses made back to the main lake (a distance estimated to be ~ 270 meters) showed this to be 29.24 meters below the ridge. This established the anterior lake as being at an elevation approximately 19.8 meters higher than the main lake.

Data gathered by the party which had proceeded directly to the head end of the lake to survey the feeder stream revealed the following features:*

1. The stream, which was fairly clear, crosses swampy ground adjacent to the lake.

2. It has a sandy beach at its point of entry to the lake.

3. It has only a thin gravel layer 500 meters upstream.

4. It shows a high tidal zone with evidence of crab shells well upstream of the point at which the stream enters the lake.

5. While no fish were seen, amphipods and numbers of small flies and midges were in evidence.

6. A boulder-strewn rapids exists approximately 1 km upstream from the lake.

7. Flow in the stream was estimated to be around 2.5 M^3/sec (75 cfs).

Lake temperature adjacent to the point of stream entry was measured at 7° C. Its pH was 6.7.

The only other noteworthy features along the lakeside off Bahia Cordes were:

1. The presence of an operating sawmill and dwellings midway up the lake and across from the anterior lake.

2. Evidence of hacienda-type fencing presumably for animal enclosure at the right-hand entrance to the lake near the sandbar.

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*Personal communication from H. G. Senn.

By evidence of the lakehead party who had an opportunity to question an old man at the sawmill, a 16" brown trout had been caught in a gill net set the preceding night. The same man claimed that in the wintertime, both lake and feeder stream freeze over solidly and by his testimony, the winds blowing down its length are "unbearable".

Analysis and Conclusions

Although the channel approach to the finger lake off Bahia Cordes has well documented soundings (see Appendix I), Captain Silva moored Elicura well offshore and uncharacteristically showed no disposition to move closer in to shore. His edited log may give reasons for this and bears close examination on the point.*

Though there are clear indications that this area supports marine life in profusion, the lake access from Bahia Cordes is relatively narrow and the sandbar across its entrance might create ingress problems for other than shallow-draft vessels. However, it appears likely that hatchery sites could be developed at the head end of the lake served by the stream; equally, a hatchery might be located on the right-hand shore utilizing gravity-fed water from the lake. If water quality from the stream and anterior lake are adequate for the proposed hatchery, factors which mitigate against the site's use in the author's view are: its remoteness, and the fact that even on a day when the waters of Bahia Cordes itself are relatively calm and safe for small-boat operations, the lake valley funnels the winds down the length of the lake and creates very unpleasant conditions.

In the author's view, the conditions under which both the primary site-selection team and the site-selection review team conducted their missions were almost unprecedentedly good. Seen under the normal conditions which prevail throughout the Magellan Straits, most of the areas viewed would probably be far less appealing as long-stay sites at which to create small and isolated communities.

If we can accept the old-man-of-the-sawmill's evaluation of this area, taken in conjunction with the other adverse factors mentioned above, the region does not commend itself to the author as a prime hatchery site for the purpose of this project. It may, however, have utilization as a release or enhancement area.

2.7 Friday, April 23: Site 4 - Lago la Botella and Lago Titus, on Estero Condor, off Canal Jeronimo, Lat. 53° 30'S, Long. 72° 30'W.

Early on the afternoon of April 22, Elicura departed Bahia Cordes and, sailing via Canal Jeronimo, reached Estero Condor that evening in preparation for landing parties to survey Lago la Botella.

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*Captain Silva undertook to make this available via C.E.N./G.N.R. or R.D.M.

Observations

Elicura made an initial anchorage at first light on the morning of the 23rd. Shoregoing survey parties were impressed by the presence in enormous numbers of "rivers" of shrimp-like crustaceans which could be seen on all sides of the ship and could subsequently be seen in great quantities from the shoregoing dinghies.

In the main, Lago la Botella appeared to be of very great depth and only when a close approach was made to the point at the head of the lagoon where the stream entered was any barrier of rocks found to impede progress to shore in the small boats.

Subsequently, Elicura weighed anchor and, taking careful soundings, was able to relocate with her ramp down on the shoreline just off to the left of the stream's confluence. This demonstrated clearly that the landing of construction equipment, materials, and supplies would be easy at this site. Gradients on both sides of the stream, when viewed from the landing beach, appeared gentle for a sufficient distance from the stream bank to allow access roads to be cleared without difficulty up to the feeder lake, Lago Titus, some 250-300 meters above the stream's point of entry to Lago la Botella.

The stream itself has a rocky bed but ran clear and unstained. There was evidence of reasonably abundant under-rock life--snails, amphipods, etc.--and for some reason unexplained, since it is an entirely freshwater lake, a marine claim shell was found on the lakeshore.

Water data collected at the point where the stream left the lake indicated: water temperature 6.5° C, pH 6.8. Measurements of stream depth and velocity give a calculated total flow of the order 2.3 M^3/sec ($\sim$ 80 cfs). Water samples for chemical analysis were taken in bottles P953, 2241, 235, P454, P1085, and P1485.

The freshwater lake (Titus) above Lago la Botella was estimated to be some 2 miles (3,000 meters) long. Verbal evidence provided on the afternoon of April 23 by staff at the relatively nearby copper mine, Pto. Cutter (see later) suggest that the lake is snowfed and at the height of the spring snowmelt could have its surface level raised as much as two feet above the levels our survey parties observed.

The copper mine employees also informed us that in the depth of winter some icing over of the lake could be expected; also that a buildup of ice at the head of the stream could cause an ice blockage which might create problems were a hatchery intake to be established there (see later this section, Analysis and Conclusions).

Hearsay data also from the copper mine workers suggest that over the previous four years, a minimum winter temperature of -12° C was recorded. Rainfall in the area is estimated to be of the order of 7 meters per year.

The presence of clearly identifiable old Indian trails encourages employees from the copper mine to visit the lake site, although their fishing excursions have never resulted in the catching of or observation of any brown trout there.

One aquatic species noted in the lake by the survey parties was a type of "candle fish". Flies of the "noseeum" type, gnats, and several birds were in evidence.

A Chilean Navy navigation book translated for us by Captain Silva made reference at this site to the old Indian trails (confirmed) and also to the fact that the stream dries up periodically. The mine staff were somewhat sceptical of this latter observation. However, it should perhaps not be entirely discounted and could factor in to site-development decisions.

Analysis and Conclusions

Of all the sites so far observed, Site 4, Lago la Botella, appears to have some clear advantages. Shore access of LSM or other relatively shallow-draft vessels is assured. The topography of the site is such that development of roads, hatchery, and personnel site facilities would not be difficult. Stream flow, temperature, pH, and visual quality appear adequate.

The area appears sheltered; the lake site or sea lagoon make congenial backgrounds for a relatively isolated community. The presence at Pto. Cutter of the copper-mining community reduces the sense of isolation, encourages some social intercourse with others outside the small purely hatchery community, and provide backup resources of both labor and materials with special reference to machinery or domestic spares, machine shop, or workshop facilities. Common use might well be made of one or both of two service vessels located at Pto. Cutter, the 45-foot Akade and smaller Navarino.

The adjacent interface between the freshwater lakesite and seawater lagoon may also be a plus for development studies which could be undertaken as subsidiary to the main thrust of a salmon-production hatchery unit at the site.

While the total head between the point at which the stream leaves the lake and enters the seawater lagoon is estimated to be only of the order of 2 meters at high water, 4 meters at low water, a 1-meter gain could, relatively cheaply and with advantage, be achieved by constructing a dam or spillway control at the lake outlet. A crude calculation performed by R. Mayo suggests that a civil construction of this type designed to elevate lake water surface level by only 1 meter would provide additional water storage volume in the lake to serve a hatchery of the size envisaged for this project (10-20 million eggs) for a whole year.

While a higher dam or spillway could readily be constructed, some reservations were expressed about this: a) on the grounds of need, b) on the grounds that ice pressures could be problematic, and c) because raising the lake surface more than 0.66 - 1 meter could result in other outlets around the lake perimeter negating the effect of the higher dam.

2.7.1 Secondary mission to visit copper-mining camp at Pto. Cutter

After the morning survey at Lago la Botella, Elicura departed her second inshore mooring at this site in the early afternoon and sailed to the copper mine at Pto. Cutter where the information reported in the preceding section was obtained.

The survey party and Captain Silva went ashore at 1400-1430 hours and had an extended interview with the "caretaker" manager of the mining operation and his two foreman deputies. Only a skeleton staff was in residence at the mine whose normal complement of 200 miners and support workers had been furloughed pending an upturn in world copper prices which would enable the mine to resume economic working. Normal copper ore production from the mine was quoted at 400 tons per month. Copper prices for economic production need to be up to $1,600/ton and the mine is capable of producing $640,000 worth of copper ore every quarter of a year. Miners' wages were quoted at $2.00 (U.S.) per day (an indication that were their skills to be utilized for ground development at the Lago la Botella site, the labor component of cost would not be high, even if the cost of bringing them to and from the site were to be factored in).

In addition to the normal copper ore crushing and refining facilities, which were not of sufficient interest to the survey party to examine closely, the Pto. Cutter site featured extensive support operations. There are power-generating facilities for 12-1300 Kw; several large air compressors; fleets of trucks and ancillary workshops to suit. All in all, the mine support facilities offered a second-to-none complement to any hatchery construction program to be undertaken in the vicinity.

Additionally, and again of possibly significant value to any hatchery operations at Lago la Botella, are the presence of the 45-foot motor vessel Akade and smaller Navarino at anchor at Pto. Cutter. The Akade is set up as a mine personnel carrier for mine crew rotation between the workings and home base at Punta Arenas. (The crews work approximately a 28-day shift before being relieved and taken to Punta Arenas for leave.) The Akade is available for hire or charter.

2.8 Saturday, April 24: Secondary site mission to Bahia San Nicolas on Estrecho de Magallanes, west of southernmost point of Brunswick Peninsula

On the evening of Friday, April 23, Elicura made passage from Pto. Cutter to an anchorage at Bahia San Nicolas where charts showed a river of possible interest to the project. The temporary Pto. Cutter mine manager and his deputies had identified existence at this site of a now defunct sawmill, the ruins of which are clearly identifiable on the bayshore. A small dwelling at the site of the sawmill was still occupied by an elderly man to whom Elicura delivered some basic supplies. The size of the stream clearly matched what might be expected of a logging operation. The stream size was pinpointed by the mine operatives as "big enough to float logs; with strong enough flow to cause problems for a man on horseback attempting to ford it."

Observations

This site is considerably more open than the previous four visited, being merely a shallow indentation on the Magellan Straits shoreline.

While throughout the entire preceding five-day period, Elicura had enjoyed weather conditions of nearly flat calm, a conspiracy of wind and wave resulted in fairly choppy seas in the early morning hours this day. Accordingly, Captain Silva limited the shoregoing party to himself in the smaller ship's longboat with just two permitted passengers aboard. Mayo and Rothwell were elected, and their respective reports will provide particulars of this site's characteristics with their evaluations of its potential utility to the project.

After departing from Bahia San Nicolas in the midmorning of April 24, Elicura made good passage back to Punta Arenas, docking and putting the survey party and crew ashore at approximately 1630 hours.

2.9 Sunday, April 25: Brunswick Peninsula, west of Punta Arenas - overland survey of three rivers on Seno Otway

Substantially refreshed and replenished by an end-of-voyage dinner for Captain Silva, his wife, and ship's officers, to say nothing of a night in a Cabo de Hornos Hotel bed instead of a ship's bunk, the final leg of the survey was undertaken on Sunday, April 25. An early morning start was made overland by truck. The engineering party--Mayo, Rothwell, and the author--with driver provided by IFOP, headed north along the surfaced highway out of Punta Arenas in the direction of the airport.

Observations

Beyond the Punta Arenas Airport, the metalled highway ends and as the road veers westward, its surface degenerates to a dirt road. In the weather conditions which prevailed, the road surface, while somewhat potholed, was easily drivable; however, there were clear indications that this highway was hardly an all-weather, year-round road. Under conditions of snow, ice, or after rain and snowmelt, there were indications that the road could well become undrivable by anything less than four-wheel-drive and possibly specially equipped vehicles.

The first river site reached was Rio Grande, with an estimated flow of over 1 M^3/sec. Its temperature was measured at 4.5° C; its pH 7.2. The river has a rock and gravel base. One water sample was taken in bottle P1237.

The presence of fishermen on the bank of this stream is an indication that there is an existing though unidentified natural population of fish here.

Seno Otway, a large body of almost enclosed sea, was found to have a salinity of 24 ppt indicating the dilution effect of snowmelt and river runoff through the late summer/early autumn period.

Next reached was another river unidentified on the map by name, so-called Rio Algo for reference purposes by the survey party. This river was crossed by a broken bridge. Its water was turbid and estimates of flow were in the range of 1-2 M^3/sec. Water temperature was 4.5 - 4.7° C and a pH reading of 7.4 was recorded. A water sample was taken in bottle P2231.

Final destination, Rio Caleta, in a National Park campsite area, was reached by mid-day. The survey party made its way upstream along the bank of this river, which was much larger than those previously seen that day. A dilapidated suspension bridge, suitable for foot travel and animals only, crossed the river some 200–300 meters above its confluence with Seno Otway. The river water was turbid and stained peaty brown. Its flow rate was estimated to be in the range of 2-4 M^3/sec. Water temperature was measured at 5° C; pH was recorded as 7.4, and at the point above Otway where the measurement was taken, salinity, as expected, was 0 ppt. The round-trip journey from Punta Arenas to Rio Caleta was approximately 95 Km.

Analysis and Conclusions

There were no indications at any of the river sites investigated on Peninsula Brunswick/Seno Otway that biological, physical, or chemical considerations would preclude the operation of a salmonoid hatchery at any site.

Given that year-round measurements of water chemistry, flow, and temperature would meet the biological needs of a hatchery fish population, engineering development of all the sites viewed appeared perfectly feasible. However, none of the sites adjacent to the access road had any significant head advantage, i.e., no upstream falls or rapids were in evidence.

From the viewpoint of site development, materials supply, and operational maintenance, the presence of the dirt highway link with Punta Arenas must clearly present advantages over the remote marine sites visited earlier in the survey. However, too much stress should not be laid on the case of overland access. There are considerable grounds for suspicion that unless a significant improvement in the highway surface can be brought about, there may well be many times in a normal year when the river sites viewed will be wholly inaccessible. This may be particularly true if heavy goods vehicles traverse the highway with materials for hatchery construction.

In sociological terms, families located at a hatchery complex in this area would probably feel a sense of integration with the population center at Punta Arenas and also with the sheep-rearing farm communities in the areas connected by the road.

Of less definable virtue is the National Park aspect of the major sites visited. The presence in the areas immediately contiguous with a hatchery operation of members of the general public enjoying camping holidays and weekends could be positive or negative factors. The presence of curious outsiders may constitute a welcome break in hatchery routine and the sight of many new faces might be welcome to the wives and families of hatchery staff. On the other hand, large numbers of the curious at periods of peak hatchery operations can be frustrating, annoying, and deleterious to successful operations.

2.10 Monday, April 26: Punta Arenas - Meetings with Chilean Navy personnel in Public Works, Shipbuilding and Repair Departments and with civil engineering contractors

On the morning of Monday, April 26, a courtesy call was made to the Punta Arenas headquarters of the Chilean Navy. Members of the project team met and thanked for their cooperation in the survey effort Senior Officer Louis Bravo Bravo and his aide, Cdr. Computsky. The latter-named officer subsequently introduced the engineers on the team to the Naval officer responsible for liaison with Navy-related public or civil engineering work in the district, Rodrigo Solar Lantano. This officer identified a number of competent civilian engineering contractors whose expertise could be of assistance to the hatchery construction phase of the project from preliminary site surveying to materials procurement, and, should it be required, construction of a floating hatchery. Cited were: Carlos Macintyre, Hadley Compania, Jupermare P.A., and the Navy's own shipbuilding and repair yards (ASMAR) under Chief Engineer and Commandante Carlos Quinones Lopez.

Later in the morning in the Navy shipbuilding and repair yards, a lengthy meeting was held with Cdte. Quinones, his engineering aide, and Naval architect.

In the context of the Kramer, Chin & Mayo floating hatchery concept, discussions took place about the Navy yard's capability of carrying out detailed design and fabrication of a complete floating hatchery in any of the modular sizes developed by the KC&M group. While admitting to no experience with concrete barge constructions, assurance was given that within a 13-foot draft limitation, no problems would be presented in building even the largest KC&M module (a 50×10^6 egg-production unit some 60 x 16 meters in area). Facilities exist in the yard for fabrication of vessel hulls to a thickness up to 1/2". Given preliminary design drawings, ASMAR could take specifications and develop detailed design drawings to suit their materials standards and fabricating capability. Some suggestions made by Cdte. Quinones were that

1. All "foreign" equipment should be procured by the project to obviate currency regulations problems.

2. Items such as generators, pumps, valves, and control systems should be procured by the project.

3. Piping, electrical wiring, etc., could be supplied by ASMAR.

4. Millwork, interior finishes, plumbing fixtures, etc., would also be supplied by ASMAR.

5. For ease of maintenance, spares, and repairs, it was recommended that all U.S. equipment and standards be adopted (in the Chilean Navy, 440 v A.C. 60 cycle is standard).

6. Generators in the 25-100 KVA range were commonly supplied by Caterpillar (very well represented in Punta Arenas) or by Cummins (perhaps not quite so well represented).

7. Regarding the hatchery vessel hull itself, Cdte. Quinones thought it desirable to secure a vessel code classification since this would facilitate its insurance as a seagoing barge.

8. The useful life of the barge would need to be specified along with acceptable painting standards. The Cdte. expressed the view that while local Chilean paints were acceptable for vessel interior finishes, they are not so good for exteriors. The project barge could possibly with advantage be specified as requiring a three-coat epoxy finish coat and this would need to be procured in the U.S.

Cdte. Quinones and his staff were able to study several conceptual drawings by KC&M and when it was suggested that the probable vessel size would be geared to 18 x 10^6 egg production and the barge size (smaller than that depicted) would probably be of the order of 40 meters x 15 meters ($\sim$400 tons), the Cdte. indicated that in this size range, any 3,000-HP ship or above could tow her to a suitable location.

Referencing the need for substantial oil storage capacity at the hatchery site where the energy rate demand per month for boilers, generators, spare heaters, etc., could well be 20,000 gals., we were advised that the local oil company, ENAP, could fabricate storage tanks to code and with approved welds.

In a further discussion on the most suitable fuels available to the project, it was pointed out that on a purely cost basis, liquified natural gas was available in the Argentine but not in Chile, that the initial price was $140 per M^3, but transportation costs would be high.

A supply of diesel oil could always be assured by the Chilean Navy in an emergency. Bunker oil and "Navy Special" (between diesel and bunker) could also be dependably relied on. The Chilean Navy uses all diesel, costing 17.5¢ (U.S.) per litre, $175 per M^3. The 8-knot liquified natural gas tender "Polar Gas" which we had earlier observed at her moorings in Punta Arenas harbor is considered somewhat uneconomic and is currently up for sale.

Concluding the office meeting, Cdte. Quinones assured us of ASMAR's interest in cooperating and helping our project in any way.

We were then taken on a conducted tour of the shipyard which employs, I believe, between 350 and 400 people and whose workshop and fabricating facilities are clearly well capable of meeting our project needs should the concept of the floating hatchery barge be adopted.

Meeting with representative of civilian contractor, Carlos Macintyre, afternoon of Monday, April 26

In a meeting set up in the conference room of the Cabo de Horno Hotel, the project's engineering group had an opportunity to discuss the type and level of assistance which might be forthcoming from one of the contractors recommended by Cdr. Lantano. Acting for Macintyre of Casella 42-D, Punta Arenas, was Sr. Adolfo Rojo Fajardo (tel. 23384).

In wide-ranging talks about the possible ways the project's aims could be achieved, reference was made to the barge concept and, taking Lago la Botella as a preferred site of reference, to site development programs in general. Sr. Rojo Fajardo regarded near proximity of the Pto. Cutter copper mine and its workers as a big asset at this site.

The possibility which had already been discussed among the project engineers of constructing a dam or spillway control at the head of the stream between Lago Titus and Lago la Botella was broached. This scheme aims to give a head of water some 5 meters above Botella's low-water level (perhaps 3 meters above the high, assuming a 2-meter tidal rise or fall). It supposes that a barge-type hatchery will be located on Botella's shoreline. An existing recess in the shoreline (deepwater since Elicura came ashore there) could, by cutting and filling, be used to float the hatchery barge into position and then, using ballast, to settle her at the desired elevation with raceways in the normal tidal ranges.

Topographic Survey

Recognizing a prior need for a topographic survey of the site to be carried out, Sr. Rojo Fajardo expressed his organization's willingness to undertake and complete this work by the end of July if desired. He agreed that while rather more difficult at this time of year than in the later (summer) months of the year, the penalty would be merely one of increased cost.

Sr. Rojo Fajardo's spirit of cooperation was impressive. He appeared willing to initiate preliminary investigations of the site on a no-cost basis but was urged not to do so. It was agreed that any work undertaken must be paid for and carried out on the basis of a letter request from us which would define the scope of work to be undertaken. For example, it would be necessary to specify how far on each side of the stream between Titus and Botella the survey should extend. The distance from the head and foot end of the stream should be agreed on, as should the matter of contours and intervals between. In response to such a request, Macintyre could develop a costed proposal defining a phased program of work for project approval or modification.

In conclusion, while it is clearly impossible to evaluate any engineering company's ability to handle a specific job on the basis of one interview with one man, Macintyre appears to be acceptable to the Chilean Navy and their spirit of voluntary cooperation is encouraging.

A commitment to the company at the topographic survey stage, it was made plain, did not necessarily mean any commitment in the subsequent phases of site development. On the contrary, it was made clear that all aspects of design, procurement, and installation on site would be let on the basis of competitive bids, and these terms were readily understood.

2.11 Tuesday, April 27: Santiago - Review meeting between project personnel and representatives of Servicio Agricola y Ganadero (SAG)

Those present were the entire project team and three representatives of SAG. (The meeting was postponed and when rescheduled started early. Accordingly, introductions were incomplete. Names of the SAG personnel can be obtained from T. J. or C. E. N.)

The meeting was chaired by Project Coordinator T. Joyner but no set agenda was followed.

Generally, for the benefit of the SAG personnel present, subjects discussed at the meeting ranged across a spectrum of topics which had been informally aired in a late-night get-together attended only by project personnel in the Emperador Hotel the previous night when the entire first and second survey parties were in a position to compare notes for the first time since the debriefing in Punta Arenas on Sunday, April 18.

There seemed to be a consensus that unless there was some clearly identifiable biological advantage from a salmon-rearing viewpoint in going to remote sites, these could only present problems.

Nothing that the project personnel had seen on their shipborne surveys precluded development of any of the sites from an engineering viewpoint. However, Algo, Julio, Cordes, and the two subordinate sites at Fortescue and San Nicolas did not commend themselves immediately as ideal locations. The logistics of site development, materials supply, operation, and maintenance were all considered needlessly difficult.

In a change of viewpoint from that expressed at the April 18 meeting in Punta Arenas, the two Chilean members of the second survey party expressed some reservations about the ease with which personnel could be induced to relocate with or without families in such splendid isolation.

Of the sites viewed, only Lago Titus/Lago la Botella appeared to commend itself to the survey groups and some analysis of the reasoning for this seemed desirable. Basically, any warmth for adoption of this site came down to its relative ease of access and development, an easier logistics problem vis-a-vis other sites by virtue of its accessibility by the Navy, and its proximity to another human habitation center at Pto. Cutter. The workshop facilities at Cutter also promised useful backup to the project's own hatchery facilities. Another advantage at Botella is its scenic appeal, which had a positive psychological effect on the survey parties. The relative ease with which foot passage could even now be made along the level stream banks between the marine Lago la Botella and freshwater Lago Titus held promise that the site could easily be developed for both hatchery (floating or otherwise), support facilities, and homesites.

The existence in close proximity of a seawater and freshwater interface was held out as a "plus" for the site. But this contention was queried as having little relevance to the project's main aims and thrust.

Other virtues which commend Botella are the apparent abundance of marine crustaceans immediately available at certain times of the year to hatchery-released fish and evidence of both avian and aquatic life in the area. (Perhaps even the presence of old Indian trails in the area is psychologically beneficial, an indication that through ages past man had found this site congenial.)

Increasingly, the problems which the project might encounter because of staff isolation came to the fore. The need for training programs which would require perhaps 2- to 3-year terms by North American experts was discussed. Again mere financial incentives were considered inadequate to offset the stringencies of enforced isolation.

Viewed in these lights, those river sites on the Brunswick Peninsula visited overland on Saturday, April 17, and Sunday, April 25, became a more attractive focus for the project's attention. Finally, it was conceded that there would be merit in upgrading the potential of, and taking closer second looks at, the land-accessible rivers in the Punta Arenas region. Additionally, some of the freshwater lakes and rivers in the Lago del Toro region of Chile, north of Puerto Natales should also be carefully considered and viewed as potentially promising hatchery locations.

The existence of trout in these rivers was noted. Problems which might arise in certain locations because of man-made river obstructions (at least one power station dam on one river) were also commented upon. However, the consensus seemed to be that these need not inhibit or frustrate any programs of smolt release in the southerly areas which it was the project's intention to seed. Rather, communications by water or road from a judiciously sited hatchery would allow fish transportations of quite limited duration and release could be effected highly successfully.

The important consideration is to select a site at which a successful hatchery operation could be mounted free from logistic and staffing problems, and one where the attractions of the environment would encourage 2- to 3-year contract workers with the necessary experience and expertise to relocate and pass on their skills to indigenous trainees.

3. GENERAL SUMMARY AND CONCLUSIONS

If it may be assumed that the sites reviewed in Section 2 of this report prove, year round, to have satisfactory temperature, pH, and water quality for viable salmon hatchery operations, other criteria must be applied to the selection of a preferred site. Critical judgments must be applied so as to identify the advantages and disadvantages of each site; where adverse factors may be common to all, ways to minimize their effects must be examined. This section of the report attempts to do this; it follows with some conclusions and makes recommendations about charting of future policy.

3.1 Sites Accessible by Sea

Of the four prime and two subordinate sites surveyed from Elicura during the period April 20-24, the following summary observations may be made:

3.1.1 Site 1 - Algo is remote, offers good anchorages, and the physical nature of the land and its contours would permit civil engineering site constructions with reasonable economy. Road access between shoreline and freshwater lake could also be achieved at acceptable cost.

3.1.2 Site 2 - Julio also is remote; it does not lend itself to close inshore navigational work and could make landing of construction equipment, materials, and supplies difficult. A floating hatchery may find application at such a site. Nonetheless, buildings for support facilities, personnel homesites, and an access road between sea and freshwater lake would be difficult and expensive to construct.

3.1.3 Site 3 - Bahia Cordes. While easier to reach from Punta Arenas than the first two sites visited, hatchery sites served by the stream at the head end of the finger lake or the anterior lake midway along its right-hand shoreline could prove difficult for a seagoing vessel to service because of the sandbar at the entrance to the lake. However, there is nothing to suggest from the land contours that sites could not be developed at acceptable cost. The area appears exposed and there are indications that under certain conditions, its aura would be grim.

3.1.4 Site 4 - Lago la Botella. While further from Punta Arenas than Cordes, the site has a number of advantages. It has good anchorages, is sheltered, and is believed to be in reasonable proximity to other areas having good salmon release potential.

The distance, elevations, and physical features of lake, stream, and saltwater bay augur well. One feature of the area suggests that a floating hatchery could find application here. Proximity to the copper-mining community at Pto. Cutter assures low site-development cost, machine shop, and some spare-part facilities, as well as social intercourse. The site is scenically attractive and its aura benign.

3.1.5 Subordinate Sites at Bahia Fortescue and Bahia San Nicolas

Fortescue did not have any great appeal, nor from the reaction of Messrs. Mayo and Rothwell who viewed Bahia San Nicolas, did it commend itself as having clearly identifiable superiority over the prime marine Sites 1-4.

3.2 General Site Criteria

A number of common observations can be made about these sites:

3.2.1 Logistics. All sites are remote and will attract supply and logistics problems, possibly associated at some future time with the more pressing commitments of the Chilean Navy. Some backup means of supply and relief would therefore seem mandatory.

3.2.2 Environmental Effects. The sheer remoteness and isolation of these sites is likely to create sociological problems not normally encountered in comparable hatchery locations elsewhere, except possibly some of the more remote Alaskan regions. Even here it is likely that the hatchery workers are drawn from population centers where some social activities can be pursued and where social contacts extend beyond one's fellow workers and their families.

Many qualified and otherwise eminently suitable professional and nonprofessional potential employees may find the idea of working in a tiny closed community so unattractive on a year-round basis as to make recruitment difficult. Even if the dedicated absorption in their work mitigates against this effect so far as the hatchery workers are concerned, wives and families are likely to be so affected. Unless extremely skillful blending of talents and personalities can be achieved, the greatest single cause of probable failure at any hatchery built at the sites under consideration is likely to be due to a breakdown of human morale.

The general aura of the sites throughout the entire Patagonian region can contribute to this breakdown of morale. When seen under good conditions, the scenery in this region is spectacularly beautiful. By usual standards, weather conditions during the period of the survey were exceptionally good. However, there were clear indications that in poor weather, an aura of depressing gloom could prevail and this effect must not be ignored.

While the matter was touched on only briefly at the meeting held on Tuesday, April 27, in SAG's offices, an assumed hatchery complement as set out in the Mayo manning projection reduces to four families of perhaps four persons per unit and another six or eight single workers for a field force of some 24 persons. While a group this size may not suffer the privations in terms of human companionship that are felt by lighthouse keepers and like workers, they nonetheless will be under exceptional and unusual strains. This is particularly true of the "attached" personnel, i.e., wives and children with no specific work function to occupy their energies at the hatchery unit.

As a measure to minimize this problem, "working" wives trained as teachers, nurses, etc., would probably be best suited to this environment. Furthermore, as congenial an atmosphere as possible should be aimed for in the design and layout of the entire community. While this author first warmed to the floating hatchery concept and fully recognizes its advantages and merits in certain conditions of service, some reservations must be expressed about adoption of this concept except where there is a clear and provable technical or cost advantage. In environmental terms the floating barge-type hatchery does not integrate with the virgin scenery of the sites under review as well as a building constructed from natural materials and keyed to a community of support facilities and houses of common architectural caliber.

As a measure to offset morale problems, it may be advisable to broaden the project's aims and attempt from the beginning to create a prestige establishment with international eminence, thereby attracting large numbers of applicants from whom most careful screening and selection can be carried out. Financial rewards are not, in the view of this author, a meaningful incentive for the type of dedication necessary to attain the optimum levels of achievement desirable for the success of this project.

An atmosphere similar to that created in the international centers of Antarctica could be a method of approach to justify consideration. The award of internationally prestigious scholarships for graduate and postgraduate studies might also be considered. If this approach is made, then consideration may have to be given to modifying the major thrust of the project and instead of concentrating exclusively upon the production of large numbers of salmon for seeding this area as proposed, peripheral research may also be introduced to broaden and enhance the spectrum of interest in the work and as a measure to overall program prestige enhancement.

With all the foregoing in mind, the most attractive of the "marine" sites surveyed is, in the author's opinion, that at Lago la Botella. In addition to the features of this site summarized in Section 3.1.4, the la Botella/Lago Titus site offers the following additional advantages:

1. There is an apparent abundance of marine life in the area to encourage successful introduction of exotic species.
2. The existence of seemingly sheltered bodies of fresh water at Lago Titus and marine waters in Lago la Botella could lend themselves to a program of enclosure or cage-rearing studies in both environments with application at other locations around the world. The opportunity to pursue this type of experimental and research work with commercial

application outside immediate Chilean waters could attract dedicated research workers as well as commercially funded scholarships.

Even discounting the potential for experimental or research work at the close fresh and saltwater interfaces of Lago Titus and Lago Botella, this site is still considered the best of those evaluated for the project's major thrust.

Rio Algo would be this author's second preference, with Cordes and Julio relegated to nonstarter status.

3.3 Sites Accessible Overland

If the philosophy expounded above of broadening, enhancing, or giving greater prestige to the Seeding the Southern Ocean with Salmon main goal cannot gain acceptance and concentration has to be made on the major thrust of egg and smolt production, then in this author's view, serious consideration should be given to rethinking the site-selection program. A concentration should be made on more easily accessible sites, preferably having overland access to existing population centers.

From observations made in the Brunswick Peninsula/Seno Otway region April 17 and 27, there are at least three river sites south of Punta Arenas and a like number west of that city which are accessible by vehicle and which would prove satisfactory for the project's purposes.

While the author cannot speak for the sites south of Punta Arenas, the three river sites--Grande, Algo, and Caleta--referred to in Section 2.8 of this report could all, with advantage, be more closely evaluated and a preferred site selected on one of them.

3.4 Power Supplies

Power demand at a selected hatchery site is not likely to be significantly "site related", i.e., whether a "marine" site is chosen (with or without a floating hatchery) or whether a land-accessible site is picked, the facilities and their operation will not vary radically.

In order to minimize energy costs and to reduce logistic problems and dependence on outside delivery agencies, clearly it behooves the project to examine local sources of power closely.

An early SSOWS publication depicted an artist's concept of a barge-type hatchery, one intriguing feature of which was a floating pressurized water line supplying a turbine generator (and presumably hatchery needs as well). The pressure head was developed behind a dammed stream. However, from the author's observations, the sites visited would not lend themselves to economic adoption of this technology.

While it may prove feasible to construct spillway dam or run-of-the-stream generators at several of the sites viewed, the balance between cost and output would probably limit power production to meeting only auxiliary or emergency standby demands at the site. The major electrical power requirements associated with hatchery water-heating and pumping systems, as well as those for facilities and homesite supply, could probably best be met initially from diesel-powered generators.

After the early years of site operation when the success of the project has been demonstrated, phased investment in long-range site development could well justify a change in this philosophy.

Because energy costs at the site are likely to be a constantly increasing component of operating cost, any opportunities for saving should not be ignored. Accordingly, as part of a general monitoring and data-gathering program, evaluations of wind strength, direction, and frequency should be made with a view to installing auxiliary wind-powered generators. Evaluations should also be made to determine the role of solar energy systems for space-heating requirements in both hatchery and homes.

3.5 Conclusions

Increasingly, through the period of the site review team study, there was a growing consensus which was expressed with increasing frequency and feeling that the remoteness of marine sites was not of itself any great virtue. If the biological prerequisites for successful salmon culture could only be found at such remote locations, then clearly this was justification for seeking out the best of them.

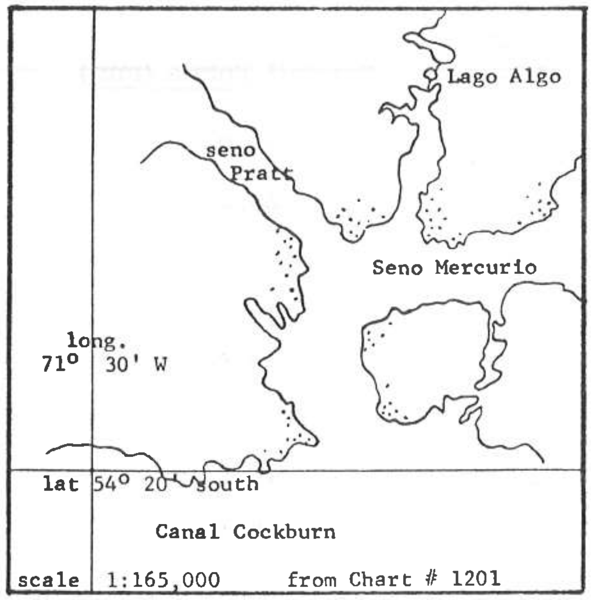
Recognizing the degree of dependence on the Chilean Navy which would be a consequence of such a site choice, however, and having an increasing awareness of the logistic and human problems to be found, "overland" sites attracted increasing favor.

As was reported in Section 2.10, meetings of project and SAG personnel in Santiago April 26 and 27 reached a consensus, endorsed, and strongly supported the project leadership's view that if remote "marine" sites had no special virtue, renewed site evaluations should take place in the Brunswick Peninsula/Seno Otway region. Furthermore, it was agreed that a focus should be made on "inland" water in the region near Puerto Natales where there are rivers and lakes of seemingly suitable character.

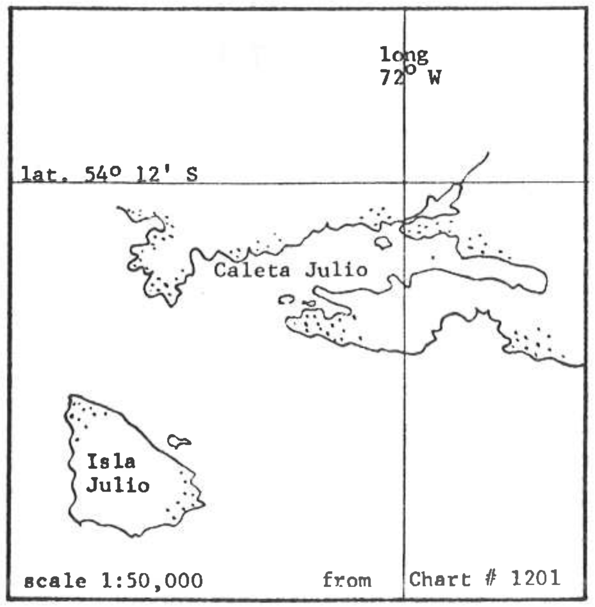
If this area holds out equal biological promise to that of the Magellan Straits area while obviating logistical and human problems, then it would be ill advised not to extend the site search to this area as quickly as practical.

APPENDIX I

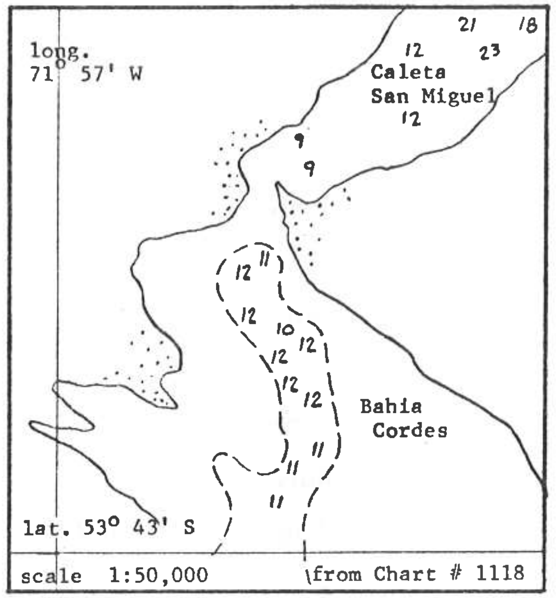
Charts of the region are available from the Coast Guard Office, Punta Arenas. Seaways and channels named in the text are identified from "Atlas Hidrographia de Chile" General Chart 56 and detail charts 1105, 1109, 1114, and 1201.



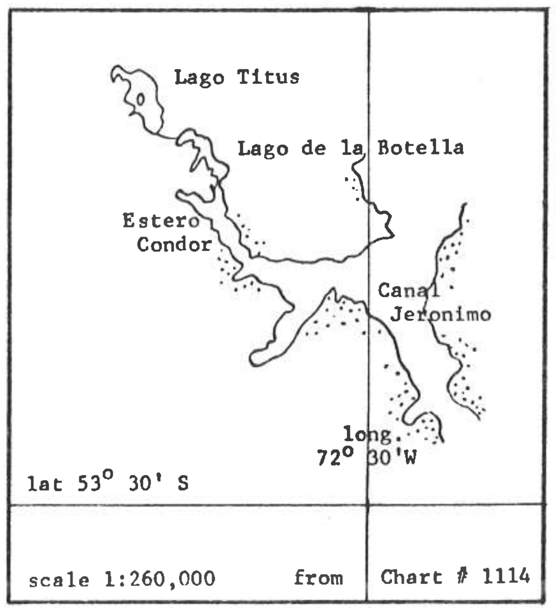
I. Seno Pratt and Seno Mercurio.



II. Caleta Julio.



III. Bahia Cordes.



IV. Lago de la Botella.

APPENDIX II

General Meteorological Data for Punta Arenas
(1 year only) from:
Derrotero de la Costa de Chile

	T max (°C)	T min (°C)	Rainfall Totals (mm)
Jan.	15.4	6.1	22.0
Feb.	15.0	8.6	20.2
Mar.	14.3	5.6	35.1
Apr.	9.0	2.9	139.5
May	7.4	1.9	10.3
June	7.7	-1.1	84.7
July		-1.7	46.5
Aug.	7.2	1.0	36.8
Sept.			13.2
Oct.	11.8		23.6
Nov.	12.4	4.9	13.6
Dec.	15.1	6.6	7.4

APPENDIX III

Lists of Selected 35 mm Slides Taken in Southern Chile
April 17-25

1st Box Kodachrome

Slides	1- 9	Punta Arenas
	10-16	Punta Arenas harbor and Armada de Chile
	17-18	At sea, Estrecho de Magallanes, evening, April 19
	20-25	Site 1 - Rio Algo, Tuesday, April 20
	26-27	Canal Cockburn
	28-30	Site 2 - Caleta Julio, Wednesday, April 21
	31-39	Canal Barbara

2nd Box Agfachrome

Slides	1- 5	Site 3 - Bahia Cordes, Thursday, April 22
	6- 7	" Anterior lake, Bahia Cordes, Thursday, April 22
	8-14	Site 4 - Lago la Botella, stream and Lago Titus, Friday, April 23
	15-18	" Lago la Botella anchorage, stream confluence and Elicura beaching area, Friday, April 23
	19-20	Pto. Cutter copper mine, Friday, April 23
	21-25	Secondary site, Bahia San Nicolas, Saturday, April 24
	26-29	Peninsula Brunswick/Seno Otway, three river sites, Sunday, April 25

REPORT OF

Harry Senn

Washington Department of Fisheries

INTRODUCTION

The second Task Force assignment was to make on-site inspections of a number of hatchery locations: Lago Algo, Lago Julio, Rio Aguafresca, Rio Cordes, Rio San Juan, and Lago Botella. This team was composed of Ron Mayo, Guido Celedon, Pablo Aguilera, John Spencer, Colin Nash, and myself, with Guy Rothwell being present from the original team.

In the afternoon of April 19, 1976, we left Punta Arenas in the Chilean Navy ship ELICURA, a World War II LSM. The ship was commanded by Comandante Silva, Carlos Hollvx and assisted by fellow officer Millar, Oscar (Chris) Drago 2nd Comandante, and a crew of about 20. Francisco Visl Guzhan, Carlos Mender Zambrano, and Roberro Farenkrog Rosenkrans were the other three officers.

On Saturday, April 24, the inspection trip of four assigned sites was completed and the return to Punta Arenas was accomplished. Two other sites were inspected, aided by vehicular travel from Punta Arenas.

Part I of this report briefly covers the 8-day inspection tour and Part II relates to matters which the group might consider at future meetings regarding where to go from here.

I. ON-SITE INSPECTION

A. Lago Algo

This system consists of two lakes connected by a quarter-mile-long river. A river from the lower lake flows 400 meters to the sea. This short stream has 2-meter and 5-meter waterfalls 120 and 300 meters, respectively, downstream from the lower lake. A measured 1.3 metric tons per second (M.T.P.S.) of water was leaving lower Lago Algo, a lake of less than 100 acres in size. A short stream connects the two lakes.

Aquatic conditions in the outlet are viable, with lots of attached aquatic moss and heavy populations of amphipods within the moss. The water color was brownish, typical of Washington bog lakes.

The potential exists for a gravity-flow land-based development at Algo near the mouth of the river on either the left or right bank. Two meters of peat covers an apparent rocky substrate. The bay near Rio Algo is well protected and affords potential for docking facilities.

B. Lago and Rio Julio

Like Algo, the source of Rio Julio is a relatively large lake of some 100 acres, more or less. The river leaving the lake exhibited water of greater clarity than Algo, but still possessed some peat coloration.

The pH and water temperatures were taken and will be mentioned in reports by others. Water leaving Lago Julio was flowing 2.4 MT/S and gradually dropped some 6-10 meters of elevation over a 400-meter rocky streambed into the sea. At this point, a 700-meter x 400-meter lagoon exists. The outlet of the lagoon where it enters the open sea is 60 meters wide and some 6 meters deep.

The topography is such that a land-based hatchery could not be accomplished easily. As a floating hatchery site, it is excellent, however.

C. Rio Cordes

On April 22, 1976, the Elicura dropped anchor one mile offshore near Cordes Lagoon. By small boat, the two Chileans, Guy Rothwell, and I motored through the two-mile-long by one-mile-wide lagoon to the mouth of Rio Cordes.

The lagoon entrance has a very picturesque setting where a long, low, tree-covered spit necks the lagoon down to where the entrance is only several hundred meters wide. The lagoon itself, as reported by an old-timer, is very windswept and ices over in the winters, ruling out a floating hatchery. The lagoon near the river mouth is very, very shallow. A small intermittent sawmill exists on the lagoon. Brown trout are known to be in the area, as the old-timer who lives there year round removed one from his gill net in our presence.

Rio Cordes was flowing an estimated 2.5 MT/S with a 5° C temperature. The water is fairly clear, with the gravel in the lower half mile of river overlying peat deposits. The lower mile of flats on each side of Rio Cordes are also composed of peat, making road construction along the river highly unfeasible. Small streams trickle through bog deposits and are very coffee colored.

D. Rio and Lago Botella

On Friday, April 23, we investigated this site which appears to be the "best" of those selected for our review.

Lago Botella is a relatively large lake of 100-plus acres with a 150-meter-long river descending 2 meters elevation into Botella Bay. River flows were measured at 2.3 MT/S with a 6.8 pH at 6.5° C.

Relatively abundant food organisms are present in the stream, lake, and especially the bay. A reasonable site is available for a gravity-flow land-based station with good area for marine rearing pens. Landing sites are available.

There has been a rumor of the outlet of the lake going dry; however, it appears unlikely. The erosion or waterline on the lake is 2 feet above the present lake level, giving rise to the belief that possible icing conditions exist during the winter and spring, blocking the outlet and raising the lake level.

The Cutter copper mine is only several hours away by boat. The most significant points I came away with from a meeting in the mine office are: (a) labor is $2.00 per day, and (b) skilled people exist who might help during any hatchery construction.

E. Rio San Juan (Brunswick Peninsula)

The mouth of Rio San Juan was visited directly from Punta Arenas. There is nothing of value to report except that it is a 6 plus MT/S river, very brown, and very cold in the winter.

A possible development site exists upstream where Lago San Juan exists with a reported waterfall on its outlet.

F. Rio Aguafresca

This is a 0.5 MT/S, coffee-colored stream likely dropping much lower in flow at times. The upper tributaries were inspected; these had flows of 0.1 MT/S each and were already very, very cold at 5° C.

Note: Approximately 5 kilometers from the end of the concrete highway toward Aguafresca is a 1 MT/S stream which may have an excellent potential for a release area. This should be checked out.

Summary and Views on Site Selections

Generally we agree, a "one day" fact-gathering mission for the purpose of selecting a hatchery site has its most value as broadly analyzed by individuals, calling upon their engineering or biological experiences.

The results of specific tests such as pH and water temperatures and flows can change daily, but more particularly throughout the season. pH, as an example, can be 6.0 on one end of a lake and 9.0 on the windblown end during the same sunny day. Generally, the pH of all areas as taken was below 7.0 and the temperature between 5° and 7° C in rivers without lakes and with lakes, respectively.

Measuring heavy metal levels would be of value, while freshwater samples measuring total dissolved solids would only be meaningful for a natural stocking program, not a necessity for artificial production.

Data from plankton samples in the release areas may be extremely valuable as survival differences between release sites, as in Washington waters, are believed related to these factors.

Only as a last resort would I recommend the development of any one of the sites reviewed; the extreme remoteness and the extreme natural elements are two reasons for this conclusion. Water is the other.

Fish culture is a science blended with an art. Given that the science is understood, the end product depends on the attitude and attention given by the manager and staff. When given the proper working atmosphere, people perform. The quality of water is the remaining factor which is a key to success. Water quality appears, at best, as poor as the poorest source presently used in salmon propagation in the Pacific Northwest states.

The question is, then, "Where do we do from here?" Thoughts on this are presented in Part II.

II. WHERE DO WE GO FROM HERE?

The writer feels very strongly that the chances of establishing salmon in the Southern Ocean are great. "Overnight" success is unlikely, but through the initiation of a sound program of propagation and through patience and by working with four or five generations of returning salmon, success is likely for one or more species.

In addition to the elements for a successful propagation program, the writer will also relate his views on the management of salmon which might be applied to Chilean waters.

A. The Hatchery Selection

Table I, as used by the hatchery people in the Washington Department of Fisheries, covers mainly the key elements which may be considered in the selection of a hatchery site. Actually, the site-selection team has automatically considered many of the points as listed. However, a good checkoff list might be used for discussion purposes by future site-selection teams.

While the Lago Botella and Algo systems were the top two choices for development in the Straits of Magellan, the writer feels Drs. Nash and Joyner's conception of looking further north in the Puerto Natales region is a must. The selection for the quality of water should be the "order of day" if a chinook and chum program are to be included. One metric ton per second or 30 cfs is very adequate but quality is the key to success. Some disease-free water as spring and some waters with a good temperature range should be achieved within the system even if ground water has to be developed as a supplement.

Now that a floating hatchery may not be the end product, the design of the proposed hatchery subjects itself to further input. There is a balance between starting ponds, as raceways, and the rearing areas where production should be conducted for the purpose of easy operation and for the overall economics. It is believed the concept of design should view the raceways as starting ponds, not for the prime purpose of production.

The larger areas of 1-3 acres, as at the Cowlitz Game Hatchery or at Skagit Hatchery, or George Adams Hatchery, or in Hokkaido, etc., are the type which must be incorporated to make a system function economically with quality fish. The system as used in Hokkaido for chum salmon but modified by the Washington Department of Fisheries to accommodate two species is excellent for a multispecies program. A review of this plan may be of some value to the Task Force, as it incorporates the most up-to-date design by the Washington Department of Fisheries for multispecies salmonoids including chum or pink incubation and rearing.

B. Species Consideration

Without question, chum or pink appear to be the most feasible of all species to rear, especially from the standpoint of the energy output as related to the calories received. On the other hand, intuitition tells us it may be the most difficult to establish. This latter view is based on unsuccessful attempts in the State of Washington to establish Puget Sound chum stock into the Columbia River system. The delicate nature and size of these fish as smolts does not help.

Coho, on the other hand, are a very hardy species with many races readily available for transplant. In recent years coho have been successfully established in the freshwater lakes of the Great Lakes system and in the marine waters of the Atlantic coastal states. In Washington, excellent survivals can be achieved on coho released during a six-month period, March-August. This provides for a flexibility in the release timing, an advantage which may be needed in the Southern Ocean. The length of their migration can be controlled.

Quality chinook salmon smolt would appear to be the most likely winner, the one which would respond immediately. Biologically and broadly stated, chinook can be successfully released to a marine environment, in the Pacific Northwest, between April and July of their first year of life and between February and June of their second year of life. Again, provided quality smolts were released, a 10-20% survival could be obtained for these one-year-plus smolts.

As Connie Mahnken said, "New Zealand had success with the introduction of chinook with little help from man in regards to rearing."

In summary, the ultimate in success may be with the chum or pink salmon species; however, the immediate success is more likely to occur with the chinook or coho. On the other hand, the value of immediate success will have far-reaching influence on the support for the program, thus allowing time for the ultimate goal.

C. Release Considerations

The release time of any of the artificially propagated salmon species would seem most logical to be during the spring or lengthening daylight period. The ideal condition to achieve would be to experience a natural migration from the artificial environment. While the quality of the smolt is a must, the individual size of fish released should be larger than the natural smolts for each species. Generally, the writer feels chum and pink could be successfully reared in fresh water to a size of 1 gram and even up to 20 grams each, coho from 25 to 30 grams each, and chinook from 5 to 50 grams each. These wide ranges of sizes are mentioned to show the latitude for a broader time in which they can be released or will migrate on their own. Hopefully, a number of releases can be conducted over time for each species with a fraction of the population identified prior to release.

There have been many total disasters in the transportation of smolt salmon to river mouths in the State of Washington to feel easy about this procedure.

Transportation of smolt salmon from the mother station should be highly justified before becoming a reality. Transportation causes stress and smolts can stand very little stress. The writer feels a large brown trout population within their migration route may cause less loss than the stress of smolt transportation.

Release ponds, on the other hand, afford a much greater chance for success with a very economical procedure for expanding the production of certain mother stations. A release pond might be described as a low-cost rearing area of 1-3 acres, or small lake, net pens, etc., where sufficient water interchange is available to handle millions of pre-smolts and smolts. Once transferred from the mother station in the tough pre-smolt conditions, a feeding program could triple their size prior to release. Coho, as an example, might be transferred to the Punta Arenas area from a site 200 miles to the north.

Possibly 2 million smolts could be received by the release pond on "Rio Maria", for example, weighing 50,000 lbs. and be released 5 months later weighing 150,000 lbs. Chinook or chum could have been used as an example; however, the point here is that the handling of smolts at the time of release has not been fully mastered, especially lengthy handling. Trucking, on the other hand, is the best-known method in the Pacific Northwest for transporting fish.

The release of coho or sockeye salmon fry in freshwater lakes has merit; however, one might expect production levels to be very low, in the 2-kilogram-per-acre level. Even at that, a 100-acre lake might produce 40,000 smolts from a fry plant of 100,000.

Releasing smolt for the purpose of natural spawning seems questionable in the first four areas reported on, as the spawning gravel was missing. The upper watershed on several of these may afford a different situation, however. Several streams in the Punta Arenas area afforded excellent areas for spawning.

Again it should be said that there is every indication that salmon can be established in the area of the Straits of Magellan. The immediate success with chinook and/or coho is likely, with chum being more difficult but anticipated over a long haul. Patience will pay off.

TABLE I. HATCHERY SITE INVESTIGATION REPORT OUTLINE

I. General Description

A. Geographic Area

1. Site Location

2. Release Location

3. Fishery Location

4. Soil Types

B. Proximity to Services

C. Proximity to Urban and Industrial Development

D. Natural Elements

E. Relationship to Existing Facilities

F. Political Requirements

G. P-R Requirements

H. Reduce Natural Mortalities (Pollution, Predators)

II. Water

A. Fresh or Salt

B. Gravity

C. Pump

D. Source

1. Well Water

2. River Water

3. Spring Water

E. Quality

1. Test

2. Presence of Aquatic Life

F. Quantity

1. High Flow

2. Low Flow

G. Temperature

III. Facilities

A. Incubation

1. Species

2. Numbers

3. Water

a. Quality

b. Quantity

c. Controlled Temperature

4. Type of Units

5. Disease Controls

B. Rearing

1. Species

2. Numbers

3. Size

4. Water

C. Pond

1. Number of Units

2. Type and Size

D. Feed and Feeding Procedures

E. Effluent

F. Disease Control

G. Release

1. Species

2. Time

3. Size

4. Location

5. Fish Quality

6. Fish Quantity

7. Environmental Condition

8. Method of Release

9. Interaction with Other Species and Natural Stocks

H. Adult Trapping

1. Type

a. Gaffing

b. River Barrier and Trap

c. River Barrier and Diversion Fishway

d. River Barrier and Effluent

e. Effluent Only

f. Barrier and Seining

g. Fishway Trap with Hauling

2. Holding Facilities

a. Water Quality

b. Water Quantity

c. Pond Type

(1) Earthen

(2) Concrete

(3) Automated

I. Equipment

1. Housing and Services
2. Hatchery or Building
3. Freezers
4. Auxiliary Standby Generator, Yes or No
5. Shop
6. Storage
7. Feeders
8. Trucks
9. Tools
10. Screens (Pond)
    a. Flat
    b. Powered
        (1) Belt
        (2) Drum
11. Intake
12. Supportive Equipment

IV. <u>Ownership and Costs</u>

A. Land
1. Quantity
2. Purchase Cost-Future Value
3. Development Costs

B. Facility Development Costs

C. Facility Cost-Benefit Ratio

D. Labor Requirements

V. Production Recommendations and Potentials

A. Refer to Table on Smolt Production

B. Fishery(ies) to Serve

C. Species and Species Interaction (Biological and Political)

D. Magnitude of Contribution

E. Optimize Natural and Hatchery Harvest

REPORT OF

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National Marine Fisheries Service

I have received the trip reports from Spencer, Mayo, Bienfang, Rothwell, and Senn and am adding mine to the lot. Having had the advantage of reviewing the above five reports, I have taken the liberty of removing sections of my report that are redundant or text that is adequately covered by others. I have limited my comments to:

1. Presenting background information on what is presently known about pink and chum feeding habits in the North Pacific marine environment, and how it might relate to the Southern Ocean. The data are perhaps timely in light of Paul's feelings (and mine) that the Chilean estuaries may not support large numbers of planktivorous fry and fingerlings. A sample program is urgently needed before we proceed with the introductions. It is interesting to note that the Japanese have similar doubts and are calling for a similar program at Coyhaique before they introduce large numbers of chum salmon in that region.

2. Hydrological data--synthesizing river and lake information by Paul, Tim, Guy, and myself. Evaluation of individual freshwater sites visited in the Magallanes has been eliminated as the subject is adequately covered by others.

3. A detailed plan for the oceanographic-limnological sampling program for 1976-1977. The plan reflects my own opinions as to who should conduct the various sampling projects. It should be pointed out that the critical months for the sampling program in Chile are September-December; therefore, time is of the essence if sampling is to proceed this year.

4. Information on the availability of hatchery feeds in Chile. The need for artificial feeds is especially important for chinook and coho rearing programs as suggested by Harry Senn. Some insight was gained on our visit to the Rio Blanco trout hatchery on: feed formulations presently used for trout and chum; local availability of major feed constituents; status of manufacturing facilities and the level of expertise of Chilean personnel in compounding these diets.

I. BACKGROUND INFORMATION ON FEEDING HABITS OF PINK AND CHUM SALMON FRY IN THE NORTH PACIFIC OCEAN

Recent technological advances in rearing salmon in hatcheries now make it possible to release tens of millions of chum and pink fry into individual estuaries.[1] The success of individual year classes of pinks and chums depends largely on the availability of the proper feed organisms in the estuary at the time of outmigration. It is during this critical estuarine period that the greatest losses occur, more so than during later oceanic life stages when the fish is a more opportunistic predator capable of feeding on a wider range of food organisms.

The recent success of Japanese chum salmon hatcheries[2] is attributed primarily to two factors: extended rearing and timing of release. Extended rearing substitutes artificial feeding in hatcheries for less dependable supplies of planktonic feed organisms during the critical period of estuarine growth. Thus larger fish (about one gram) are released with a subsequent improved survival to return. Similarly in North America, extended rearing has resulted in improved ocean survival for coho, chinook, and sockeye when reared to 20 g, 7g, and 5g size, respectively.

After emerging from the spawning gravel, pink and chum fry migrate immediately to saltwater and begin to feed. A number of important studies have been conducted in recent years to quantify the food and feeding habits of fry in the estuary. The picture is one of a selective feeder early upon its entry into the estuary, becoming more opportunistic as the fish grows.

The period of outmigration near the southern geographical limit of pink and chum salmon begins in March, peaks in May, and ends in June. (The meteorological analogue in the Southern Hemisphere would be September, November, and December.) In the northern range of the species, outmigration may not occur until April.

Upon leaving the streams, the fry begin to feed on zooplankters such as calanoid copepods, larvaceans, barnacle nauplii, cladocerans, and other small crustaceans. Chum fry tend to eat more larger hard-shelled organisms and epibenthic forms than do pink fry (Bailey et al, 1976). Similar feeding habits have been described for pink and chum salmon fry over most parts of the species range: Kamchatka Peninsula (Andrievskaya 1968), the Strait of Georgia and San

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[1]The Japanese now release about one billion fry annually from Hokkaido and Honshu hatcheries.

[2]In 1975 more than 14 million adults of hatchery origin returned to the Japanese coastal fishery, worth an estimated $160 million.

Juan Islands (Annan 1958; Barraclough 1967; Robinson, et al, 1968), the north coast of British Columbia (Manzar 1969), and southeastern Alaska (Chamberlain 1906; Bailey, et al, 1976).

By contrast, studies in Puget Sound and the Canadian San Juans have shown epibenthic organisms to be relatively more important than pelagic zooplankters in the early feeding stages (Gerke and Kaczynski 1972; Healey et al, 1976; Simenstad and Snyder 1976). The choice of feeds may be dictated by necessity as outmigration begins earlier near the southern limit of the range, prior to the major spring plankton bloom.

Chum and pink fry are both species and size selective as to preferred prey organisms. In Alaska most food items were between 0.3 and 3.0 mm long. Copepods constituted 30% of the total food volume while larvaceans constituted 34%. The remaining 36% was composed of various other plankton forms including a few epibenthic animals. Selective feeding by fry has been shown to occur in Alaskan estuaries (Bailey et al, 1975) and also has been demonstrated in the laboratory (LeBrasseur 1969). Relatively more cladocerans, decapod zoeae, and larvaceans and relative fewer barnacle nauplii were eaten by salmon than appeared in plankton samples. Benthic and intertidal forms of mysids, cumaceans, isopods, and amphipods were also found, indicating occasional feeding along the bottom and shoreline areas.

The dominant prey organisms in north Puget Sound early in April and May are harpacticoid copepods. Later in the summer, the common diet may emphasize harpacticoids but is diversified to include a higher proportion of larger epibenthic or pelagic crustaceans and fish larvae (Simenstad and Snyder 1976). Stomach contents also include cumaceans, decapod zoeae, and euphausids.

In Hood Canal, the diet was similar with epibenthic gammarid amphipods and harpacticoids predominating early in the season (April). From May through July, there was a shift to insects, larvaceans, and other more pelagic zooplankters including larvaceans, fish larvae, and euphausid eggs.

In British Columbia, individually marked cohorts of chum fry were found to spend up to 18 days on the mudflats at the mouth of the Nanaimo River during the early part of the downstream run (March-May) but only 1.5 days on average on the flats in June (Healey et al, 1976). Fry abandoned the mudflat at the end of May and began to migrate away from the shore. The dominant prey organisms was harpacticoid copepods during residence on the flats, shifting to a more catholic diet of pelagic zooplankters as the population migrated from the nearshore environment.

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II. PROPOSED CHILEAN SAMPLING PROGRAM

We believe an intensive one-year sampling program is required in order to estimate the capacity of Chilean estuaries to support pink and chum salmon fry and coho, chinook, and sockeye fingerlings. The problem of evaluating carrying capacity of South Chile estuaries for artificially produced chum and pink fry is most pertinent. The lack of information available on zooplankton standing stocks and species composition or temporal changes in the plankton would make the release of these two species in Chilean estuaries uncertain.

Study Objectives

The sampling program should address the following questions:

1. How does the known diet of the fry in the North Pacific Ocean compare with the available food organisms in Chilean estuaries?

2. What is the estimated carrying capacity of the Chilean estuaries using known food consumption rates and standing stock measurements in those estuaries?

3. Who are the potential predators and competitors in the Chilean ecosystem and what is the likely outcome of such pressure on the introduced salmonids and on the indigenous species?

4. And finally, how can oceanographic and meteorological data be used to predict the period of peak zooplankton abundance in Chilean coastal waters and the optimum time for release?

The objectives of the sampling program are therefore as follows:

1. Determine abundance, seasonality, and size distribution of pelagic and benthic zooplankton stocks important as food for salmon fry and fingerlings.

2. Relate temporal changes in chlorophyll and zooplankton abundance to seasonal variations in environmental parameters.

3. Develop techniques to predict seasonal blooms using oceanographic and meteorological data.

4. Examine seasonal hydrology of the source waters for the hatchery.

Cooperating Agencies

Coordination of field sampling, administrative management of the program, data analysis, and preparation of the final report should be under the Oceanic

Institute. Paul Bienfang (OI) should be made Senior Investigator in charge of program coordination. Guy Rothwell should be in charge of design and construction of the lake and/or river instrumentation package for continuous recording of water temperature, lake level, air temperature, and wind speed and direction.

The research should be carried out insofar as possible by Chilean research agencies (SAG, IFOP, University of Chile, Catholic University, Patagonian Institute, etc.). We are satisfied that a simple, straightforward program of field sampling can be conducted and data adequately analyzed by experts within Chile (Table 1). The following oceanographic-meteorological-limnological program is designed for sites visited in the outer islands of the Magallanes and the Skyring-Otway watershed system in April, but could be applied to other areas such as the Torres de Paine with only slight modification. It is assumed that sampling will take place at the two most preferred hatchery sites. Some general activities need not be conducted at all sites providing they are not too widely separated (i.e., meteorological).

Sampling Periods

The sampling periods (15) should be monthly for a period of at least one year with increased sampling frequency during months when salmon fry and fingerlings would normally be released and when the plankton bloom is in progress. Monthly samplings will be conducted from August through September 1976 (Table 2). Sampling frequency will be increased to twice monthly from October to December, the period of the bloom and the meteorological analogue for outmigration in the Northern Hemisphere. Monthly samplings should be continued thereafter to complete one full year.

Table 2. Sample Times.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sampling	15								15	15	15	15
Dates	31	29	31	30	31	30	31	31	30	31	30	31

Field Support

Field support will be supplied by IFOP out of the Punta Arenas Laboratory. IFOP representative will be Guido Celedon. There are two IFOP vessels of sufficient size for use in the Magallanes or Skyring-Otway areas. The larger of the two is located in Punta Arenas; the other in Puerto Natales. A portable, wooden laboratory building should be constructed to be assembled on the deck of either vessel. The laboratory could be assembled before each cruise or lifted intact by crane (at least in Punta Arenas) from vessel to dock. It would provide bench space for preserving samples, recording data, filtering chlorophylls, and storing

Table 1. Proposed field sampling program - salmon project, Magallanes Province, Chile.

Sampling or Monitoring Activity	Procedure	Equipment Required	Sampling Frequency	No. of Stations
FIELD SUPPORT				
Vessel	Provide oceanographic platform, transportation to and from field stations	Vessel with portable deck laboratory and winches, vehicle	As required	--
LIMNOLOGY				
Water chemistry	Water samples at surface, above and below thermocline (pH, total alkalinity, metals, water temperature, dissolved oxygen, turbidity)	Van Dorn bottles with thermometers, pH meter, Spectrophotometer, Winkler titration equipment	Monthly	1
Temperature profiles	Vertical profiles, surface to bottom (temperature, dissolved oxygen, depth)	Hydro-Lab, deck recording unit	Monthly	1
Zooplankton	Semi-quantitative tows with opening-closing nets, above, below, and in thermocline	Clarke-Bumpus	Monthly	1
Chlorophyll	Water samples at surface, above and below thermocline	Van Dorn bottles, Millepore filter app., Spectrophotometer	Monthly	1
Lake bottom contouring	Sonic profiles along predetermined grid	Echo sounder, Zodiac	Once	--
Surface temperature	Continuous record of lake surface temperature at instrument tripod	Foxboro 30-day recorder	Continuous	1
Lake level	Continuous record of lake surface level, recorded at instrument tripod	Tide gauge	Continuous	1
METEOROLOGY				
Weather	Air temperature, rainfall, wind speed and direction. Recorded at instrument platform (tripod)	Recording thermistor, anemometer, rain gauge	Continuous	1
Light	Integrated, weekly means measured at Punta Arenas Airport?	Solarimeter	Continuous	1
OCEANOGRAPHY				
Water chemistry and temperature	Vertical profiles, surface to bottom (temperature, conductivity, dissolved oxygen, depth)	Hydro-Lab	Monthly	3
Chlorophyll primary productivity	Bottle cast, sample depths determined by light transmission - deck incubation	Van Dorn bottles, photometer, productivity kit, Secchi Disc.	Monthly	3
Zooplankton	Semi-quantitative oblique tows, bottom to surface, replicated, 1/2 hour in duration	1/2 meter (63 cm) Nitex nets (210 micron mesh) TSK meters	Monthly	3
Nekton	Oblique tow, bottom to surface in outer channel only, 1/2 hour duration	Isaac-Kidd midwater trawl	Monthly	1
Epi-benthos	Bottom cores (top 10 cm), replicated four times	?	Monthly	2

the hydro lab and other oceanographic equipment and could be used for both fresh and saltwater sampling projects. The building should be provided with power, heat, and a sink.

Oceanographic Sampling

It is necessary to occupy a minimum of three oceanographic stations at each hatchery site. The first station should be as near the proposed hatchery as is practical and therefore will necessarily be a shallow, predominantly freshwater station. For example, in the case of Lago Julio, the station would be in the fore-bay. The third station would be located in the closest deepwater channel where diurnally migrating species are likely to occur. In addition to replicated net tows in the surface mixed layer at this station, deepwater tows with midwater trawls should be made (Table 1). The purpose here is to determine the local availability of larger forage organisms, pelagic predators, and potential competitors of migrating fingerlings. The second station would be located intermediately between 1 and 2. The sampling sequence should be completed on either a flooding or ebbing tide.

Much time could be saved if environmental measurements (salinity, temperature, dissolved oxygen) could be obtained with a low-cost continuous-recording, remote sensing system like a Hydrolab. This would eliminate bottle costs except for chlorophyll samples and for calibrating the polarographic dissolved oxygen probe.

Hydrology-Limnology

Only one limnological station is necessary in the freshwater drainage system, whether it be a lake or river.

Meteorology

An instrumented station should be constructed for continuous records of air and water temperature, lake level or river flow, wind speed and direction, and rainfall. The instrument will be serviced monthly by the limnological team and data sent to the Oceanic Institute.

Satellite Recall System

It was pointed out to the Task Force by one or two of the Chilean scientists that we met that a Satellite Recall Capability for certain environmental data already existed in several of the international Antarctic programs.

Availability of using such a Satellite Recall System for specific data should be investigated by the Task Force team. It might be possible to locate two temperature probes, for example, in some of the remote waterways where additional data would be relevant to that which can be gathered by the more usual means.

It is recommended that the project budget for two probes, and that the Task Force negotiate with the appropriate authorities for acquiring and installing them into the project's data collection base.

III. SUITABILITY OF LAKES AND RIVERS FOR SALMON CULTURE

Lakes and rivers visited by the site-selection team were examined for watershed characteristics (size, slope, vegetation, origin of runoff, exposure) and hydrology (water temperature, pH, flow, color, and clarity). All lakes and rivers examined, whether in the Magallanes Islands (Tables 3 and 4) or on the Brunswick Peninsula (Table 4) exhibited pH and temperature suitable for the culture of Pacific salmon. The highest quality water was found at:

	Place	pH	Temperature	Color
1.	Rio Azopardo	7.3	6.0	Crystal clear
2.	Rio Sullivan	7.0	6.0	Crystal clear
3.	Little Rio Azopardo	6.9	4.0	Clear, light brown
4.	Rio Cordes	6.6	4.0	Clear, light brown
5.	Rio Coisel	6.9	5.0	Clear, light brown
6.	Rio de la Botella	7.1	7.5	Light brown

A generalized classification scheme was devised based on pH and water temperature. These three classes are:

1. Lowland lakes, rivers, and bogs of near-zero gradient with pH 6.0 - 6.5, temperature 7.0 - 8.0° C. Example: Lago Mercurio.

2. Lakes and rivers arising in low-gradient watersheds with pH 6.0 - 6.5, temperature 6.0 - 8.0° C. Example: Lago Cordes.

3. Lakes and rivers arising in high-gradient watersheds with pH 6.5 - 7.5, temperature 4.0 - 8.0° C. Example: Rio Azopardo.

It is my impression that freshwater quality is only just adequate. We did not find the "pristine" salmon waters expected at the outset of the trip. No groundwater was available, only surface runoff of unknown quality except for the simplest of properties, temperature and pH. Furthermore, the probable ephemeral nature of water flow in most of the small riversheds and attendant variations in water quality associated with variable flow cast some doubt on the potential of a fully functional year-round hatchery being established at any of these sites. I must confess that, contrary to expectations, water quality was disappointing.

IV. MANUFACTURE OF SALMON FEEDS IN CHILE

The culture of most salmon species in North America requires feeding in the hatchery. The amount of feed required depends on the species reared and the size of that species at the time of smoltification and release. Thus, coho smolts at 15 grams each require a longer rearing period and more feed than chinook which only have to be reared to 7-gram size. Therefore, feed may constitute the major annual operational cost for salmon hatcheries because of its high cost. In Chile, the manufacture and supply of feeds to hatcheries in the far south may become a significant logistic problem adding significantly to the cost of smolt production. The magnitude of these cost increases depends on the capability of the Chileans to manufacture feed from locally available constituents.

The capability for the manufacture of salmonoid feeds does exist in Chile. A dry pelleted regimen is presently manufactured at the Rio Blanco trout hatchery located in the mountains northeast of Santiago. The diet is based on locally available anchovy meal. Most other major constituents (Table 5) are also available locally. The formula was originally suggested for use by Francisco Ovalle, a former student of Dr. E. Salo of the University of Washington. Sulfa and TM-110 (Pfizer) is used in the feed for treatment of disease.

Table 3. Lake and river properties - cruise of the Lientur, April 7-16, 1976.

River or Lake	$Q(M^3)$	Q Max	Temp. (°C)	pH	Area watershed (KM^2)	Color	Description
Rio Fox	3.0	36	6.5	6.4	120	Light brown	Flat - low lying
Rio West Owen	0.1	1	7.0	5.6	22	Light brown	Flat - low lying
Coisel S.W. (Rio)	0.05	--	5.0	6.8	12	Brown	Steep
Coisel N.E. (Rio)	0.2	1	4.5	7.5	3	Clear	Steep
Rio Coisel	10.0	70	5.0	6.9	100	Clear, light brown	Flat but some steep tributaries
Trib. Rio Coisel	0.03	0.3	--	--	--	Clear	Steep
Rio Lientur N.	0.9	2.7	7.0	6.3)	144	Red	Flat - low lying
Rio Lientur S.	1.0	4.0	6.0	6.9)		Clear, light brown	Flat - low-lying rises from lake
Rio Azopardo	>100	> 300	6.0	7.3	2,900	Clear	Rises from large lake (Fagnano)
Little Rio Azopardo	5.0	25	4.0	6.9	102	Slight red	Steep valley
Rio Algo W.	0.3	1.5	4.5	6.5	8	Med. red clear	Steep valley
Rio Algo	10.0	30.0	5.0	6.7	30	Light red	Steep valley - rises from Lago Algo
Rio Engano	2.0	4.0	6.0	6.4	11	Red	Flat - rises from Lake Engano
Rio Mercurio	2.0	6.0	8.0	5.5	11	Dark red	Flat bogland - rises from Lago Mercurio
Rio Julio	10.0	30.0	--	--	50	Light red, clear	Steep - rises from Lago Julio
Rio Cordes	7.0	35.0	4.0	6.6	70	Light brown, clear	Steep, large valley
Rio Cordes N.W.	0.1	1.0	4.5	6.5	--	Clear	Steep, waterfalls
Rio de la Botella	10.0	30.0	7.5	7.1	24	Light brown	Steep - alkaline rock exposed

Table 3 (cont.)

River or Lake	$Q(M^3)$	Q Max	Temp. (°C)	pH	Area water-shed (KM^2)	Color	Description
Rio Sullivan	3.0	9.0	6.0	7.0	75	Crystal clear	Steep - alkaline rock exposed
Lientur Sluice	7.0*	35.0	7.0	--	144 (see above)	Light brown	Flat and steep valleys; rises from Lago Lientur
Lago Fox			8.0	6.2		Light brown	Flat - low lying
Lago Don Bosco			8.0	4.7		Dark red	Flat - small bog sampled
Lago Utero			4.0	6.6		Red	Steep drainage - pond
Lago Algo			6.0	6.4		Light red	Steep, ice fields
Lago Engano (upper)			8.0	6.4		Light red clear	Flat - low lying
Lago Engano (lower)			7.5	6.2		Light red clear	Flat - low lying
Lago Mercurio			8.0	5.5		Dark red	Flat - low lying
Lago Julio			8.0	6.2		Light red clear	Steep
Lago Cordes			7.0	6.2		Light brown	Small low lying - adjacent Rio Cordes
Lago de la Botella			7.5	7.1		Light brown	Steep - alkaline rock exposed

*Estimated - not measured.

Table 4. River properties - Brunswick Peninsula near Punta Arenas, April 17, 1976.

River	$Q(M^3)$	Q Max	Temp (° C)	pH	Color	Description
Unnamed	0.2	5.0	9.0	7.2	Light brown	Flat - low lying
Rio de la Fresca	2.0	10.0	9.0	7.1	Light brown	Flat - low lying
Rio San Juan	20.0	50.0	5.0	6.9	Brown; turbid	Flat but with some steep tributaries

Table 5. Trout diet formula - Rio Blanco Hatchery, Chile.

	Percent
Fish meal	46
Safflower (flour)	18
Wheat middlings	16
Milk powder	15
Hake oil	3
Vitamin pack	1
Yeast (brewers)	1
	100

Vincente Orellana, the hatchery manager at Rio Blanco, informed us that when all the trout hatcheries were in full production he was making up to 8,000 kilos of feed per month. His maximum daily capacity is about 300 kilos per day, or a projected annual capacity at Rio Blanco of about 96,000 kilos. This amount of feed is sufficient to produce approximately 160 million 0.8 g chum fry, or 80 million 0.8 g pink fry, or 7.5 million 7.0 g chinook fingerlings, or 4.9 million 10.0 g sockeye fingerlings, or 3.3 million 15.0 g coho fingerlings (based on a 2:1 feed conversion).

Fish meal is purchased by the hatchery every six months and is Chilean in origin. Samples of two such meals and a finished trout pellet were analyzed for proximate composition at the NMFS Pacific Utilization Research Center in Seattle (June 1976). Results are presented in Table 6. The meals are fairly typical in proximate composition but the feed is low in lipid (3.1%) and should be adjusted to contain between 10 and 15 percent oil. The low oil content is the probable cause of slow growth of both the trout and chum salmon (several hundred) presently being grown at Rio Blanco. The chum salmon, although apparently healthy, have been held at the hatchery since March 1975 and weight only about 20-25 g each (temperature range 5-12° C). High mortality occurred when the chum were fed a dry pellet but dropped to an acceptable level when a moist pellet was substituted.

Table 6. Proximate composition of Chilean fish (anchovy) meals and a trout pellet.

	Protein	Water	Fat	Ash
Meal 1 (fine)	69.6	7.9	5.6	13.3
Meal 2 (coarse)	69.5	7.7	5.7	12.8
Trout pellet	45.4	8.6	3.1	10.2

The equipment in the feed preparation room is quite modern and new, having been installed within the past 3-5 years. A list of that equipment is presented in Table 7. It can be seen that production capacity is limited by the mixing-drying process. In addition to the feed preparation room, three storage rooms contain 56 m^2 of floor space for constituents and 75 m^2 for finished feed.

Table 7. Feed preparation equipment - Rio Blanco Hatchery, Chile.

Equipment Type	Manufacturer	Model	Capacity
Pellet mill	Dravo	39 Inch	600 kilo/hr.
Mixer	OSO	R-150	70 kilo/hr.
Dryer	Glatt Cyclonic	TR-30	30 kilo/hr.
Seive	Universal-Racine, Wisconsin	S	--

Conclusion

The Rio Blanco Hatchery has a modest but modern feed production facility and is staffed with personnel experienced in the manufacture of trout feeds. Unfortunately, there was talk that SAG intended to convert the facility over to the production of hog and chicken feeds; such a move should be discouraged in light of the recent interest in the production of feeds for salmon hatcheries. The major dietary constituents of trout and salmon feeds are available in Chile, solving, at least in part, the major logistics problem. But the logistics of transporting large amounts of finished dry or frozen feeds from Santiago to Punta Arenas is still formidable and consideration should be given to either moving the existing facility or constructing a new feed preparation facility in the commercial center nearest to the hatchery.

REPORT OF
Paul K. Bienfang
The Oceanic Institute

I. INTRODUCTION

The first Task Force party, consisting of T. Joyner, C. Mahnken, G. Rothwell, and myself, were charged with evaluating approximately 20 potential hatchery sites and selecting the most appropriate sites for inspection by the second Task Force.

The following report, reflecting an oceanographic/biologic rather than engineering or salmon background, stresses the environmental and food chain considerations apparent at the various sites.

I think it will be helpful (for the present synthesis of all participants' reports, as well as for both immediate and future planning and participation) to discuss an obvious fact: that this is a project of tremendous scope. It encompasses scores of disciplines; it will take place in an environment that is familiar to none of us; and its success will require extensive amounts of information from many, many fields, some of which may be unknown at this time. Admitting this, it seems unrealistic, if not naive, to assume that a priori one could anticipate and understand all the forces coming to bear in such an effort; or, further, to rationally devise a schedule which would allow adequate inspection of all elements. There will be surprises. It would seem reasonable, therefore, to approach future aspects of the project with the notion in mind that from time to time the environment we are seeking to control will reveal itself to be different than we expected, and we should be ready to respond to these surprises with complementary prudent courses of action.

Seeding the Southern Ocean with Salmon is a project comprised of many complex logistic and theoretical problems embracing many disciplines. We must admit that we do not at this point know as much as we would like to ensure its success. The best we can do is to do our best, and I feel the multidisciplinary approach is a prudent first step and testifies well for the thoughtfulness and thoroughness of the project's planners. The next rational steps would seem to be to make the most of what we have (i.e., view and record environment we saw accurately) and design future activities so as to reveal unknown facts necessary to ensure success. In particular, there is very little known about the environment we are dealing with. Rational planning would seem to necessitate a thorough preliminary study to ascertain as much as possible about the nature of the beast we are seeking to control.

II. SITE SURVEYS OF FIRST TASK FORCE EXPEDITION

We visited approximately 24 sites of varying size and character between April 7-16, 1976. Following each day's trip ashore, we would sit down together, discuss what we had seen, and compile our scribbled notes into one body which survived as a table included in Connie Mahnken's report. Guy Rothwell made a remarkably good set of sketches of several locations which are in his report, and Captain Herrera also compiled an extremely helpful table concerning access which is also to be found in Guy's report. In addition to these documents, I include a table of what seemed to me to be the salient features of the best sites we saw; these include Lago Lientur, Rio Azopardo, Lago Algo, Lago Julio, Bahia Cordes, and Lago de Botella.

Site Summary

1. Lago Lientur

    Virtues: Size, extensive delta area, presence of forepond systems.

    Limitations: Brackish lake, heavily colored, low head, limited building space.

2. Rio Azopardo

    Virtues: Ample building area, copious freshwater flow, great gravel, high pH, clear water.

    Limitations: Bad marine access, persistent bad weather spot, far from Punta Arenas.

3. Lago Algo

    Virtues: Well protected, amphipods numerous under rocks, considerable flow, ample head, ample construction area, adequate landing/anchoring sites for large vessels, large lake feeding the stream system.

    Limitations: Configuration of stream crevasse very steep and narrow (difficult building), colored water, temperature 5° C, far from Punta Arenas, terrestrial access logistics inconvenient.

4. Lago Julio

    Virtues: Temperature = 8° C, well protected, good marine access, freshwater forepond, considerable freshwater head, clear water, good gravel.

    Limitations: Far from Punta Arenas, little available land for hatchery site, landing sites not very good, affected by West Wind, terrestrial access logistics are inconvenient.

5. Bahia Cordes

Virtues: High biological activity evident, many small fishes existing in streams, proximity to Punta Arenas, ample building area, extremely large forepond-bay system to provide semi-protection and high food supplies for outgoing fry and which is clearly amenable to design to capture of returning adults.

Limitations: Low head on stream, access by large vessels delivering equipment is uncertain, affected by West Wind.

6. Lago de Botella

Virtues: Evidence of high biological activity by large standing stocks of benthics, large plankton populations evident in nearshore area where we did nightlighting, well protected, good anchorage and in general good marine access, topography allows convenient terrestrial logistics.

Limitations: Far from Punta Arenas, rather limited head on lake system, reduced forebay system which would afford little protection to fry in first weeks after release, i.e., no real nursery area.

III. MINUTES OF COMPILATION/SYNTHESIS MEETING, SANTIAGO

When we all got together to discuss our impressions of the expeditionary days, several points of discussion seemed to highlight the meeting; these topics follow.

1. Topic: Saltwater access

Comments: Seawater is wanted for pumping to precondition the fry prior to release to minimize the fresh/saltwater shock.

Fresh/saltwater estuarine area is valuable in providing maximum food and time during which feeding can take place in a protected area prior to ocean proper.

Seawater proximity means proximity of oceanic predators.

The fact that we inspected under conditions of low freshwater flow is only an assumption.

Seasonal variation in freshwater flux appears large.

2. Topic: Why go off mainland?

Comments: Engineers state that there must be compelling reasons to take on the logistical problems of locating on an uninhabited, difficult-to-reach island, as opposed to nearer the Punta Arenas/Puerto Natalis area.

The point is made that the Serrano system (north of Puerto Natalis) has a road, large freshwater flux, good water, trout present, a hydro plant. The salmon barge idea to surpass trout predation is presented; returning capture is extremely easy. Note is made that this is still in the upper watershed area.

3. Topic: Preliminary study

Comments: It was suggested that since a preliminary study of the candidate environments could probably not yield a definitive answer as to the quantity of salmon the system can support, why not just go ahead and build the hatchery and see what happens.

It was responded that the study would include investigation of many facets of the project which will definitely affect project success and that the study would surely describe what types and how much of suitable food would be available and would describe the seasonality of same which is translatable to increased survival through properly timed release of the brood. It was also pointed out how little is generally known about nearly all facets of the area, and the point made about rational planning based on as many known facts as possible.

The initial comment was rephrased as "when do we stop studying and decide we have enough?"

4. Topic: Expected logistical/personnel difficulties

Comments: The point made that specifications, costs, etc., are necessary; we must have ideas of the logistic costs, the cost of personnel (high salary anticipated necessary), minimum of two years for professional types; extremely good conditions for the workers and their families are essential and expensive.

The point made that to put people on islands, it means to give them the right vehicles, to give them securities; they are independents, the process should afford many types of help from cities (hospitals, supplies, etc.). A good boat is required in case of emergency and dependable articles all down the line. The boat should be big and able to access to adjacent areas.

The point made that the proper salmon professionals are not in Chile; therefore, they must be imported from the Northwest.

Comment made that would not be a problem, anticipating a two-year obligation. Comment made that a long-term Chilean manager could work with the U.S. expert to keep the continuity of logistic details and environment.

IV. WATER COLOR DISCUSSION

Comments and discussions about the property of water color arose with surprising frequency in connection with nearly all the prospective sites. This recurrent concern would seem to typify the case of a widespread phenomena of this area which is different from the expected. The problem lies not in the determination of coloration (which was evident to everyone), but rather in drawing conclusions about water quality and its fishery effect based upon 1) the water color and 2) experience/knowledge from other parts of the world regarding the water color - water quality relationship.

Water color, in itself, is not a water property; it, rather, reflects various properties in the water imparted to it through its recent history from rainfall to runoff. These properties are only proportional to (related to) the water color under conditions of similar history, i.e., the experience over the watershed. The nature of the watershed, in turn, is affected by the previous geological, climatological, and biological history of the environment. These histories would appear to be different in Southern Chile from those we are familiar with in the northern hemisphere. For example, the watersheds we walked were matted with dense carpets of moss populations the likes of which I have never seen.

Thus, the color of the waters in Southern Chile may well mean something very different than we might expect based upon northern hemisphere experience. We should, of course, make note of what we have seen; however, it seems we should be cautious regarding conclusions based upon our previous water color - water quality experience.

V. WATER QUALITY ANALYSIS

Preliminary water quality criteria for the culture of the five species of Pacific salmon have been supplied from the records of Kramer, Chin and Mayo. Briefly they can be summarized as follows:

Gas Saturation

Oxygen: Maximum = 105% sustained saturation, minimum = 6 mg/l.

Nitrogen: Maximum permissible saturation, eggs and early rearing, 100% saturation; normal rearing, 105% saturation.

Temperature

Incubation Water: The temperature should fall in the range of 48 to 55° F.

Rearing Water: The temperature should stay in the range of 40 to 65° F., with 50 to 55° F. being desirable.

Holding Water for Adults: The temperature should be less than 56° F.

Turbidity

Hatchery Building: 2 JTU maximum (incubation).

Rearing and Holding: 60 JTU maximum.

The acceptable pH range for rearing water is 6.8 to 8.0.

Heavy Metals

It is known that heavy metal concentrations in rearing water are damaging to fish. It is known also that the damage done is related to the strength of the concentration, to the age of the fish (or egg), to the length of exposure and probably to several other factors simultaneously.

Unfortunately, little definitive work has been done that will enable stating with accuracy the probable long-term acceptable maximum concentrations. Suggested maximum long-term acceptable concentrations found in water passed through a glass fiber filter are:

Heavy Metal	Symbol	Concentration
Iron	Fe	0.300 mg/l
Manganese	Mn	1.000
Aluminum	Al	0.100
Zinc	Zn	0.040
Lead	Pb	0.010
Mercury	Hg	0.100
Cadmium	Cd	0.002
Copper	Cu	0.005
Fluoride	F	1.500
Chromium	Cr	0.010

Metabolite production will be calculated using the following equations:

Nutrient or Waste Product	Per Pound Moist Type Food Mean	Per Pound Dry Type Food Mean
NH^4-N	0.0203	0.0289
NO^3-N	0.02	0.024
PO^4-P	0.0114	0.0162
COD	1.35	1.89
BOD	0.42	0.60
Suspended Solids	0.37	0.52

The units for the above equations are in pounds of metabolite per pound of food fed (F).

Based on results of the Bonneville Buffering Study conducted for the Bonneville Dam Fish Hatchery on the Columbia River, CO^2 production will be estimated as half the oxygen consumption or:

lbs. CO^2 produced = 1/2 lbs.O^2 consumed.

The following table illustrates the effect of pH and temperature upon the distribution of ammonium and ammonia ions in water. The toxicity of ammonia in water is a function of its ionic state. Specifically, the ammonium ion (NH^4+) itself is relatively nontoxic while ammonia (NH^3, the gaseous form) is exceedingly toxic. Thus, where the pH is relatively low, there is little or no ammonia gas component and toxicity is low. Where the pH is high, the percentage of ammonia gas present is higher and toxic effects may be observed.

Ammonia tolerance criteria is as follows:

	3-in. Fish	6-in. Fish	
Allowable Un-ionized Ammonia (NH^3)	0.0075 mg/l	0.01 mg/l	Coho
	0.002 mg/l	0.005 mg/l	Chinook

The maximum values of other waste products are:

NO^2-N (Nitrite)	0.5 mg/l
CO^2	6 mg/l
NO^3 (Nitrate)	10 mg/l

Water quality analysis was not a part of the premeditated site-selection evaluation during the first visit. Several water samples were collected during the trip to provide preliminary indicators of the quality at each of the sites selected for re-evaluation by the second team. The samples, collected in bottles kindly provided by IFOP, were taken from San Miguel, Lago la Botella, Cordes Stream, Cordes Lake, Lago Julio, Lago Algo, Rio Aguafresca, and Rio Caleta. The determinations were made in Chile by the Universidad de Chile, Instituto de Metalurgia, and the Departamento de Obras Civiles, and are gratefully acknowledged.

UNIVERSIDAD DE CHILE
INSTITUTO DE METALURGIA

LABORATORIO QUIMICO

CERTIFICADO DE ANALISIS PUBLICO

Nº 00131[illegible]

ORDEN N.º 1827 FECHA DE RECEPCION 19 de Mayo de 1976

DUEÑO

CARTA N.º Sra. Irma Vila

PROCEDENCIA Proyecto "Introducción de Salmón en Magallanes

N.º INTERNO	N.º MUESTRA	~~PESO~~		ANALIZADA POR		~~LEYES~~		OBSERVACIONES
Sol	(ppm)	Cu -	Cr -	Mn -	Fe -	Ag -	Cd -	Zn -
	1	0.11	0.00	0.00	0.09	0.00	0.00	0.47
	2	0.16	0.00	0.00	0.36	0.00	0.00	0.38
	3	0.16	0.00	0.00	0.28	0.00	0.00	0.49
	4	0.11	0.00	0.00	0.03	0.00	0.00	0.23
	5	0.13	0.00	0.00	0.47	0.00	0.00	0.40

ANA MARIA SOTO
QUIMICO ENSAYADOR

DIRECTOR

VALOR E°

Santiago, 25 de Mayo de 1976

UNIVERSIDAD DE CHILE
DEPARTAMENTO DE OBRAS CIVILES
Casilla 5373 - Santiago

I N F O R M E

MUESTRAS:	Aguas. Proyecto: Introducción de Salmón en Magallanes.
SOLICITADO POR:	Sra. Irma Vila. División de Pesca. Servicio Agrícola y Ganadero.
ANALISIS PEDIDO	Nitrógeno Kjeldahl total Residuo filtrable Conductancia específica.
METODO DE ANALISIS	Standard Methods for the Examination of Water and Wastewater 13th Edition 1971. APHA -AWWA-WPCF.

RESULTADOS:

LUGAR DE MUESTREO	PARAMETROS		
	N Kjeldahl total mg/l de N	Residuo filtrable a 180°C mg/l	Conductancia Específica a 25° C umhos · cm^{-1}
Bahía Algo (P 1803-P 2368-P 648)	0,84	19	42,7
Río Caleta (P 337 -P 1829-P 964)	0,84	85	84,3

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LUGAR DE MUESTREO	PARAMETROS		
	N Kjeldahl total mg/l de N	Residuo filtrable a 180 °C mg/l	Conductancia específica umhos · cm⁻¹
Cordes Streart (P 1850)	4,28	130	48,5
Lago La Botella (P 1485-P1085-235)	0 62	23	39,2
San Miguel (P 1297-P 391-P1157)	1,65	965	1.593,0

OBSERVACIONES

Siguiendo indicaciones entregadas por S Irma Vila todas las muestras se filtrar previamente por filtro de vidrio.

Las muestras para N Kjeldahl no fueron servadas (H_2SO_4 hasta pH 2) en el te no.

Ana María Sancha
Químico
Sección Ingeniería Sanitaria

Santiago, 15 de Junio de 1976.

VI. ZOOPLANKTON COMPOSITION

The decision to make a cursory inspection of the types of zooplankton found in the Southern Chilean waters was also an afterthought conceived in Santiago. We were able to borrow the necessary equipment from Irma Vila. This inclusion, however, met with considerably more success than the metal analysis. This information is very important as these organisms will provide the food source for the released salmon and the survival of the latter will depend entirely upon the suitability and abundance of the zooplankton.

The collections were made in a variety of ways: horizontal tows, vertical tows, night-lighting capture, and hand-capture at the shore. Since the collection conditions could not be duplicated at the various stations, no density values or locality identifications are included. Rather, a list of the various taxonomic groups collected at all the stations is given, and since this information is apparently unavailable elsewhere in Chilean files, it, in itself, constitutes new information.

Zooplankton groups found in Tierra del Fuego:

- Shrimps (Galeteid)
- Copepods (Calanoids, esp. Acartia sp. 0.1-0.2 cm)
- Decapod larvae
- Crab zoea
- Amphipods (Gammarids, 0.5-1.0 cm)
- Amphipods (Hyperiids, .5-2.0 cm)
- Bryoyoans (Cyphonautis larvae)
- Polychartes (1.0 cm)
- Coilinferate medusae (1-2 cm diameter)
- Fish eggs
- Larval fish (0.5-1.0 cm)
- Octopus (3 cm)
- Trout (10 cm)
- Sculpins (6 cm)

It is interesting to note the mollusc larvae were never encountered through the beach shoreline areas in several of the sites supporting abundant mollusc populations. This observation will be discussed further in other sections of the report.

VII. IMPACTS FROM INTRODUCTION OF EXOTIC SPECIES

The idea that the large-scale introduction of an exotic species to this environment might have adverse environmental impacts was raised on several occasions, and this is probably the only point of opposition or scepticism to the venture that I've encountered. I think the concern is sincere since exotic introductions seem to have a rather poor track record historically; at least the unsuccessful ones often stand out.

Logically, neither side of the issue is entirely defendable since there are far too many unknowns to provide empirical conclusions either way. I made some observations and I have some thoughts on the subject which I hope will lead us to the most prudent dealing with the concern.

First, it appeared that our party was defensive about the issue, seemed to bristle at its mention, and relied, in part, on rather emotional arguments in the project's defense. This is unfortunate in a way, but certainly understandable. It seems the obvious stand is that "the impact of the salmon introduction is unknown at this time; what can we do to acquire information pertaining to this problem?" It seems reasonable to assume that with a little rational effort, and fact and process finding, we could become satisfied that we had made the best impact evaluation possible, based on the state of the art. This is as far as we can logically proceed and because this is a scientific venture, I think we're obligated to exercise this rational approach to such problems.

Along these lines, the following might be possible: 1) initiate communication with polar ocean ecologists in an attempt to find what is known about what's there, what it does, and how much it does. Find out what are the likely organisms to be in most direct competition with the salmon, etc. 2) conduct several samplings to determine existing carnivore populations, types, ages, gut contents, etc., presently in the shoreline area in question.

Incidentally, I am left quite unconvinced by the argument that if the impact turns out to be adverse, the salmon can be shut off as they return to spawn. There are a couple of things about this that leave me uncomfortable. How would one determine, qualify, or rank this "adverse impact"? Also, there are practical problems associated with discontinuing an operation such as this, particularly if it's profitable. But even notwithstanding these concerns, the ability to control the salmon with such surety seems remote. There are many, many streams and estuary systems in the area which can support salmon and certainly some of these other environments will be utilized by maverick spawners which lose their way home; and, given the remoteness of the region, it's unlikely that the pump could be completely shut off.

Importune for the approach that this is a question we will continue to explore so we can be assured the issue is given a rational analysis as information allows.

VIII. NEED FOR LONG-TERM, NEARSHORE STUDY

An astounding fact to this inhabitant of "developed" parts of the globe was the virtually total lack of scientific knowledge about the area in question. When talking to people in Santiago about the Punta Arenas/Tierra del Fuego regions, I got the feeling I was inquiring about life on Mars.

We know nothing about the structure or dynamics of the marine food chain that is a priori expected to support these extremely large populations of salmon. We know nothing about the types, sizes, abundance, or seasonality of the foods which must supply a stable, persistent substrate source for the salmon fry as they find their way to the oceanic regions away from the release site. It must also be admitted that we know nothing about the response of the existing ecosystem to the introduction of a large, exotic population of carnivorous salmon.

In my notes on food considerations at various sites, I was constantly surprised by the low pelagic zooplankton stocks. There were generally not extensive delta areas which are areas of naturally higher productivity. I've been told that the epibenthic copepods and harpactacoid copepods are an important food source for salmon and these tend to rely heavily on the bacterial (heterotrophic) food web.

It seems that there is ample cause for concern about the ability of this environment to provide a persistent, ample supply of fry food. We have no data on the production rate of primary producers (whether algal or bacterial, pelagic or benthic). There are several features we've seen which could support the idea of limited production rates: 1) low light and temperature; 2) low decomposition rates on land, if representative of aquatic co-processes would mean low heterotrophic production rates which would control the productivity of harpactacoids (fry food); 3) copious supplies of fat mussels on beaches had growth ring structure which suggested that they were very old and implying that the absence of grazing rather than prodigious growth accounted for the impressive standing stocks; 4) zooplankton tows were generally sparse. There is the notion that if it were possible for the secondary trophic level to support large tertiary stocks, representatives of those stocks would be exploiting it. The questions are obvious: are large tertiary stocks supported? And, if so, what are they and how will their presence affect the survival of the salmon fry; also, if not, why not and, more importantly, how will this affect the survival of the introduced salmon. Practical answers to these types of questions are possible and will greatly affect the confidence and rationale applied to our future efforts.

In addition to determining the abundance, size distribution, and seasonality of the pelagic and epibenthic zooplankton, efforts can be made to determine secondary production rates which set the levels of food which can be persistently available to the salmon fry.

Without food availability information, it is possible that the first batch of fry would exhaust the food supply for a prohibitively long time. The popular notion that the southern area represents an immature food web in which the salmon counterpart does not exist at present argues for the impact as described above because such a system would mean that the existing stocks, whatever they are, are the product of an ungrazed system. Thus existing zooplankton food stocks are closer to gross than net production and the establishment of a fishery would significantly reduce these food stocks for succeeding populations.

I feel that seasonality phenomena will be extremely important to the optimum survival of the salmon fry. The region is sub-antarctic and thus fluctuations in climate, sunlight, production, food supplies, and reproduction organisms are expected to show strong seasonal trends. This means that the availability of fry food will likely vary over wide limits throughout the year; likewise I would expect that the survival of fry would show complementary variation with the food availability. Survival of fry can undoubtedly be enhanced by timing the fry release to coincide with the greatest food availability. It is likely to assume that we looked at the system during conditions of low food availability (late fall). The abundant mollusc populations must contribute tremendous amounts of mollusc larvae to the pelagic zooplankton population at spawning time, for example. However, we did not collect a single mollusc larvae in our tows. It should be easily possible to determine the time of year the mollusc larvae are released and/or the zooplankton stocks are most abundant so that fry can be released to the greatest food supply possible to enhance survival.

The previous comments apply to the general case but are meant in particular for the nearshore area of the site in question where the fry will first be responsible to feed for themselves. Considerations of sub-antarctic pelagic predator populations will be pretty much outside the scope of the project, I feel. It may be feasible to do some general sampling and information gathering to determine the types of predators but the information would have to be limited. But to hedge the bet because we have to cop out on the question of oceanic predation, I feel we should concentrate our efforts on the nearshore area which will support the salmon fry for the first month or so as they work their way to sea. Knowing the seasonal cycles of food availability we can ensure, by timed release, that when the salmon do have to compete with (and avoid) whatever that they are the biggest, fastest, fattest, meanest that they can be.

A preliminary draft of a sampling program designed to answer some of the concerns raised in the previous discussion follows.

IX. SAMPLING PROGRAM FOR PROSPECTIVE SALMON SITE, TIERRA DEL FUEGO, CHILE

Subject: Oceanographic parameters

Duration: One year

Frequency: Monthly (9 months); bimonthly (bloom conditions)

Location(s): Final site candidates

Purpose: To describe available food supplies and their seasonal variation; to determine the time, duration, and magnitude of the spring bloom in order to guide the timing of fry release to coincide with maximum food availability; to describe seasonality of key chemical parameters affecting salmon survival.

Objectives: To determine the abundance, size distribution, and seasonality of the pelagic and epibenthic zooplankton stocks; to describe seasonal variations in temperature, salinity, pH, dissolved oxygen, and chlorophyll A; to ascertain, at one time only, the ambient levels of a spectrum of metals present in the freshwater system.

Data collection specifics:

1. Temperature: By probe; vertical profile in estuary; freshwater source.

2. Salinity: As for temperature

3. pH: As for temperature.

4. Dissolved oxygen: Winkler Titrations

5. Metal concentrations: Atomic Absorption Spectrophotometer

6. Chlorophyll-A: Duplicate samples from .5 meters; filter, freeze, and send to lab for analysis.

7. Epibenthic zooplankton: Core samples in shallow zone; 5 replicates, due to expected high variability; send to lab.

8. Pelagic zooplankton: Surface (1 m) tows with 330 μ mesh net; 3 replicates; send to lab for analysis.

Specifics of 6 and 7 regarding procedures for handling, storage, preservation, etc., necessary to acquire the various types of information is omitted for brevity.

9. Tidal cycles: Rainfall and runoff quantities and seasonality; flooding, freezing, thawing and snow cover information.

10. Carnivore sampling: To determine the abundance and types of potential fry predators; also gut content inspection to determine present food sources of same.

X. SUITABILITY OF FUTURE PARTICIPATION BY CHILEAN AGENCIES AND PERSONNEL

In short, I was extremely impressed by the personnel, facilities, equipment, and interest encountered in the various governmental, military, and scientific agencies in Chile. The efforts of Irma Vila, Guido Celedon, and Alphosa Herrera stand as hallmarks in the total effort and I feel their continued involvement will be extremely worthwhile. Dr. Tarcisio Antezana of the Instituto Biologia Marina Montemar expressed great interest in project involvement and is certainly a capable scientist. Several of the students in Irma's group who are planktologists and limnologists were interested in pursuing various facets of the project as thesis topics. The Instituto de la Patagonia, located in Punta Arenas, is a well equipped laboratory and has the equipment and personnel (phytoplankton types) to participate in various facets of the sampling project described earlier. I feel these various facets of Chilean participation will be good for the project in general and will ease logistic difficulties arising from sampling, preparation, analysis, and transportation elements.

CHAPTER V

SUMMARY ASSESSMENT OF PHASE II

A summary meeting of the Southern Ocean Salmon Project Task Force was held at the NMFS Northwest Fisheries Center in Seattle on September 9, 1976, followed by a second meeting at the State of Washington Department of Fisheries offices in Olympia on September 10, 1976. In attendance were Senor Ivan Petrowitsch, Director of Division Proteccion Pesquera (SAG), and Dr. Irma Vila, Universidad de Chile, who had been invited especially for the meeting.

The members of the Task Force who attended the meetings were Dr. Joyner (team leader), Paul Bienfang, Earl Combs, Conrad Mahnken, Ronald Mayo, Tony Novotny, Guy Rothwell, Harry Senn, John Spencer, and John Spinelli.

Dr. Wally Pereyra, NMFS (NOAA), was also invited to attend and become a member of the Task Force both for his specialized knowledge in gear technology and for his knowledge of Chile.

The meetings were chaired by Colin Nash, and the main points of the meetings are summarized at the front of this Appendix. The agenda for the two meetings was as follows:

September 9 - NMFS Northwest Fisheries Center, Seattle

I. Program Overview

   A. ICLARM

      1. Program structure

      2. Program funding

   B. Long-range goals

      1. Optimize world production of salmon

      2. Develop International Salmon Range Management Plan to:

         a. coordinate monitoring and surveillance of ocean salmon ranges

         b. maintain worldwide inventories of

            - salmon stocks
            - seed availability
            - seasonal range conditions
            - production, harvest, and escapement

c. predict and maintain statistics on worldwide production.

3. Develop model regional management system for Southern Ocean.

C. Short-range goals

1. Assist Chilean government with the establishment of salmon stocks in its southern coastal waters and in

2. Developing a model national interface for an International Southern Ocean Management System.

II. Review of Phases I and II Operations

A. General discussion on reports and presentation of slides

B. Recommendations for Phase II

1. Postponement of the floating hatchery concept

2. A proposed hatchery in Ultima Esperanza

3. Secondary planting sites (transport of fry from hatchery)

a. Canal Jeronimo: Lago de la Botella (Fo. Sullivan, alternate)

b. Paso Ingles: Bahia Cordes - Caleta San Miguel - Rio San Bernabe

c. Southwestern Isla Dawson: Lago Lientur (between Seno Brenton and Canal Gabriel). (Seno Otway: Rio Caleta, alternate.)

4. Coyhaique expansion

a. holding and feeding facilities at hatchery

b. transportation system for moving fry

c. estuarine holding pens in Aysen

5. Salmon feed production

a. assessment of sources of ingredients and production logistics

b. investigation of potential for krill or Munida fishery

c. production facility location (Punta Arenas, Puerto Natales?)

d. possible side effects

- stimulation of salmon and trout rearing in Chile
- export of high-grade feed

September 10 - Washington Department of Fisheries, Olympia

III. Phase II Followup Requirements

A. Freshwater environment studies

B. Marine environment studies

C. Environmental impact studies

D. Economic impact studies

IV. External Interfaces

A. Antarctic Treaty countries

B. Scientific Committee on Antarctic Research/Scientific Committee on Oceanic Research

C. Japanese International Cooperation Agency project at Aysen

D. UNDP/FAO

V. Summary of Events

Sept. 9	Meeting, NMFS, Seattle	NMFS Aquaculture Project, Manchester Domsea Farm, Manchester
Sept. 10	Meeting, Washington Department of Fisheries	Cowlitz Salmon Hatchery Cowlitz Trout Hatchery
Sept. 11	George Adams Hatchery	Hood Canal Hatchery
Sept. 12	Westport Sport Fishery	
Sept. 13	University of Washington Dept. of Fisheries	Issaquah Hatchery
Sept. 14	Green River Hatchery	Departures

The tours of the fish hatcheries in Washington were organized by Harry Senn specifically for the two Chilean colleagues on behalf of the Washington Department of Fisheries. The hatcheries selected demonstrated specific points of interest relevant to the proposed project in Chile.

Additional visits in the Seattle area were made to the NMFS Aquaculture Center and the Domsea Farm at Manchester, organized by Conrad Mahnken; and to the University of Washington Department of Fisheries, organized by Tim Joyner.