ABSTRACTS FOR PAPERS TO BE PRESENTED AT
1984 INTERNATIONAL CONFERENCE
ON BIOLOGY OF PACIFIC SALMON
SEPT 5-12th, 1984
VICTORIA/AGASSIZ, BRITISH COLUMBIA
The process of home stream selection by mature Pacific salmon has been
the subject of extensive experimental research. However, the
mechanisms of migration from oceanic feeding areas to coastal waters
prior to upstream movement are poorly understood. This paper
critically examines three hypotheses proposed to explain the oceanic
phase of salmon homing migrations: the "random movement with weak
homeward bias" model of Saila and Shappy (1963), the "physiological
optimization" model of Leggett (1977) and the "map and compass" model
of Quinn (1982). While not mutually exclusive, all three models have
major weaknesses. Saila and Shappy's model was based on assumptions
concerning salmon energetics and migration patterns now known to be
inaccurate. Leggett's model is weakened by the long distances a salmon
would have to travel at sea before experiencing significant changes in
physiologically important conditions. Quinn's navigation model
necessitates use of the earth's magnetic field as a map but there is
currently evidence of only simple magnetic compass orientation by
salmon. Despite the weakness of these specific models, they indicate
the kinds of experiments needed to further understand salmon migrations
at sea.
The 1972 and 1973 brood Columbia River fall chinook coded wire tag recoveries from the Spring Creek Hatchery and other data sources were reviewed to determine the characteristics of the marine migration and distribution of Lower Columbia River fall chinook. The tag recovery information was helpful in constructing patterns of marine recoveries, growth and maturation.

The marine life history of chinook salmon is divided into three periods: out-migration, marine residency and return migration. Out-migration is a period when fingerling chinook enter salt water and actively migrate north. Relatively early in their marine life, they settle into a region where they are recruited to the ocean hook and line fishery in the second or third year of life. The marine residency period begins when the juveniles end their active northward migration and continues until they are maturing adults starting to return to their natal rivers to spawn. The movements of chinook during marine residency are not clearly understood. These movements can be described by two attributes. Dispersal describes the scattering of fish into other regions independent of age, season or other variables. Directional migration is movement in a distinct direction as a function of age, season or other variable. Both attributes have important management implications. Two hypotheses describing the directional migration attribute are discussed. The 'age-dependent migration' hypothesis says that chinook gradually move northward during the marine residency period. The 'stationary resident' hypothesis says that chinook stay in the same general region throughout marine residency. Some evidence from marine tagging supports the latter hypothesis and a pattern of low dispersal.

The third period of the marine life history, the return migration, is a period of active migration back to the natal river. Change in the average size of age 3 Spring Creek chinook in different marine areas and months suggests that active migration of mature Spring Creek chinook is taking place in August and most of them have entered the river by the first of September. Return migration through marine waters probably does not exceed thirty days.
To elucidate the role of oceanic environments on the ascending migration of salmon, the effects of sea surface temperature and zooplankton abundance on the return timing of sockeye in rivers in Bristol Bay, Alaska, were analyzed.

Sockeye salmon migrate from the central Bering Sea (basin area) in late May through June to the southeastern Bering Sea (shelf area), and finally ascend the rivers in early July. The peak return date of sockeye in the eight rivers (Kvichak, Naknek, Egegik, Ugashik, Igushik, Nuyakuk, Wood and Togiak) did not reveal consistent correlation among them. However, the correlation was generally high between the proximate two rivers.

The mean temperature ranged between 4.4 and 7.9°C in the basin area, and between 3.6 and 8.6°C in the shelf area during 1957-1982. The peak return date was inversely related to the temperature in the two areas. The temperature relation between the basin and shelf areas reversed at 5.4°C. It is expected that when the basin temperature is below 5.4°C, sockeye will encounter the lower temperature in the shelf area, but when the basin temperature is above 5.4°C, sockeye will experience a higher temperature in the shelf area than in the basin area. The temperature appeared to be significantly regressed to the peak return date when the basin temperature was above 5.4°C. The annual fluctuation of peak return date tended to be greater when the basin temperature was higher.

The mean zooplankton biomass (g wet weight/10³ m³) was from 250 to 782 g in the basin area and from 297 to 1227 g in the shelf area during 1965-1982. An inverse relation existed between the temperature and zooplankton biomass in the basin area. In the shelf area, the zooplankton biomass was low in cold and warm years. The peak return date tended to be later when the zooplankton biomass was higher in the basin area. No clear relation was found between the peak return date and zooplankton biomass in the shelf area.

Results suggest that in cold years, low temperature causes low growth rate, slow maturation and late return of sockeye salmon, despite higher zooplankton biomass in the basin area. By contrast, in warm years, high temperature accelerates growth and maturation, and early return, in spite of lower zooplankton abundance.

A consideration is presented to interpret the relations among temperature, food availability and return timing, with an emphasis on the importance of the spatial relation between zooplankton and sockeye salmon in water column in response to light and weather conditions at sea.
The fish pathogen *Vibrio anguillarum* causes the devastating fish disease vibriosis. This bacterium harbors a 65 kb plasmid, pJM1, which specifies a very efficient iron-uptake system associated with the high virulence phenotype. Further characterization of the pJM1 plasmid-mediated iron-uptake system was achieved by molecular cloning in a cosmid vector. Recombinant DNA molecules containing regions of pJM1 DNA were in vitro packaged, transduced and mobilized to the appropriate iron-uptake deficient non virulent *V. anguillarum* strains. The final recipients were scored for ability to grow under iron-limiting conditions as well as to synthesize specific components of the pJM1 iron-uptake system, such as the siderophore and the outer membrane receptor. The results suggest that a pJM1 DNA region of about 20 kb, is responsible for the iron-uptake characteristics of this bacterium. Moreover, iron-uptake proficient bacteria, obtained after introduction of the cloned iron-uptake region regained full virulence, demonstrating the intimate relation existing between these two properties. Knowledge gained from this work is being used in efforts to apply recombinant DNA technology in the development of efficient measures for the control of vibriosis and other important fish diseases.
Growth of the fastidious, slow growing *Renibacterium salmoninarum* using simple and complex media is assessed. The bacterium appears to have an absolute requirement for L-cysteine; the effect of other additives such as serum on growth was usually related to the size of the inoculum. It is concluded that growth of *R. salmoninarum* is governed by rate limiting metabolic processes. The isolation and characteristics of a variant of *R. salmoninarum* that does not require cysteine or serum are described. Also, the use of this variant for possible commercial production of vaccine is discussed.
Innate Resistance of Some Pacific Salmon Stocks (Oncorhynchus spp.) to the Haemoflagellate Pathogen Cryptobia salmositica

S. Bower
- Nanaimo, B.C.

Eleven laboratory-reared stocks of juvenile Pacific salmon representing four species were shown to differ in their susceptibility to Cryptobia salmositica. Oncorhynchus keta from the Big Qualicum River, 3 stocks of Oncorhynchus tshawytscha from the Quesnel (Fraser River system), Big Qualicum, and Nanaimo rivers, two stocks of Oncorhynchus kisutch from the Kitimat and Bella Coola rivers, and Oncorhynchus nerka from the Fulton River (Skeena River system) were all equally susceptible and suffered high mortalities following intraperitoneal inoculation with as few as 100 flagellates per fish. In contrast, O. nerka from Weaver Creek (Fraser River system) was resistant with no mortalities occurring following challenge with as many as $10^6$ flagellates per fish. Three other stocks of O. kisutch were intermediate in susceptibility with the Big Qualicum River stock slightly more resistant than stocks from the Tenderfoot River (Squamish River system) and the Capilano River. The high resistance of the Weaver Creek O. nerka was in part associated with factors in the blood which destroyed C. salmositica in vitro at titers up to 1:8. This anti-Cryptobia activity probably involved complement because 1) the reaction resulted in the lysis of flagellates 2) the activity was heat labile (inactivated at 40°C for 20 min) and 3) an antigen: antibody complex (Renibacterium salmoninarum and R. salmoninarum specific antibodies) and lipopolysaccharide (LPS isolated from Escherichia coli) that are capable of activating fish complement by the classical and alternative pathways, respectively, depleted the lytic activity. However, the non-specific activation of the complement system by C. salmositica was unusual in that zymosan, another non-specific activator of the alternative complement pathway, had little effect on the anti-Cryptobia activity. The complement mediated lysis did not result from activation by the classical antigen-antibody pathway because it occurred 1) in plasma from fish lacking specific antibodies against Cryptobia (naïve fish) and 2) in plasma absorbed with the parasite to remove any cross-reacting antibodies. However, at least one component in the lytic reaction depended on disulphide bonds since treatment with 2-mercaptoethanol destroyed the lytic activity. Further work is required to completely understand the innate resistance shown by salmon because the plasma from resistant O. kisutch stocks did no show any anti-Cryptobia activity in vitro and the plasma from susceptible O. nerka from Fulton River had this activity but at a reduced level compared to Weaver Creek O. nerka.
Vaccination was evaluated as a method for controlling bacterial kidney disease (BKD) due to *Renibacterium salmoninarum* (RS) in Pacific salmon. Four evaluation studies were conducted: three using sockeye salmon (*Oncorhynchus nerka*) and one using coho salmon (*O. kisutch*). The vaccines tested were all derived from formalin-killed RS cultures and included cell-associated and extracellular antigens: whole cultures, intact cells, culture supernatants and the extracellular proteins contained therein, disrupted cells, and various crude cell fractions. The vaccines were administered by intraperitoneal injection (with and without Freund's complete adjuvant), or by feeding, spraying, or the two-step hyperosmotic infiltration method. The efficacy of the vaccines was determined by comparing mortalities in vaccinated and unvaccinated fish following natural or experimental (injected) challenge with the live pathogen. Although both sockeye and coho salmon were shown in preliminary tests to be capable of producing antibodies against injected formalin-killed RS cells, antibody production observed in these vaccine experiments was at best feeble. These results differ from the promising anti-BKD vaccination findings reported in the literature for Atlantic salmon (*Salmo salar*) and rainbow trout (*O. gairdneri*), and suggest that members of the genus *Oncorhynchus*, unlike those of the genus *Salmo*, may be incapable of benefitting from anti-BKD vaccination.
A common genetic stock of coho salmon are annually stocked in the Great Lakes. In the lake environment(s) the coho have a defined life cycle and common food source (smelt and alewife). As such, the health of the coho, in part, reflects the health of the lake ecosystem.

We have monitored the pathobiology of sexually mature coho salmon from lakes Ontario, Erie, and Michigan since 1977. Coho from each lake have its own "signature" of pathological responses which based on interlake and annual observations have an environmental etiology. Health parameters linked to environmental factor(s) include thyroid dysfunction, endocrine status, liver pathology, serum cholesterol, serum fatty acids, growth and fecundity. Furthermore, health responses recorded in feral coho salmon induce parallel pathobiological responses in rodents fed diets contaminated with Great Lakes coho. These investigations have formed the framework of cohort epidemiological studies of sports fishermen who consume Lake Ontario salmonids.
Recently, in order to protect against infectionable fish diseases, many investigators studied oral immunization for fish, such as Duff (1942), Ross and Klontz (1964), Anderson and Ross (1972) and Kusuda (1977) etc. But mechanisms of oral immunization for fish still remain unsolved in detail.

The authors reported that antigenic protein was ingested through the gut of rainbow trout using vegetative enzymatic protein, horse-radish peroxidase (HRP) as an antigen at the 2nd North Pacific Aquaculture Symposium September 1983.

This antigenic protein- HRP- estimates about 40,000 molecular weight and belongs to rather small protein group.

Therefore, concerning the problem that more large molecular weight protein would be possible to pass through the digestive tract without any digestions or disintegration by digestive enzymes, the authors planned following experiments using rabbit immunoglobulin G against HRP. Rabbit antisera were prepared by immunization with mixture of HRP and Freund's complete adjuvant once a week for four weeks. Then rabbit antisera were taken out from carotid artery of the animals.

After checking the titer of antisera against HRP, rainbow trout approximately 150 grams of body weight, were given three ml of antisera into the esophagus and stomach by syringe connected flexible plastic tube. Control fish were given normal rabbit sera with the same method.

After three hours from the administration of sera, experimental fish were sacrificed and fixed all digestive tract from esophagus to rectum by McLean and Nakane's method. Then, all digestive organs, such as esophagus, stomach, duodenum etc. were frozen sectioned and stained by Karnovsky's method with diaminobenzidine (DAB) after slice specimens were reacted with HRP solution in moisture chamber.

If the antisera presented in the slice of specimens, they would be reacted with HRP by antigen-antibody reaction and easily demonstrated by DAB staining method histochemically.

Consequently, all fish which were given rabbit antisera against HRP perorally showed DAB positive granules in mucosal epithelial cells and lamina propria cells of esophagus and stomach.

On the other hand, control fish given normal rabbit sera did not demonstrated DAB positive granules in mucosal epithelial layer or lamina propria of their digestive tract.
Results of the experiments suggest that relatively large protein, such as immunoglobulin G, molecular weight approximately 160,000, are ingested into mucosal epithelium cells of esophagus and stomach of the experimental fish within three hours after peroral administration of protein for rainbow trout, then ingested protein transfer to submucosa of digestive tract without being digest.

The author have interests for these phenomena as a basis or oral immunization for fish.
In the past decade, an ever increasing number of chemicals have been demonstrated to alter the immune response. In particular, the persistent halogenated aromatic hydrocarbons (i.e. PCB, TCDD) are known to suppress immune function. The ability of fish to bioaccumulate halogenated aromatic hydrocarbons (HAH) has been well documented. For example the concentration gradient of HAH from water to Lake Ontario coho salmon is 1.5 million fold. This has focused concern as to the potential health hazards associated with dietary consumption of these fish.

As an approach to assessment of this situation we have fed sex matched three-week-old C57B/6J mice coho salmon from the Great Lakes and the Pacific Ocean. These studies indicate that consumption of a nutritionally balanced diet containing 30% coho salmon from Lake Ontario for 60 days results in a significant decrease in the humoral immune response (IgM, IgG and IgA) as measured by the Jerne plaque assay technique. This immunosuppression correlates with HAH levels found in Lake Ontario coho salmon.

We are currently investigating the etiology and mechanism of immunomodulation at the cellular level and the potential effects on fish health.
Time-temperature relations during incubation were examined for data compiled from experiments, from the literature and from British Columbia salmon hatcheries for Pacific salmon (Oncorhynchus) and Steelhead trout (Salmo gairdneri). Nine models, ranging from the single-parameter thermal sums model to a four-parameter general growth model developed by Schnute (1981), were tested and compared. The latter was found superior in explaining development time to 50% hatch as a function of both constant and ambient temperature. Mortality rates also were examined and upper and lower temperature thresholds were found using probit analysis. In addition, experimental data were gathered at constant temperatures to further explain the effect of temperature on embryonic development. Development times to thirty embryonic stages were recorded for each temperature and species. Of these, four stages were chosen (four-cell, commencement of epiboly, completion of epiboly and well-eyed embryo), for which the general growth model again was used to develop equations to explain variations in rates of embryonic growth as a function of temperature for the six salmonid species.
One of the primary purposes for constructing Lost Creek Dam on the upper Rogue River, Oregon, was to enhance populations of anadromous salmonids downstream. Water stored in the reservoir during winter is used to augment flow during summer, and a multiport withdrawal structure enables control of the water temperature released. Increases in summer flow accompanied by reduced river temperatures were expected to increase the rearing capacity of the stream, reduce prespawning mortality, and expand the spawning distribution of spring chinook downstream.

Extensive sampling of juvenile and adult spring chinook from 1974 to 1983 has shown that the net effect of the dam since it began operating in 1977 has been detrimental to spring chinook. A Ricker-form stock-recruitment relationship, including two environmental variables, predicted that operation of the dam decreased production of spring chinook by 33%. Reduced production was predicted to result from lower survival of eggs to fry. Lost Creek Dam has warmed river temperatures from October through January and caused juvenile chinook to emerge before environmental conditions are favorable for their survival. By comparison, a correlative simulation model of the spring chinook population indicated that operation of the dam reduced production by an average 8.9% from 1977 to 1982. Additionally, the model indicated that the sport catch of spring chinook in the river was reduced by 3.3 to 11.2% each year from 1977 to 1982 as a result of reduced angling efficiency with the altered flow regime. We did find that operation of the dam reduced prespawning mortality of spring chinook by up to 10% of the wild run and up to 57% of the hatchery run. The spawning distribution of spring chinook has not expanded downstream as anticipated, and fish have ceased to spawn in 2 km of the river immediately below the dam.

Strategies for reducing detrimental effects and increasing benefits will be discussed.
Environmental factors during the freshwater and ocean residence were tested for significance in the stock recruitment relationship of 1960-79 brood spring chinook from the Rogue River. The number of spawners, the number of average weekly flows that exceeded 7,500 cfs during egg incubation, and maximum river temperature in January accounted for 88% of the variation in recruitment. Spawner abundance alone accounted for 56% of the variation. This relationship indicates that environmental influences on eggs and alevins as they incubate in the gravel are the most important factors that control production of spring chinook in the Rogue River. Field sampling has demonstrated that emergence timing of fry is highly correlated to the river temperature in January. We hypothesize that higher temperatures in January cause chinook fry to emerge earlier at a time when their survival is poor. Sampling of chinook fry from 1976 to 1983 indicated that the abundance of fry was also highly correlated to the number of eggs deposited, the maximum daily flow during egg incubation, and the maximum river temperature in January. These factors accounted for 99% of the variation in fry abundance. We conclude that peak flows and river temperature during egg incubation are the most important environmental factors causing variation in abundance of spring chinook. Further, we recommend that environmental factors be incorporated into stock-recruitment relationships to improve estimates of the maximum sustainable yield and optimum escapement.
Salmon Enhancement Strategies in Prince William Sound, Alaska
B. Allee
- Prince William Sound Aquaculture Corporation, Cordova

A large scale strategy for salmon enhancement is rapidly being developed in Prince William Sound based upon a comprehensive regional management plan integrating user group needs and demands, and biological economic feasibility. Historical catch data and escapement estimates provide the biological context under which enhancement strategies are being proposed. State of Alaska, regional aquaculture associations and private non-profit organizations are jointly contributing to this effort. This paper will present data describing the freshwater and marine performance of four hatcheries in Prince William Sound to date and present future scenarios for hatchery production.

Data will be presented projecting economic return to the commercial fishery of hatchery pink and chum salmon. Past data on exvessel price versus commercial catch will be discussed in the context of economic feasibility and return on invested capital to the commercial fishery. The economic and biological feasibility of private non-profit hatcheries versus public hatcheries will be discussed.
Salmones Antártica Ltda. is an affiliate Company to Fundación Chile and operates three salmon ranches and a cage farm in Southern Chile. These farms are described. Present and future carrying capacity is given. Releases and returns are presented for the oldest farm (Curaco de Vélez) and a possible reason for the wide range of observed results is given.
Ocean Ranching of Chinook Salmon (Oncorhynchus tshawytscha) in New Zealand: Past Results, Present Experiments, and Future Prospects
P.R. Todd and M.J. Unwin
- Ministry of Agriculture and Fisheries, Christchurch

There are presently eight facilities making releases of juvenile chinook salmon (Oncorhynchus tshawytscha) in New Zealand. Seven of these are privately owned ocean ranching farms, and the first started releases in 1976. Percentage total returns, calculated from coded wire tagging, range from 0 - 0.33% for the 1977 to 1979 brood years. Incomplete brood year returns for 1980 and 1981 vary from 0 - 1.19%. Increased percentage returns have resulted from delayed releases of up to 12 months after hatching.

Releases from the government operated Glenariffe Salmon Research Station began in 1977, and percentage returns for complete brood years from releases made between January and April (6-9 months after hatching) did not exceed 0.6%. A release of yearlings in August 1979, produced a return of 2.5%. A second yearling release (in August 1982) produced a 1.4% return of 2-year-old fish in 1983. Results to date for the 1984 season are presented.

Returns from hatchery releases made between January and April have similar age structures to the wild population (10% 2-year-olds, 70% 3-year-olds, 20% 4-year-olds). For the August 1979 release of yearlings, the returning adults comprised 36% 2-year-olds, 50% 3-year-olds and 14% 4-year-olds.

In 1983 a series of experiments were begun at Glenariffe to determine the relationship between the size of juveniles at release, the time of year at release, and the percentage adult return. Five batches of up to 90,000 tagged fish were released each month from April to August. Each batch consisted of up to three size groups, and comprised up to three replicate samples within each size group. Results to date for the 2-year-old fish returning in 1984 are presented.

The future development of ocean ranching in New Zealand is discussed, and the relationship between ocean ranching and other salmon aquaculture methods (pond and sea cage rearing) is assessed.
Variability in Diel Migration Patterns of Adult Sockeye (Oncorhynchus nerka) and Reconstructions of Historical Escapement Data for Selected British Columbia Sockeye Stocks

K.D. Hyatt, G.J. Steer and J.I. Manzer

Canada - Fisheries and Oceans
Pacific Biological Station

Changes in productivity of sockeye stocks generally rely on analyses which make use of annual estimates of escapements. For a number of British Columbia sockeye stocks escapement estimates have been obtained through procedures which rely on enumeration of fish migrating past fixed locations in rivers. A detailed examination of historical changes in procedures applied to several British Columbia sockeye stocks and new analysis of diel migration data obtained from these procedures indicate how subtle and poorly documented procedural changes may influence assessments of stock-recruitment relationships.
Temporal Variability in Adult Sockeye (Oncorhynchus nerka) Salmon Escapements to Two Adjacent Nursery Lakes on Vancouver Island, British Columbia

J.I. Manzer, G.J. Steer and K.D. Hyatt
- Canada - Fisheries and Oceans
Pacific Biological Station

Electronic counts of sockeye salmon (Oncorhynchus nerka) returning daily to Great Central Lake (1975-83) and Sproat Lake (1980-83) on Vancouver Island, British Columbia are used to describe seasonal fluctuations in escapements. The estimated total annual escapements to Great Central Lake for these years ranged from 112,000 to 368,000; to Sproat Lake, 146,000 to 248,000. For each stock the seasonal patterns between years were markedly dissimilar but rather similar in the same year for which comparisons are possible. Factors which possibly influence annual and seasonal patterns are examined.
The feasibility of using patterns and linear discriminant functions to estimate the contribution of Alaskan and Canadian stocks of sockeye salmon (*Oncorhynchus nerka* Walbaum) to the fisheries of southern Southeast Alaska and northern British Columbia was examined using data collected in 1982. Significant and persistent differences were found in the patterns of scale growth during freshwater and early marine life history between stocks originating in Alaska and Canada. Sockeye salmon from Alaskan stocks grew less and slower during their lacustrine residence than did fish from Canadian stocks. Also, Alaskan fish rarely exhibited spring plus growth, while Canadian fish almost always did. Because jackknife accuracy for the linear discriminant function remained high when data for each of four age classes was pooled (93.3% average for four age-specific models vs. 88.2% for one age-pooled model), the variation in patterns between nations is greater than within nations across years. When the Stikine River stocks were separated from other Canadian stocks, a small penalty in accuracy was paid; scales from Stikine River fish were misclassified most often as being from other Canadian stocks.

A sensitivity analysis on the way in which scales are selected for model construction was conducted with a second set of scales of known origin. Because model accuracy proved robust to the manner of scale selection, no prior knowledge regarding migratory pathways, stock abundance or age composition was required to draw samples to represent each nation.

We conclude that scale pattern analysis is a cost effective and efficient method for estimating the contribution of each nation's stocks to the fisheries of the other. Because interannual variability in scale patterns is small, programs with historical models can be developed to provide estimates of interception rates during each fishery.
Despite the record returns of sockeye salmon to Bristol Bay in recent years, stocks of this species in other areas of the state are depressed. This paper presents an overview of the hatchery, lake fertilization, lake stocking, and fishpass programs in Alaska directed at sockeye salmon.

During 1983-84, the Department of Fish and Game, FRED Division, successfully cultured 55 million sockeye salmon. Sockeye are cultured at the Kasilof, Trail Lakes, and Big Lake Hatcheries and at the Gulkana Hatchery; the latter is a stream-side incubation complex. Additionally, 15 million sockeye eggs were obtained from salmon that returned to Karluk Lake, Kodiak Island, and planted as eyed eggs into the Upper Thumb River, a tributary of Karluk Lake. Approaches to reducing the risk of occurrence of infectious hematopoietic necrosis virus (IHNV) outbreaks in hatcheries are discussed.

In 1984, the number of lakes that received commercial fertilizer in an effort to improve the rearing habitat for juvenile sockeye increased to seven. First adult returns from lake fertilization projects are expected during 1984. To help ensure fry recruitment to fertilized lakes, the Beaver Falls chum salmon hatchery in southeast Alaska was converted to a sockeye salmon central incubation facility. This is a small facility operated in an experimental mode. One experiment with the plant of sockeye into a barriered lake has been unusually successful and there is much interest in initiating more of these projects.

Of the 19 fishpasses throughout Alaska, six of these routinely "pass" sockeye. Some fishpasses are moderately successful while others are wildly so. The soon to be completed Bakewell Fish Pass will be accompanied by releases of hatchery fry from the Beaver Falls Hatchery into Bakewell Lake above the fishpass.
Sockeye Salmon (Oncorhynchus nerka) Smolt Production from Glacial, Clear, and Organically Stained Alaskan Lakes: An Empirical Approach to Assess Fry Rearing Limitation

J.P. Koenings
- Alaska Department of Fish and Game, Soldotna

Enhancement strategies designed to increase sockeye salmon smolt production from glacial, clear and organically stained lakes in Alaska center on two approaches. The first is stocking spring fry in lakes having underutilized forage; and the second is adding nutrients to the epilimnion of lakes to stimulate the production of fry forage. The strategy employed depends on the ability to ascertain the existing balance between rearing fry densities, and the quality and quantity of forage i.e., an assessment of rearing limitation.

Smolt population characteristics from a wide variety of lake types are used to define the fry:forage balance point. Lakes termed 'at capacity' or balanced produce >85% age 1.0 smolt at <65 mm or <2.2 grams. In contrast, lakes producing >85% age 1.0 smolt at >65 mm or >2.2 grams are characterized as having underutilized forage i.e., are escapement or spawning area limited; and still other systems producing <85% age 1.0 smolt (a large percentage of age 2.0 smolt) are characterized as having overutilized or seasonally unavailable forage.

As sockeye fry are almost obligate planktivores (zooplankton being primary forage), zooplankton populations strongly mirror the relative magnitude of sockeye predation pressure as indicated by smolt quality and quantity. As a consequence, lakes producing small numbers of large smolt (i.e., >85% age 1.0 smolt, >>65 mm in size) held unchallenged large body-sized cladoceran zooplankters, either differing species and/or large forms of co-existing species, compared to severely challenged, small body-sized zooplankters in lakes producing large numbers of small smolt (i.e., <85% age 1.0 smolt; <65 mm in size).

Finally, using only those systems defined as being rearing limited, and through normalizing system smolt production (biomass and numbers) on the euphotic volume of each system, Alaskan lakes tend to produce approximately 22,000 smolt (range 12,000-47,000) or approximately 90 kg of biomass (range 34 to 262) per 1 x 10^6 m^3 of euphotic volume. This empirical approach to define long term 'at capacity' sockeye smolt production is now being tested in lake systems by yearly stepwise increases in fry stocking densities. Observed responses by both the zooplankton community and in the resultant smolt population indicate general agreement to both this empirical approach and to the concept of using smolt populations as key indicators of a lake system's ability to rear sockeye fry.
Many theories have been proposed to explain the long-term decline of the Karluk River sockeye salmon (*Oncorhynchus nerka*), including overfishing of midsummer subpopulations. Proponents of this theory have necessarily assumed the existence of subpopulations. The purpose of this study was (1) to determine if the Karluk sockeye run is differentiated into genetically distinct units (subpopulations) on the basis of biological and behavioural characteristics, and (2) to explore various theories of the decline of the run. Significant differences in age, length, and fecundity of spawners, and in length and direction of migration of fry were demonstrated between seasons and, in most cases, between areas of spawning. At least part of each character difference was attributed to heredity. We conclude that the Karluk sockeye run is composed of subpopulations and that overfishing of midsummer subpopulations was the most likely cause of the initial decline.
To evaluate the potential impacts of large scale kelp harvesting on B.C.'s commercial fisheries resources, fish and plankton were sampled in three types of shallow nearshore habitats in Queen Charlotte Strait. Sampled habitat types included those which would be attractive for commercial harvesting of the bull kelp (Nereocystis leutkeana) and the giant kelp (Macrocystis integrifolia). Also sampled were sites with no kelp bed component. This summary presents the results of these studies as they apply to coho salmon.

Coho were first collected during the March/April sampling period. From then through the May/June - July/August and into the September/October periods coho continued to be caught. During this time, shifts in modal lengths associated with growth were apparent. The data collected from fish in their first year of marine life indicated there was an uneven distribution of fish size and abundance amongst the habitat types. Coho were more abundant and larger in the non-kelp than in the bull kelp habitat.

In contrast trophic information showed that fish in their first marine year experienced greatest feeding success in the Nereocystis environment. Further the composition of plankton in the bull kelp habitat was more favourable to coho feeding than was the plankton in either the giant kelp or non-kelp habitats.

Thus, using abundance as an indication of habitat importance, the non-kelp habitats of the Queen Charlotte Strait area are more important to coho than kelp habitats are. Further it appears that feeding success and prey composition do not control the distribution of coho among shallow nearshore marine habitats.
Use of the Campbell River Estuary, British Columbia, by Wild and Hatchery-Reared Juvenile Chinook Salmon (Oncorhynchus tshawytscha)

C.D. Levings¹, C.D. McAllister², and B.D. Chang¹
- ¹Canada, Fisheries and Oceans
  West Vancouver Laboratory
- ²Canada - Fisheries and Oceans
  Pacific Biological Station

From March 1982 to December 1983, juvenile chinook salmon (Oncorhynchus tshawytscha) were sampled by beach-seine in the Campbell River estuary and adjacent waters of Discovery Passage in order to examine estuarine residence by wild and hatchery stocks. The abundance of wild juveniles was much higher in 1982 than in 1983. The peak abundance of wild stocks were similar in the estuarine and transition zones, while the peak abundance of most hatchery stocks were higher in the transition zone than in the estuarine zone. For both wild and hatchery stocks, abundance in the marine zone was much lower than in the estuarine and transition zones.

Wild juvenile chinook entered the estuary mostly as fry migrants. There was a gradual seaward migration of wild stocks from the estuarine zone to the transition zone and then to the marine zone. Wild juveniles were present to the estuarine zone mainly in May, in the transition zone in June to early July, and in the marine zone in July. The residence times of individual wild fry migrants in the estuarine and transition zones were greater than that of individual hatchery fish, probably because of size-related differences in the ability of juvenile chinook to tolerate seawater. Hatchery stocks, except for the first experimental release in 1982, entered the estuarine and transition zones simultaneously and entered the marine zone 1-30 d later. However, because hatchery releases occurred over a 2 month period, hatchery fish were abundant in the estuarine and transition zones from May to June, since hatchery fish were most abundant there and production hatchery releases occurred when wild stocks were in the transition zone.

There were no significant differences between years in the growth of wild and hatchery stocks, but the growth of wild juveniles appeared to have started earlier in 1983. For hatchery stocks, higher growth was shown by groups released earlier in the year.
Ecological and Management Implications of the Competitive Interaction between Juveniles of Chinook Salmon (Oncorhynchus tshawytscha) and Brown Trout (Salmo trutta) in an Artificial Stream

G.J. Glova and M.S. Field-Dodgson
- Ministry of Agriculture and Fisheries, New Zealand

Chinook salmon (Oncorhynchus tshawytscha) from California and brown trout (Salmo trutta) from Europe have been established as self-perpetuating stocks in New Zealand for approximately a century. Their coexistence in some of the major river systems on the east side of the South Island presented the unique opportunity to investigate the competitive interaction between two salmonid species which did not co-evolve in the Northern Hemisphere, but which are likely competitors for resources in freshwater because of their similar morphology and ecological requirements. During the summer period (January-March) experiments were carried out in a stream simulator with a natural food supply to test the effects of prior residence on social dominance, microdistribution and downstream displacement on fingerling-size (fork length range 55-75 mm) fish, the life stage for which interspecific competition between these two species is probably greatest. Three types of experiments were carried out: one consisted of chinook salmon having prior residence over brown trout as is usually the case in nature, a second of the reverse conditions, and a third in which both species were released into the simulator simultaneously.

In all but the chinook salmon prior-residence experiment, brown trout demonstrated competitive superiority in terms of positions held in the dominance hierarchy, and in feeding and use of cover in the system. Chinook salmon tended to be contained by the highly aggressive brown trout as a "socially subdominant group" in the least desirable area of the pool in terms of available food and cover. However, when chinook salmon were given prior residence, brown trout were competitively disadvantaged and unable to establish social dominance and to occupy choice feeding sites. In all experiments, both species preferred the pool environment, chinook salmon exclusively, while small and medium size brown trout of very subordinate social status frequently occupied the riffle. Overall, downstream displacement was minimal for both species, even when density in the system reached relatively high levels, and aligned with the minimum outmigration of populations in nature at this time of year.

The ecological and management implications of these findings will be discussed, with particular emphasis on strategies for stock enhancement.
Comparison of the Effects of Time and Size at Release on Survival of Juvenile Coho Released from Three British Columbia Hatcheries

R.B. Morley and H.T. Bilton
- Canada - Fisheries and Oceans
Pacific Biological Station

Studies on the effects of time and size at release of juvenile coho salmon on their subsequent survival, growth, and age at maturity have been completed or are in progress at 3 British Columbia hatcheries. At each location, 3 sizes of nose-tagged juveniles were released on each of 4 dates, within the period mid-April to early July. Returns of adults and jacks (precocious males) to the hatchery and to the fishery were subjected to response surface analysis to determine the time-size combinations giving maximum returns at each location. At Rosewall Creek experimental hatchery, east-central Vancouver Is., maximum adult returns of 43.5% were predicted for release of 25.1 g juveniles on June 22. At Quinsam hatchery, a more northerly warm water production hatchery on eastern Vancouver Is., maximum adult returns of 11.2% were predicted for release of 15.7 g juveniles on June 4. At Capilano hatchery, a cold water production hatchery on the lower mainland, maximum adult returns were predicted from release of 19.2 g juveniles on June 1. For all locations, production of jacks was favoured by early release of large juveniles. At Rosewall Creek and Quinsam hatcheries, time of release had a much greater influence on adult returns than did size at release, with a fairly narrow "time window" for optimum returns and a sharp decline in returns with late release. Time of release was not so critical at Capilano. At all locations there was an interaction between time of release and size at release, the optimum release weight increasing with time. The releases at Quinsam and Capilano hatcheries were repeated a second year to examine for annual variability in the optimum time-size combinations. Collection and analysis of data is incomplete, however preliminary return data for the second Quinsam study shows close agreement with the first study. This suggests annual variability may be low. Results so far, strongly indicate site-specific differences limiting maximum returns, as well as differences in the conditions of time and size at release needed to obtain these maxima.
Little is known about the specific genotypic or environment factors which effect the age salmonid fish reach sexual maturity. Numerous cases of an empirical nature have been cited as evidence for hatchery propagation reducing age at maturity and adult body size. Anecdotal evidence is also available to suggest that salmon and steelhead hatchery operations have changed time of spawning within seasons. There is clear evidence of early sexual maturity of intensively cultured rainbow trout.

We have evaluated the growth and body size of three consecutive generations of a fall spawning rainbow trout stock with regard to time of spawning within season. Each generation consisted of 90 - 95 full-sib families identified by date of spawning of their dams and granddams. Age of fish was defined as days from fertilization. The results suggested there is a negative correlation between growth rate and age at maturity, but that early maturing fish are smaller at maturity. Fish from eggs spawned and fertilized early in the season grew at a slower rate and achieved a smaller body size at one year of age than fish spawned late in the season. Males mature at one year of age were larger prior to reaching maturity than males not maturing until age two, however, both groups of males achieved about equal body weight at two years. There was also indirect evidence that mature yearling females were from faster growing families. The overall results suggest that early maturing individuals possess genotypes for fast growth rate and that fast growing fish will mature earlier than slow growing fish provided they achieve a minimum body size by their normal spawning season. The latter effect can be either genetic or environmentally induced.
Comparison of Returns of Chum Salmon (Oncorhynchus keta) from Short Term Salt Water and Fresh Water Rearing at Iwate Prefecture, Japan
Chikara Iioka
- Iwate Prefectural Government, Japan

Experimental short term salt water and fresh water rearing research was conducted to evaluate chum salmon (O. keta) release strategies and timing. Returns of fin marked fish from 1972-76 brood years released in Yamada Bay and the Orikasa River which drains into it were examined between 1974 to 1982. Little difference was observed between the survival rates of fish which had been short term salt water reared and those which had been short term reared in fresh water. The size of the juvenile chum salmon at time of release from both salt and fresh water rearing influenced migration from coastal waters and return rates. The return rate of short term fresh water reared fish was the highest for fish released at an average weight greater than 1.3 g. These fish reared in coastal waters until they reached an average weight of 8 g (lower size limit 4-6 g). The return rate of short term salt water reared chum salmon was highest when fish were released at an average weight of 8 g. Based on observations of migration patterns and return rates, it is suggested that mortalities of fish between the 1.3 and 8 g size which reside in Yamada Bay might not be as high as was once thought. A body weight of approximately 8 g and fork length of approximately 9 cm appear to be prerequisites for successful completion of the off-shore transition. Three year old chum salmon made up a larger percentage of the return for those brood years which experienced the best marine survivals. However, an increasing number of 5 year old chum salmon have been seen at several of Iwate Prefecture's rivers which have the largest salmon returns. A larger percentage of older age classes of fish was observed in the returns of short term salt water reared fish than in fish which had been short term reared in freshwater. The timing of the adult return was not affected by the short term rearing strategy applied. Both groups were harvested in the same area, but a higher percentage of short term salt water reared fish were harvested in the fishery. This is considered to be a positive economic consideration for short term salt water rearing.
Genetic Differences Between Stocks of Sockeye Salmon in Southeastern Alaska

G.A. Winans1 and J.H. Helle2
- National Marine Fisheries Service
  1Seattle, Washington,
  2Auke Bay, Alaska

The genetic population structure of sockeye salmon (Oncorhynchus nerka) in southeastern Alaska is described using patterns of variability in electrophoretically-determined protein variants. Electrophoretic variability at 20 loci (previously determined to be polymorphic) was examined in 2000 fish. Stocks of sockeye salmon were sampled from lake systems of Prince of Wales Island (five systems), southern mainland/coastal islands of southeastern Alaska (five systems) and the Lynn Canal area (five systems). Levels of variation differed significantly among the systems but not in a definite geographic pattern. Allele frequencies at the four most polymorphic loci also varied significantly among the samples, but again, there was little correspondence between the genetic similarity and geographic proximity among the samples. The pattern of variation in these sockeye samples resembled a mosaic. In an attempt to explain this mosaic pattern, we examined the correlation of genetic variability with ecological and geographic parameters of the respective watersheds. The temporal stability of allele frequencies in five locales was demonstrated in analyses of data from 1982 and 1983, and in an examination of allelic variation between the classes within a sample. We present examples of how these allele frequency data can be used for discriminating stocks of sockeye salmon in local mixtures.
The genetic compositions of chinook salmon (Oncorhynchus tshawytscha) collected from ten different Alaska drainages have been used to study the structure of Alaskan stocks. The drainages included southeastern Alaskan and western Alaskan drainages. The fish sampled included spawned-out adults, rearing juveniles, smolts, and returning adults caught in gill net fisheries in or near the drainage. Multiple collections were taken from most drainages or regions. Starch gel electrophoresis was used to obtain data from thirty-six biochemical genetic loci. Of these loci, nineteen were polymorphic; but the average heterozygosity per locus population was only approximately 0.03.

Nei's genetic distances were used to examine the relationships among the collections. Differences were confirmed by using log-likelihood ratio analysis. Many of the western Alaskan samples were taken from the gill net fisheries, which might obscure any minor population structure existing within a drainage or region. However, with the exception of one Yukon River tributary, all the western Alaskan collections were similar. The upriver samples from the southeastern Alaskan transmountain drainages, the Taku, Stikine, and Unuk Rivers were similar to the western Alaskan collections. The lower river samples from the transmountain systems were somewhat different from the upriver collections, and the collections from three coastal systems, the King Salmon, Farragut, and Tahini Rivers, were markedly different from each other and all others.
Preliminary Investigation of Genetic Structure of Chum Salmon (Oncorhynchus keta) in the Noatak and Kobuk River Drainages of North Western Alaska

R.H. Davis and C. Olito
- Alaska Department of Fish and Game, Anchorage

Tissues were sampled from nine subpopulations of chum salmon, five subpopulations from the Noatak River drainage, and four subpopulations from the Kobuk River drainage. Samples were screened for genetic variation at 30 loci using starch gel electrophoresis and histochemical staining. Genetic variation was observed at six of these loci. Only four of these loci were polymorphic using the .95 criteria (i.e. frequency of the most common allele < .95). Genetic variability at the other two loci was the result of only three heterozygous individuals. One fish in each of the Selby River, and Squirrel River samples was heterozygous for a CK-1 variant, and one fish in the Selby River sample was heterozygous for an MDH-B variant.

Average heterozygosities ranged from .021 - .026, lower than observed in other areas of the State. Genetic distance and F statistic indicate a high degree of genetic uniformity among the subpopulations sampled, however contingency chi-square analysis revealed significant heterogeneity (P < .01) among subpopulations collected within the Noatak River drainage.
I surveyed allozyme variation at the Ldh-4 locus in 29 populations of sockeye salmon (Oncorhynchus nerka) in British Columbia, and examined Ldh-4 allele frequencies over the North American range of this species. Two alleles, Ldh-4^100 and Ldh-4^115, were present in populations over the species range, but the Ldh-4^115 allele was present at frequencies exceeding 5% only in some populations in northern British Columbia and Alaska. Ldh-4^85, present at frequencies of less than 10%, was virtually confined to populations of the Skeena River drainage. Gene diversity and maximum likelihood ratio analyses revealed significant variation in Ldh-4 allele frequencies among major geographic regions, among smaller areas within regions and among populations within the Nass and Stikine River drainages. Factors which may explain the distribution of the Ldh-4^115 allele in North American sockeye population are discussed.
Heterozygosity and Morphological Variability of Chum Salmon (Oncorhynchus keta) in Southern British Columbia

T.D. Beacham and R.E. Withler
- Canada - Fisheries and Oceans
Pacific Biological Station

We compared variability in two meristic and six morphometric characters with heterozygosity within and among 27 populations of chum salmon (Oncorhynchus keta) in southern British Columbia. Among individuals, there was no relationship between levels of heterozygosity at 10 electrophoretic loci and degree of meristic or morphometric variation. Decreased morphological variance was not associated with increased heterozygosity. Morphological variance and heterozygosity did not change with age for chum salmon maturing at three to five years of age. Among populations of chum salmon, increased levels of heterozygosity were not associated with decreased variance of morphometric or meristic characters. Our results do no support the hypothesis that more heterozygous individuals show less phenotypic variability than more homozygous ones due to a canalization of morphology during development.

Genetic distances between pairs of chum salmon populations were significantly correlated with pairwise Mahalanobis distances derived from meristic, but not from morphometric characters. Chum salmon are morphometrically adapted to the natal stream environment, whereas biochemical and meristic characters in these populations may be less affected by local selective forces.
Gene frequencies of coho salmon (Oncorhynchus kisutch), chinook salmon (O. tshawytscha), and steelhead trout (Salmo gairdneri) along the northern coast of Washington were assessed by electrophoretic methods. The objective of this study was to describe differentiation in allozyme frequencies among conspecific populations from the Quillayute, Hoh, Queets, and Quinault rivers. The study was designed to examine interdrainage variation for naturally spawning fish, differences among conspecific races, and differences between hatchery and naturally spawning fish. Subordinate levels of variation (intradrainage and interbrood) were estimated or subsumed to allow interpretation of the above sources of variation.

(Work is still in progress)
Genetic data can be used to identify and calculate the contribution of various stocks to a mixed stock fishery if the allelic frequencies of the contributing stocks are 1) known, and 2) exhibit significant differences among the contributors. In this study we examined all major contributing natural and hatchery stocks of chum salmon from Puget Sound and Hood Canal, Washington. Biochemical genetic data were collected at a total of 30 loci from over 5000 individuals. These data were analyzed for significant frequency differences and a model was developed to estimate the proportions of the identifiable contributing stocks in a mixed stock sampling. Samples from mixed stock fisheries were analyzed and estimates of the proportions of contributing stocks were made and compared within and between years.
Genetic Population Structure of Chinook Salmon. I Columbia River Drainages
G. Winans, F. Utter, G. Milner and D. Teel - National Marine Fisheries Service, Seattle

We examined electrophoretic protein variation in chinook salmon from over 50 locales (=stocks) in the Columbia River Basin. Using data from 44 loci, we describe the magnitude and patterns of variability within and between stocks (i.e., the genetic population structure). Generally, there are 8-12 polymorphic loci (at the 0.99 level) in each stock; and there is a trend for hatchery stocks to exhibit more electrophoretic variation. In several locations, data were available from an 8 yr period; in situations where no hatchery transplants were involved, allele frequencies are not statistically different through time. Using a (1.0, 0.5, 0.0) coding scheme for the genotype data, we ran several multivariate statistical analyses on the total data set to view patterns of geographic variation. Several multivariate constructs or functions describe specific multiple-allele covariation patterns and identify major geographic groups of stocks in the Columbia River Basin. These stocks are, for the most part, genetically homogeneous. We relate the existence of these groups to extant or historical barriers to gene flow in the Columbia River Basin. The multivariate functions defining these stock groups can be used to assign individuals of unknown origin to their most likely place of origin. Knowledge of the genetic population structure of chinook salmon in the Columbia River Basin can be used to conserve and enhance the genetic resources of this species.
The genetic structure of chinook salmon populations from California through southeastern Alaska is examined. Analyses of allelic frequency data at 21 variable loci (detected by electrophoresis) indicate differences based primarily on geographic variables. Early and late run fish historically returning to the same areas tend to be more similar to one another than to runs of the same timing returning to distant areas. Major geographic units were indicated within the Columbia River, on the Washington and Oregon coasts, in Puget Sound and the Fraser River. Absence of strong distinction between some geographically distant groups (e.g., lower Columbia River and Sacramento River) may reflect such factors as a finite sampling of loci or low levels of genetic variation rather than strong genetic similarity. The findings are discussed relative to geological histories of the regions involved and the direct and indirect effects of transplantations.
Induced triploidy, gynogenesis, and androgenesis are genetic engineering techniques that are presently being applied to salmonids. Triploidy can be readily induced by heat or pressure treatments of eggs shortly after fertilization. Triploid salmonids are of interest because of their sterility and because triploid hybrids between species frequently survive better than diploid hybrids. Gynogenesis and androgenesis involve irradiation of gametes before fertilization followed by treatments to suppress cell divisions and produce diploids with both chromosome sets from the female or the male parent. These techniques can be useful for sex control and for rapid inbreeding.

Gene transfer and nuclear transplantation are genetic engineering techniques that are likely to be useful for genetic improvement of salmonids in the future. Two approaches to gene transfer are the transfer of random DNA sequences or chromosome fragments into embryos followed by selection for individuals carrying desirable traits, or the transfer of specific DNA sequences into embryos. It must be possible to isolate and clone the genes for valuable traits for the transfer of specific DNA sequences to be useful. Nuclear transplantation involves micromanipulation of nuclei in fertilized eggs. It could be useful for cloning of selected individuals and for the recovery of genotypes from cryopreserved cells.
The extent of genetic determination of age at maturity in chinook salmon is a very important consideration in the culture and management of this species. Changes in this trait can have an influence on characteristics ranging from the success of natural reproduction to the viability of populations as a fishery resource. Consequently, the genetics of age at maturity was investigated in three brood-years (1972, 1973 and 1974) of the chinook salmon population that returns to the University of Washington hatchery. A series of crosses were performed among adults of different ages, as determined by various types of marks. Three year classes of males (2, 3 and 4) and two year classes of females (3 and 4) were used in the crosses. Progeny from each type of cross were reared under equivalent conditions, tagged with distinctive coded-wire tags, and released to migrate to the ocean. Data were obtained on catch, return to the hatchery, and the physical characteristics (length and weight) of the fish as adults. In addition, a series of F1 crosses were performed to assess genetic change in the second generation. Initial analyses of the return results indicated that there are genetic factors defining age at maturity, as measured by returns to the hatchery. Further, a large portion of the phenotypic variability appears to be maternal in origin, although further analyses are being conducted to quantitatively assess the extent and source of the genetic influence. Analysis of catch data did not reveal any apparent genetic relationship between parental age and age at capture. However, other factors such as ocean distribution need to be analyzed before definitive conclusions can be reached. Implications of these results for culture and management of chinook salmon will be discussed.
Intergenotypic competition in coho salmon
C. Busack
- University of Mississippi
B. Riddell
- Canada - Fisheries and Oceans
  Pacific Biological Station

Intergenotypic interaction is the dependence of any individual's performance for a particular trait on the genotypes of the organisms with which it is reared. The phenomenon can have severe consequences in selective breeding programs, ranging from decreased efficiency to negative selection response, but has so far received little attention from aquacultural researchers. To examine interactions in "routine" salmon hatchery operations full-sib families of fingerling coho were reared for several months in both single-family (SF) and multiple-family (MF) groups under otherwise identical conditions. Fish were weighed monthly. Family rankings by mean weight were identical under both rearing regimes but the among-family variance was 1.3 to 3 times higher in MF than in SF tanks, strongly suggesting an interaction exists which can bias genetic variance estimates. Unexpectedly, within-family variances in SF and MF tanks were identical, opening the possibility that the interaction is at least partially based on sibship association. This contention is supported by recent behavioral studies demonstrating sibling recognition in this species. As interaction could have significant impacts on selective breeding programs, but also on enhancement and mitigation hatcheries by reducing effective population size, additional experiments should be undertaken to more completely characterize it. Breeding plans taking the interaction into consideration could then be formulated to ameliorate its effect.
Comparisons of Growth Responses in Juvenile Chinook Salmon (Oncorhynchus tshawytscha) from the Nanaimo and Big Qualicum Rivers

D.A. Sorensen, W.C. Clarke and B. Riddell
- Canada - Fisheries and Oceans
Pacific Biological Station

A pilot study was undertaken to compare growth, food consumption, and food conversion efficiency in two stocks of chinook salmon (Oncorhynchus tshawytscha) from the Nanaimo and Big Qualicum rivers. Fish were fed by hand several times daily to satiation with OMP pelleted feed and the amount provided was recorded. Fish were individually weighed at biweekly intervals from 2 until 10 weeks after ponding. The initial and final weights of fish from both stocks averaged about 1.80 g and 10.80 g respectively.

The Big Qualicum stock showed slightly larger specific growth rate and smaller food consumption than the Nanaimo stock. While these differences were not significant statistically, the resulting difference in food conversion efficiency in favour of the Big Qualicum stock was significant. The implications of these results in an aquaculture selection programme are discussed.
Genetic Relationships in Closely Related Species of Steelhead Trout (Salmo gairdneri) and Kamchatkan Trout (Salmo mykiss): Systematics and Its Zoogeographic Implications

T. Okazaki
- Fisheries Agency of Japan
  Far Seas Fisheries Research Laboratory, Shimizu

The steelhead trout (Salmo gairdneri) originating in the continent of North America is widely distributed in the North Pacific Ocean. The Kamchatkan trout (Salmo mykiss) which has its closest affinities to the steelhead trout is distributed on the Asian side and the anadromous population of the Kamchatkan trout is also presumed to be distributed in the North Pacific. However, the taxonomic relationship between them has not been established. This report examines the allelic frequencies and some biological features of the steelhead trout and the Kamchatkan trout collected in the North Pacific through Japanese research operations from 1972 through 1983.

The western population was separated from the central and eastern population based on the frequencies of LDH-4 variants. The analysis of the temporal and spatial density suggests that the former corresponds to the Kamchatkan trout. As considerable genetic heterogeneity through isolation during the glacial periods is known among the steelhead populations in North America (i.e., a coastal group and an inland group divided at the crest of Cascade Mountains), genetic divergence among the above three groups were estimated. In terms of genetic distance, the coastal group of steelhead was more close to the Kamchatkan trout than to the inland steelhead. Furthermore, their estimated divergence time and topographical evidence indicate that the coastal steelhead and the Kamchatkan trout shared the same refuge during the last glacial period.

This finding as well as the fact that the two species are separable only by the difference in vertebral counts strongly indicates that the steelhead and the Kamchatkan trout should be recognized as a single species. Refuges for the above three groups during the last glacial period and their postglacial dispersal are discussed.
Effects of Environmental and Developmental Factors on Cortisol and Glucose Stress Responses in Juvenile Salmonids

B.A. Barton and C.B. Schreck
- Oregon State University, Corvallis

Changes in plasma levels of glucose and, more recently, cortisol have been used as indicators of stress in both salmonid culture operations and population monitoring programs. Little concern has been demonstrated for other genetic, developmental or environmental factors which may modify these physiological stress responses. Since 1982, our laboratory has been investigating the potential effects of such factors on these stress-induced changes. Although there does not appear to be a great difference among salmonid species in either response to a brief handling stress using similarly-sized fish, the cortisol stress response in coho salmon more than doubled from 80 to 166 ng/mL over the smoltification period. In juvenile chinook salmon subjected to repeated brief handling stresses spaced 3-h apart, post-handling levels of both cortisol and glucose demonstrated an additive pattern; peak cortisol levels were 182, 296 and 496 ng/mL, and peak glucose levels were 84, 134 and 204 mg/dL for the single, double and triple stresses, respectively. When different recovery periods between the handling stresses were used, a greater plasma cortisol response to a second stress was observed after a 12-h recovery than after 1 or 3 h of recovery; glucose responses to the second stress were not affected. Differences in cortisol elevations were not influenced by time of day. Chinook salmon chronically infected with 'tail-rot' and cold-water disease did not exhibit elevations in cortisol above ca. 250 ng/mL when subjected to similar experimental protocol.

Other chronic environmental conditions affect cortisol and glucose levels in response to stress. After acclimation at 7, 12 and 21 °C, peak cortisol concentrations in juvenile chinook salmon after handling were similar at ca. 210 ng/mL for all three temperatures, but elevated levels persisted for longer at 7 °C. However, the peak glucose concentration of 113 mg/dL at 21 °C represented a response three times those found for the lower temperatures. Starving juvenile chinook salmon for 3 wk did not influence peak cortisol levels or rate of recovery from brief handling, but resting cortisol was notably lower at ca. 15 ng/mL in starved fish compared to ca. 50 ng/mL in fed fish. No differences in stress responses in fish fed low, normal or high fat diets were apparent. When environmental acidity was used as chronic stressor, juvenile rainbow trout responded to subsequent brief handling with a plasma cortisol increase to 338 ng/mL at pH 4.7 compared to 136 ng/mL at ambient pH. Characteristic glucose responses to handling stress, evident at pH's closer to neutrality, were masked by a continuously elevated glucose level in response to chronic exposure to low pH.

Our continuing studies clearly show that other factors modify cortisol and glucose responses to stress and that these factors should be taken into account when interpreting experimental results. Further, we suggest that a "standardized" response pattern with well-acclimated healthy fish be established as a comparative baseline control in any stress investigations.
The Gonadal Differentiation of Monosex Genotypic Female Chinook Salmon (Oncorhynchus tshawytscha) Following Androgen Immersion of Alevins
G.A. Hunter\textsuperscript{1}, J. Stoss\textsuperscript{2}, E.M. Donaldson\textsuperscript{1} and I.J. Baker\textsuperscript{1}
\textsuperscript{1}Canada – Fisheries and Oceans, W. Vancouver Laboratory
\textsuperscript{2}Finmark Landbrukskole, Norway

The development of a technique for the production of all female groups of chinook salmon has great potential value for the culture of this species. Specifically this technique will permit the rapid enhancement of both endangered and underdeveloped chinook stocks as well as provide a cost effective method for holding captive broodstock.

Current methodology requires the initial masculinization of genetic females via androgen treatment of the alevins and fry. The resultant sex reversed females produce sperm containing only the X gonosome. This milt is then used to fertilize normal ova resulting in the production of 100\% female offspring. The objective of this study was to examine the influence of androgen immersions on the masculinization of monosex female chinook salmon. The results suggest that masculinization of genetic females may be achieved by immersion of the alevins alone. Management applications of the technique will be discussed.
The First Release of Hormonally Sterilized Coho Salmon (Oncorhynchus kisutch) into the Marine Environment

E.M. Donaldson¹, G.A. Hunter¹, I.J. Baker¹ and E.T. Stone²
- ¹Canada - Fisheries and Oceans, W. Vancouver Laboratory
- ²Canada - Fisheries and Oceans, Capilano Salmon Hatchery

This report describes the growth and contribution to sports and commercial fisheries of the first group of hormonally sterilized coho salmon released into the marine environment. The objective of this release was to demonstrate that sterile coho would not undertake the normal anadromous migration at 3 years of age but remain in the marine environment, continue to grow and contribute to a variety of fisheries.

The study was conducted at the Capilano Salmon Hatchery, North Vancouver, using a group of 39,000 offspring from the 1978 brood. Hormonal sterilization was achieved by the immersion, for two brief periods, of eyed eggs and alevins in water containing 17-methyltestosterone. Treatment was continued for 12 wk into the fry stage by incorporating the steroid in the diet at 10 mg/kg. All fish were administered a coded wire nose tag and double fin clip in the spring of 1980. A subsample of 1,000 fish were moved to net pens at the Pacific Biological Station to follow their growth and survival in captivity. The remainder of the group was released from the hatchery in June, 1980 along with other production fish.

Sterile fish contributed to the sports and commercial fisheries in their 2nd, 3rd, 4th and 5th yrs with the majority caught in their 3rd and 4th yrs. Those sterile coho which were caught in their 4th and 5th yrs were significantly larger than those sterile or production fish caught in their 3rd yr. Similar results were obtained from the captive group which are now in their 6th yr.

The utility of the sterilization technique as a tool for the management of Pacific salmon stocks will be discussed.
Nutritional and Environmental Strategies for Enhancing Juvenile Pink Salmon Growth and Survival

D.A. Higgs¹, J.R. Markert¹, M.D. Plotnikoff¹ and J. Van Tine²

¹Canada - Fisheries and Oceans, W. Vancouver Laboratory
²Canada - Fisheries and Oceans, Quinsam River Hatchery

Most juvenile pink salmon are released from British Columbia hatcheries as small unfed fry. About 2.5% of these fish return as adults. Recent evidence suggests that feeding pink salmon before release improves ocean survival probably because large, rapid growing fry may be less prone to predation than their small counterparts. Therefore, our goal has been to develop nutritional and environmental strategies for promoting pink salmon growth during culture. In this regard, we assessed in two 42-day laboratory studies the efficacy of varying diet composition and moisture content (texture) and time of seawater entry in relation to swim-up.

Best growth and survival during culture were achieved by employing dry or moist diets comprised of high nutritive value components, i.e., steam processed fish meal coupled with a high level of freeze-dried zooplankton. Moreover, pink salmon growth and survival were noted to be inversely related to time of seawater entry after swim-up, regardless of diet treatment. Poorest growth was observed for pinks fed conventional hatchery foods, i.e., Oregon moist pellets, at all seawater transfer times. The foregoing trends were confirmed recently in a pilot-scale hatchery study.

The potential for improving the cost effectiveness of pink salmon culture will be discussed.
Various researchers have suggested that commercial fish diets may contain steroids. Meal and oil in fish diets, in many cases, are derived from reproductively mature teleost fish, i.e. herring, which often have high circulating plasma levels of androgens including testosterone and 11-ketotestosterone in the range of 80-400 ng/ml with additional high concentrations in the testes. Furthermore, an unexplained apparent increase in the incidence of male sexual precocity in salmon has been noted in many state, federal, and private salmon hatcheries. We have identified the male sex steroid hormone, testosterone, in various salmon diets at levels of approximately 50-150 ng/g feed. The diets were examined for steroids by an initial series of extractions with 0.5 ml 1N NaOH/2 mls of ether, followed by separation by elutions with ethyl acetate on celite chromatography. The extracts were then subjected to radioimmunoassay to determine the quantity of the identified steroid per gram of diet. Endogenous steroids in salmon are known to influence, in part, the various processes associated with development, survival, smoltification, and reproduction. Normally, juvenile fish in the wild would not be exposed to steroids in their diet. Hatchery-reared fish, on the other hand, may be exposed to relatively high levels of steroids throughout the freshwater rearing phase. The biological ramifications of these steroids in fish diets on development, fitness, and ultimate seawater survival are significant and will be discussed.
An Assessment of the Applied Use of Hormones to Induce Early Maturation and Spawning of Oregon Aqua-Foods Yaquina Coho
F.D. Ratti
- Oregon Aqua-Foods, Inc., Springfield

Large-scale applications of hormones were tried by Oregon Aqua-Foods over a period of four years in an attempt to accelerate maturation and spawning of adult coho salmon. Brood stock records show that treatment of coho brood with hormones accelerates spawning within each year ahead of untreated brood. However, a comparison of spawning dates between years suggests that interannual variation masks the effects of hormone treatments. The percentage of treated adults has been increasing each year, but the dates of early spawning have not decreased accordingly. Other variables do correlate highly with interannual timing of egg takes. The mean date of spawning varies with the timing of adult returns to the recapture facility at Yaquina Bay, in an inverse relationship. The dates of early egg takes can be predicted by the amount of decrease in the ambient water temperature of the McKenzie River, in which the brood are held from October through November. Large-scale production trials also show two unfavorable side effects from hormone treatment of brood. There have been increases in brood mortality and decreases in egg viability of treated groups.
Pink salmon (Oncorhynchus gorbuscha) were introduced to Lake Superior in very small numbers, 21,000 fish, at Thunder Bay, Ontario, Canada in 1956. Since that time, they have become established in all 5 Great Lakes exhibiting strong odd and weak even year stocks. Until 1980, the abundance of pink salmon in Lake Superior was rapidly increasing, streams often experiencing odd year runs of 10,000 fish or more. However, the 1981 spawning run was almost a complete failure with streams which had abundant 1979 runs only containing a few hundred fish. The 1983 run was similar to 1981.

In general, Lake Superior pink salmon appear to be no more than a smaller sized version of their Pacific coast counterparts with the major difference between stocks being their age structure. The common occurrence of 3-year-old pink salmon is unique to Lake Superior and may preclude the genetic divergence based on spawning stock which is apparent in the Pacific. Pink salmon that matured at 3-years of age had different growth patterns than those that matured at 2-years of age. The sex ratio of 3-year-old pink salmon was highly skewed towards females. Three-year-old females had a lower fecundity and a poorer egg quality than 2-year-old fish. The major limiting factor to the abundance of the Lake Superior population of pink salmon appears to be limited spawning habitat. Due to their plasticity in life history, pink salmon have adapted well to their Lake Superior environment and have become a permanent member of the Great Lakes salmonid community.
Precocious Male Maturity in Two Stocks of Chinook Salmon
(Oncorhynchus tshawytscha) Transplanted to an Experimental
Hatchery in Southeastern Alaska

J.J. Hard, A.C. Wertheimer, W.R. Heard and R.M. Martin
Auke Bay Laboratory, Alaska

Progeny of 1976-brood Chickamin River and Unuk River stocks of chinook salmon (Oncorhynchus tshawytscha) were reared to the smolt stage in southeastern Alaska at Little Port Walter, the site of an experimental hatchery 250 km northwest of their natal streams. The fish were sorted as fingerlings into nine groups based on four factors: stock, release timing, size at release and culture salinity. A total of 18,431 Chickamin River and 22,508 Unuk River smolts were tagged and released from the hatchery in 1977 and 1978. From 1978 to 1982 an estimated 1,416 fish from released Chickamin River stock and 1,634 fish from the Unuk River stock were recovered in various fisheries or as maturing fish returning to the release site. Male sexual precocity rates ranged from 0-16.7% for the Chickamin River stock and 71.4-95.1% for the Unuk River stock. Stock and size at release were significant (P<0.01) in determining precocity rates. Size of age 5 and 6 mature chinook from the Chickamin River stock were larger than those from the Unuk River stock (P<0.05). Knowledge of stock differences in precocious maturity can benefit chinook salmon enhancement by preventing choices of broodstock which have undesirable maturation age structures.
precociously maturing males (jacks) occur in all species of Pacific salmon. They have been ascribed on one-hand to ill-health, hormonal imbalance, contamination and other non-adaptive physiological processes, and on the other-hand to an adaption for the species. During the last several years my laboratory has used a game-theoretic approach to study the evolution of jacks. We believe, in contrast to previous explanations, that jacks evolved as an alternative reproductive strategy which has equal fitness to "normal" males. Jacks specialize at "sneaking" matings rather than "fighting". However, success from sneaking is negatively frequency-dependent, thus an equilibrium frequency exists at which the life-time fitness of sneaking and fighting males is equal. Females fitness, by contrast, is not negatively-frequency dependent for alternative body sizes. Thus, female "jacks" do not usually occur. Fishing pressure will increase selection for jack males by increasing their relative probability of surviving to maturity. This may explain some of the recent trends seen in jack frequency. Data from coho salmon will be used to illustrate these points.
In a two year study of a wild population of coho salmon in Western Washington, we have looked at the breeding success of individual marked adult females. All returning adults (about 200) were tagged and followed throughout their life on the spawning ground. Nest depth, position of each nest, duration and success of guarding, and site quality were obtained for about 50% of the populations in each year.

The largest females (70–75 cm) dug their nests twice as deep and guarded them almost four times as long as the smallest females (40–45 cm). Large females were also better fighters and sometimes displaced smaller females guarding nests. As a result, 60% of nests made by the smallest females were destroyed, whereas less than 10% of nests made by the larger females were destroyed.

The effect of substrate quality on egg and alevin mortality was tested by the burial of eggs in the study stream. Differences in substrate quality lead to an additional 11% egg mortality difference between the largest and smallest females.

When all mortality in the study population is taken into account, the difference in reproductive success between the largest and smallest individuals due to competitive ability is about 20 fold, as opposed to a mere 3.5 fold difference in their fecundity. This study clearly demonstrates the previously unrecognized importance of competition and female body size on the reproductive success of wild salmon.
Fitness Sets in Salmon Management

J.E. Lannan
- Department of Fisheries and Wildlife
  Hartfield Marine Science Center
  Newport, Oregon

Reproductive fitness is defined genetically as the relative contribution of an individual in a breeding population to subsequent generations. The goal of fisheries management is to maintain stock fitness at a level which enables the stock to perpetuate itself in the face of fishing and natural mortality in a variable environment.

Population fitness is described by a probability distribution \((W)\) with mean \(\bar{W}\) and variance \(V_W\). For a given species this probability distribution is constrained by the species reproductive strategy and life history pattern.

The genetic concept of fitness can serve as a conceptual framework for fisheries management by restating the management goal to be the maintenance of this probability distribution over time. This conceptual framework is based upon the assumption that the probability distribution reflects the genetic variation necessary for adaption through the range of environments encountered by the stock.

Application of this conceptual framework would required deriving a system of equations which express the probability distribution of stock fitness in terms of certain population variables, including population size, age structure, and migration.

In this report an illustrative example of the application of a fitness model to fictitious pink and chum salmon stocks is presented. The model utilizes equations adapted from contemporary population genetics. Features of the model and problems associated with its application are discussed.
Growth and Adaption to Seawater by Juvenile Fall Chinook Salmon in Relation to Rearing Temperature

W.C. Clarke and J.E. Shelbourn
- Canada - Fisheries and Oceans
Pacific Biological Station

A laboratory experiment was conducted to determine the effects of freshwater rearing temperature, time of entry into seawater, and seawater temperature upon growth and seawater adaption of juvenile fall chinook salmon. Sixteen treatment combinations were used in a 3-factor composite factorial design to examine the effects of freshwater temperatures of 6.9 - 17.1°C, seawater temperatures of 9.4 - 14.6°C and transfers to seawater from April to June. Performance in seawater was evaluated using plasma sodium concentrations 24h after transfer and growth rate during weeks 2 to 4 after transfer. Growth in sea water was expressed as a ratio to that of fish of the same size and temperature in fresh water. Optimal regulation of plasma sodium concentrations occurred following transfer of fish from 12 - 15°C fresh water to sea water from mid May through June. Seawater temperatures had relatively less influence on osmoregulatory performance although there was an optimum at 10°C. Relative growth in seawater was greatest after transfer from 8 - 13°C fresh water to 13 - 14°C sea water during the period from mid May through June. For seawater temperatures of 8 - 12°C, the optimum time for transfer was advanced to early May.
Changes in Salinity Preference of Chum and Coho Salmon during Development

Munehico Iwata¹,³, Hiroyuki Ogura¹, Shichiko Komatsu³, Keiji Suzuki², R.S. Nichioka¹ and H.A. Bern¹
- ¹University of California, Berkeley
- ²Kitasato University, Kesen, Iwate, Japan
- ³Otsuchi Marine Research Institute, University of Tokyo, Otsuchi, Iwate, Japan

Although all mature chum salmon (Oncorhynchus keta) entering the Otsuchi River in Iwate prefecture in Japan are collected for artificial propagation, in the past chum spawned in this river less than 1 km from the mouth in November, and the young migrated to the sea as fry soon after yolk absorption in March. This is in contrast to the upstream spawning location of coho (O. kisutch) and other salmonids that are resident in fresh water for more than a year. In previous study, we found that the ability to regulate plasma Na concentration after transfer into seawater decreased beginning in May as the fish became heavier. Consequently, we examined chum for changes in seawater preference during and after the natural migration season of this population, in April and May, respectively, using a salinity preference tank (150 x 60 x 90 cm) in which fish could select preferred salinity by entry into an appropriate chamber. Chum salmon fry from Otsuchi River, 0.4 - 0.9 g in body weight in April and 1.2 - 3.0 g in May, were used. In both months, the preference of freshwater fry and of fry adapted to isotonic water for 24 hours, for isotonic water (11 ppt, diluted seawater) or for seawater (33.5 ppt), was observed over a 19-hour period.

In April, freshwater fish distributed themselves equally in the two chambers when both contained fresh water. On the other hand, at the end of 2 hours, 60 to 80% of freshwater- and isotonic-water fish preferred to enter seawater. By 19 hours, both groups of experimental fish significantly (90-98%; P<0.05) preferred seawater over the original water. In May, freshwater and isotonic-water fish both preferred the original water over seawater during a 2-hour test (P < 0.05). At 19 hours, freshwater fish greatly preferred isotonic water (92%; P<0.01); however, only 43% of freshwater fish moved to seawater. Isotonic-water fish continued to prefer seawater (80%; P<0.05).

In conclusion, both freshwater and isotonic-water-acclimated chum fry showed a strong preference for higher salinity in April; the preference of both groups for seawater decreased in May when downstream migration was already complete. The present findings are in accord with our previous studies of changes in plasma Na-regulatory ability and downstream migration behavior, but are contrary to results with chum salmon obtained in Canada by Houston (1957), Baggerman (1960) and McInerney (1964). The difference may arise from genetic diversity and resultant differences in adaptability to different environments. The salinity preference of coho salmon is currently being examined during the parr-smolt transformation in Berkeley, California, using a similar salinity preference tank. The coho data will be compared with the chum data, and the effect of hormones on seawater preference will be discussed. (Aided by Japan Ministry of Education, Science and Culture, by California Sea Grant Project R/T-78, and by National Science Foundation grant PCM 81-10111).
Lipids influence buoyancy, membrane transport and flavor of fish. However, the physiologically most important role of lipids is to serve as energy reserves. During smoltification of steelhead trout (*Salmo gairdneri*) and coho salmon (*Oncorhynchus kisutch*), there are significant alterations in lipid class composition, fatty acid composition and lipogenic/lipolytic enzyme activity. The total lipid content of dark muscle, liver, light muscle and serum is depleted during the spring smolt transformation of steelhead trout. Although cholesterol and other lipid classes (depending on tissue) are reduced, this depletion is primarily due to decreases in triacylglycerol content. The major storage depots of steelhead are mesenteric fat, dark muscle and liver. The fatty acid components of the several lipid classes of steelhead parr tissues tend to be more saturated than those of smolt tissues; the fatty acid composition of the smolt resembles the typical marine lipid pattern (large proportions of long-chain polyunsaturated acids). Fatty acid synthesis in coho salmon mesenteric fat and liver decreases during smoltification. Neutral lipid (sterol) synthesis in these tissues remains unchanged. Conversely, lipolysis in coho salmon mesenteric fat, dark muscle and liver, as measured by triacylglycerol hydrolysis, increases during smoltification. Triacylglycerol lipase activity is correlated with tissue total lipid concentration. Triacylglycerol hydrolysis in coho salmon liver slices is stimulated by norepinephrine. These data suggest that the biochemical basis of the smolt-associated lipid depletion is decreased fatty acid synthesis and increased triacylglycerol hydrolysis, and that hormones may play a role in changing the pattern of lipid metabolism. (Aided by Calif. Sea Grant projects R/F-78 and R/F-79 and by NSF grant PCM 81-10111.)
Cyclic changes in common indices of smolting in coho and spring chinook salmon were compared to the time of release promoting maximal survival. In coho salmon, thyroxine showed peak concentrations in April, gill (Na+K)-ATPase activities reached a maximum in May, and ability to tolerate 35 o/oo seawater reached a maximum in June. Maximum survival of coho salmon released from Big Creek Hatchery occurred in fish released in June. In spring chinook salmon, thyroxine concentrations reached a maximum in November, gill (Na+K)-ATPase activity reached a peak in October, and maximum survival occurred in juveniles released from Cole River Hatchery in August. Maximum survival in 35 o/oo seawater seemed to be a function of size rather than time. We conclude that the use of these indices to predict survival may not be as successful as the use of the calendar.
Physiological measures of the parr to smolt transformation were determined for yearling spring-run chinook (Oncorhynchus tshawytscha) salmon that were either migrating down the Columbia River or retained in the hatchery. Gill Na\(^+\)-K\(^+\) ATPase activities were greatly elevated in yearling chinook smolts that had migrated 714 km whereas plasma thyroxine and triiodothyronine levels showed little change when compared to controls held at the hatchery. Thus, that portion of the smoltification process expressed as increasing gill Na\(^+\)-K\(^+\) ATPase activity was suppressed during hatchery confinement. Underyearling (zero-age) fall chinook salmon migrated more rapidly when released in May than in March or April. The increased migratory rate could be attributed in part to a shift from shoreline to midriver migration, a shift that appeared to correspond to the progress of smolt development as measured by gill Na\(^+\)-K\(^+\) ATPase activity. It is suggested by these results that chinook salmon that are released from the hatchery at a time when physiological measures are appropriate migrate at a faster rate and are presumably better adapted for entry into the ocean. It is also indicated that the process of smoltification may continue in the river after the fish are released from the hatchery and that complete smoltification may be dependent in part on downstream migration.