A STUDY OF FACTORS AFFECTING EXPLOITATION OF PACIFIC SALMON IN THE CANADIAN GANTLET FISHERY OF JUAN DE FUCA STRAIT

by

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ABSTRACT

North American Pacific salmon (Oncorhynchus spp.) are heavily exploited in coastal fisheries of the gantlet class (Paulik and Greenough, 1966). The Canadian fishery of Juan de Fuca Strait, British Columbia, is a particularly complex example involving four gear types: gillnet, seine, troll and sport which harvest, at various times, large numbers of all salmon species. Because salmon are highly available to fishing gears, exploitation must be carefully regulated. This study, based on various field data and catch statistics, documents factors affecting exploitation: seasonal timing of exploitable salmon, distribution and amount of fishing gear, relative gear efficiency, accessibility of salmon to the gear, vulnerability of salmon to the gear. All species and gears are covered to varying degrees.

Each species has a characteristic seasonal timing, but species vary in run duration and timing consistency between years. There are considerable overlaps in species timing which complicate intraseasonal management. In general sockeye (O. nerka) enter in July and August followed by pink (O. gorbuscha) from mid-August to early September, coho (O. kisutch) in September, and chum (O. keta) in October. Chinook (O. tshawytscha) migrations intermingle with all species. Additionally, chinook and coho are exploited on oceanic migrations.

Fishing gears are distributed over ninety linear miles from the Bonilla-Tatoosh net line to Victoria. During the August-October net fishery seines fish within five to ten miles of the net line; gillnets fish offshore, from the net line to Sheringham Point, the eastern commercial boundary. Sports fishermen are clumped near shore, east of Sheringham Point, in close proximity

to launching or marina facilities.

Gear types showed obvious overall differences in relative gear efficiency, based on catch and effort statistics from two or more gear types operating at the same time in a particular area. For example on coho, one seine equals 265 sport units; one gillnet, 63 sport units; and one troller, 8 sport units.

Migrating salmon of all species favoured offshore Canadian waters except near Sooke; all species avoided waters east of Race Rocks where 30 per cent of the sport fleet fishes, the discrepancy was least pronounced for chinook. Based on troll catches using standardized gear, coho favoured surface waters above 27 meters; chinook were most abundant below 36 meters. During periods of spawning migration activity, all species favoured the 18-36 meter depth stratum.

Gillnets were directionally size selective for all species, but direction and intensity of selection varied between species and between months within species. Because fleet mesh distribution remains relatively constant each year, changes in fish size will have a pronounced effect on gillnet exploitation.

Troll gear was species and size selective; however of importance, subtle fishing techniques have a significant effect on selectivity of lures and may be a serious source of bias in empirical lure studies. Coho decreased in susceptibility to hook and line gear between mid-August and mid-September, apparently due to decreased feeding intensity; this has the effect of lowering hook and line catch success for constant abundance. Future studies on lure selection should stress selective mechanisms rather than empirical description.

The complexity of interseasonal and intraseasonal management strategies applicable to the Juan de Fuca fishery undoubtedly are best studied using techniques of systems analysis. However, present gantlet fishery simulation models (Royce et al., 1963; Paulik and Greenough, 1966, detailed in Greenough, MS 1967), although highly sophisticated, lack sufficient generality for direct application to the Juan de Fuca situation.

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	20	"75 per cent...."
14	22	"Crew sizes range from five to eight....."
29	5	"of the October out-migrants...."
40	13	"during August and September."
131	17	"Figure 17"
171	20	$\mu_1 = 1 - e^{-q_1 f_1}$
	21	$\mu = 1 - e^{-(q_2 f_2 + \ldots q_n f_n)}$
	22	$\mu_t = 1 - e^{-f_t}$
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INTRODUCTION

Exploitation of most North American Pacific salmon (Oncorhynchus spp.) occurs in coastal fisheries for short time periods each year. Many of these fisheries are characterized by fishing gear harvesting salmon passing through the fishing area, thus salmon are said to " 'run the gauntlet' of successive units of gear" (Beverton and Holt, 1957).

Coastal fisheries of the gantlet[1] class (Paulik and Greenough, 1966; Greenough, MS 1967) are usually of great complexity involving simultaneous operation of two or more gear types on perhaps four salmon "runs" where each run is highly available to the gear (as defined by Cushing, 1968); as a result, exploitation must be intensively managed. To apply management regulations, many complex variables relating to biology of exploited salmon, to fishing gears (and fishermen) and to interactions between exploited salmon and fishing gears, must be clearly understood; some of these are within the scope of this study.

Management of salmon fisheries is split into two levels (Paulik and Greenough, 1966), interseasonal management which considers general fishing strategies necessary to obtain preresearched escapement goals, and intra-seasonal management which executes objectives of interseasonal management using fishing strategies of more specific natures.

Examples of interseasonal fishing strategies stem from the pioneering study of Ricker (1954) on stock and recruitment. Since 1954, various authors

[1] These authors preferred the term "gantlet" because its derivation gave it a more precise definition in relation to salmon fisheries.

(Ricker, 1958a; Doi, 1962; Larkin and Hourston, 1964; Paulik, et al., 1967; Tautz, et al., 1969) have compared yields using strategies which differ in the way available stock(s) are fractioned into harvest and spawning escapement.

Interseasonal studies, although analytically sophisticated, have done little to ease problems of day to day fishery regulation. The fishery manager, in carrying out interseasonal objectives, must decide on such diverse strategies as: (1) periodic time period and area closures: (2) permanent reservation of part of a fishing area or period for exclusive use of one gear type; (3) division of catch between competing gears, particularly the case of sport versus commercial gear (Mathews and Wendler, 1968); and, perhaps most odious, (4) restriction of each gear's fishing efficiency. Clearly, these strategies involve problems not only biological, but also economic, social and political.

Only recently have analytical models approached the realism necessary to be relevant as intraseasonal management tools; previously this management was almost entirely empirical. Paulik and Greenough (1966) report on a gantlet fishery simulation model (written in DYNAMO and described in detail by Greenough, MS 1967) for quantitative study of intraseasonal management policies. The model incorporates two species (one with three stocks), two gear types (mobile and fixed) and three subdivided areas in five interrelated model sectors (migration, gear, mobile gear decision-making, fishing, management). This appears to be a more specialized and sophisticated case of the simulation model reported by Royce et al., (1963) for study of effects of variable fishing intensity on economic and biological sectors of salmon fisheries in International

Pacific Salmon Convention waters and Puget Sound.

No matter how cleverly devised, management strategies and associated models, particularly in relation to intraseasonal management, require empirical data on numerous factors affecting exploitation. It is the purpose of this study to document some of these factors for the Canadian gantlet fishery of Juan de Fuca Strait: (1) seasonal timing of exploitable salmon; (2) distribution and amount of fishing gear; (3) relative gear efficiency; (4) accessibility of salmon; and (5) vulnerability of salmon. All salmon species are covered to varying degrees along with four gear types: gillnet, seine, troll and sport.

Description of the Study Area

Juan de Fuca Strait occupies approximately 1300 square miles (90 by 15mi.; 145 by 24km.) situated in the southwest region of British Columbia between 48° and 48°40' north latitude (Figure 1). It is the major oceanographic entrance-exit for Georgia Strait. On the Canadian side the Gordon, San Juan and Sooke Rivers, all moderate sized systems, flow into the Strait.

The Strait contains two basins of depths greater than 50 fathoms (90m.) separated by a sill of 33 fathoms (60m.) lying southward from Victoria. A mid-Strait trough of 100 fathoms (182m.) depth extends from the Pacific Ocean to approximately Sheringham Point. A 20 fathom (36m.) shelf extends along the Vancouver Island (and American) shore varying in width between 1.25 and 2.0 miles (0.4 to 3.2km.). Maximum width occurs between Sombrio and Sheringham Points. Swiftsure Bank, at the northern side of the entrance 12.5 miles (20.1km.) southwest from Bonilla Point, rises to a depth of 20

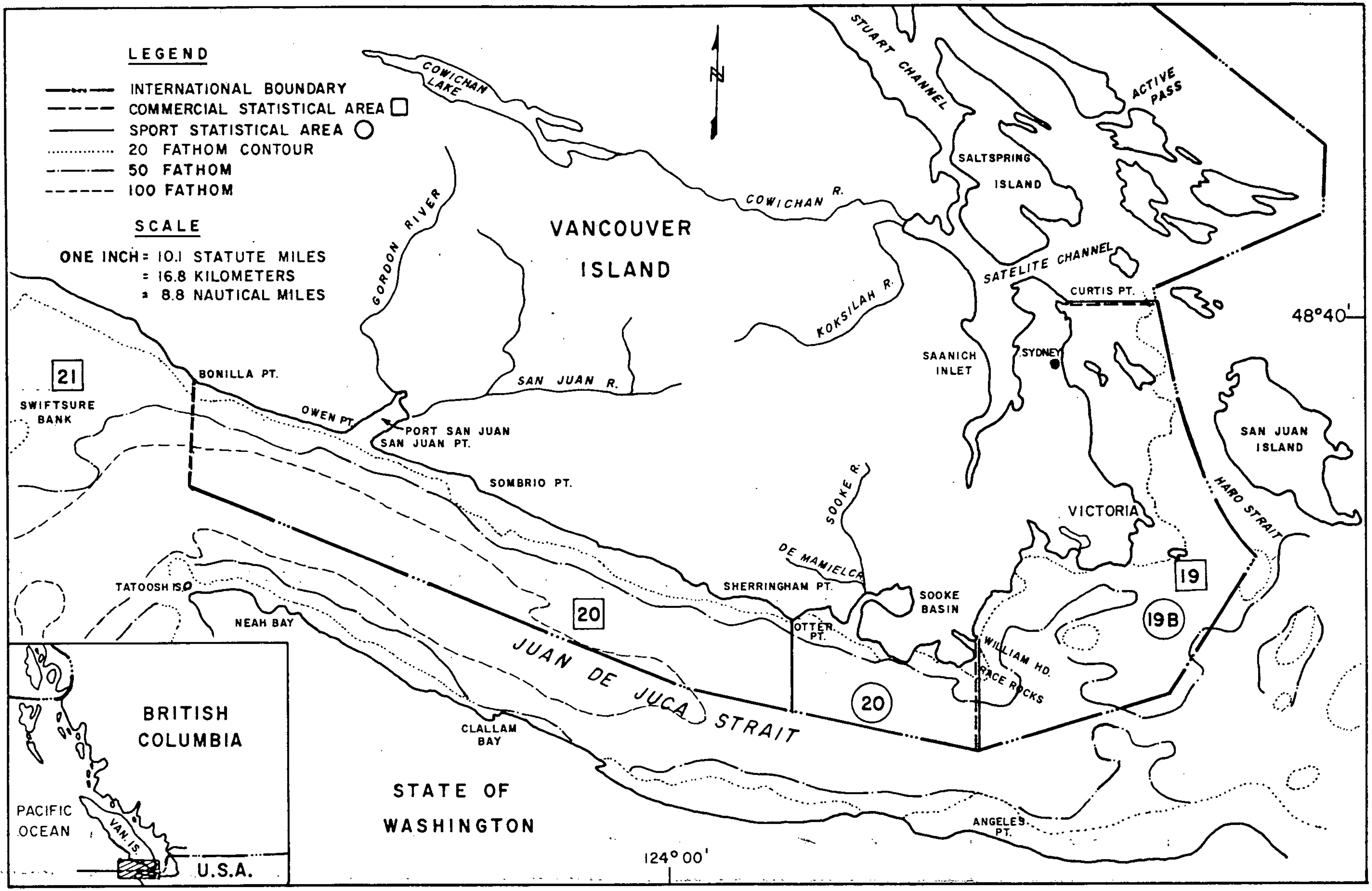

Figure 1. Juan de Fuca Strait showing location of statistical areas.

fathoms (36m.).

Climate is generally mild. Precipitation varies from 107in. (272cm.) per year at Neah Bay to 27in. (70cm.) at Port Angeles, and is heaviest in winter, generally falling as rain; mean air temperatures range from 40°F (3°C) in January to 64°F (17°C) in July (Herlinveaux and Tully, 1961). In summer, winds from the west dominate and are strongest off Victoria, often peaking in the afternoon (small craft warnings are common). At this time it is not unusual to encounter continually diminishing winds while moving west even though near gales blow off Victoria and Sooke. In the winter winds from the east and northeast dominate and are strongest at the entrance. The first major storms normally occur in mid-September.

Incidence of fog is highest between July and October, ranging from four to ten days per month depending on the location (Herinveaux and Tully, 1961). Summer fog occurs most frequently at the entrance.

Within the Strait there is a net ebb flow (Tully, 1941); Herlinveaux, 1954; Herlinveaux and Tully, 1961) strongest near and parallel to the Vancouver Island shore and extending to approximately 35 fathoms (64m.) in depth. This reflects Georgia Strait drainage and Coriolis force. Georgia Strait drainage varies closely in strength with intensity of land drainage into the Strait, which in turn peaks at time of maximum Fraser River discharge in June (Waldichuk, 1957). A deep countercurrent or net flood flow of ocean waters compensates the net ebb flow and is strongest on the south side of the Strait.

In the vicinity of Swiftsure Bank, Tully (1941) noted that in summer the combination of prevailing northwest winds and northward moving net ebb flow, "wake stream", resulted in localized zones of upwelling or black colored surface water where temperatures may be as much as five degrees colder than surrounding green colored waters. Lane (1962) noted that discontinuities in the general outflow at the entrance sometimes caused formation of isolated surface pools (to 30m.) of low salinity.

Throughout the Strait tidal currents are superimposed on the non-tidal current pattern. These currents are rotary in direction near Swiftsure and generally east-west in the Strait, although a large eddy is present from Victoria to Pedder Bay (Herlinveaux and Tully, 1961). The ebb is longer and stronger than the flood, particularly near the Canadian shore, due to net surface outflow. General tidal turbulences (surface eddies and boils, shear zones) are present off many points but are strongest south and east from Race Rocks. In 1967 and 1968 test trollers noted that close to shore (within 3mi. (4.8km.)), primarily west of Otter Point, tidal currents were often variable in direction and intensity, and seldom corresponded with predicted current directions or velocities given in Canadian Hydrographic Service Tables.

During summer, water properties west of the sill are essentially homogeneous to between 30 and 90ft. (9 to 27m.), the beginning of the halocline, which generally extends to about 203ft. (62m.). Water below the halocline is of oceanic origin. Water above the halocline is a mixture of Georgia Strait and oceanic waters. Mixing takes place east of the sill where water properties are essentially homogeneous from surface to near the bottom. Density structure at all locations is dominated by salinity; temperature merely reinforces this structure. In general the thermocline and oxycline, when present, parallel the pycnocline.

For comprehensive treatment of general oceanography, tidal currents and non-tidal currents, refer to Herlinveaux and Tully (1961), Herlinveaux (1954) and Tully (1941) respectively.

Present Regulation, Gear Fishing Patterns and Species Orientation

On a time period basis two net fisheries operate in Juan de Fuca Strait, one during the last two weeks of June (the June fishery) regulated by authority of the Canada Department of Fisheries and Forestry (CDFF), and the other during August, September and October (the fall fishery) regulated first by the International Pacific Salmon Fisheries Commission (IPSFC), and after mid-September, by the Canada Department of Fisheries and Forestry. Appendix Table 4B outlines fishing dates for the June and Fall fisheries (1958 to 1968).

Regulation of the June fishery is relatively uncomplicated due to low fishing effort. Netting is restricted to waters between the Bonilla-Tatoosh line and San Juan Point (Figure 1). Prior to 1968 only gillnets participated (five seine deliveries in 1968). Fishing normally commences at 6 p.m. on the second or third Sunday evening in June and continues uninterrupted for three to five days per week for one to three weeks.

After closure of the June net fishery, the IPSFC assumes regulatory control for the purpose of managing Convention Area pink (O. gorbuscha) and sockeye (O. nerka) stocks. The Commission relinquishes control between August 11 and October 7 (Appendix Table 5B) once sockeye and pink stocks have voided the Strait. Since 1961, IPSFC regulations have prohibited netting in Area

20 until the beginning of August to protect early migrating sockeye stocks. IPSFC regulations also restrict Area 20 trollers on odd years to fishing week days while pink salmon are abundant.

During the fall fishery weekends are usually closed, as is the case for the June fishery. The type of net gear initiating weekly fishing is regulated; in addition, seines and gillnets must alternate daily fishing times. Since 1958 gillnets have fished first every year except 1961, 1962 and 1966 (Appendix Table 5B). Gillnets commence fishing on Sunday evening at 6p.m. and fish overnight until 6a.m. when seines commence their 12 hour fishing period. This pattern is repeated an equal number of times each week for both gear types.

While under Department control, the fall fishery usually lasts until late October (Appendix Table 4B). Gear type initiating weekly fishing and alternation of each gear's daily fishing times are not regulated, although by "gentleman's agreement" gillnets and seines switch fishing times to avoid congestion. Usual opening time is 6p.m. Sunday evening, thus gillnets initiate weekly fishing; few seines bother to fish until approximately 6a.m. the following morning. Trolling is not under net regulation.

Troll regulations are confined to size limits and chinook (O. tshawytscha) and coho (O. kisutch) seasons and are enforced by the CDFF. Within the open portion of Area 20, trollers may retain all salmon above three pounds (1.4 kg.) round weight, or two and one-half pounds (1.1 kg.) dressed weight (head on). Open seasons, detailed below, are complicated because San Juan Point is the legal dividing line between "outside" (west coast) and Georgia Strait regulations.

	"Outside"	Georgia Strait
Chinook	April 15 - October 31	April 15 - September 30
Coho	June 15 - October 31	July 1 - September 30

There are no sport seasons in Juan de Fuca Strait; the only marine regulations pertain to minimum size (12in. (30.5cm.) total length) and bag limit (four salmon per rod per day).

Each Juan de Fuca gear type exhibits a relatively constant annual pattern of operation (Figure 2). Gillnet and seine effort peak around mid-August, reflecting sockeye and pink abundance, large fleet size (section B) and relatively lenient regulations (Appendix Table 4B). During August and September, weekly effort (as a per cent of seasonal effort) varies between 9 and 14 per cent for both gears but rapidly declines in October as exploitable salmon void the Strait and weather worsens. Seine participation drops off fastest. Troll and sport activities are similarly distributed, both peak between late August and early September, reflecting pink and coho in-migrations; secondary peaks occur during June. Weekly sport effort is near or below one per cent per week from November to the end of April.

Seines catch most salmon; however, without sizable odd year pink runs, gillnet harvest would be highest as gillnets dominate catches for the remaining four species (Table I). Sport plus troll catch is about one-twentieth of the combined net catch. It is noteworthy, however, that hook and line gears harvest close to one-half the total chinook catch.

Pink and coho salmon combined contribute about 75 per cent of each

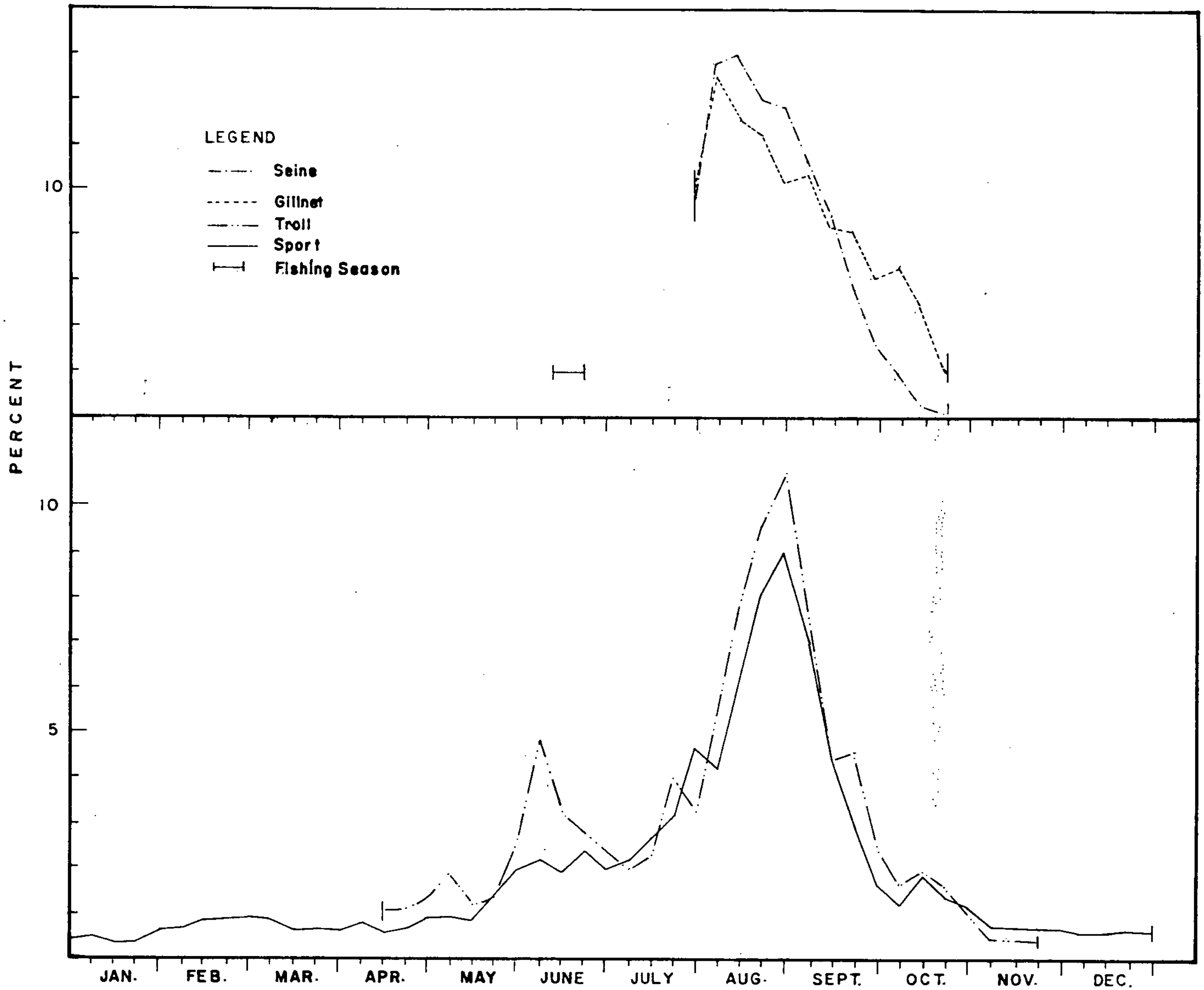

Figure 2. Average weekly per cent of total seasonal effort for Juan de Fuca gear types: gillnet and seine based on 1963, 1966 and 1967 data. Troll and sport based on 1965 to 1967 data.

TABLE I. Average annual (1963-1968) salmon catch by gear type, for the Canadian fishery of Juan de Fuca Strait.*

	Sport	Troll	Gillnet	Seine	Total
Coho	17, 300	7, 000	236, 100	184, 600	445, 000
Chinook	7, 700	4, 900	11, 000	8, 500	32, 100
Pink+	15, 400	19, 900	138, 000	916, 100	1, 089, 400
Sockeye	-	800	125, 200	200, 500	326, 500
Chum	-	-	21, 600	4, 100	25, 700
Total	40, 400	32, 600	531, 900	1, 313, 800	1, 918, 700

*Source: Appendix Table 1B, commercial; Appendix Table 2B, sport.

+Pinks are only abundant in odd years, double these figures for odd year average.

gear's catch (Figure 3). Sockeye contribute between 10 and 25 per cent of the net catch but do not contribute significantly to hook and line gear. Chinook, on the other hand, form approximately 15 per cent of troll and sport catches but make virtually no contribution to the net gear. Only chum (O. keta) salmon are unimportant to all gears.

Since 1963, total annual catch by the Juan de Fuca fishery averaged 1.92 million salmon (Table I); counting only odd years (because of pink cycling) would increase the average to 3.0 million. Commercial catch usually ranks second or third highest of provincial statistical areas on odd years and is generally within the top seven on even years. Sport catch ranks second (Appendix B). It is probable that the Juan de Fuca fishery as a whole, given reasonable economic valuation of the sport contribution, is near, if not uppermost, in British Columbia in total value of its salmon resource.

History of the Fishery

The Juan de Fuca fishery, since introduction of the Sooke traps in 1904, has involved fisheries events of national and international consequence (of note, the Fraser River Salmon Treaty, ratified by Canada and the United States in 1937). Exploitation has continuously intensified throughout which major changes in gear composition have transpired. Of particular interest is the recent rise in recreational participants. In consideration of the varied history of this fishery, I have included a capsule review in Appendix B.

Figure 3. Species composition (per cent) of the annual catch by each Juan de Fuca gear type.

Description of Gear Types

Gillnets fishing the Strait (Plate 1) are among the top producers in British Columbia. In general they are relatively fast, over 33 ft. (10 m.) in length and well equipped with navigational aids to deal with hazards from night fishing, fog, frequent passage of coastal and deep sea freighters, and continuous heavy ocean swells.

Legal maximum net dimensions are 300 fathoms (546 m.) in length measured along the cork line, and 90 meshes in depth (extension or stretched measure). In other coastal areas only 200 fm. and 60 meshes are legal. Mesh sizes[2] range from 5-1/8 in. to 6-1/2 in.; consequently, the effective operating depth is approximately 45 ft.(14 m.). Ocean nets are normally hung at a ratio of 2.5 to 1 (7.5 fm. web to 3 fm. length) and are of nylon thread usually colored dark green to near black (Todd, MS 1969). In recent years gillnetters have switched mesh sizes from 5-1/8 in. - 5-5/8 in. to 6 in. - 6-1/2 in. around the beginning of September in order to increase efficiency on the larger coho and chum salmon.

Of approximately sixty purse seines regularly fishing the Strait, over 95 per cent are table seines (Plates 2 and 3) as only a few drum seines choose to operate in heavy ocean swells. Table seines are among the largest fishing vessels in the province, most exceed 50 ft. (15 m.) in length, some are over 100 ft. (30 m.); many participate in fisheries for other species (halibut, groundfish, herring) when not fishing salmon. Crew sizes range from eight to ten compared to a solitary operator for gillnets.

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[2] H. Grainger (CP Branch, CDFF, Victoria Office), personal communication.

Plate 1. Juan de Fuca gillnets in the Gordon River during a closed fishing period. Note troll-gillnet conversion boats.

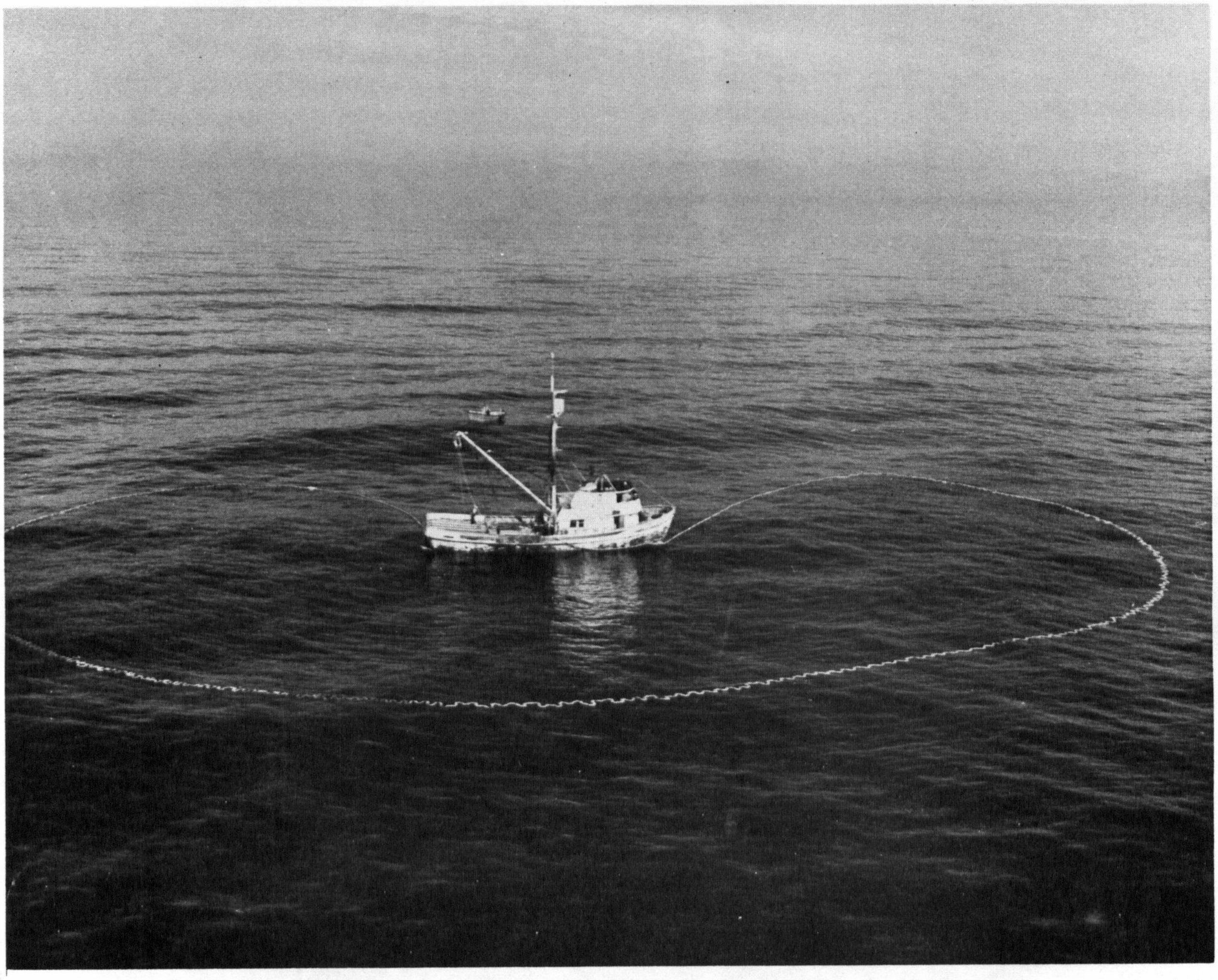

Plate 2. Table seine beginning to purse net. Note net skiff (background) now acts as tow-off boat to prevent fouling of net. (Courtesy CDFF)

Plate 3. Brailing the catch. (Courtesy CDFF)

Legal seine length is 300 fathoms measured along the cork line. Depth is not regulated but generally no more than nine or less than four seine strips are used (one hundred meshes per strip, minimum mesh size 3.5in.) depending on length and hanging of the net as well as the species sought. Effective fishing depth ranges between 120 ft. (37m.) and 250ft. (76m.). Power skiffs or power boats are used to assist seine boats in the seining operation; open sets of twenty minutes duration are permitted (power skiffs not permitted elsewhere).

Most trollers fishing Area 20 are less than 30ft. (9m.) in length. The larger west coast type trollers generally avoid the Strait as catches would seldom meet expenses. Some Juan de Fuca trollers are converted sport boats using hand instead of power gurdies. There are no restrictions as to number of lures and lines or rigging of lures and lines; however, most small trollers are physically limited to two lines. Operating depth is at the discretion of the fisherman; depths fished would generally range between 15 and 40 fathoms (36m. to 73m.) depending on bottom topography and species sought. Lures used cover three general forms: spoons (coho or chinook types), plugs, and hoochie-dodgers (flashers). General rigging of terminal gear is not too dissimilar from that presented in Appendix A for test troll gear (see also Pitre, 1970, Figure 1).

Sport boats cover a range of sizes from hand-powered skiffs, through fast runabouts (15-22ft.) to large cabin cruisers. Generally, the more sea-worthy boats prevail as strong westerlies are common in summer. Many sports fishermen rent vessels from marinas in Oak Bay, Victoria, Pedder Bay, and Beecher Bay; the ratio of pleasure to rental boats is usually about 10:1.

Most sport fishermen in the Strait fish terminal gear (usually spoons or flashers with bait or artificial lures attached) with zero to 12 ounces (340gm.) of detachable lead weight (CDFF sport sampling, summer, 1965, unpubl.). Length of line varies from less than 50 to over 300ft. (15-91m.), however, due to light weights and buoyancy of the line trolled gear would be unlikely to fish below five fathoms (9m.) no matter how much line is released. A few more experienced sports fishermen mooch (stationary fishing using bait), use accessory steel lines with heavy lead cannon balls, or use planers to deepen terminal gear.

Department restrictions limit marine anglers to one lure per line and no accessory angling equipment run by artificial power; number of rods per angler is not limited.

A. Seasonal Timing of Exploitable Salmon

1. Introduction and Methods.

In a gantlet fishery where multiple species are highly exploitable, it is clearly important to determine timing of each run[1] if each species' escapement is to be realized. When the fishery is composed of competing gear types of different harvesting capabilities and species preferences (for example, commercial net fisheries versus sport fisheries), regulations can be adjusted to benefit the least efficient gear if catch sacrificed by more efficient gears is not excessive. Such manipulation would depend, in part, on seasonal timing of each gear's "exploitable salmon."

Emphasis is placed on seasonal timing of exploitable runs through Juan de Fuca fisheries as inferred from commerical and sport catch statistics, tagging data (chinook and coho only) and as reported in previous studies. Exact timing of runs and peak abundance within runs can seldom be precisely forecast because of fluctuating abundance of distinctly timed stocks, oceanographic and climatological variations, and in some cases, biases due to differences in availability of different species to indexing gears. Variability between species in such characteristics as sharpness of the period of peak abundance, number of peaks, symmetry of the distribution and mean date of time-abundance curves

[1] As used here, a run refers to a single species' appearance in the fishery. Each run is an assemblage of stocks where each stock is a group of fish that should be treated as a homogeneous unit in an optimum management program (Paulik and Greenough, 1966). In practice, identification techniques usually only allow definition of clusters of stocks, called major races: for example, Henry (1961) defined certain major Fraser River sockeye races using scales. The more popular definition of race is a population of salmon which will spawn in a particular river or tributary at a particular time of the year (Mason, 1965). This is often an impractical definition for purposes of fishery regulation.

is related to differences between species in such characteristics as number of component stocks, diversity of geographical areas and spawning times represented by component stocks, and so on.

For the Strait of Juan de Fuca fisheries, coho timing may be estimated from weekly Area 20 gillnet plus seine catches (1951 to 1968), weekly Sport Area 19B and 20 catch per unit effort (CPUE), 1967 test trolling CPUE, and 1968-1969 CDFF tagging. Chinook timing may be estimated from weekly net catches (1963 to 1968), 1969 CDFF tagging and weekly troll CPUE (1963 to 1967). Pink, sockeye and chum timing may be estimated by weekly Area 20 net catches (1959 to 1968). Appendix A details field methods for test trolling.

2. Observations and Interpretations.

a) Coho salmon

i) First phase.

Timing of exploitable coho through Juan de Fuca Strait consists of two phases represented by distinct life history stages. The first phase, between September and May, is composed of sexually immature coho in the latter stages of their first and beginning of their second ocean year (aged 2_2 or 3_2 depending on timing of annulus formation). These coho seldom exceed the minimum size limit[2] for commercial gear, but they are exploitable by sport gear. Test trolling in 1967 began capturing 2_2 coho in Ba III during August (Appendix Table 3A). Catches increased

[2] Three pounds (1.4kg.) round weight; 2.5 pounds (1.1kg.) dressed weight.

to the project's end and during charter periods (Cp) five and six (September 4-October 11) catches increased in Ba I suggesting a slow out-migration. Milne et al., (1958) observed similar timing of immature coho (37.5cm., 14.8in.) in 1957 seine tagging at the entrance of the Strait.

To test whether 2_2 coho present at this time were in fact out-migrants, 1156 were seine tagged (Floy spaghetti-anchor tags)[3] off Sooke and Victoria between October 7 and 10, 1968. For comparison, 1158 coho were tagged in Saanich Inlet between October 11 and 15, 1968, and 678 were tagged in Stuart Channel between March 11 and April 2, 1969. Saanich Inlet tagged coho were recovered by sports gear throughout the winter in the tagging areas and in Stuart Channel. Summer recoveries were in the tagging location and by troll gear on the west coast of Vancouver Island. Stuart Channel coho were recovered between April and the end of August by sport and troll gear in the tagging area, in Saanich Inlet and north of Active Pass to Campbell River. Very few were recovered by west coast trollers. In comparison, only one Sooke-Victoria tagged coho (a jack recovered at Minter Creek Hatchery, Puget Sound) was recovered east of Victoria prior to August 31; before this date all recoveries were by west coast troll gear and sport and net gear at the entrance of Juan de Fuca Strait. Thus, the 2_2 age class of coho present in Juan de Fuca Strait during October reared in west coast waters and were in all likelihood actively out-migrating at the time of tagging. Their contribution to the annual coho sport catch

[3] Floy Manufacturing Co., Seattle, Washington.

during this migration is reasonably high, averaging approximately 15 per cent (August to December catch of coho $\leq$ 3 lb. as a per cent of the annual coho catch, Appendix Table 2B), but recruitment is incomplete at this time. Less than 30 per cent (Figure 4, hatched distribution) exceeded the sport size limit (11.5 in., 29.2 cm. fork length). The recruited portion probably increases somewhat between October and December.

Fifteen Puget Sound hatchery marks (1965 brood) were recovered during August to October, 1967, test trolling (Table II) indicating that hatcheries contribute to the fall out-migration. These represented three groups of Puget Sound hatcheries (Godfrey, 1969 MS), northern Puget Sound -southern Georgia Strait (233, 000 marks released), middle to south Puget Sound (397, 000 marks released) and Hood Canal (161, 000 marks released). Of the three groups, marks from the middle to south Puget Sound group had highest representation, (one recovery per 33, 000 marks versus one recovery per 161, 000 marks for the other groups). Sooke-Victoria tagging in October, 1968, provided, in 1969, 14 hatchery recoveries (11 from mid to south Puget Sound hatcheries) as well as two recoveries in the Fraser River, British Columbia.

Sizable sport CPUE peaks between February and May (Figure 5) suggest that out-migrations continue well into early months of the year. Out-migrations from August to December are not indicated in Figure 5. February to May CPUE peaks suggest several possible migration patterns. Perhaps coho migrate slowly through Area 19B, starting off Sidney (assuming British Columbia origin) and gradually working

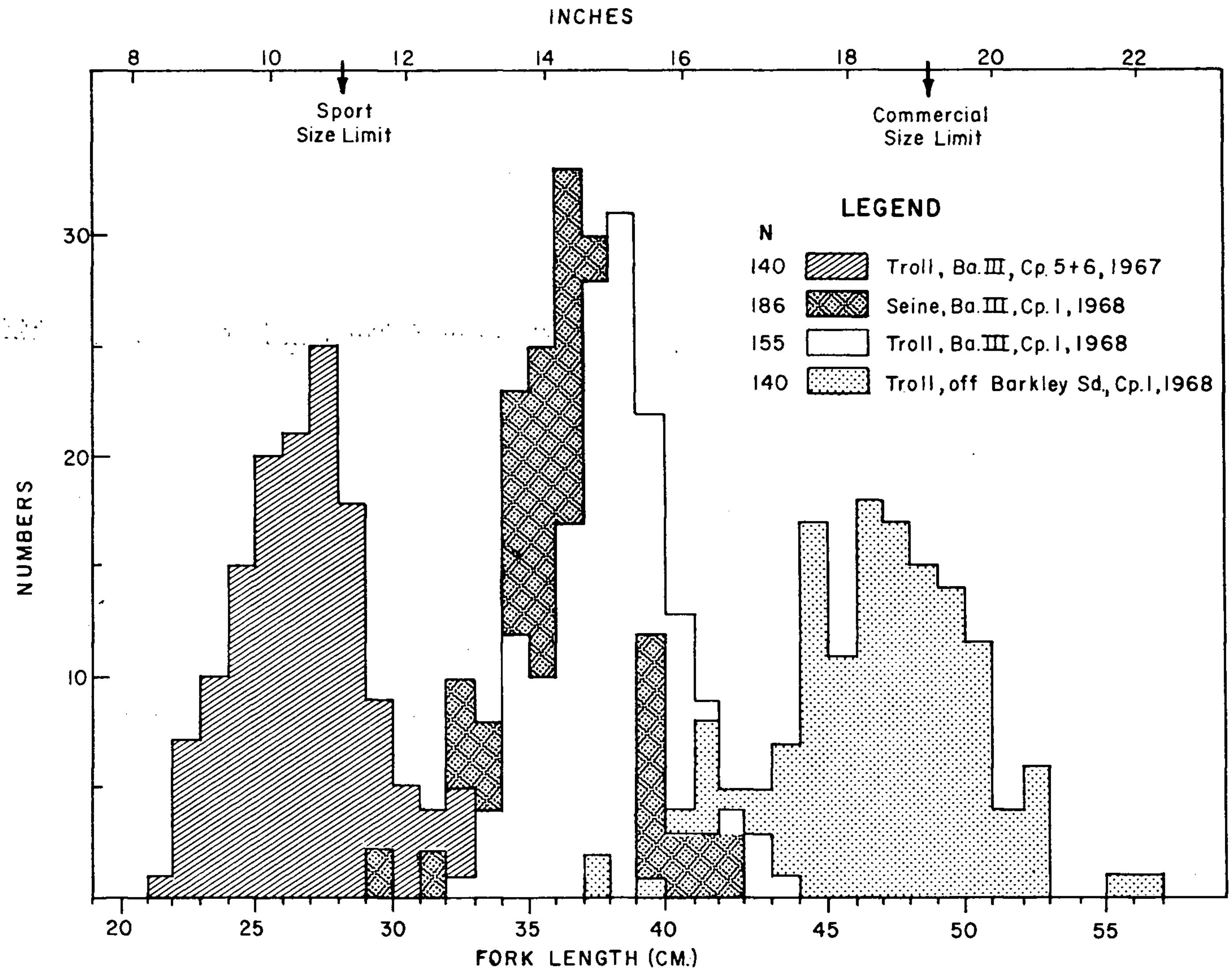

Figure 4. Length frequency distributions of troll and seine caught out-migrant coho salmon in Juan de Fuca Strait (1967 and 1968) and troll caught coho salmon on the west coast of Vancouver Island (1968).

TABLE II. Recovery of Puget Sound hatchery marks (1965 brood) during 1967 test trolling.

	Hatchery Mark		
	LV LM	RV RM	LV RM
August 16-30		1	1
September 1-15	1	4	
September 16-30		4	
October 1-15		3	1
Total	1	12	2
Hatchery Group	George Adams Hood Canal ⏟ Hood Canal	Green R. Issaquah Minter Ck. Puyallup Skykomish ⏟ Middle to south Puget Sound	Nooksack Skagit Samish ⏟ North Puget Sd. South Georgia Strait

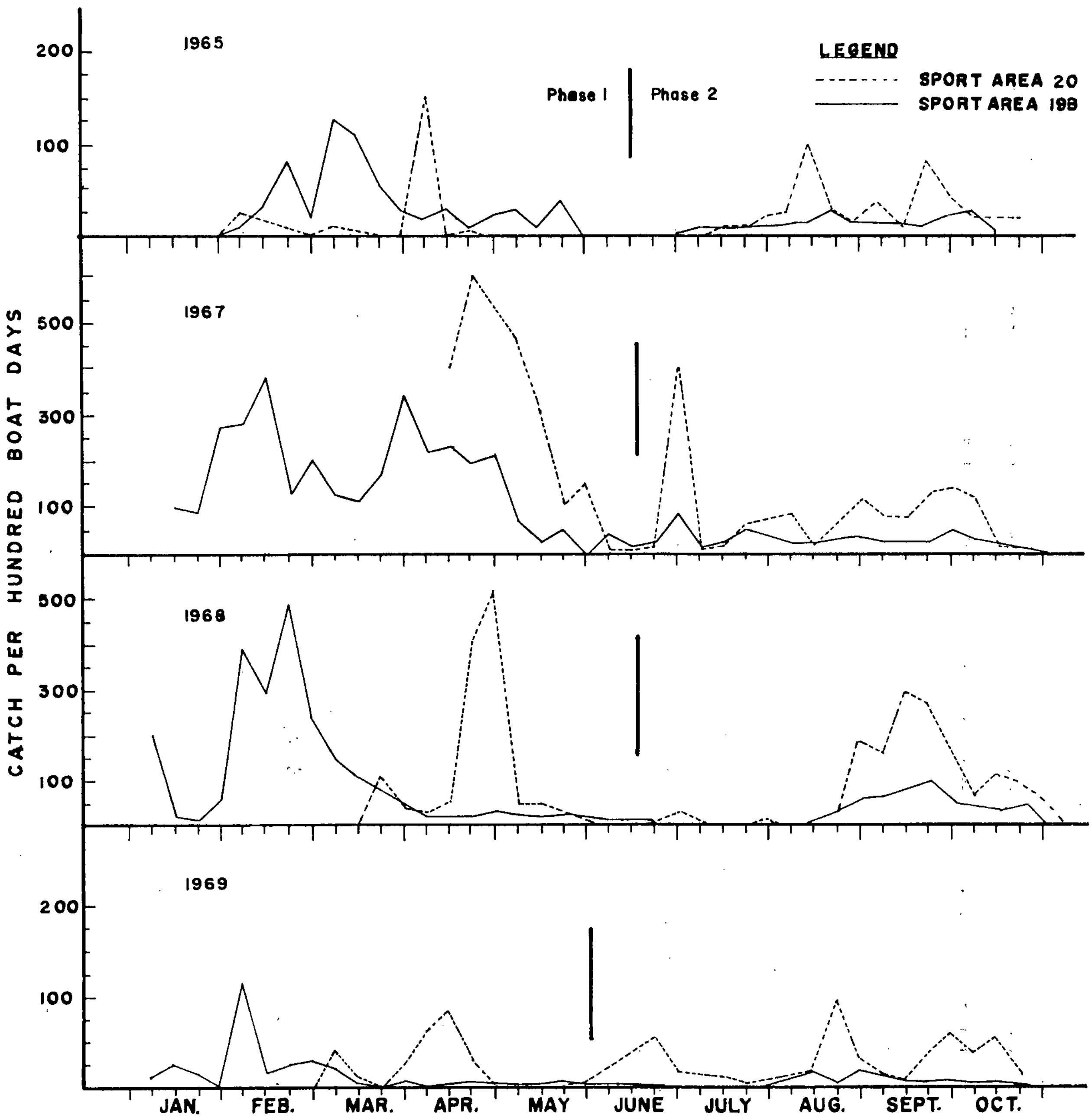

Figure 5. Weekly sport CPUE on coho salmon in Sport Areas 19B and 20, 1965, 1967 to 1969.

through the Victoria area, then in April or May, beginning a rapid out-migration which gives rise to a single sharp peak for Sport Area 20. Alternately, it is possible that the Sport Area 20 fishery misses one or more earlier peaks because of low or poorly distributed effort (adverse weather) or because prior to April out-migrant coho pass south of the range of sport gear (note Figure 15, which indicates October out-migrants favor offshore waters in Sport Area 20).

The January to May time period has been highly variable in contribution to coho sport catch, averaging 40 per cent of the annual catch (1963 to 1968) but in some years exceeding 80 per cent. The April-May peak is of particular interest as it coincides with increasing sport effort.

As implied, it is not certain whether February to May CPUE peaks represent out-migrating coho. For instance, Jensen (1956) and Bayliff (1953) inferred from various tagging experiments that Puget Sound stocks (natural and artificial) had completed oceanic migrations by mid winter. On the other hand, Allen (1956) demonstrated that coho found in north Puget Sound undergo oceanic migration in June of their second ocean year. On the basis of this conflict, and lacking information on Georgia Strait (B.C.) coho, it was reasonable to suspect that the April-May peak might not represent an outward migration.

To assess direction of migration, 218 coho were seine tagged (Floy spaghetti-anchor tags) off Sooke and Victoria between May 1 and 14, 1968. These were part of the April-May CPUE peak of Figure 5. For comparison, 23 coho were tagged on May 15 and 16 in Satellite Channel. Recovery patterns paralleled results of the October experiment. All recoveries (4) from Satellite Channel tagged coho were in southern Georgia Strait during the summer; of 40 Sooke-Victoria recoveries, most were by west coast troll gear from northern Washington to Barkley Sound and by Juan de Fuca net gear in the fall, none were recovered east of Victoria prior to August 30. It is apparent that the 1968 April-May peak consisted of out-migrant coho and it is inferred that this is the case for other years, although the magnitude of this out-migration varies considerably between years (compare areas under Figure 5 CPUE curves for 1965 and 1969 with 1967 and 1968). In reference to the Puget Sound experiments, it is interesting to note that four of nine recoveries in or near fresh water were from Puget Sound hatcheries and streams; the remainder were in or near the Fraser River. Note that all May out-migrants sampled exceeded the sport size limit; however, few would exceed the commercial limit[4] (Figure 4).

The various catch statistics suggest size selection by troll gear as well as growth of coho. From catches taken in the same area and time period (Figure 4), mean fork length for seine caught coho was 36.0cm. (14.4in.) compared with 38.2cm. (15.0in.) for the troll catch. Assuming that the seine sample represents the population size distribution (60 feet of herring web was added to the bunt end of the net), then test troll

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[4]Coho season for troll gear opens July 1 east of Port San Juan and June 15 on the west coast. Fork length of 48cm. is approximately equivalent to round weight of 3 pounds, from the length-weight relation of Appendix Figure 8A.

gear selected larger out-migrant coho.

Regarding growth, the interesting comparison is between May out-migrant coho and coho captured at the same time off Barkley Sound (Figure 4). Speculating that both groups had, in the fall, a size distribution similar to that of the out-migrants (Saanich Inlet and Sooke-Victoria tagged coho had identical size distributions in October), then west coast coho, during the intervening seven months, grew faster than May out-migrants [mean lengths: 27.6 cm. (10.9 in.) for October out-migrants; 38.2 cm. (15.0 in.) for May out-migrants; and 47.5 cm. (18.7 in.) for west coast coho; converted to round weights (Appendix Figure 8A), 0.56 lb. (0.25 kg.), 1.29 lb. (0.68 kg.) and 2.89 lb. (1.31 kg.) respectively.] Monthly instantaneous growth rate (g)[5] for May out-migrants was 0.140, for west coast coho 0.234. Milne (1951 and 1964 MS) reported consistent seasonal differences in size between west and east coast Vancouver Island troll caught coho (west > east). Seasonal analysis of coho stomachs (Prakash, 1962) suggested west and east coasts differ markedly with respect to quality and quantity of available food. If ecological differences exist, the above observations suggest that early out-migration timing confers a significant growth advantage. Further studies might examine stock composition and west coast rearing areas of distinctly timed out-migrations and the question of growth compensation for late out-migrants as elaborated by Zamakhaev (1965) for other fish species.

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[5] $g = \ln(Wt/Wo)/t$, $t = 7$.

ii) Second phase.

The second phase for exploitable coho occurs between June and October and is composed of sexually maturing coho aged 3_2. Milne (1964 MS) estimated that over 95 per cent of the west coast troll and Fraser River gillnet catches belonged to this age class. All Juan de Fuca gear types participate to varying degrees in the harvest of these coho.

As with phase one, certain timing subdivisions are apparent. In some years, notably 1967 and 1969, sport CPUE peaks near the end of June suggested an early summer migration. Test trollers in 1967 noted a progression of coho catches from basic-daily areas west of II C prior to June 24 to basic-daily areas east of II C after June 24 (Table III). At this time, schools of salmon, presumably coho, were sighted at the surface further to the east each day. A similar but less pronounced pattern of catches occurred towards the end of July. These observations provide reasonable confirmation of early inward coho migrations in 1967. However, this does not appear to be a regular phenomenon now nor in the past, as some have suggested. For instance, Rounsefell and Kelez, (1938) calculated average (1911-1934) proportions of the season's coho catch taken during seven-day periods for traps in Rosario Strait, at Point Roberts and off Bush Point (outer Puget Sound). In all cases, less than 7 per cent of the annual catch occurred between May 5 and August 11 compared to 37-42 per cent of the annual trap catch between September 15 and 29, substantiating the relative unimportance of early in-migrations.

TABLE III. Daily coho catch measured in terms of catch per hundred hook hours by test trolling gear, charter period one (June 19-29), 1967.*

Date	Daily Area	Basic Area I	Basic Area II	Basic Area III
June 19	A	11.2	17.6	0
20	B	9.4	4.7	0
21	C	4.5	0	0
22	A	20.4	8.7	0
23	B	11.5	8.0	0
24	C	6.1	0	0
25	A	4.2	8.0	0
26	B	9.7	11.0	0
27	C	9.6	41.9	0
28	A	6.7	21.4	7.3
29	B	16.0	20.6	4.4

*Appendix Figure 1A details location of basic and daily areas.

To Area 19B-20 sports fishermen, however, early migrations appear exceptionally available relative to their abundance, as evidenced by high CPUE which marks their passage.

Coho are abundant at the entrance of the Strait as early as July and usually continue in numbers to late September. Net fishing during July, prior to 1957, (Figure 6) occasionally harvested close to 40 thousand coho weekly. This should not be construed as the beginning of the main migration, as Canada-United States tagging in 1957 and 1958 (Milne, et al., 1958 and 1959) indicated that most coho milled at the entrance of the Strait (west of Port San Juan) until late August when the main in-migration began. Tag recoveries in Juan de Fuca Strait and east of Victoria from CDFF tagging in 1968 and 1969 (Table IV) substantiate timing results of the 1957-58 program.

Peak in-migration varies from late August to late September. In most years, maximum net catches (Figure 6) occur during the first two weeks of September; this corresponds fairly well with historical timing to inside traps (Rounsefell and Kelez, 1938). Annual variability in peak abundance, and in some years apparent bimodality in peak abundance, (1965 and 1969, Figure 5) probably reflects differing abundances and timing of a multitude of "major" stocks (artificial and natural) which must comprise the total coho run. Aro and Shepard (1967) point out that British Columbia coho spawn in about 970 of 1500 accessible streams but the top 25 streams support only 34 per cent of the total Canadian escapement, in contrast to over 60 per cent for other salmon species.

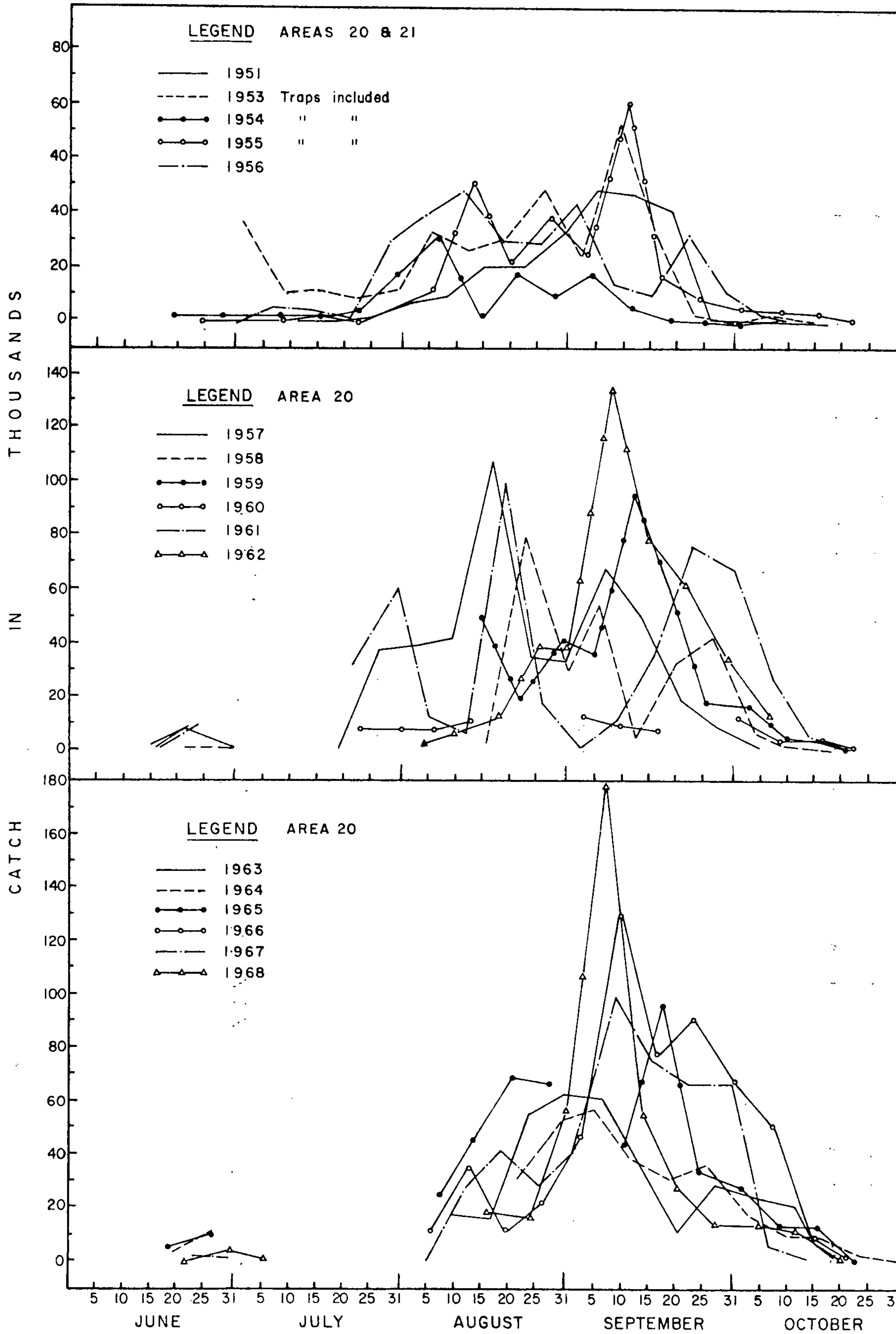

Figure 6. Weekly net catch (gillnet plus seine) of coho salmon in Areas 20 and 21, 1951 to 1968.

TABLE IV. Coho tag recoveries (1968 and 1969) inside the entrance of Juan de Fuca Strait from coho tagged in the Strait in 1968 and off the southwest coast of Vancouver Island in 1969.[+]

	Tagging 1968	Tagging Period 1969		
Recovery Period[*]	May 1-July 12	Mar. 15-Apr. 15	Apr. 30-June 29	July 3-Oct. 7
June			(6)	} all recovered west of Clallam Bay
July			(10)	}
August 1-15	(2)[**]		2(14)	(1)
August 16-31	2(2)		(15)	2(7)
September 1-15	4(28)		5(21)	3(1)
September 16-30	9(1)	1	14(3)	4(3)
≥ October[++]	11	1	33	16

[+]Numbers tagged: Strait by seine and troll gear, 486; west coast by troll gear, period one, 97; period two, 1486; period three, 251. (K. Pitre, pers. comm.).

[++]About 60% recoveries from Puget Sound hatcheries.

[*]Recoveries in year of tagging.

[**]Bracketed recoveries by Canadian and American Juan de Fuca Strait sport and commercial fisheries; unbracketed recoveries by all gears east of Victoria.

British Columbia coho stocks south of Johnstone Strait generally spawn in near coastal rivers and streams, although some are found in the Shuswap system of the Fraser. Peak spawning generally occurs during October and November (Aro and Shepard, 1967).

Timing of the main fall in-migration occurs when all fishing gears are close to peak activity; consequently, high exploitation is not unexpected. One anomaly, however, is rather low coho contribution to sport gear (less than 50 per cent of the annual coho catch), especially when considering the high coho abundance and peak timing of sport fishing effort. This may well be related to changes in coho accessibility and vulnerability as the season progresses (see later sections).

b) Chinook salmon

Timing of exploitable chinook salmon is without doubt the most complex of all five species. In addition to out-migration and in-migration phases, some chinook remain in the Strait for extended time periods, perhaps as semi-permanent "resident" populations.

Timing of out-migrations (phase one) of first ocean year sexually immature chinook is virtually undocumented. Test trolling in 1967 began capturing 1_1 and 2_2 chinook during Cp3 (July 26 to August 8, Appendix Table 3A). Catches (BaIII) showed the largest increase during Cp6 (September 26 to October 11) when 44 were landed. Ageing of readable scales (Appendix Table 5A) indicated over 50 per cent sub-twos (stream types, aged 2_2, more than one year in fresh water). Based on test troll catches, first ocean year chinooks were not nearly as abundant as 2_2

coho, during comparable charter periods. Chinooks averaged about 26cm. (10.2 in.) fork length which, in combination with apparent low abundance, suggests this age class is of little importance to sport gear. Sport catch statistics provide no indication of first ocean year chinook timing as the three pound or less category includes second ocean year as well as small third ocean year chinook.

To confuse matters regarding out-migrations, certain CDFF chinook taggings (1963 to 1967, unpublished) at various Georgia Strait locations produced west coast summer troll recoveries of chinook which at time of tagging were obviously in their second or third ocean year. This implies either that outside stocks contribute to Georgia Strait rearing populations, or that immature chinook from inside stocks split marine "residency" between inside and outside waters.

The chief indication that some chinook rear in the Strait came from 1967 test troll data. Throughout the study period (June 19 to October 11) catches of 2_1 and 3_1 aged chinook were highest in mid-Strait (BaII) between Port San Juan and Sheringham Point and near Swiftsure Bank (Figure 15). Except during Cp1 and 2 (June 19 to July 19), over 90 per cent were immature and were more abundant near shore in almost all daily areas. The 2_1 age class consistently formed the highest percentage of the BaII test troll catch (Appendix Table 5A). Consistent catches between charter periods, a mid-Strait catch peak and the high proportion of immatures and age class 2_1 (notwithstanding gear selectivity, Section E) suggest that moderate numbers of 2_1 and 3_1 chinooks (relative to high abundance on west coast continental shelf areas) form a semi -permanent rearing population in the Strait, primarily along the narrow shelf which extends the length of the Strait. Most 2_1 chinook were below the commercial size limit (Figure 7), but they exceeded the sport size limit and their consistent presence would therefore be of considerable value to the more regular sports fishermen.

In-migrations of sexually maturing chinook (phase two) probably occur throughout much of the year (Aro and Shepard, 1967). This is particularly evident when examining historical Georgia Strait and Admiralty Inlet trap catches of Rounsefell and Kelez (1938) and recent Fraser River gillnet catches presented by Mason (1965), Godfrey (1968 MS) and Milne (1964). In all cases, allowing for effects of seasonal regulations, chinook catches were highest from May through to October. Undoubtedly, a large portion of chinook contributing to inside fisheries passed through Juan de Fuca Strait. Both Godfrey and Mason show two periods of apparently higher Fraser abundance as inferred from catch peaks, May to July and late August to September.

Relating the above timings to Juan de Fuca Strait is difficult considering the restricted net fishing period and fluctuating troll effort. On this basis, troll CPUE (Figure 8) appears the best timing index. The pattern between years is anything but consistent. In general, many sharp peaks occur during April, May and June. After mid-August there is an apparent lull until late October when CPUE increases to June-July levels. It is doubtful whether the latter peak represents a significant

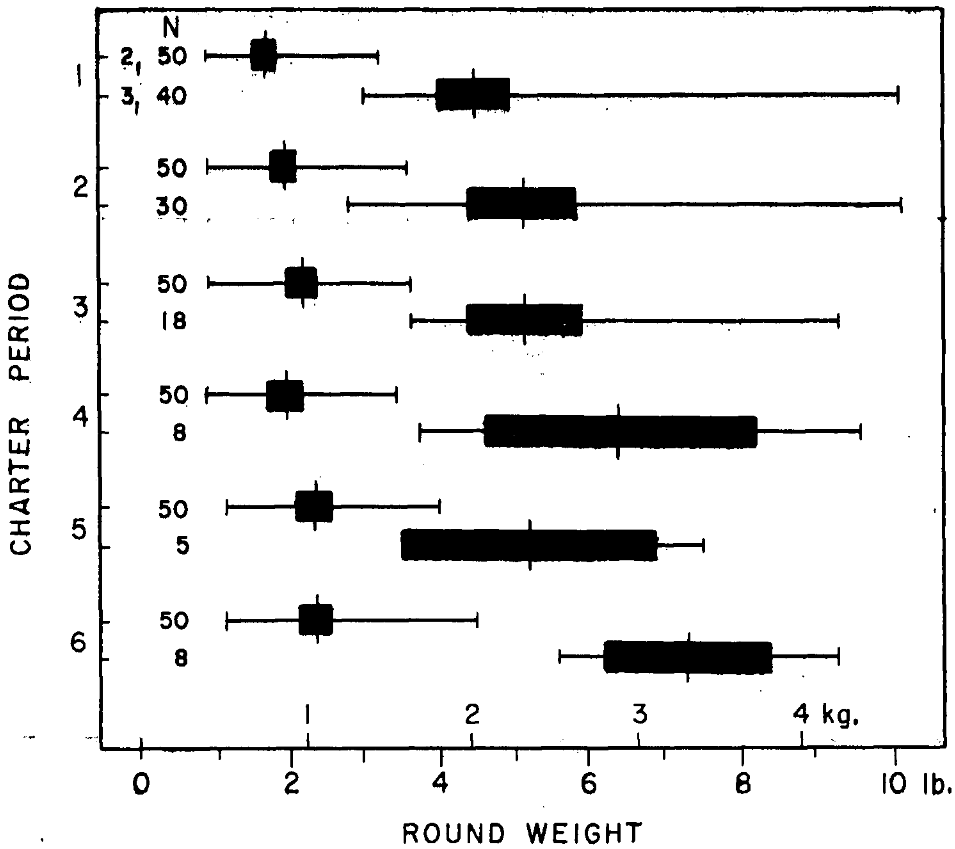

Figure 7. Round weight of 2_1 and 3_1 chinook caught by test troll gear in 1967. Vertical line equals mean, bar equals 95% confidence limit on the mean, and horizontal line equals range.

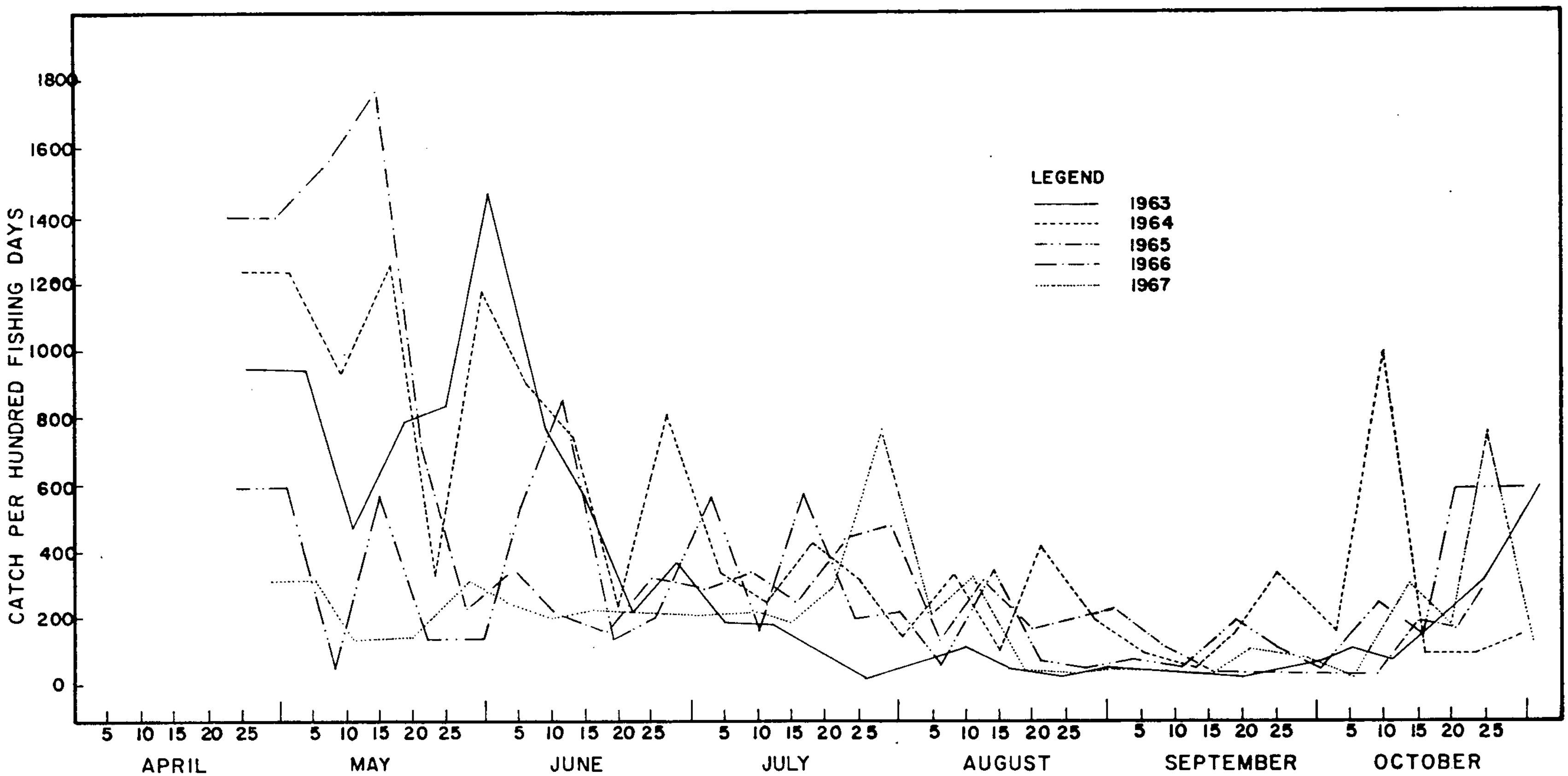

Figure 8. Weekly troll CPUE on chinook salmon in Area 20, 1963 to 1967.

in-migration insofar as it occurs later than reported catch peaks for inside fisheries. Area 20 net catches (Figure 9) are consistently highest in mid-August dropping rapidly thereafter. This peak appears on the troll CPUE graph, but it is low compared to earlier troll CPUE. The net-troll discrepancy may result from a change in species orientation by troll gear or perhaps reflects a change in chinook catchability (susceptibility). Mathews and Wendler (1968) noted that spring run Columbia River chinook were approximately five times as catchable by hook and line gear as fall run chinook and postulated that this reflected a behavioural difference between the two runs.

Tag recoveries (Table V) from 1969 CDFF west coast tagging imply that inside chinook stocks on the west coast from March 15 to the fall, pass through the Strait during August and early September. Five inside recoveries prior to August confirm earlier in-migrations which are likely larger than recoveries indicate, due to low recovery effort early in the season.

The extended chinook run is advantageous to sport and troll fisheries as it provides exploitable salmon during most of the year, and particularly when other species are absent or in low abundance. Hook and line effort from late fall to early summer might be higher (see Figure 2) were it not for generally poor weather. Wind speeds at Victoria (1922-1945) averaged over eleven miles per hour between December and July with periods of relatively strong west and southwest winds (13.7 to 17.8mp between March and June (Boughner and Thomas, 1948, from Herlinveaux, 1954).

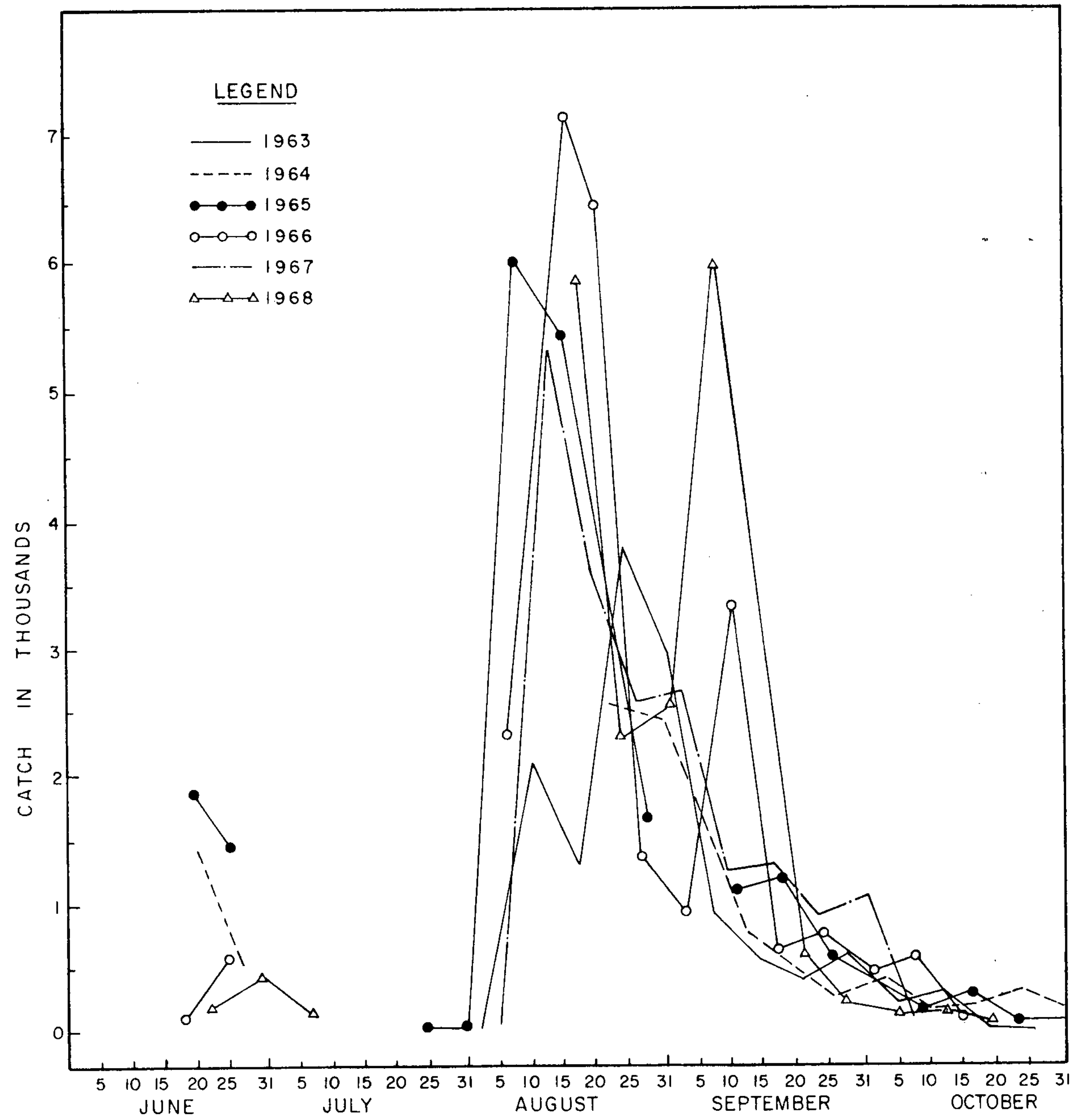

Figure 9. Weekly net catch (gillnet plus seine) of chinook salmon in Area 20, 1963 to 1968.

TABLE V. Chinook tag recoveries (1969) inside the entrance of Juan de Fuca Strait from chinook tagged off the southwest coast of Vancouver Island in 1969.*

	Tagging Period		
Recovery Period	March 15 - April 15	April 30 - June 29	July 3 - October 7
April	1		
June		2	
July		2(2)	
August 1-15	(2)**	(4)	(1)
August 16-31	1(1)	7(4)	(2)
September 1-15	2	5(2)	(1)
September 16-30+		5(1)	(1)
≥October+	5	18	5

*Numbers tagged: period one 257; period two, 2208; period three, 938. (K. Pitre, pers. comm.).

**Bracketed recoveries by Canadian and American Juan de Fuca Strait sport and commercial fisheries; unbracketed recoveries by all gears east of Victoria.

+About 70% recoveries from Puget Sound hatcheries.

The prolonged chinook in-migration probably reflects diversity of spawning area and timing, as well as numbers of contributory stocks (artificial and natural). Mason (1965), in a review of chinook life history, points out that many coastal rivers (generally south of Vancouver Island) have up to three distinct fresh water spawning runs extending from April to October. In the Fraser system, chinook are found in 29 tributaries covering almost all waters accessible to salmon. Spawning times show a wide range. In some tributaries spawning initiates in June, peaking in July, whereas at the other extreme (generally the more coastal tributaries) spawning may not begin until October, peaking in November (Aro and Shepard, 1967).

Age composition of in-migrants is only partially known. Between 1957 and 1959 Fraser gillnet samples (Milne, 1964 MS) were dominated by ocean age four, followed by three, two and five. It is reasonable to suppose that Fraser River age classes are also present in Juan de Fuca in-migrations in roughly the same order of importance.

c) Pink salmon

In southern British Columbia waters, presence of exploitable pink salmon is exclusively an odd-year phenomenon. Out-migration timing is poorly documented, but exploitation is negligible as few pinks exceed the sport size limit. Pinks rear in offshore waters bordered by approximately 145°W, the Gulf of Alaska and the Columbia River (Neave, 1966a). They do not appear in coastal areas until June of their ultimate year as age class 2_1.

Inshore spawning migrations through Juan de Fuca Strait are excellently documented by Vernon et al., 1964, and Hourston et al., 1965. Pinks appear regularly in the net fishery (odd years) in late July (Figure 10), reach peak abundance between August 20 and 31, and decline to low levels by the second or third week in September. Net catch timing closely follows total abundance data based on tagging from Vernon, et al., (1964, Figure 29).

Ten streams produce about 95 per cent of the total run which is divided into three major stock groups: Fraser River, Canada non-Fraser, and Puget Sound. Spawning of Canada non-Fraser stocks peak during October; start and end of spawning ranges from August to November (Aro and Shepard, 1967). Canada non-Fraser stocks generally pass through the fishery earliest, about August 15, followed by United States Puget Sound stocks and main-stem plus upper Fraser (above Hell's Gate) stocks about August 25 and, finally, lower Fraser tributary stocks approximately one week later.

On the basis of data presented by Hourston et al., (1965), the dominant Fraser plus other Canadian streams contributed over 70 per cent of the catch between 1951 and 1963. All Juan de Fuca gear types make high catches of odd-year pinks, generally over 50 per cent of their total annual catch of all species.

d) Sockeye

The majority of exploitable sockeye passing through Juan de Fuca Strait are of Fraser River origin (Verhoeven and Davidoff, 1962;

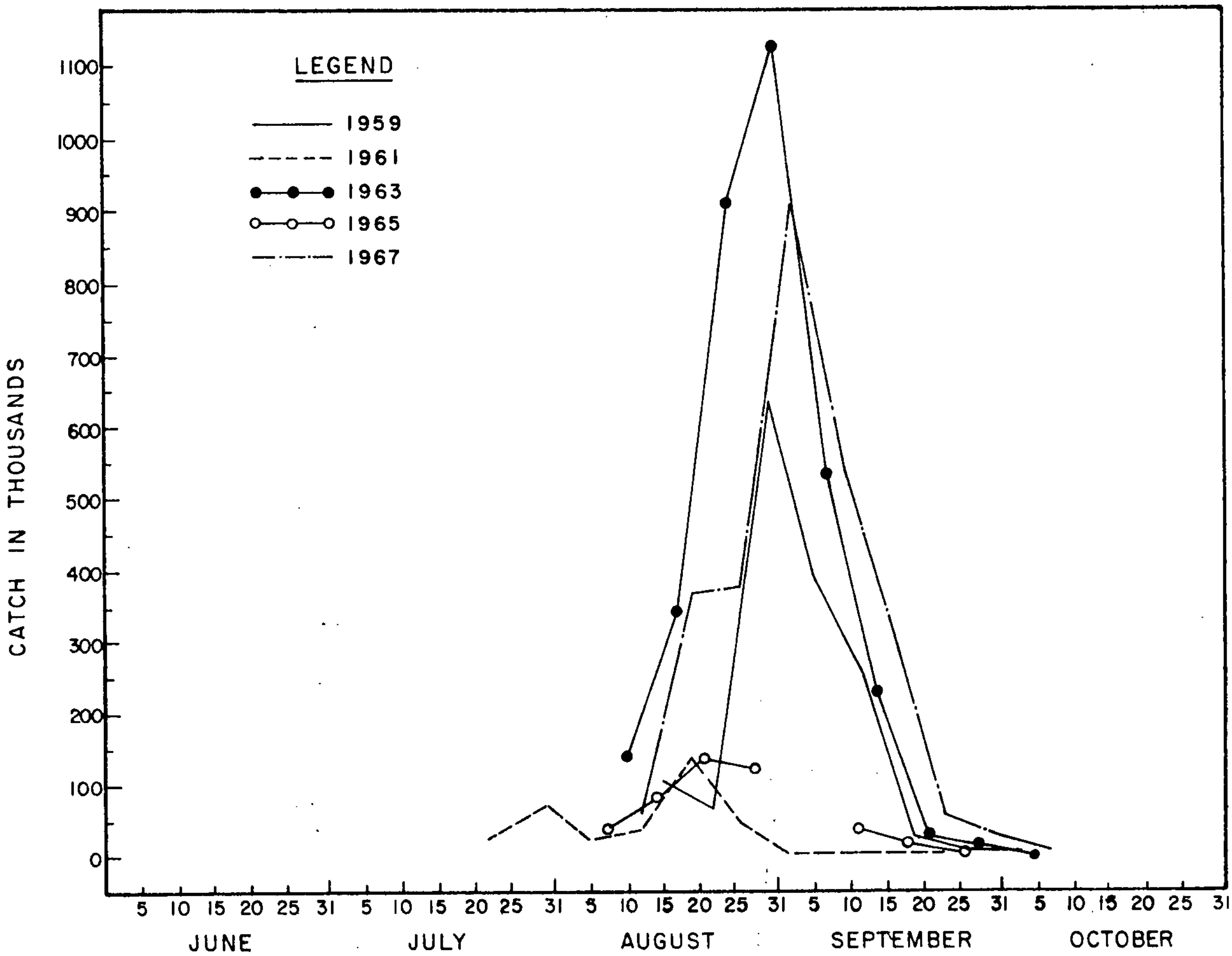

Figure 10. Weekly net catch (gillnet plus seine) of odd year pink salmon in Area 20, 1961 to 1967.

Killick and Clemens, 1963); however, since 1968 an artificially enhanced stock from Lake Washington has increased in importance.

Juvenile sockeye leave the Fraser in spring of their second year of life (Killick and Clemens, 1963) and apparently undergo rapid out-migration as few are captured inshore during the summer months (Ricker, 1966). Sockeye at this age are not caught by sport or troll gear; in fact, Juan de Fuca hook and line catch of sockeye is negligible at all times.

Based on sampling from Sooke traps, sexually maturing sockeye return through Juan de Fuca Strait between mid-June and the first week in September (Killick and Clemens, 1963). Peak timing of the Fraser run depends on stock composition. Since 1959 various combinations of the Horsefly, Chilko, late Stuart and Adams River stocks produced considerable variability in peak net catch (Figure 11). Killick and Clemens, based on scale analyses by Henry (1961), place peak abundance of Horsefly, Chilko, late Stuart at Sooke traps between July 26 and August 1. Horsefly sockeye arrive about five days before Chilko and late Stuart sockeye. Early Stuart sockeye peak first, on approximately July 4; Adams River sockeye peak last, about August 20. Gilhousen (1960) assessed annual variation in peak migration date of Adams sockeye passing through San Juan Island fisheries. For nine cycle years (every four years) between 1926 and 1958, peak occurrence varied between August 7-10 in 1926 and September 2 in 1958; six cycles peaked between August 24 and 31.

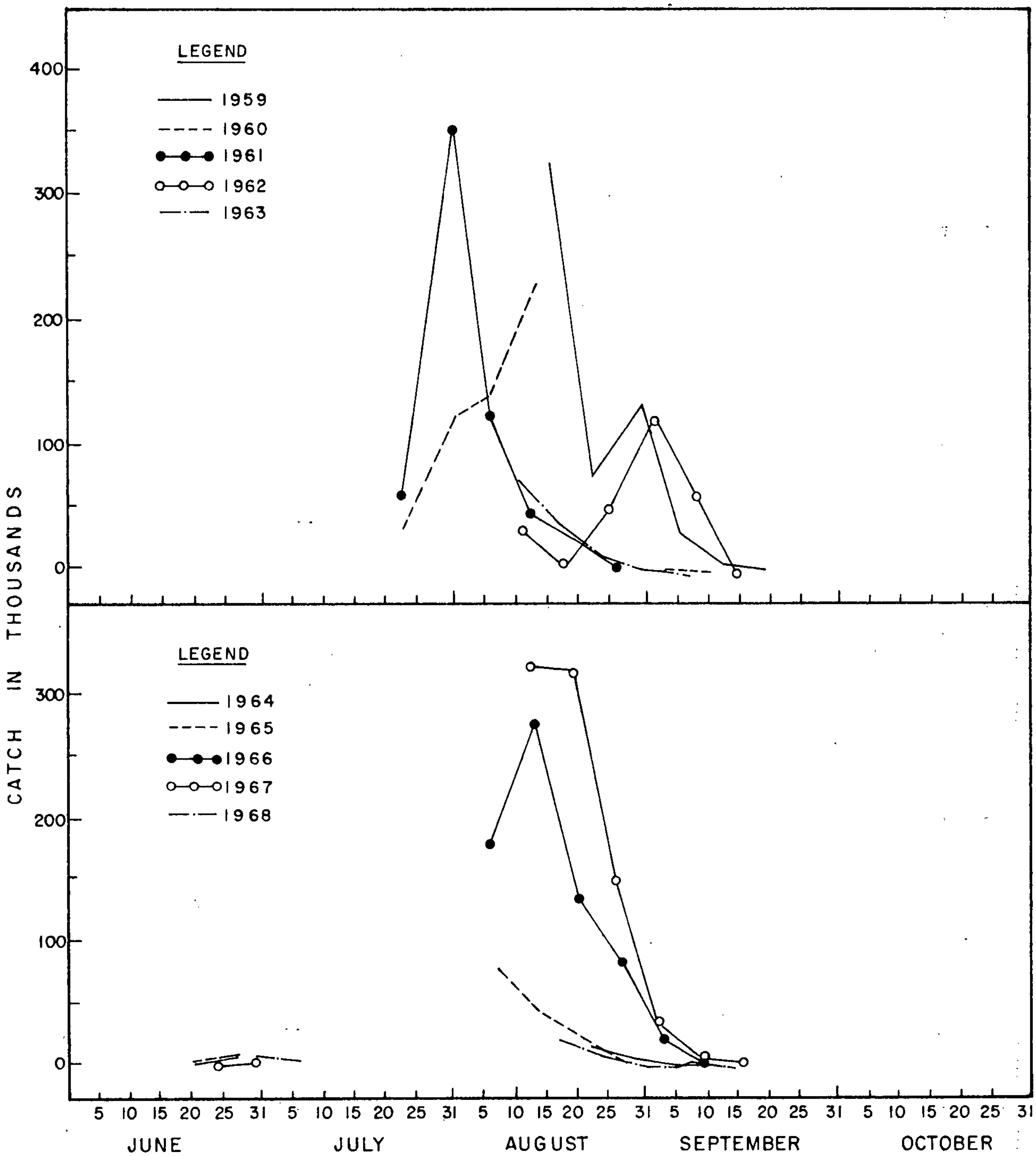

Figure 11. Weekly net catch (gillnet plus seine) of sockeye salmon in Area 20, 1959 to 1968.

With the exception of Adams River sockeye, the stocks proceeding to areas above Hell's Gate appear earliest in the Strait and are followed by stocks which spawn below Hell's Gate, with exception of Pitt River sockeye (Killick and Clemens, 1963). Timing of peak spawning (Aro and Shepard, 1967) shows closer correspondence with migration timing through Juan de Fuca Strait. For instance, early Stuart stocks spawn during early August, Horsefly sockeye peak in late August, Chilko and late Stuart peak during September and Adams River sockeye peak in late October.

Approximately 90 per cent of Fraser sockeye return as age class 4_2 (Killick and Clemens, 1963); only four minor stocks have significant representations of older sockeye. The 3_2 age class (usually less than 3 per cent of the run) generally peaks one year prior to expected large returns of 4_2 sockeye.

Since 1961, Canadian net fisheries in Juan de Fuca Strait have been closed between June end and the beginning of August to conserve early migrating Fraser stocks (notably early Stuart). Consequently, on years when Horsefly, Chilko, late Stuart and Adams River stocks are in low abundance (1964, 1965, 1968), relatively few sockeye are taken by net gear and weekly catches progressively decline after the fishery opens. On Adams River "big years" (1958, 1962, 1966) and "sub-dominant years" (1959, 1967), weekly catches are high during August. In 1967 Fraser pink salmon and Adams sockeye overlapped in timing, seriously complicating IPSFC management of the fisheries to the extent that equal division of the sockeye catch between Canadian and American fishermen was impossible (IPSFC, 1967).

e) Chum salmon

Timing of chum out-migrations to oceanic feeding grounds are poorly documented. As with sockeye and pink salmon, chum are exploited only during inshore spawning migrations.

Chums first appear in Juan de Fuca net catches about mid-August (Figure 12), although peak catches seldom occur until late September and early October. By mid-October net effort is on the wane, therefore, declining chum catches do not necessarily represent passage of peak chum abundance.

Neave (1966b) states that most chum mature in their third and fourth years of life, but mature fifth year fish occur regularly in the catch.

Chum in southern British Columbia rivers and streams spawn from October to January. In the Fraser system chum stocks of the Chehalis River spawn relatively early in October compared to chum of the main-stem Fraser, Chilliwack, Vedder and Harrison Rivers which spawn in December (Aro and Shepard, 1967). Chum spawn close to the sea in most rivers and streams and only one hundred miles above salt water in the Fraser River (Neave, 1966b).

In contrast to pinks and sockeye, chums form a minor part of the Juan de Fuca net catch and are seldom caught by hook and line gear.

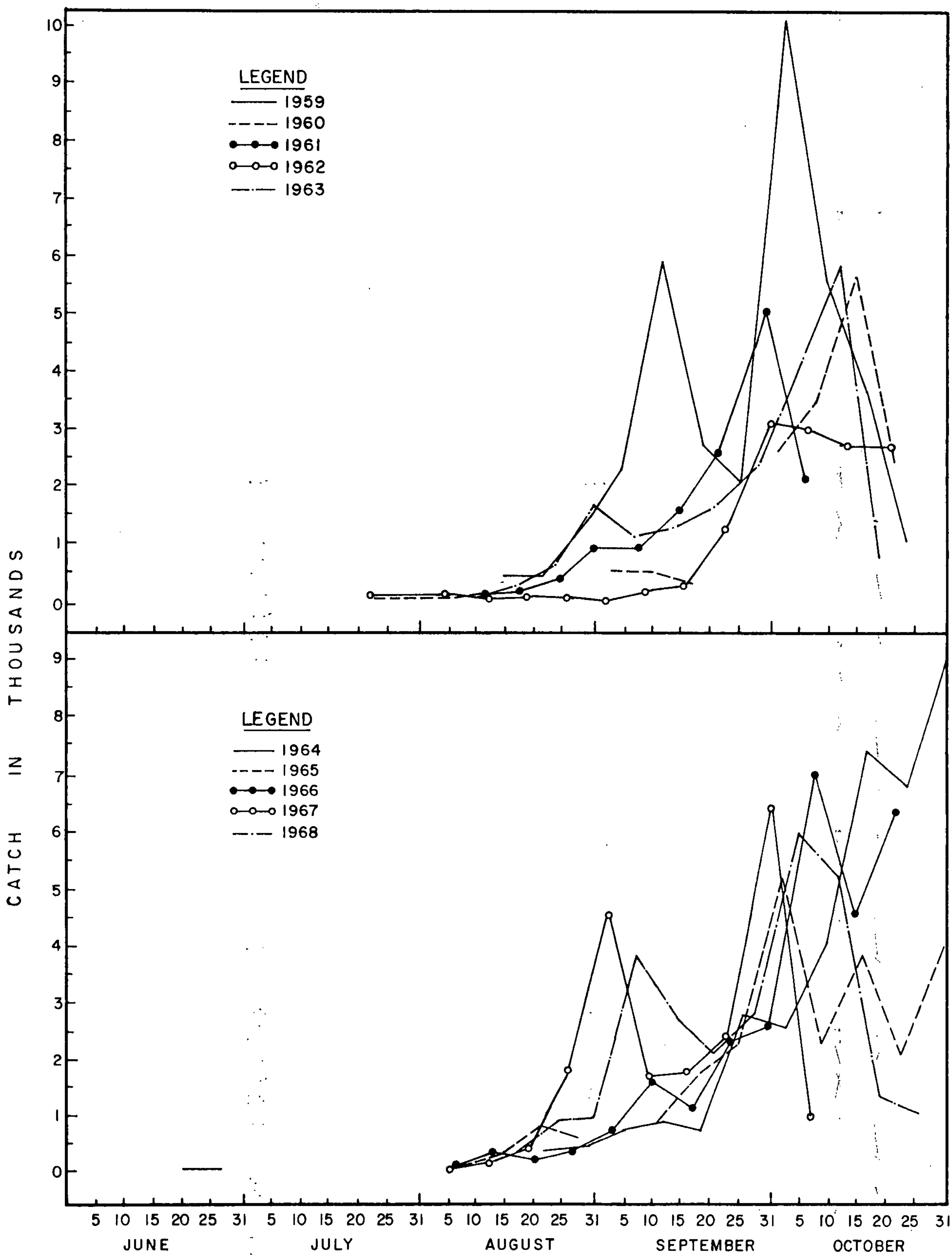

Figure 12. Weekly net catch (gillnet plus seine) of chum salmon in Area 20, 1959 to 1968.

3. Summary

Coho and chinook salmon are exploited during oceanic migrations by sport and troll gear, and during inshore spawning migrations by all Juan de Fuca gear types.

Pink, sockeye and chum salmon are exploited exclusively during spawning migrations, pinks by all gears, sockeye and chum only by net gear.

Each species has a characteristic seasonal timing through Juan de Fuca Strait (summarized by Figure 13); but species vary in run duration and timing consistency between years.

In general, differences in ecological diversity between species in terms of numbers of component stocks, spawning areas and spawning times affects duration and peak timing of each run.

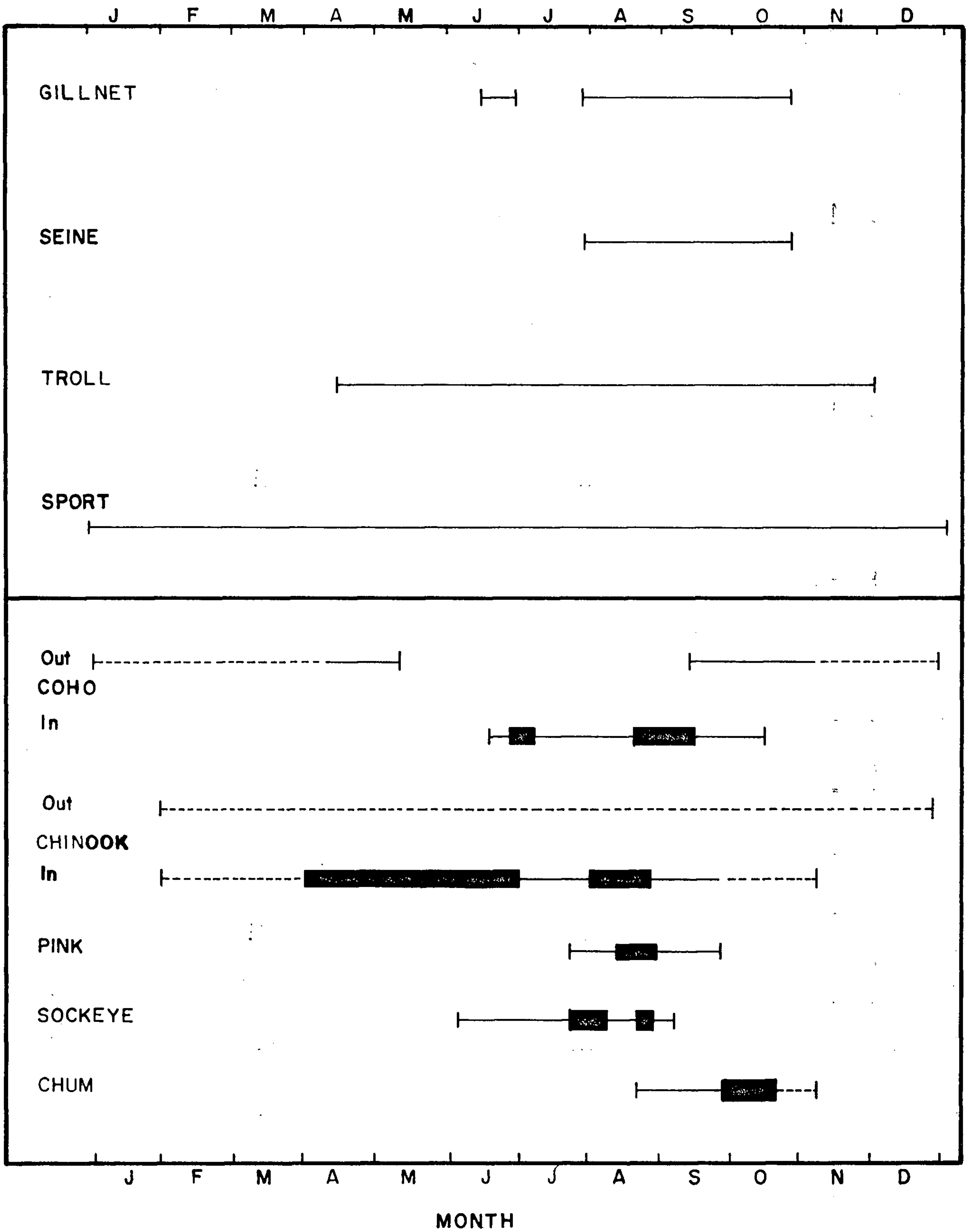

Figure 13. Seasonal timing of Juan de Fuca gear types and exploitable salmon species. For salmon dotted line refers to possible timing, solid line known timing, and bar, timing of abundance peaks.

B. Fishing Gear--Distribution and Numbers

1. Introduction and Methods.

To estimate intensity of exploitation on salmon stocks (species) passing through a fishing area, it is important to know the distribution and amount of each type of fishing gear. Estimates of commercial (gillnet, seine, troll) and sport gear distribution in Juan de Fuca Strait were provided by aerial flights and observations by test troll crew members and personnel of the Conservation and Protection Branch of the Canada Department of Fisheries and Forestry.

Numbers of commercial vessels were estimated from CDFF published effort statistics; numbers of sport vessels from flight data. The Juan de Fuca fishing area was artificially gridded into six west to east subdivisions (A to F) for these estimates.

Gillnet counts were made from evening flights each week (between 1830 and 2000 hours PDT) during August and early September on either the first, second, or third weekly fishing day. In 1967 nine flights were completed by September 18 when adverse weather forced discontinuation. In 1968 four flights were completed before weather closed in on September 1. Sport gear distribution for 1967 was compiled by thirteen weekly flights either on Saturday or Sunday (between 0800 and 1100 hours PDT) during July and August. In 1968, weekday flights were added between July and September and weekend flights were extended to May, June and September. Flights for 1968 totalled 26 (15 weekend and 11 weekday).

Distribution of purse seines is based on observations by the 1967 test troll crew members and staff of the Conservation and Protection Branch.

No estimates were made of troll distribution. However, since the 1967 regulation change[1] few trollers have fished in the Strait.

Average numbers of gillnets and seines operating each monthly fishing day were estimated from 1967 and 1968 published effort statistics for Statistical Area 20 (CDFF publications of British Columbia Catch Statistics) divided by the number of days open to net fishing each month. A unit of effort is equivalent to one vessel delivery. Double deliveries and hold-over deliveries are uncommon in the Juan de Fuca fishing area, thus the above quotients provide reasonable estimates of average daily vessel count for each gear in all subdivisions.

The majority of trollers (restricted since 1967 to waters west of Sheringham Point) fishing Area 20 are day boats, thus monthly effort (1967 and 1968) divided by thirty provides a rough estimate of average number of trollers fishing on any day.

Numbers of sport vessels were estimated from monthly flight count averages (1967 and 1968). At most sport fishing locations, fleet size changes throughout the day as sports fishermen generally stay on the water for much shorter time periods than commercial fishermen. Sports fishermen also are not nearly as consistent as to starting times. Aerial flights embraced the daily period when a maximum number of sport boats would be expected. Consequently, sport count data should represent the average maximum daily fleet size each month. Note that Pedder Bay sports fishermen are included in subdivision E.

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[1] Effective July 1, 1967, all commercial fishing was eliminated in Canadian waters of Juan de Fuca Strait east of Sheringham Point.

2. Observations and Interpretations.

a) Gillnet vessels

Few vessels were observed within two miles of shore (Figure 14); the boundary encloses approximately 95 per cent of all gillnet observations. Because flights were timed for just after the daily opening, a few gillnets were usually running at flight time, others would occasionally be observed at anchor off Glacier Point. These vessels were not included in percentage calculations. On most flights, vessels would be scattered quite randomly throughout the stippled area with density gradually increasing towards the Bonilla-Tatoosh line (blue-line). Subdivision A always had the highest numbers (34%), reducing to 30 per cent in B and 18 per cent in subdivisions C and D. In subdivision D, gillnets were concentrated primarily between Glacier Point and the Sheringham line and extended more towards the center of the Strait than in waters to the west. Waters adjacent to River Jordan were generally void of gillnets. Prior to 1967 waters between Sombrio and Glacier Points were avoided as gillnets found it more convenient to fish off Sooke, within easy running distance of delivery and moorage facilities.

For August and September, numbers of gillnets for the total fishing area averaged 220 and 222 respectively; numbers dropped to 92 in October (Table VI). Reduced salmon abundance, poor weather and removal of Port San Juan delivery facilities likely contributed to this decline. Subdivision counts were estimated by the product of percen-

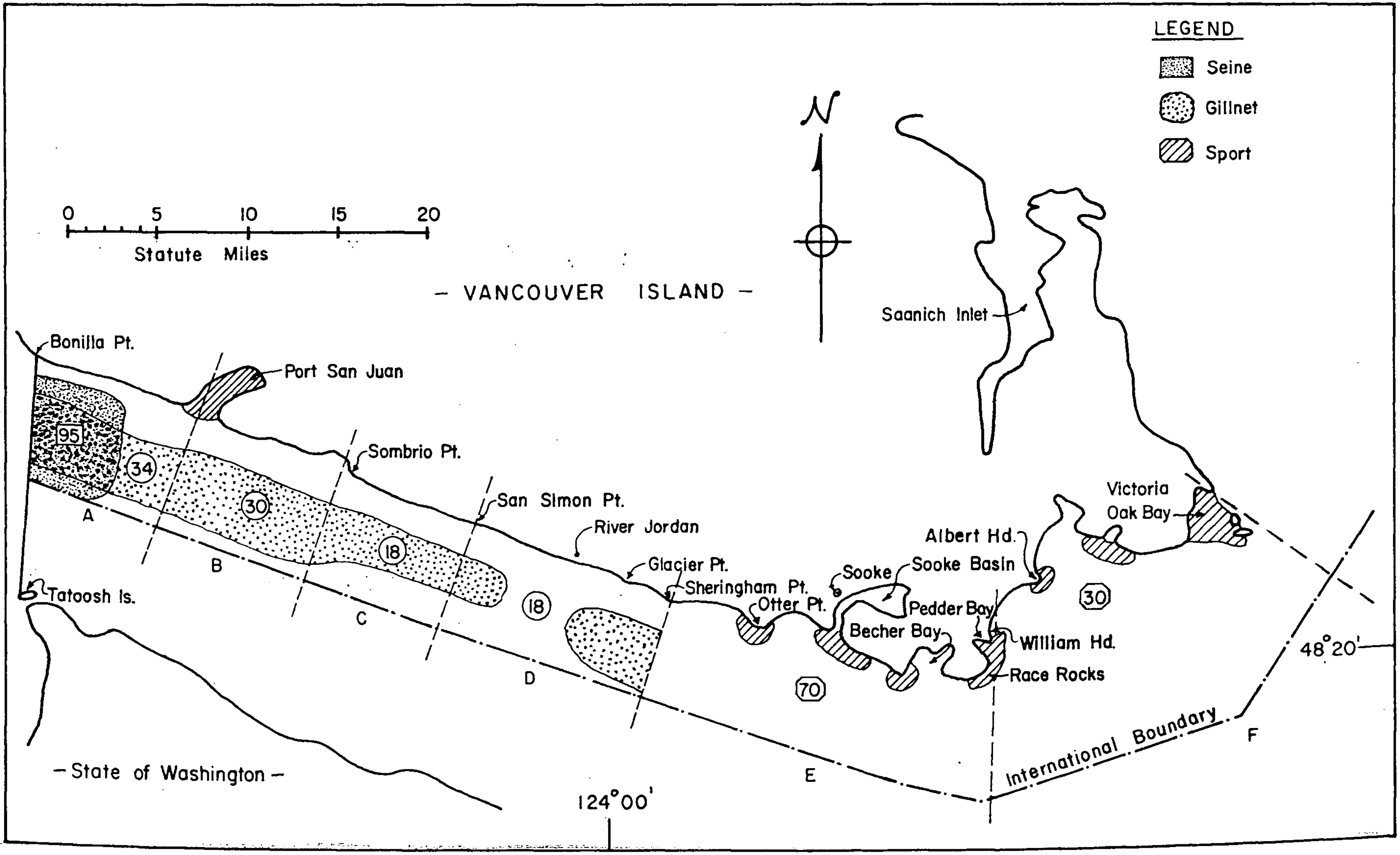

Figure 14. Spatial distribution of seine, gillnet and sport gear based on total 1967 and 1968 flights. Symbols enclose percentages by subdivision, 95 per cent of all observations within indicated boundaries.

TABLE VI. Estimated daily fleet size for commercial and sport gear in sub-areas of Juan de Fuca Strait, based on 1967 and 1968 data.

	May - June		July		August			
Sub Area	Sport	Troll	Sport	Troll	Sport	Troll	Gillnet	Seine
A	-	-	-	-	-	-	75	49
B	-	-	-	-	-	-	65	1
C	-	-	-	-	-	-	40	1
D	-	-	-	-	-	-	40	1
E	47	-	100(19)*	-	130(30)	-	-	-
F	20	-	43(8)	-	55(13)	-	-	-
Total	67	2	143(27)	2	185(43)	8	220	52

	September				October			
Sub Area	Sport	Troll	Gillnet	Seine	Sport	Troll	Gillnet	Seine
A	-	-	75	48	-	-	31	2
B	-	-	66	1	-	-	27	-
C	-	-	40	1	-	-	17	-
D	-	-	40	1	-	-	17	-
E	208(33)	-	-	-	37(6)	-	-	-
F	89(14)	-	-	-	15(2)	-	-	-
Total	297(47)	4	222	51	42(8)	1	92	2

*weekend count unbracketed; weekday count bracketed.

tages of Figure 14 and the 1967-1968 average monthly counts. On this basis in August and September approximately 75 vessels fished subdivision A, 66 fished subdivision B, and 40 fished in subdivisions C and D. Flights did not extend to October; however, it was assumed that gear distribution remained unchanged. Estimated October subdivision counts were 31 in A, 27 in B, and 17 in C and D. Within the stippled area each gillnet during August and September has about 0.5 square miles (1.3 square km.) of operating area.

b) Seine vessels

Seines were seldom observed fishing east of the shaded area of Figure 14. Within this area most were concentrated two or three miles (3.2-4.8 km.) from the blue-line (Plate 4). Prior to 1967, some seines occasionally operated in subdivision E, apparently relatively close to shore.

Number of seines was estimated at 52 in August, 51 in September, and 2 in October (Table VI). Seine counts were calculated in an identical manner to gillnet counts. Numbers vary considerably between years. For example, in 1967 monthly counts were approximately triple those of 1968 due to high pink and sockeye abundance. Based on August-September numbers each seine has less than 0.5 square miles (1.3 km.^2) of operating area in the shaded portion of Figure 14. At high vessel densities effective fishing time would decline due to increased waiting time between sets.

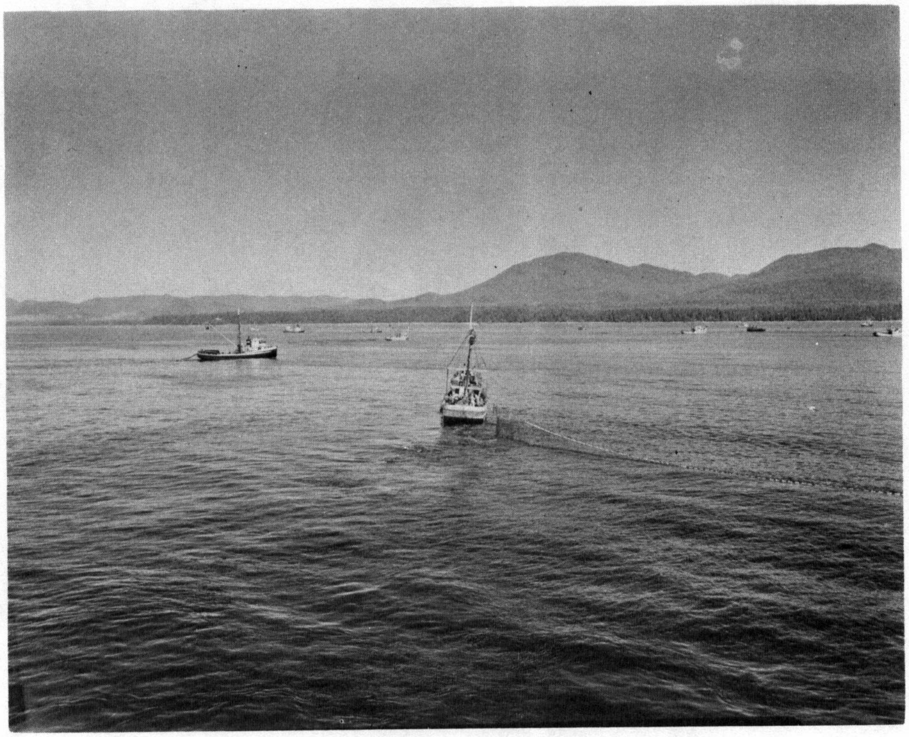

Plate 4. Juan de Fuca table seines crowding the Bonilla-Tatoosh net line during the fall salmon fishery (Courtesy, S.R. Killick, IPSFC).

c) Troll vessels

The few troll vessels observed by departmental personnel were operating just to the west of Sheringham Point. On the basis of effort statistics an average of eight vessels would be encountered on any given fishing day. Prior to 1967, troll effort was somewhat greater; most vessels operated between Race Rocks and Sheringham Point.

d) Sport vessels

Sport boats were seldom observed more than one and one-half miles from shore and tended to clump within easy running distance of available launching facilities or marinas (Figure 14). On the average, 70 per cent of daily effort occurred in subdivision E and was evenly distributed at four locations--Otter Point, off Sooke, on the west shore of Beecher Bay, and near Pedder Bay. Subdivision F effort was concentrated off Victoria Harbour or in Oak Bay, with lesser numbers fishing near Albert Head.

Daily fleet size (Table VI) was consistently five to six times higher on weekends than during the week. Counts were quite consistent between weekdays and between Saturdays and Sundays. Highest average daily weekend counts occurred during August and September (185 and 297 respectively) and reflect passage of coho and odd-year pink stocks. October sport counts were estimated by applying the percentage change in CDFF published sport effort (in boat days, 1963 to 1968 average) from September to October to the September weekend and weekday vessel counts.

Some sports fishermen venture out to Port San Juan during the fall coho and chinook migrations into the Gordon and San Juan Rivers. Fishing is normally restricted to inside waters due to heavy ground-swell. Generally less than 20 boats would be observed on any given weekend; these are not included in Table VI.

In summary, gillnets had the widest distribution; density was highest near the blue-line and steadily decreased moving eastward. Few gillnets were observed within two miles of the Canadian shore. Most seines fished within five miles of the blue-line.

Sport boats were seldom observed further than one and one-half miles from shore. Most sports fishermen operate well to the east of commercial gear, between Otter Point and Race Rocks.

C. Relative Gear Efficiency

1. Introduction and Methods.

When more than one gear type participates in a common fishery, estimation of exploitation requires that all kinds of effort be related to some standard unit which should bear a constant and direct relationship to the fishing mortality coefficient (Ricker, 1958b; Beverton and Holt, 1957). Computation of standardized effort requires estimation of relative gear efficiencies in order to adjust each gear's effort statistics to a common measure. The purpose here is to examine relative gear efficiencies with respect to gear types, species and time periods for the Juan de Fuca Strait fishery.

Relative gear efficiencies were calculated using the following generalized expression:

$$\hat{C} = \sum_{i=1}^{n} c_1 f_2 / c_2 \Big/ \sum_{i=1}^{n} f_1 \qquad (1)$$

where c_1 and f_1 are catch and effort of the more efficient gear type, c_2 and f_2 apply to the less efficient gear type, and n is the number of catch and effort series over which $c_1 f_1 / c_2$ and f_1 are summed (normally n=4). The subscripts: s for seine, g for gillnet, t for troll, and sp for sport, identify relative efficiencies. For example, $\hat{C}_{gs}$ denotes gillnet to seine relative efficiency in gillnet units, and $\hat{C}_{spg}$ denotes sport to gillnet relative efficiency in sport units. The relationship between sport and seine ($\hat{C}_{sps}$) is simply $\hat{C}_{spg} \cdot \hat{C}_{gs}$; given $\hat{C}_{spg}$ and $\hat{C}_{tg}$, the relationship between sport and troll ($\hat{C}_{spt}$) is $\hat{C}_{spg} / \hat{C}_{tg}$. Note that the first subscript denotes the units in which $\hat{C}$ is written. In calculating $\hat{C}$ daily catch and effort statistics for two or more gear types fishing simultaneously in one subdivision were used whenever possible in order to approximate the assumption of equal salmon abundance to each gear. Average relative efficiencies are denoted by $\bar{\hat{C}}$.

Estimated gillnet to seine relative efficiencies ($\hat{C}_{gs}$) for August, September and October (1963 to 1968) utilized catch and effort from first weekly fishing days (for n weeks each month) of boats delivering into Port San Juan.[1] Gillnets fish subdivision A and most of B for 12 hours each night (6 p.m. to 6 a.m.); seines concentrate in A for 12 hours during the day. Monthly $\hat{C}_{gs}$ computations (Appendix Table 1C) were omitted when less than two first weekly fishing days had sufficient data ($n < 2$). Relative efficiencies were not calculated for August 1966 because seines, instead of gillnets, initiated weekly fishing until the second week in September, reducing abundance available to gillnets fishing east of the seine area.[2]

Troll to gillnet relative efficiencies ($\hat{C}_{tg}$) for 1965 and 1966 fall periods (August to October combined, Appendix Table 3C) were estimated from week-

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[1] These are field statistics provided by personnel of the Conservation and Protection Branch (CPB). Months are based on CDFF statistical periods; 4 statistical weeks in August and September, 5 in October.

[2] Tagging studies indicate that most maturing salmon encountered in the Strait during the late summer and fall are actively migrating from west to east; depending on the species, time period, etc., migration rates probably range between 10 and 30 miles per day. Daily cohorts exploited by seines would constitute a sizeable portion of the population subsequently available to gillnets. Consequently, when seines initiated weekly fishing the assumption of equal abundance to each gear is unlikely to be satisfied. However, on first weekly fishing days initiated by gillnets, the assumption of equal abundance is reasonable because the next morning seines crowd the Bonilla-Tatoosh line and consequently should operate primarily on entering unexploited salmon.

ending troll catch and effort[3] and daily gillnet catch and effort[4] for gillnets delivering at Sooke facilities. Gillnet statistics were chosen so as to span each weekending troll period.

Sport to gillnet relative efficiency ($\hat{C}_{spg}$) for coho salmon for 1965 and 1966 fall periods (Appendix Table 4C) was estimated using weekending CPB field records for sport Statistical Area 20 and the above Sooke gillnet statistics. For pink and chinook salmon, weekending sport statistics were unavailable, consequently $\hat{C}_{spg}$ were computed using total monthly sport catch and effort for sport Statistical Area 19B-20 (Economics Branch base files) and equivalent Sooke gillnet totals (in this case n=1). Troll and sport computations were restricted to 1965 and 1966 as these were the only years with suitable statistics during which Sooke gillnets, trollers and sport gear all fished in subdivision E. Appendix Table 2C presents source catch and effort statistics.

Relative efficiencies for coho, chinook and pink salmon were compared between gear types. The effect of species, months and years on $\hat{C}_{gs}$ was assessed by analysis of variance.

2. Observations and Interpretation.

a) Gear-species comparisons

Purse seines, followed by gillnets and trollers, are by far the most efficient gear. Sport gear is least efficient. (Table VII). Averaging over species, one seine unit is equivalent, in terms of catch, to 226 sport

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[3] CDFF publications of British Columbia Catch Statistics.

[4] CPB field records.

TABLE VII. Relative gear efficiency for coho, chinook and pink salmon (in sport units).*

	Seine	Troll	Gillnet	Sport
Coho	265	8	63	1
Chinook	22	6	4	1
Pink	390	15	35	1
Mean	226	9	34	1

*Source data in Appendix Tables 1C, 3C and 4C.

units; one troll unit equals nine sport units; and one gillnet equals 34 sport units. If all gears were measured relative to seines, it would take 226 sport boats, 24 trollers or seven gillnets to equal one seine. From the gillnetter's point of view, one gillnet is equivalent to approximately four trollers ($\hat{\bar{C}}_{spg}/\hat{\bar{C}}_{spt}$), 34 sport vessels, or 0.15 seine.

Of interest are the considerable differences in $\hat{\bar{C}}$ between species within gear types. For instance, purse seines (relative to sport vessels) are most efficient on pinks and cohos, $\hat{\bar{C}}_{sps}$ equals 390 and 265 respectively, and least efficient on chinooks, $\hat{\bar{C}}_{sps}$ equals only 22. This may reflect differences in depth distribution between species or perhaps differences in species emphasis between sport and seine fishermen. By the time seines deliver, small chinooks (3 to 5 lbs. round) are usually of poor quality; consequently, seiners attempt to lump them with other species or else discard them altogether. On the other hand, for sport gear, small chinooks often form over 50 per cent of the chinook sport catch.

Differences between species for troll gear are certainly less evident than for gillnets or seines. Troll gear (relative to sport gear) was most efficient on pinks, $\hat{\bar{C}}_{spt}$ equals 15.

Gillnets (relative to sport gear) are generally similar in species emphasis to seines (Table VII); however, the relationship between pink and coho is reversed, gillnets being most efficient on cohos, seines on pinks. Todd (MS 1969) postulated that behavioural and/or swimming thrust differences between sockeye and pink may have affected selective properties of gillnets towards each species. This may be a reasonable speculation for observed differences between coho and pinks; in addition, seines could be more efficient on pinks, perhaps a function of detectability or density of schools.

Gillnet to seine relative efficiencies ($\hat{C}_{gs}$) are considered in more detail as data are available for all species for a series of years (1963 to 1968) and months within years (Appendix Table 1C). Differences between species were tested by analysis of variance using August and September $\hat{C}_{gs}$ for 1963, 1965 and 1967 as replicates. The calculated F ratio (Table VIII) was significant ($p < 0.01$). To assess which differences were significant, Duncan's new multiple range test was applied to $\hat{C}_{gs}$ for each species (Steel and Torrie, 1960).

	Chum	Coho	Chinook	Sockeye	Pink
$\hat{C}_{gs}$	1.8	3.6	4.3	4.9	11.2

Means not underscored by the same line are significantly different ($P < 0.05$). Pink $\hat{C}_{gs}$ considerably exceeded the other four species and sockeye significantly exceeded chum; however, differences between coho, chinook and sockeye, and between chum, coho and chinook, were not significant.

TABLE VIII. Analysis of variance for comparison of $\hat{C}_{gs}$ between species.

Source	SS	DF	MS	F ratio
Between species	302.94	4	75.74	15.12**
Within species	125.34	25	5.01	
Total	428.28	29		

Royce *et al.*, (1963) reported relative efficiencies for United States gillnets and seines operating between the Bonilla-Tatoosh line and Angeles Point. Values were: 4.0 for chum, 4.0 for coho, 8.0 for sockeye, and 13.0 for pinks (years and months used are not mentioned). All exceeded my computations although coho and pink are relatively close. In that the United States daily seine fleet is generally less than 10 (Royce *et al.*, 1963) compared to over 50 seines in the Canadian fleet, it is possible that decreased competition among American seines enhances their productivity relative to gillnets, hence higher $\hat{C}_{gs}$.

b) Monthly and annual comparisons

Monthly and annual comparisons are limited to $\hat{C}_{gs}$, as suitable data were not available for troll or sport gear.

To assess whether $\hat{C}_{gs}$ differed between months regardless of species, $\hat{C}_{gs}$ for coho, chinook and chum for 1963 to 1965 were arrayed as replicates for August, September and October in a single-way analysis of variance. These were the only species and years for which $\hat{C}_{gs}$ was fully replicated over the three months. The effect of months was not significant, but when all data for years and species are utilized, mean monthly relative efficiencies suggest decreasing gillnet efficiency, particularly in October (Table IX). A second possible difference between months is the amount of annual variability in $\hat{C}_{gs}$. For example, coefficients of variation, with the exception of sockeye, (Table X) are highest in September and October and lowest in August. This may explain why months did not differ using analysis of variance.

To assess whether $\hat{C}_{gs}$ showed consistent differences between years regardless of species or months, August and September $\hat{C}_{gs}$ for coho, chinook and chum were arrayed as replicates for 1963 to 1965, 1967 and 1968 in a second single-way analysis of variance. Again, no significant differences were noted.

TABLE IX. Monthly species comparison of $\bar{\hat{C}}_{gs}$.*

	Coho	Chinook	Pink	Sockeye	Chum
August	4.2	6.1	9.6	4.3	1.6
September	4.0	4.7	12.7	4.9	1.6
October	4.6	8.4	-	-	3.8

*Source data in Appendix Table 1C.

TABLE X. Monthly coefficients of variation for $\bar{\hat{C}}_{gs}$.*

	August	September	October
Coho	19	28	39
Chinook	49	96	90
Pink	22	41	
Sockeye	28	13	
Chum	49	54	49
Mean	33	46	59

*Source data in Appendix Table 1C.

It is questionnable whether the above data warrant concluding that monthly or annual differences are non-significant. Of the numerous factors affecting relative gear efficiency, some could conceivably have differential effects on each species. For instance, gillnet selection curves vary with changes in species morphometry; however, monthly or annual changes in morphometry will unlikely be parallel between species. Royce and co-authors (1963) gave passing note to considerable variation in relative gear efficiencies for each gear type from area to area and from season to season. They postulated that size of fish in the runs and schooling behaviour, among other factors, affect relative efficiencies.

In summary, Juan de Fuca gear types, seine, gillnet, troll and sport, show obvious overall differences in relative efficiency; in addition, each species exhibits a more or less unique relationship to each gear type. Further data are necessary to assess monthly and seasonal variability.

D. Accessibility of Salmon to Gear

1. Introduction and Methods.

Accessibility refers to the effect on catch by a gear of spatial (horizontal and vertical) and temporal (migration rate) distributions of salmon, particularly in relation to Juan de Fuca Strait gear types. The more general concept of availability (Cushing, 1968), which includes accessibility and vulnerability, expresses "the dichotomy of presence and absence..." as well as "the possibility that fish can be accessible and still be to some degree invulnerable.". This usage differs somewhat from Parrish (1963) who applies availability in place of accessibility and includes vertical distribution under vulnerability.

Horizontal distributions are estimated for coho, chinook, pink and sockeye in 1967 and coho and chinook in 1968 from test troll catches, corrected for effort,[1] for sample area pairs within daily areas (inshore areas 1 and 2; offshore areas 3 and 4, Appendix Figure 1A) for three charter period (Cp) groupings each year (1967-June 19 to July 19, July 26 to August 28, September 4 to October 11; 1968-May 1 to 19, May 23 to June 10, June 14 to July 12).

Vertical distributions are estimated from test troll depth of capture data for the same species and several charter period groupings. Each lure

[1] Daily test troll effort and catch (1967 and 1968) were totalled for each sample area pair and charter period grouping; catches were then corrected to the 1967 average of 635 hook hours per sample area pair and Cp grouping (Appendix Tables 6A and 7A present totalled effort). Average daily test troll catches may be estimated by dividing corrected catch (histograms of Figures 17 to 19) by eight.

depth position (Appendix Figure 6A) is assumed to sample salmon from one of six 30 foot (9 m.) depth intervals. A random sample of 50 salmon was chosen for depth distribution graphs; when fewer salmon were caught, all were utilized. Because the bottom two depth intervals were fished by two instead of four lures, catches at these positions were doubled. Field methods for 1967 and 1968 test trolling are detailed in Appendix A.

Migration rate estimates for coho, pink and sockeye are from results of previously published studies.

2. Observations and Interpretations.

a) Horizontal distribution

i) Inshore-offshore comparisons.

In 12 of 18 cases (Table XI, Figure 15) 1967 catches of coho (aged 3_2) were highest offshore west of the Sooke daily area (IIIA). However, during Cp 3 and 4 (July 26-August 28) inshore catch for the three westernmost daily areas exceeded offshore catch, perhaps indicating presence of coho destined for the San Juan River (second highest southern Vancouver Island escapement). From Sooke to the east, inshore catches more often exceeded offshore catches. In 1968 (Figure 16, Table XI) inshore catches were highest to the west, offshore catches were highest to the east, an apparent reversal of the 1967 situation.

With one exception (Pedder Bay, IIIB, Cp 5 and 6) coho aged 2_2 (grilse) were caught most frequently offshore (Table XII, Figure 15) and in several instances offshore catches more than doubled inshore

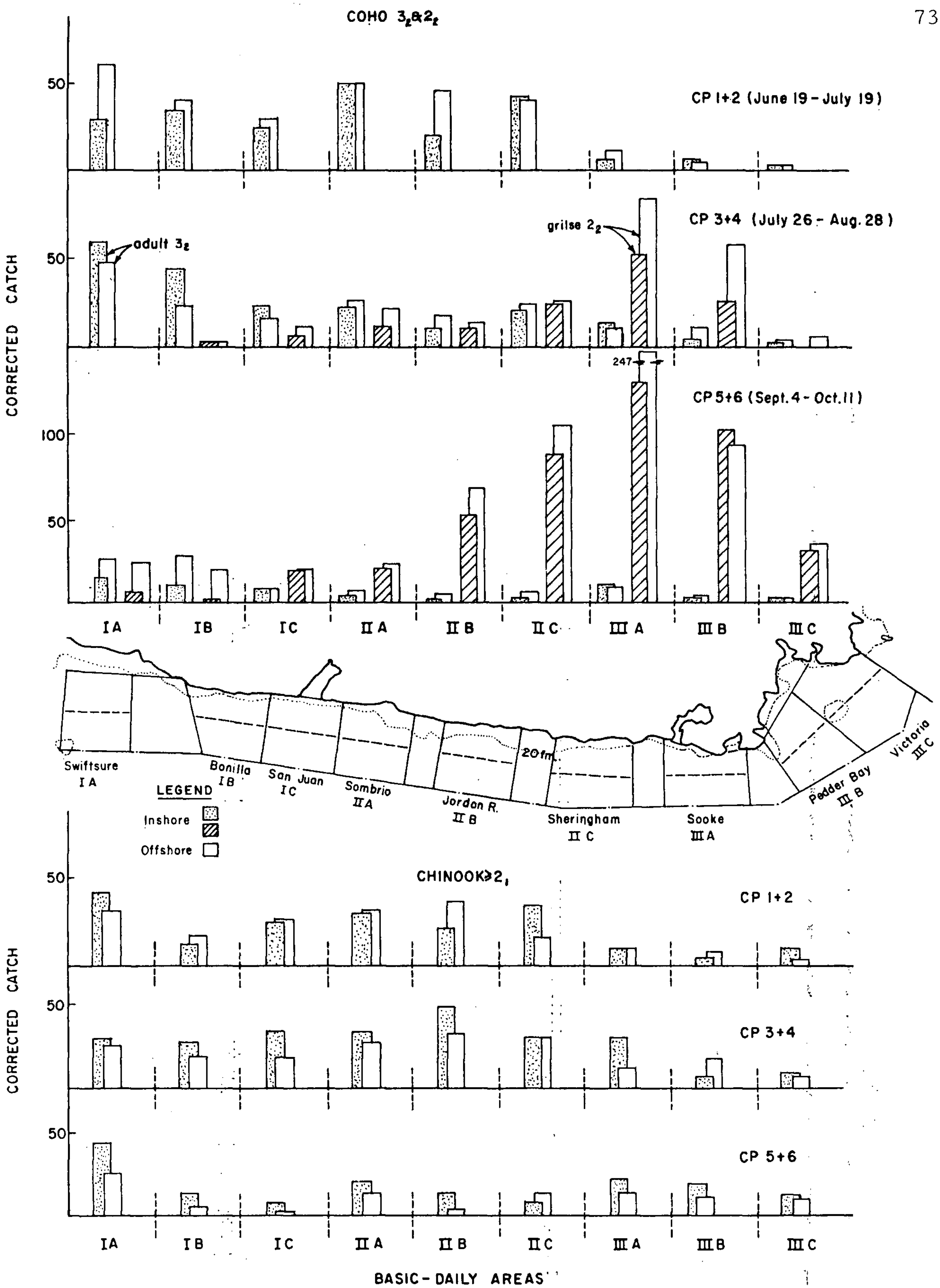

Figure 15. Inshore-offshore and west-east corrected test troll catches of coho (aged 3_2 and 2_2) and chinook salmon, 1967.

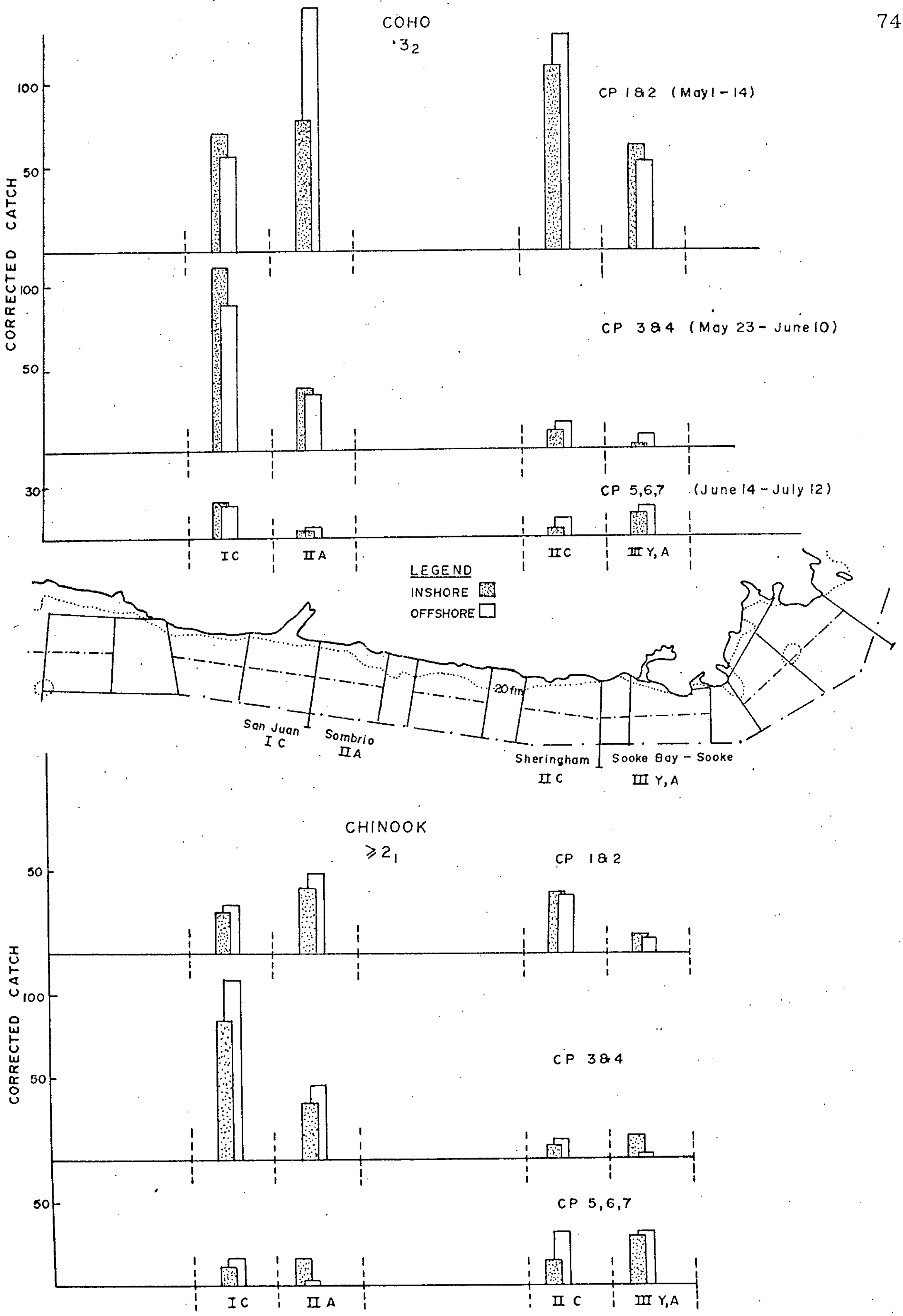

Figure 16. Inshore-offshore and west-east corrected test troll catches of coho and chinook salmon, 1968.

catches. These coho were apparently moving out of the Strait over the August to October period (see page 22).

TABLE XI. Summary of inshore-offshore coho (3_2) distribution, 1967 and 1968.

	Cp	IA	IB	IC	IIA	IIB	IIC	IIIA	IIIB	IIIC
	1&2	1	1	1	0	1	x	1	x	0
1967	3&4	x	x	x	1	1	1	x	x	1
	5&6	1	1	0	1	1	1	x	1	0
	1&2			x	1		1	x		
1968	3&4			x	x		1	1		
	5-7			x	1		1	1		

1 = highest catches offshore
x = highest catches inshore
0 = catches approximately equal
blank = no effort or insufficient catch.

TABLE XII. Summary of inshore-offshore coho (2_2) distribution, 1967.

Cp	IA	IB	IC	IIA	IIB	IIC	IIIA	IIIB	IIIC
3&4		0	1	1	1	1	1	1	1
5&6	1	1	1	1	1	1	1	x	1

During Cp 1 and 2, 1967, chinook were caught most frequently offshore west of the Sooke daily area. During the remaining time periods, inshore catches exceeded offshore catches for all daily areas except Sheringham and Pedder Bay (Table XIII, Figure 15). Inshore catches were highest along the 20 fathom line, particularly in the Sombrio and Jordan River daily area. A high proportion of chinook aged 3_1 and older (35%) in the catch characterized Cp 1 and 2; later charter periods were 80 per cent 2_1 and 3_2 (Appendix Table 5A). In 1968 offshore catches were highest in western daily areas (Figure 16, Table XIII); there was an even inshore-offshore split in eastern daily areas.

TABLE XIII. Summary of inshore-offshore chinook distribution, 1967 and 1968.

	Cp	IA	IB	IC	IIA	IIB	IIC	IIIA	IIIB	IIIC
	1&2	x	1	1	1	1	x	0	1	x
1967	3&4	x	x	x	x	x	0	x	1	x
	5&6	x	x	x	x	x	1	x	x	x
	1&2			1	1		x	x		
1968	3&4			1	1		1	x		
	5 -7			1	x		1	1		

With only two exceptions, pink and sockeye catches were highest offshore in all daily areas west of Sooke (Table XIV, Figure 17). From Sooke to the east, catches split evenly in inshore-offshore dominance.

TABLE XIV. Summary of inshore-offshore pink and sockeye distributions, 1967.

	Cp	IA	IB	IC	IIA	IIB	IIC	IIIA	IIIB	IIIC
	1&2	1	1	1	1	1	1	1	1	x
pink	3&4	1	1	1	1	1	x	x	1	x
	5&6	1	1	1	1	x	1	x	1	x
sock-eye	3&4	x	1	1	1	0	1	x	1	x

If test troll catches estimate relative abundance, sockeye, pink and coho apparently preferred offshore waters west of Sooke during spawning migrations. This preference, coupled with more predictable currents offshore, makes these waters a logical choice for gillnets (Figure 14). For the Sooke daily area all four species preferred inshore waters where most sport fishing takes place.

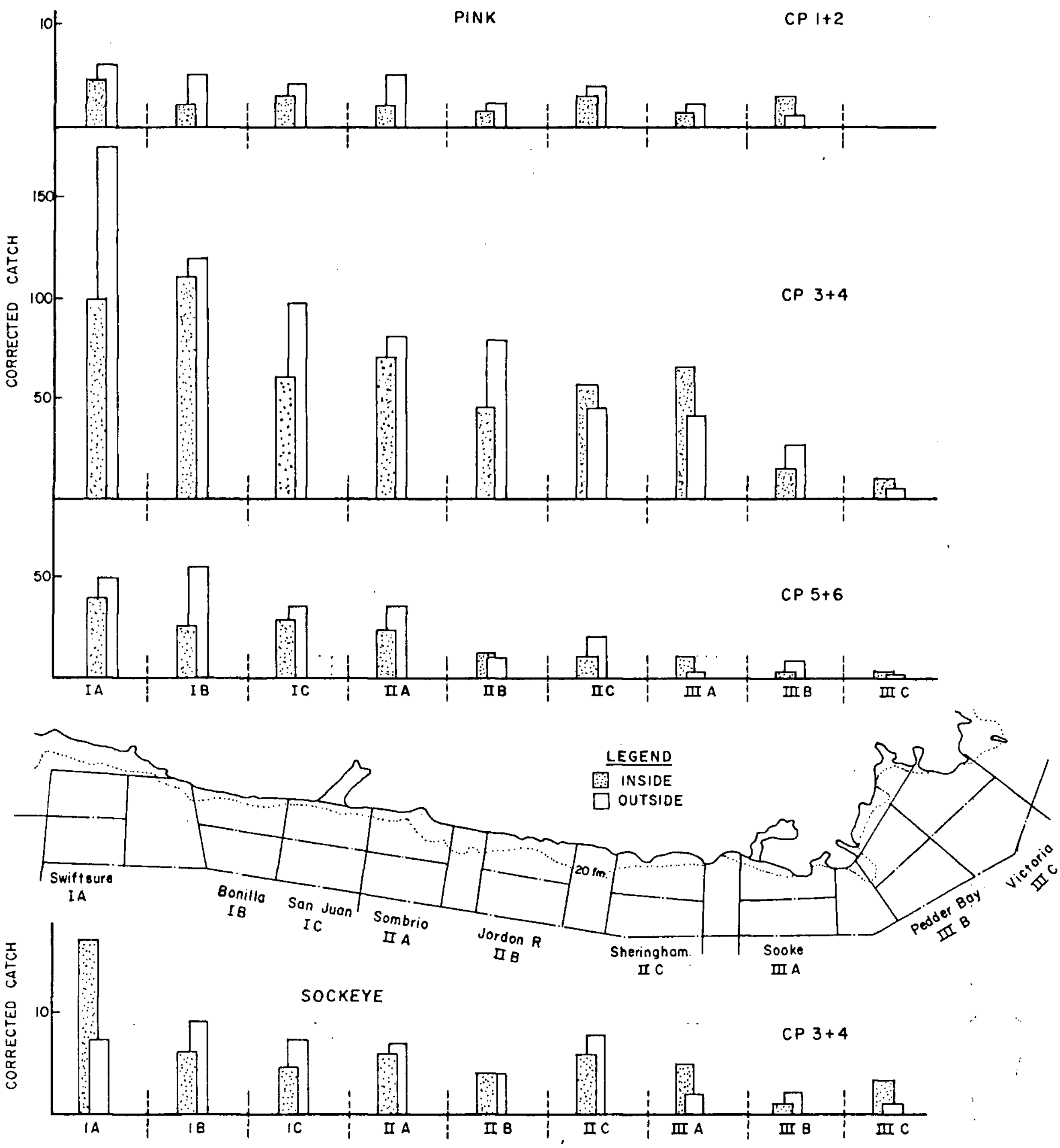

Figure 17. Inshore-offshore and west-east corrected test troll catches of pink and sockeye salmon, 1967.

ii) West-east comparisons.

Coho, pink and sockeye catches in 1967 were highest on Swiftsure Bank (Figures 15 and 17). In daily areas immediately to the east (except during Cp 1 and 2), catches usually declined considerably, then plateaued or dropped slightly until the Sheringham or Sooke daily areas where a second severe decline began. Daily areas east of Race Rocks were consistently unproductive.

The initial decline undoubtedly reflects the intense commercial fishery near the Bonilla-Tatoosh line from charter period three onwards. During this period, 23 of 54 charter days coincided with net fishery openings (Appendix Figure 3A). Waters east of Sheringham Point are closed to commercial fishing. Thus, the second decline likely represents a change in migration behaviour rather than the effects of exploitation. Perhaps tidal turbulence near Race Rocks and variable "eddy-type" currents off Victoria act as migration "barriers" causing salmon to veer south instead of following the shoreline. Previous tagging studies on coho (Milne, et al., 1958) and pink salmon (Vernon et al., 1959) demonstrated that certain stocks (Canadian and American) were abundant on the southern side of the Strait off the entrance of Puget Sound. In addition, coho and pink sport catches east of Race Rocks seldom approach Sooke levels and prior to the 1967 closure, few net fishermen operated off Victoria (Area 19).

For the first four 1967 charter periods chinook catches peaked in two locations, Swiftsure Bank and Jordan River. During Cp 5 and 6, a minor peak occurred off Sooke (Figure 15). Compared to other species, the chinook catch discrepancy between daily areas east and west of Race Rocks was not nearly as pronounced. As previously suggested, 2_1 and 3_1 chinook may "rear" for extended time periods in the Strait (see page 36).

Coho aged 2_2 appeared in 1967 test troll catches during August (Figure 15). Catches were consistently highest off Sooke and during Cp 5 and 6 catches increased slightly in outer Strait daily areas.

In 1968 coho catches (Figure 17) were initially high for all daily areas, but after Cp 1 and 2 (May 1-19), eastern Strait coho had migrated to the west coast (page 27). Eastern Strait catches remained low for the rest of the study period; western Strait catches did not decline until Cp 5-7 (June 14-July 12). Chinook catches, in 1968, showed considerable fluctuation between daily areas and charter periods compared to 1967.

b) Vertical distribution

i) Species and species-area comparisons.

Test troll catches indicate daytime vertical distribution of salmon in the top 180 feet (55m.) For 1967, species (excluding chum salmon) and species-basic area (Ba) comparisons utilized catches from charter period three (July 26 to August 8), excluding August 6, 7 and 8 because of possible influence from net gear (Appendix Table 8A). For 1968, catches of chinook and coho are compared between San Juan (IC, IIA) and Sooke (IIC, IIIA, Y) locations for three charter period pairs (Appendix Table 9A).

Coho and chinook exhibit the most diverse distributions (top, Figure 18). Coho were consistently surface oriented, 70 per cent above 90 feet

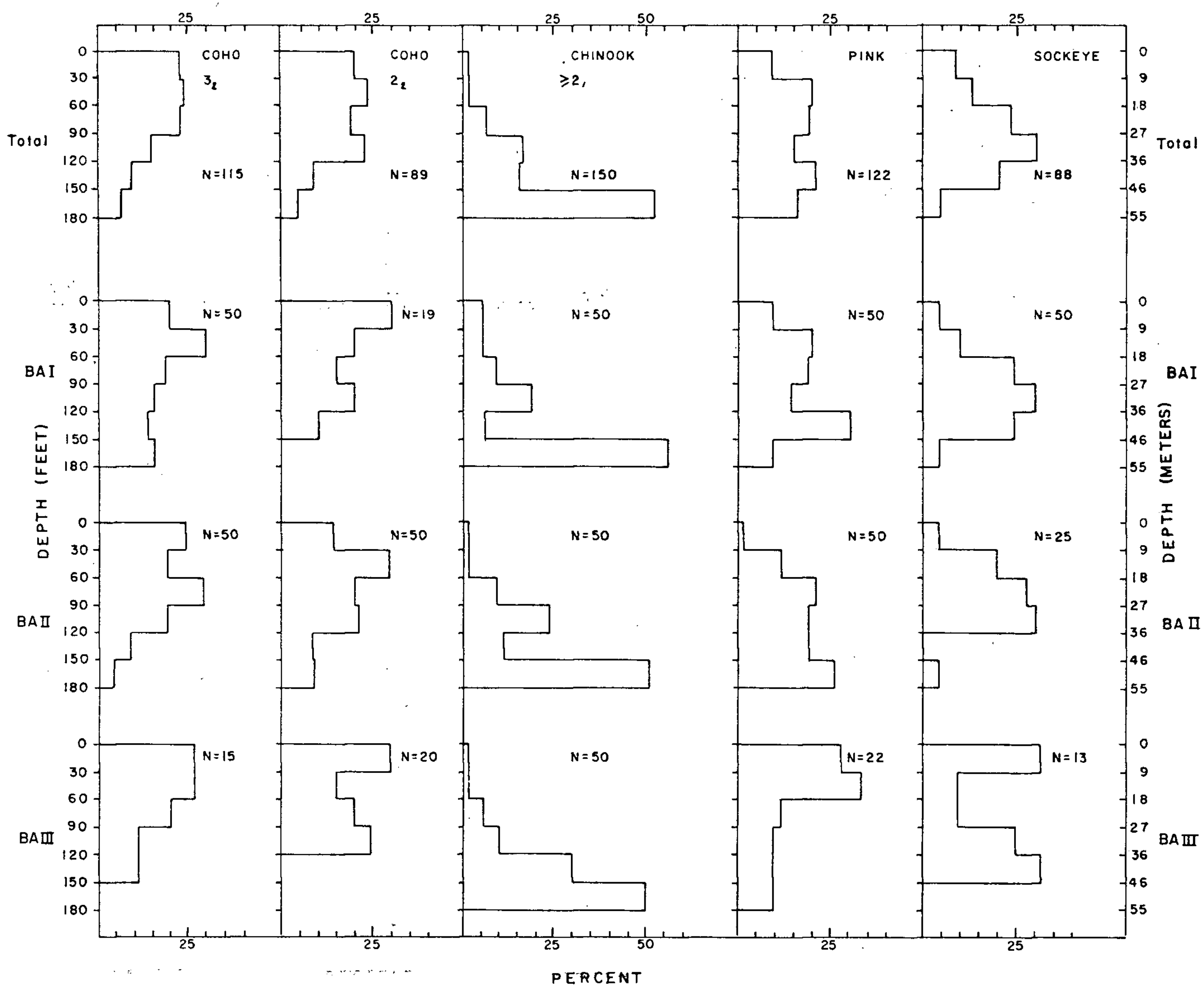

Figure 18. Percentage test troll catch of coho, chinook, pink and sockeye salmon by depth interval for basic areas and charter period three (July 26 to August 8), 1967.

(27m.) and differed little between age classes. Chinook, on the other hand, were seldom caught above 90 feet. The skewed distribution, peaking at the lowest interval (150-180 ft., 46-55 m.), suggests they continue to be abundant below the depth fished by the gear. Milne (1955) commented on a similar depth dichotomy in coho and chinook catches off southwest Vancouver Island. Coho were taken between five and ten fathoms (most at five) and chinook were taken between ten and fifteen fathoms (most at fifteen).

Perhaps temperature preferences contribute to vertical stratification of chinook and coho. For mid-Juan de Fuca Strait stations west of Sheringham Point, Herlinveaux and Tully (1961) show water temperatures between 7 and 9^{o}C below 27 m. and between 10 and 12^{o}C above 27 m.; this depth separated most chinook and coho vertical distributions. Parker, Black and Larkin (1959), during Gulf of Alaska trolling, captured most coho above 30 m. (16 fathoms) at temperatures between 10 and 15^{o}C; chinook catches were highest below 30 m. (16 fathoms) at 7 to 10^{o}C.

On several chinook graphs (e.g., Figure 18, Ba I and II), a secondary peak occurs between 90 and 120 feet (27 and 36 m.), the interval fished by the lowest bow line lure. Analysis of chinook catches by line type indicated chinook preferred bow line lures over deep line lures at all comparable depth intervals except the surface. This probably caused the secondary peak as percentage catch below 120 feet was estimated from less productive deep line lures (percentage catch below 120 feet would be underestimated). Differences between trolling lines for other species were much less apparent (Section E).

Neither chinook nor coho show marked depth differences between basic areas (Ba) although there is a suggestion of shallower distributions for Ba III.

In Ba I and II pink salmon (Figure 18) were fairly evenly distributed between 30 and 180 ft; in Ba III surface catches dominated. Manzer (1964) commented that in Gulf of Alaska sunken gillnet experiments (to 200 ft., 61 m.) pinks were generally taken shallower than sockeye or chum salmon. Night sets in 1960 caught 85 pinks, 75 per cent in the surface net (20 ft., 6.1 m. in depth).

Sockeye salmon (Figure 18) exhibited a strong mid-depth peak between 60 and 120 feet (18 and 36 m.). Overall distribution and the Ba I distribution were quite symmetrical; variable distributions for other basic areas probably reflect low sample sizes. Manzer (1964) noted a similar daytime mid-depth peak at several Gulf of Alaska stations, nighttime catches shifted surfaceward (a diurnal shift). In addition, he observed a seasonal shallowing of night and day sockeye distributions apparently correlated with intensification and shallowing of the thermocline.

Depth differences between chinook and coho in Cp 3, 1967, were fully expressed in the 1968 test troll catches (Figure 19, left side). Depth differences between areas (San Juan versus Sooke) were not noticeable, although separation into charter period groupings demonstrated some variability (note Cp 5-7, coho). In 1968 surface orientation

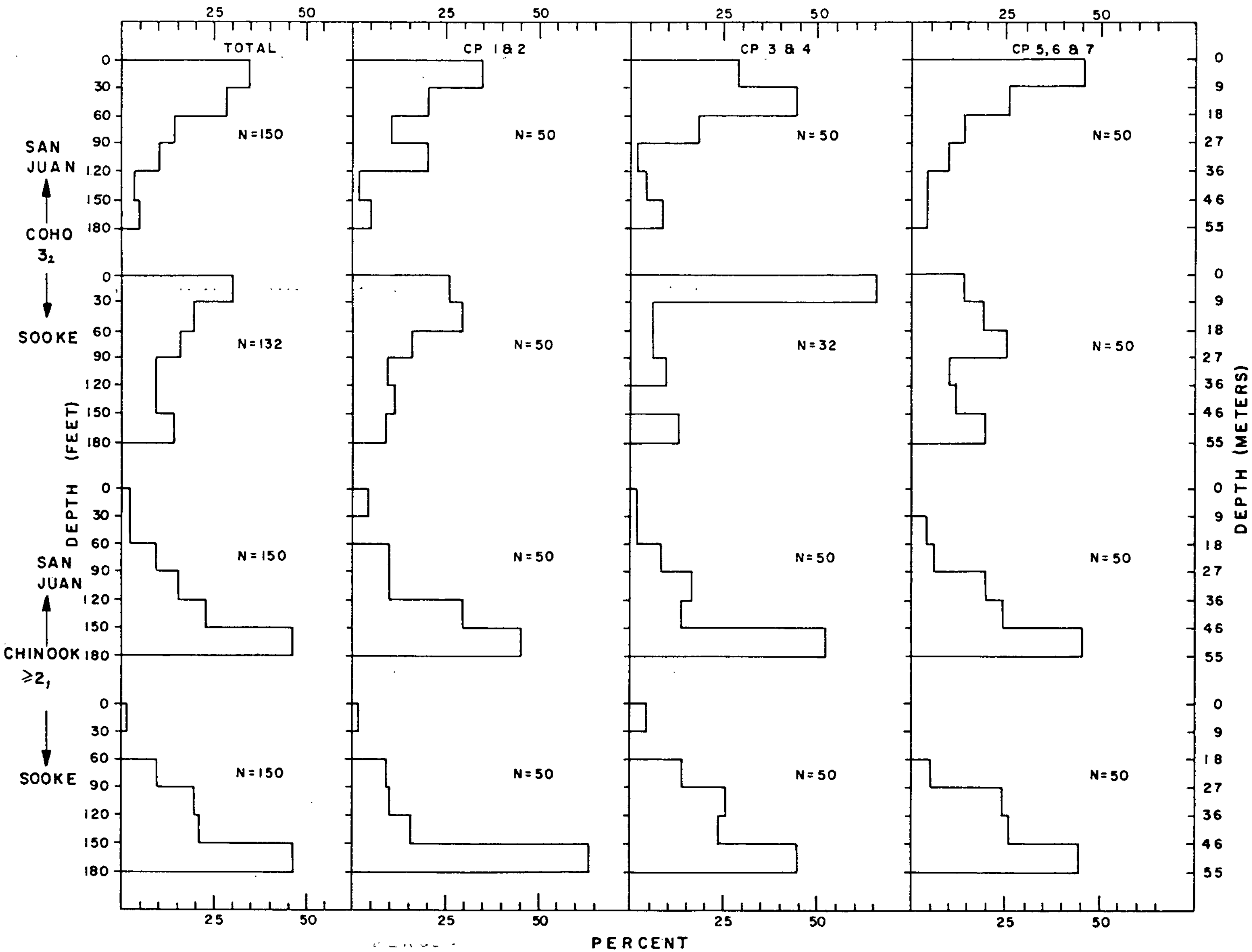

Figure 19. Percentage test troll catch of coho and chinook salmon by depth interval for San Juan and Sooke daily area groupings and three charter period groupings, 1968.

of coho was more pronounced (85% above 90 ft.).

Chinook catches in 1967 were sufficient for depth comparisons between ages and maturity stages (Figure 20). Chinook were judged maturing when ovaries weighed more than 15 grams and testes exceeded two grams. These criteria were adopted from Godfrey (1961) who separated maturing and immature 3_1 female chum and 3_1 and 4_1 male chum on this basis. During charter periods 1 and 2 (June 19-July 19), about one-fifth of the catch was maturing; one-third was aged 3_1 and older. The proportions maturing and aged 3_1 plus were considerably lower in remaining charter periods. During charter period 6 (September 26 to October 11) first ocean year chinook (2_2, 1_1) were common in the Ba III catch (α = 0.05, one tailed χ^2 test, results in Appendix Table 10A).

First ocean year chinook were shallower than second ocean year and older chinook (Figure 20, upper). The apparent difference between immature 2_1 and 3_1 chinook, however, was not significant. Maturing chinook aged 3_1 and older were noticeably shallower than immatures of the same ages. Their distribution suggests a mid-depth peak similar to that observed for sockeye (Figure 18). Within this age group chinook over 3.0 kg. (6.6 lb.) body weight were apparently depth stratified on the basis of gonad size, those with largest gonads being closest to the surface (Table XV).

ii) Species-time period comparisons.

Seasonal depth distributions are compared using charter periods in 1967 and charter period pairs in 1968. Because commercial fishing

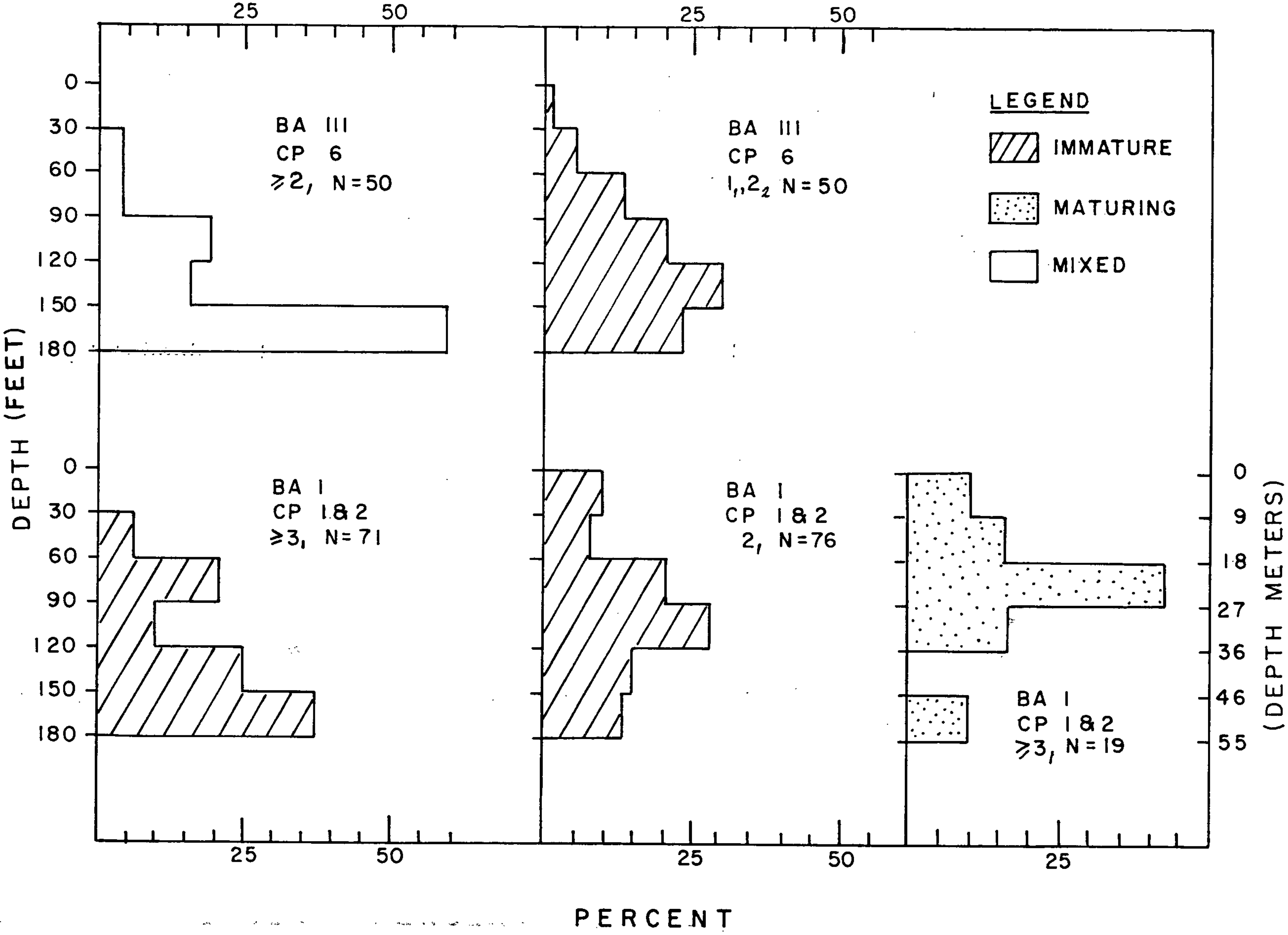

Figure 20. Percentage test troll catch of various age classes and maturity levels of chinook, salmon, 1967.

TABLE XV. Depth distribution of all chinook over 3.0 kg. (6.6 lb.) round weight for charter periods 1 and 2 (June 19 to July 19) basic area I, 1967. *

	Male			Female		
Lure Depth (feet)	Fish Wt. (kg.)	Gonad Wt. (g.)	Maturity** Index	Fish Wt. (kg.)	Gonad Wt. (g.)	Maturity Index
0 - 30	6.6	154	2.3	-	-	-
30 - 60	6.3	100	1.6	7.9	214	2.7
	4.3	33	0.8			
60 - 90	4.2	21	0.5	8.2	360	4.4
	5.8	95	1.6	7.4	200	2.7
	4.6	3	0.3	8.2	213	2.6
				3.7	21	0.6
				7.7	243	3.2
90-120	3.6	2	0.1	3.2	10	0.3
120-150	-	-	-	-	-	-
150-180	3.3	2	0.1	3.7	15	0.4
	4.3	1	0.1	4.3	20	0.5

*This size includes large 3_1 and all 4_1 chinook.

**[gonad wt.(g.)/fish wt.(g.)]100.

after August 5, 1967, may have altered depth distributions, catch samples for Cp 4 to 6 were chosen from the Swiftsure (IA) daily area (which should be unaffected by net gear). Daytime depth distributions for two hour intervals between 0600 and 1600 hours (PDT) are presented using 1967 Ba I catches for Cp 3 and Cp 1 and 2 combined.

Coho aged 3_2 showed considerable seasonal change in depth distribution (Figure 21). Initially surface orientation dominated, but by Cp 3, the coho distribution evened out somewhat and in Cp 4 a strong mid-depth peak (18 to 36 m.) was apparent, similar to that of sockeye during Cp 3 (see Figure 18). Charter periods 5 and 6 (combined because of low catches) showed a reversion to an even depth distribution. Distribution of 2_2 coho dropped somewhat after Cp 3, although the drop was not nearly as pronounced as the 3_2 depth change.

During Cp 1 and 2, chinook (second ocean year and older) were more surface oriented than at any other time, reflecting in part, shallower distribution of maturing individuals (Figure 21). Thereafter, chinooks were oriented to greater depth (note secondary peak between 90 and 120 ft.).

In 1968, coho depth distributions at the San Juan location showed no apparent seasonal trend (Figure 19). Sooke coho appeared slightly deeper during the last time period (June 14 to July 12). Chinook, in 1968, were consistently at greater depth; 80 per cent were caught below 90 ft. (27 m.).

In 1967, pinks were initially surface oriented (Figure 21). They then followed the coho pattern and by Cp 4 had formed a pronounced mid-

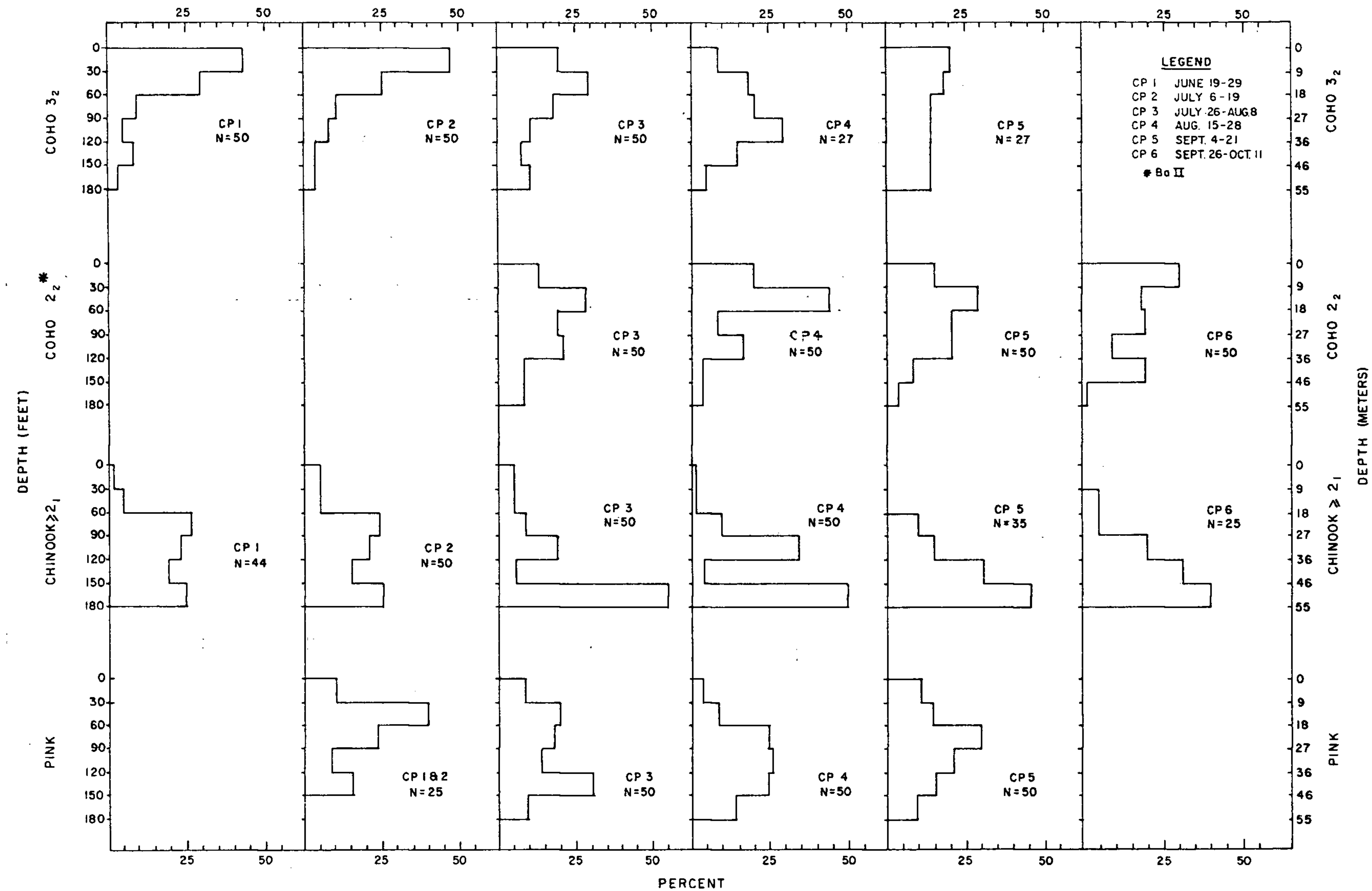

Figure 21. Percentage test troll catch of coho, chinook by depth interval for basic area I and various combinations of charter periods, 1967.

depth peak (18 to 36 m.) which continued into Cp 5.

Apparently, from the foregoing, all species during spawning migrations (see Section A), have similar depth distributions with mid-depth peaks between 60 and 120 ft. (18 and 36 m.). Coho, pink and sockeye, in 1967, preferred offshore areas as did chinook during Cp 1 and 2, although with chinook it was not determined whether maturing individuals dominated the offshore component. Offshore waters are characterized by strong ebb tidal currents (1.5 to 2.0 knots) especially towards mid-Strait; flood tidal currents increase in strength from mid-Strait to the American shore (Herlinveaux, 1954, Figure 5), all tidal currents seemed more consistently directional offshore.

Perhaps mid-Strait waters and depth preferences of 18 to 36 m. relate somehow to the salmon's change to migratory behaviour. Depth distribution of Juan de Fuca maturing salmon places them in the upper portion of the halocline separating intruding oceanic and outflowing coastal waters (Herlinveaux and Tully, 1961). At this depth there is a strong net ebb flow (6 to 8 nautical miles per tidal phase, Herlinveaux, 1954). Conceivably, favouring deeper and mid-Strait water might enhance detection of directional currents, thus stimulating "upstream" migration against the net ebb flow.

Several times in the foregoing it is implied that estimates of depth distributions from troll catches might be influenced by net operations in the immediate vicinity, particularly in areas frequented by the nighttime gillnet fishery. To assess effects of net gear, depth distributions of pink and coho, test trolled in 1967 (August 5 to 27) between the Bonilla-Tatoosh line and Jordan River (IB to IIB), were constructed for commercial fishing days (CF) and closed (NF) days (at least one day following weekly closure).

In the net area (IB to IIB) both species were distributed deeper on CF days (Appendix Tables 10A and 11A) but to the west (IA) distributions were unaffected by net gear (Figure 22). Obviously, if salmon continuously move from west to east, Swiftsure distributions would not change between CF and NF days, thus previous seasonal comparisons should be unbiased. In the net area selective removal of surface salmon by gillnets (effective operating depth 14 m.) is a logical explanation for the deeper CF distributions (this requires that nighttime effects continue during the day). Seine operating depth is similar to test troll fishing depth, thus selective depth removal by seines is not suspect. However, salmon escaping seines might do so by moving under the nets.

To examine daily changes in depth distribution, 1967 catches (Cp 3 and Cp 1 - 2) for two hour time periods between 0600 and 1600 (PDT) and three depth intervals (surface, 0-60 ft.; mid-depth, 60-120 ft.; deep, 120-180 ft.) were corrected for fishing effort, and percentage catch per depth interval determined for each time period (Figure 23, circles represent percentage total daily catch per two hour interval).

Coho were shallowest near mid-day then moved progressively deeper during the afternoon. Total catches tended to increase in the afternoon. Both time periods exhibited the same daily pattern.

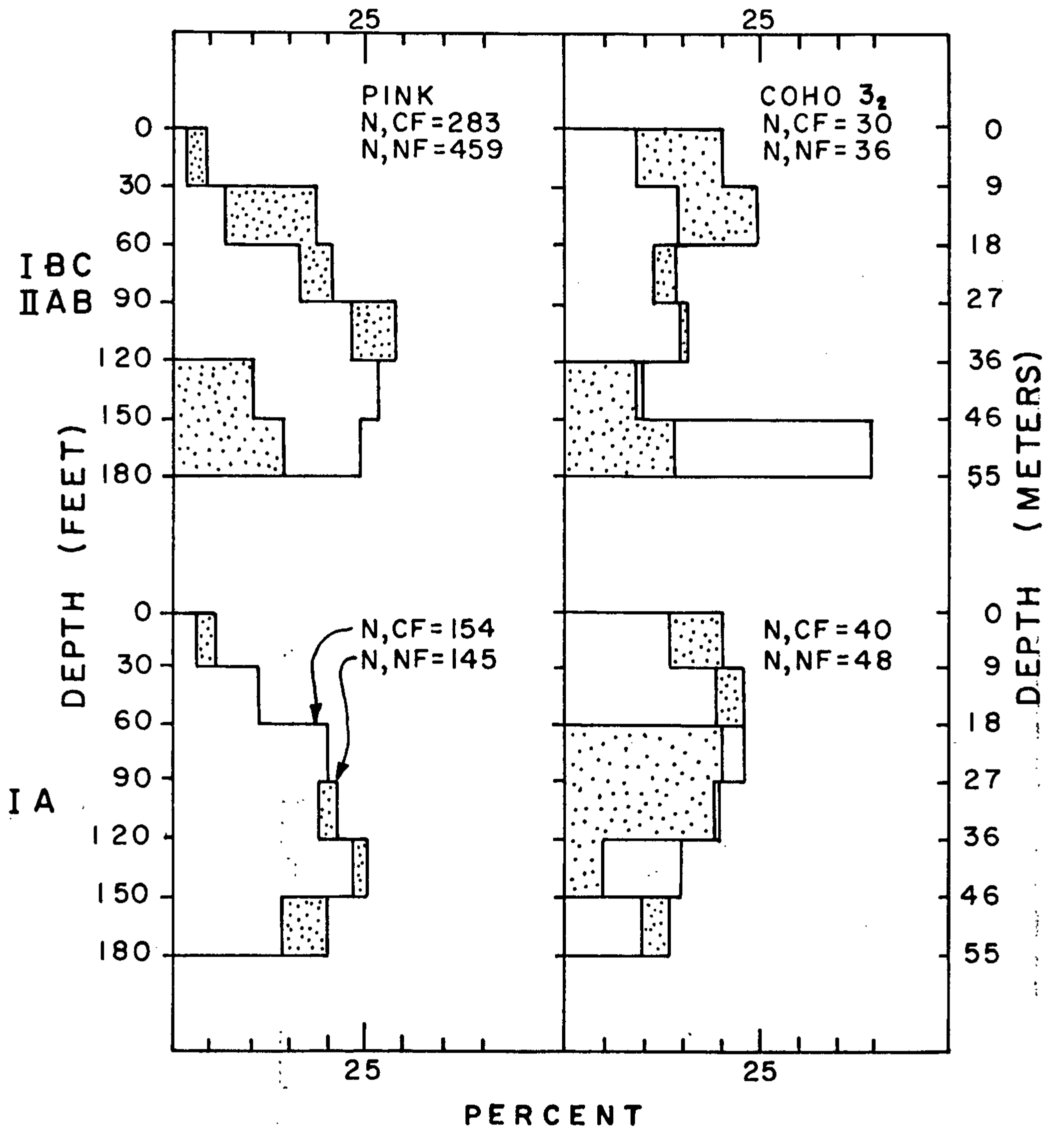

Figure 22. Percentage test troll catch of pink and coho salmon by depth interval for commercial net fishing (CF) and closed (NF) days for daily areas on either side of the Bonilla-Tatoosh net line, August 5 to 27, 1967.

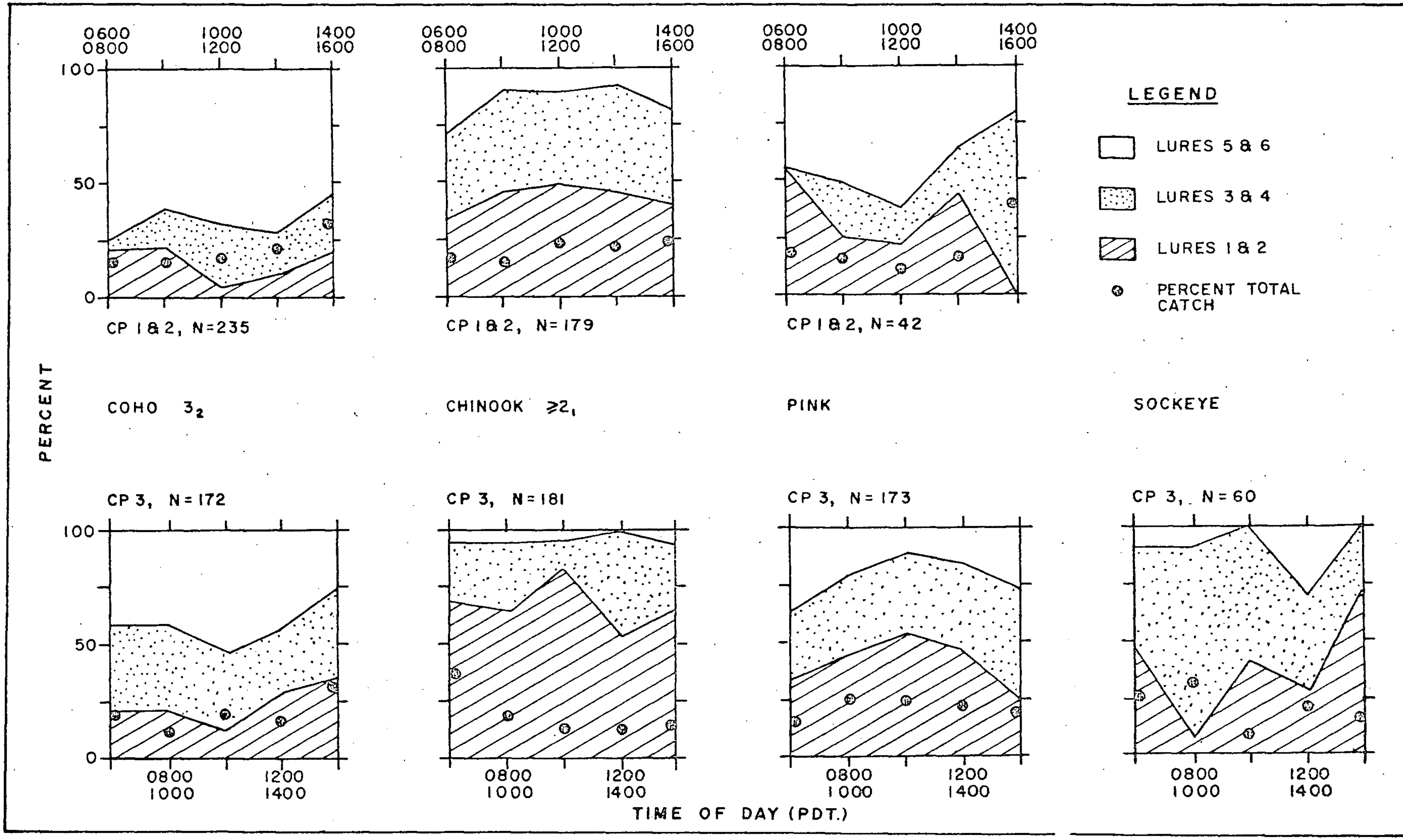

Figure 23. Percentage test troll catch of coho, chinook, pink and sockeye salmon by grouped depth intervals and five two-hour time periods between 0600 and 1600 hours (PDT) for selected charter periods in basic area I, 1967.

During Cp 1 and 2, chinook were shallowest in the morning, deepest between 0800 and 1400, and then shallowed up somewhat in the afternoon. This pattern was not obvious during Cp 3. Total catch in Cp 1 and 2 increased slightly towards afternoon, whereas in Cp 3 a strong morning (0600 - 0800) peak was evident.

Few pink were caught during Cp 1 and 2, however the capture pattern was similar to coho; total catch was highest in the afternoon. During Cp 3 pink were shallowest in the morning, increased in depth towards noon, then moved surfaceward in the afternoon. Total catch was evenly distributed throughout the day.

Sockeye were dominant at mid-depth until noon; by 1600 none were caught at the surface. Per cent total catch peaked between 0600 and 1000.

In general, daytime changes in species distributions are not extreme, certainly not as pronounced as day-night shifts noted by Manzer (1964) for chum and sockeye in offshore waters. Future studies might assess diurnal changes in coastal waters, particularly in relation to maturing salmon.

Relating daytime vertical distributions to gillnet operating depth is perhaps inappropriate considering results of high seas studies on diurnal movements. However, it is apparent that all species, except perhaps chinook, are highly accessible to seine gear which can effectively fish between 120 and 180 ft. Similarly, the same species are highly accessible to troll gear. Sports fishermen operating one lure within 30 ft. of the surface are obviously not exploiting the highest densities of chinook, pink or even coho. On the other hand, it is noted that sport gear, in terms of relative gear efficiency (Table VII), is closest to deeper operating commercial gears on chinook. Perhaps the chinook's propensity for inshore habitat (difficult to fish for commercial gears) and their tendency to regularly frequent specific locations, offsets their deeper vertical distribution more than compensating sports fishermen.

c) Migration rate

Salmon traversing the Juan de Fuca fishery migrate approximately 90 miles (145 km.) from the Bonilla-Tatoosh line to Oak Bay. Based on tagging studies reported by Milne et al., (1958; 1959), coho mill at the entrance of the Strait during August prior to the main inward migration. Once fall migration commenced, tagged salmon which were recovered had taken an average of ten days between the entrance and the San Juan Islands, a migration rate of approximately 13 miles per day (mpd). Fall Puget Sound tagging between 1950 and 1954 (Jensen, 1955) indicated a range of migration rates from 2.0 to 12 mpd within various in-sound areas.

Pink salmon tagged during spring-summer homing migrations on the high seas, travel between 5 and 40 mpd based on straight-line distances to recovery points (Royce et al., 1968). Within the Strait, Vernon et al., (1964) estimated from tagging data that pinks migrated at approximately 22 mpd; there was no indication of seasonal change in this rate or any delay at the entrance.

High seas taggings summarized by Royce et al., (1968) indicate sockeye travel between 25 and 30 mpd during their final 30 to 60 days at sea. In Juan de Fuca Strait, Killick and Clemens (1963) commented that most Fraser stocks averaged two days between the Sooke traps and the San Juan Islands net fishery, or approximately 22 mpd. It is reasonable that this rate applies throughout the Strait.

3. Summary.

Coho, pink and sockeye favoured mid-Strait waters in 1967 where gill-net effort is highest. All species avoided Canadian waters east of Race Rocks although the east-west discrepancy was less pronounced for chinook.

Based on test troll catches, vertical distribution of coho was surface oriented until mid-August; chinook were consistently depth oriented (below 90 ft., 55 m.) but differences between age classes and maturity stages were present. Pink and sockeye exhibited intermediate depth distributions. During periods of spawning migration activity, all species favoured the 60 to 120 ft. (18-36 m.) depth interval.

Pink and coho were distributed deeper on net fishing days compared to closed days.

During spawning migrations coho, pink and sockeye migrate between 12 and 25 miles per day through the Strait area.

E. Vulnerability of Salmon to the Gear

1. Introduction.

Selection processes in fisheries give rise to differences in probability of capture among members of the exploitable population (Parrish, 1963). For salmon accessible to fishing gears, three vulnerability factors may affect catch: population density (gear saturation), mechanical gear selectivity (mesh and lure selection) and fish behaviour (Cushing, 1968). Recognizing and measuring variations in vulnerability is important for several reasons: (1) to improve estimates of vital statistics biased by selective removal of certain stock components (Ricker, 1958b); (2) to determine whether long-term selectivity affects productivity through change in average fecundity (Peterson, 1954); and (3) to establish mesh sizes, lure combinations, time period or area regulations, for intraseasonal execution of interseasonal management objectives.

This section examines size selection by Juan de Fuca gillnets during the fall fishery and examines size and species selection by test trolling gear. Part four presents a field experiment examining sexual maturation and coho susceptibility (catchability) to hook and line gear.

2. Gillnet selectivity.

a) Introduction and methods

It is generally accepted that gillnets select salmon on the basis of size. However, the degree and direction of selection may vary considerably between species (Todd, MS 1969), depending on such factors as mesh size in relation to species morphometry (girth: McCombie and

Berst, 1969; Todd, MS 1969) and perhaps behavioural attributes (swimming thrust, struggling: Lander, 1969).

During the fall fishery Juan de Fuca gillnets exploit all species of Pacific salmon (Section A details timing). Mesh sizes vary between months. In August, small mesh nets (5-1/8 in. to 5-5/8 in.) are used to advantage on pink and sockeye; in September, fishermen use larger meshes (6 in. to 6-1/2 in.) which they feel increases efficiency on coho.

Most seines operate close to the Bonilla-Tatoosh line (Figure 14) harvesting actively in-migrating salmon. Therefore, it is assumed seines catch salmon prior to gillnet operations (see footnote 3, Section C) and mean weight of the seine catch estimates mean weight of the unselected population. It is also assumed that seines, using heavy web and small mesh openings, are non-selective for "legal" salmon except possibly 3_2 sockeye and small 3_1 chinook. Gillnet and seine effort are similarly distributed over the August-September period (Figure 2).

To establish presence of selection, direction of selection and approximate intensity of selection, average weights of salmon taken by purse seines ($\overline{Ws}$) are compared with average weights of the gillnet catch ($\overline{Wg}$)[1] on all species in August and September (Appendix Table 6B). Positive selection occurs when gillnets exploit larger salmon at a higher rate than smaller salmon ($\overline{Wg} > \overline{Ws}$); negative (reverse) selection occurs under opposite circumstances ($\overline{Wg} < \overline{Ws}$).

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[1] Source statistics (Statistical Area 20) from CDFF publications of British Columbia Catch Statistics.

Annual intensity of selection, $\hat{S}$, was estimated for each species and month from the following expression:

$$\hat{S} = (\overline{W}g - \overline{W}s/\overline{W}s)\,100 \qquad (1)$$

and mean selection intensity from:

$$\bar{\hat{S}} = |\hat{S}|/n \qquad (2)$$

where n equals years (Appendix Table 7B). Linear regressions and correlations of $\hat{S}$ on $\overline{W}s$ were computed for each species and month (regression results in Appendix Table 8B).

In a gantlet arrangement of gillnets some form of sequential selection may take place if exploitation and intensity of selection are reasonably high. Under these circumstances, size distributions become progressively skewed moving away from the entrance of the gantlet. To test for sequential selection in the Strait fishery, coho weights (caught during 1967 test trolling) were compared between basic areas for three charter period pairs (June 19 to July 19; July 26 to August 28; September 4 to October 11). Commercial fishing commenced on August 5 and continued to October 11.

b) Observations and interpretations

i) Species-time period comparisons.

Coho and Chinook

Coho $\overline{W}s$ fluctuates two to three pounds annually (Figure 24). As virtually all mature coho passing through the Strait are aged 3_2, annual size differences must indicate changes in growth rate. It is interesting to note since 1957 coho have been smallest on "big"

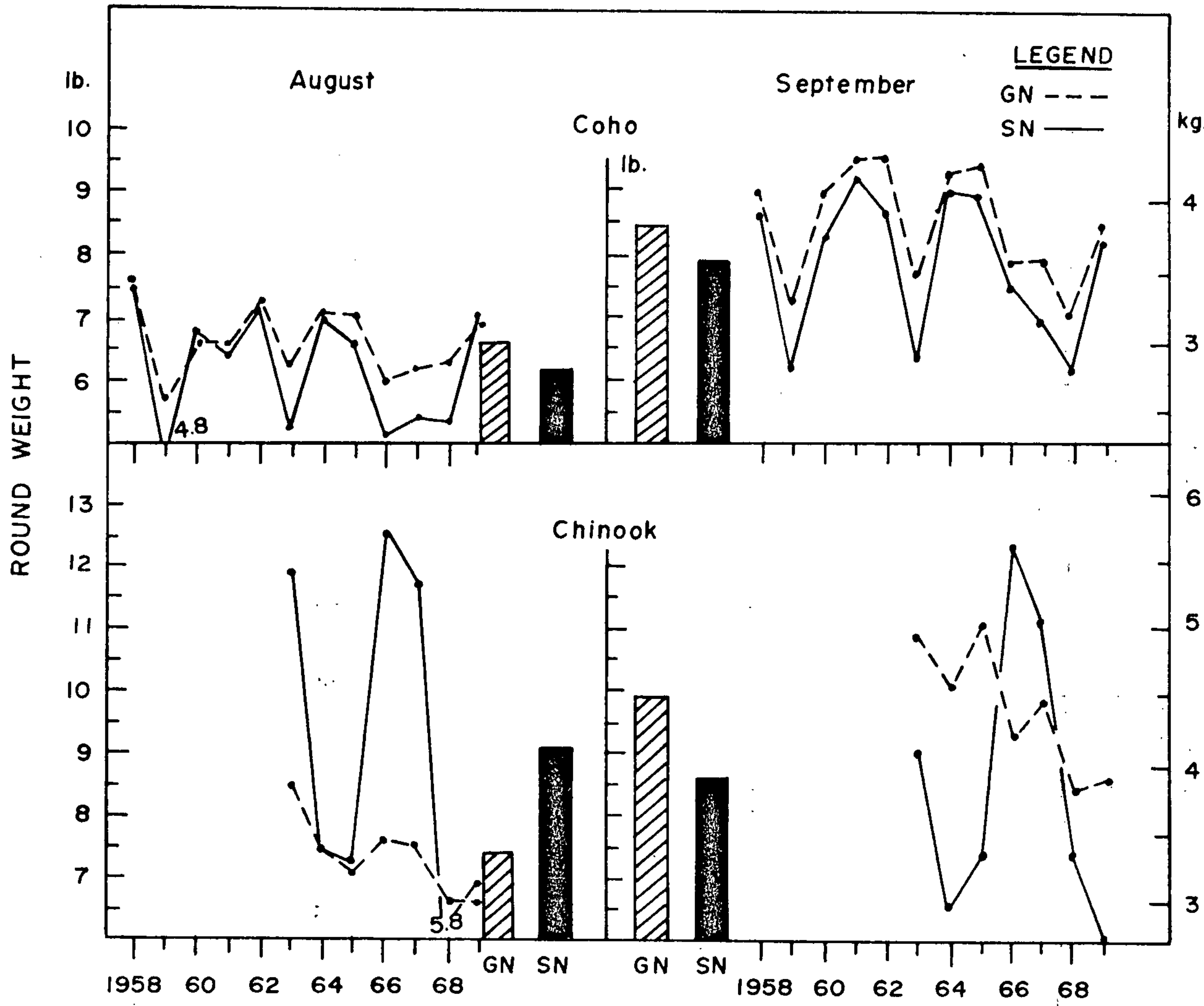

Figure 24. Mean weight of coho and chinook caught by gillnet (GN) and seine (SN) gear during August and September in Statistical Area 20, 1958 to 1969. Histograms present annual averages.

pink years (1959, 1963, 1967).

Average of monthly coho weights ($\bar{\bar{W}}s$, 1958-1969) increases from 6.2 lb. (2.8 kg.) in August to 7.8 lb. (3.6 kg.) in September. Generally, $\bar{W}g$ exceeds $\bar{W}s$ and this relationship is most consistent during September. For both months $\bar{W}g$ varies less than $\bar{W}s$ (coefficients of variation, Appendix Table 6B) which is reasonable, given fairly constant selective properties of the gillnet fleet.

Chinook $\bar{W}s$ (Figure 24) has ranged from 5.8 lb. (2.6 kg.) in August, 1968, to over 12.0 lb. (5.4 kg.) in August and September, 1966; averaged over the last seven years, $\bar{\bar{W}}s$ drops from 9.1 lb. (4.1 kg.) in August to 8.6 lb. (3.9 kg.) in September. Variable growth rates and year class dominance probably contribute much to fluctuations in $\bar{W}s$. During August, $\bar{W}s$ generally exceeds $\bar{W}g$, but the relationship reverses in September. Compared to $\bar{W}s$, monthly fluctuations in $\bar{W}g$ are much reduced, in fact, quite similar to coho (coefficients of variation, Appendix Table 6B). There is a marked increase in $\bar{\bar{W}}g$ for September of over two pounds (32%), likely due to increased mesh size (coho $\bar{\bar{W}}g$ increased 28%).

Mean intensity of selection, $\hat{\bar{S}}$, for chinook is approximately two times that for coho (Table XVI). During August, chinook undergo negative selection; September chinook undergo pronounced positive selection. Coho, by comparison, experience lower positive $\hat{\bar{S}}$ of relatively constant magnitude each month. For coho this suggests enlarged meshes compensate for change in weight resulting in similar degree and direction of selection each month.

TABLE XVI. Average gillnet selection index, $\hat{\bar{S}}$, for coho and chinook.[+]

	August	September
coho	8.4 (7.5)[*]	8.9 (8.9)
chinook	10.6 (-15.2)	31.8 (21.3)

[+]Source data in Appendix Table 7B.

[*]$\hat{\bar{S}}$, sign considered.

For both species, $\hat{S}$ and $\overline{Ws}$ were linearly related over the observed range in $\overline{Ws}$ (Figure 25, Appendix Table 8B). In interpreting Figure 25, note that the ordinate scale passes from negative selection through zero to positive selection.

Coho apparently seldom exceeded a mean weight sufficient to produce negative selection; zero $\hat{S}$ occurred at approximately $\overline{Ws}$ equals 7 lb. (3.2 kg.) in August and, by extrapolation, 9.7 lb. (4.4 kg.) in September. September mesh increase, in combination with weight gain of the coho population as a whole, probably caused the shift of the September regression line. In general, high $\hat{S}$ at low $\overline{Ws}$ suggests coho undergo reduced gillnet exploitation in years of low mean weight as a greater proportion of the total population would be invulnerable to the gear.

For chinook, the $\hat{S}$ - $\overline{Ws}$ relationship is in the expected negative direction (Figure 25, lower) although the range is extreme (-58.6 to 59.4), probably reflecting variable size distributions. Increased elevation of the September regression, rather than a shift as for coho,

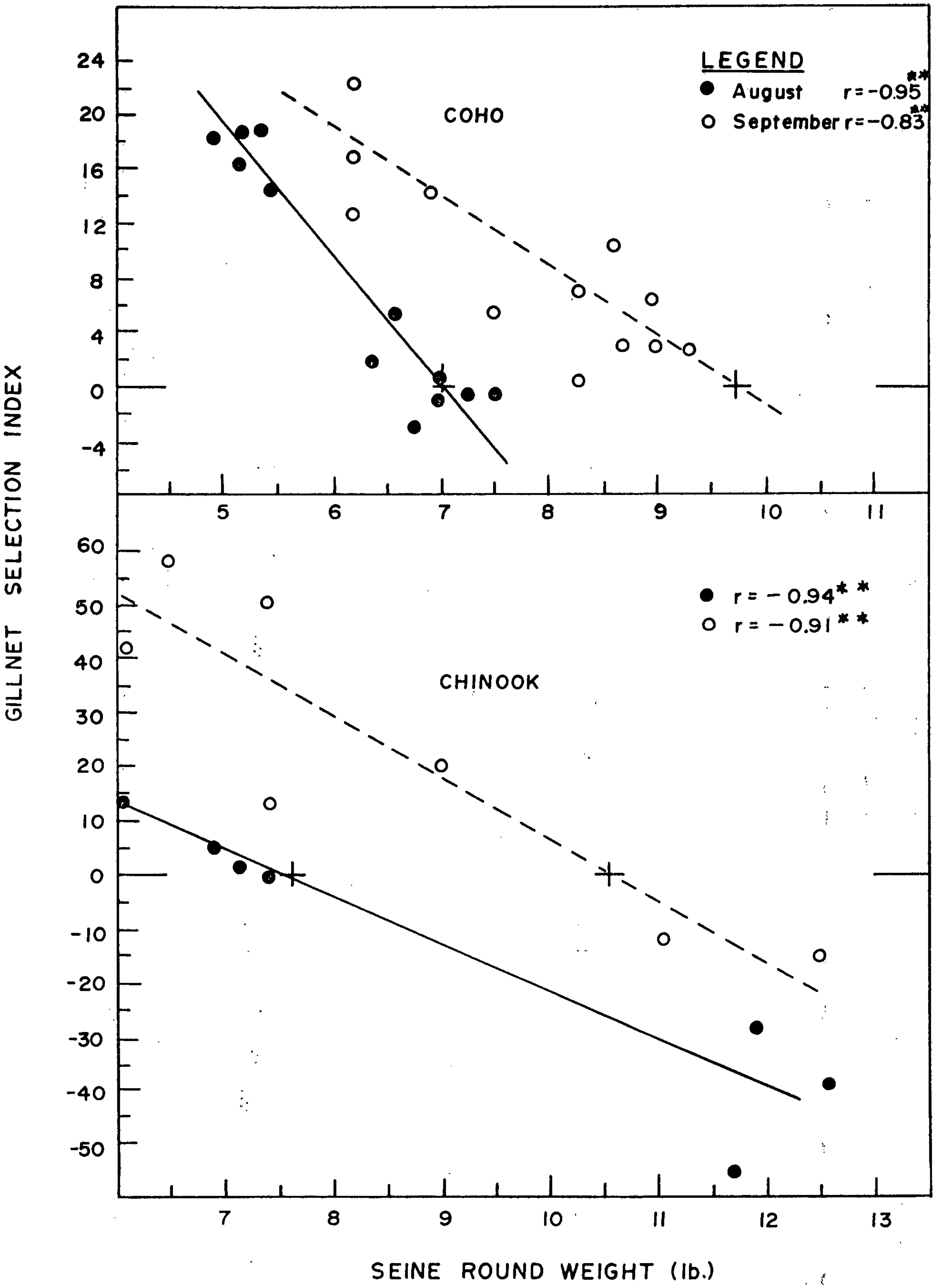

Figure 25. Gillnet selection index, $\hat{S}$, versus mean weight of the seine catch (Area 20) for coho and chinook caught in August and September, 1958 to 1969.

is not unexpected considering chinook do not increase in weight between months. Zero directional selection occurs at 7.6 lb. (3.4 kg.) in August and 10.6 lb. (4.8 kg.) in September.

Inverse correlations for both species exceeded 0.83 ($p \leq 0.01$). Close agreement between estimated mean weight of the original population and $\hat{S}$ suggests gillnets select coho and chinook primarily by weight (perhaps girth). In addition, selective action by the fleet as a whole (fleet mesh distribution) must have remained relatively constant since 1958, otherwise substantially lower correlations should occur as size distributions and selective action would seldom coincide in a directional manner unless fishermen were adept at pre-season size predictions. In this respect, Todd (MS 1969) comments that Skeena gillnetters fishing sockeye tend to use one size of gillnet regardless of annual changes in size and age composition.

If selection is related to exploitation rate, as suggested for coho, then perhaps gillnet-seine relative gear efficiencies, ($\hat{C}_{gs}$), vary with estimated intensity of selection $|\hat{S}|$. Intense selection might disproportionately reduce gillnet exploitation over seine exploitation, thus increasing $\hat{C}_{gs}$ at high $|\hat{S}|$. Apparently this was not the case for coho or chinook (Table XVII). However, this data is insufficient evidence to conclude no relationship exists.

Pink, Sockeye and Chum

Since 1957, pink $\overline{Ws}$ (Figure 26, upper) has varied inversely with abundance, perhaps indicating competition for available food on years

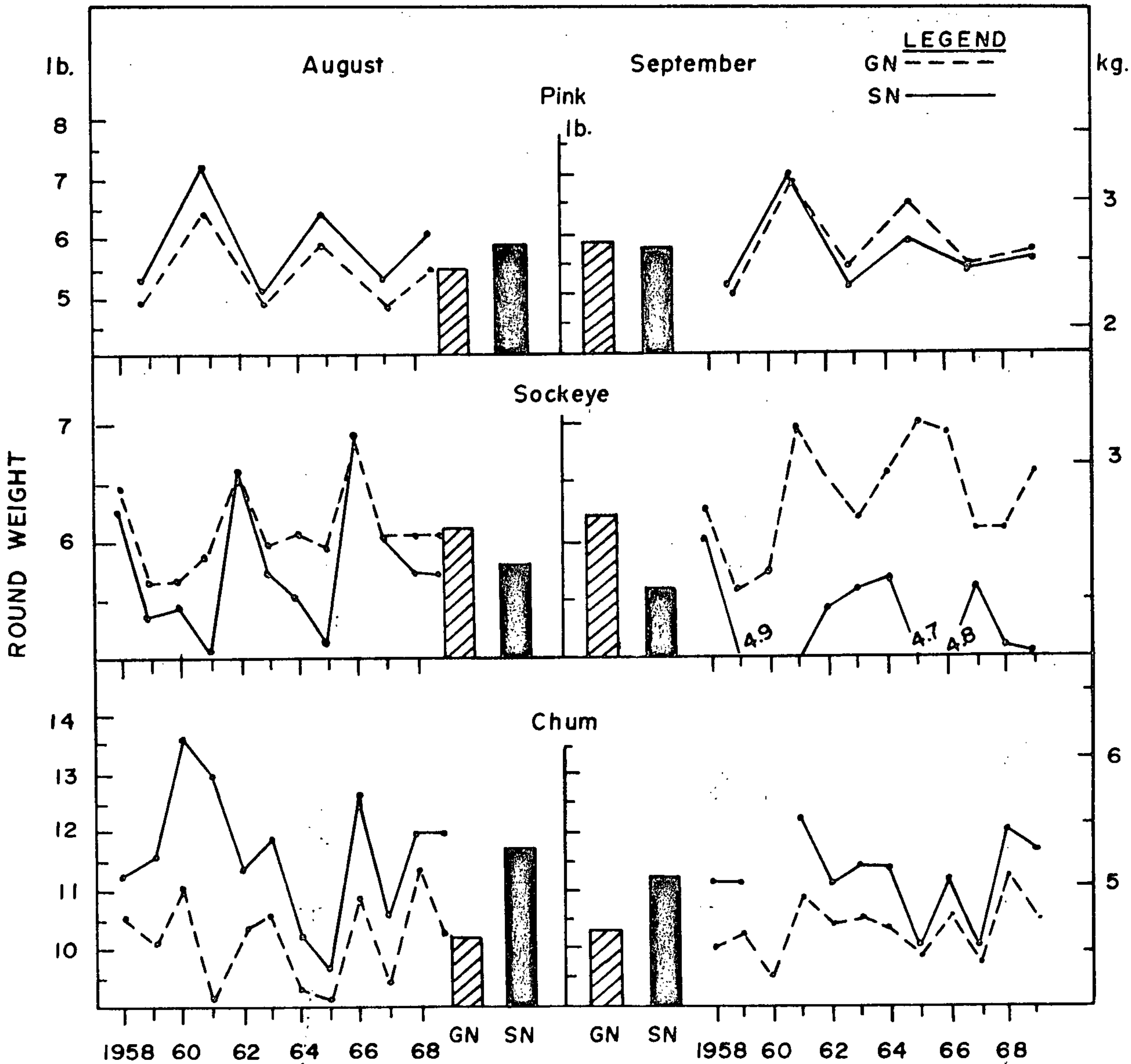

Figure 26. Mean weight of pink, sockeye and chum caught by gillnet (GN) and seine (SN) gear during August and September in Statistical Area 20, 1958 to 1969. Histograms present annual averages.

of high abundance (1959, 1963, 1967). Monthly changes in $\overline{Ws}$ are slight ($\overline{\overline{Ws}}$ = 5.9 lb., 2.7 kg., August; 5.7 lb., 2.6 kg., September) and annual variation low, less than observed for coho (coefficients of variation, Appendix Table 6B). In August, $\overline{Ws}$ exceeds $\overline{Wg}$, the relationship reverses in September (excepting 1961). Mean weight of the gillnet catch increases approximately 0.4 lb. (7%) in September.

TABLE XVII. Comparison between gillnet-seine relative gear efficiency, $\hat{C}_{gs}$, and gillnet selection index $|\hat{S}|$, for coho and chinook.

	Chinook				Coho			
Ranked	August		September		August		September	
$\hat{C}_{gs}$	$\hat{C}_{gs}$	$\|\hat{S}\|$	$\hat{C}_{gs}$	$\|\hat{S}\|$	$\hat{C}_{gs}$	$\|\hat{S}\|$	$\hat{C}_{gs}$	$\|\hat{S}\|$
1	3.2	56.8	1.2	25.3	3.2	14.6	2.3	6.2
2	3.7	1.0	1.8	13.2	3.6	6.6	3.2	12.9
3	5.1	28.2	2.0	11.7	4.4	18.9	4.0	14.5
4	8.4	0.8	2.1	51.4	4.7	0.6	4.2	22.2
5	10.7	13.8	9.5	20.1	5.2	18.6	4.9	3.0
6			11.4	59.4			5.3	5.4

Sockeye (Figure 26, middle) are approximately one pound heavier on Adams River "big" years (1958, 1962, 1966); relatively high 3_2 returns preceding "big" years appear as low $\overline{Ws}$ in 1961, 1965, and 1969. Killick and Clemens (1963) show seasonal changes in sockeye weight are governed to a large extent by changing stock composition, each stock being characterized by different size compositions. However, in most years smaller sockeye enter the fishery after mid

August. August $\overline{Ws}$ has exceeded September $\overline{Ws}$ in ten of the last twelve years ($\overline{\overline{Ws}}$ = 5.8 lb., 2.6 kg. August; 5.3 lb., 2.4 kg., September). Gillnets select larger sockeye in August although the $\overline{Wg}$ - $\overline{Ws}$ disparity is least on Adams River years. In September change in mesh size and reduced weight amplify differences between $\overline{Wg}$ and $\overline{Ws}$: $\overline{\overline{Wg}}$ increases 0.3 lb. (5%) in September.

Chum are the heaviest of all species with $\overline{\overline{Ws}}$ equal to 11.7 lb. (5.3 kg.) in August and 11.2 lb. (5.1 kg.) in September (Figure 26, lower). The August-September difference would reduce to 0.2 lb. if $\overline{Ws}$ for August, 1960, was excluded (September, 1960, excluded due to negligible seine catch). Variability in $\overline{Ws}$ was lowest of all species suggesting fairly constant growth and age composition between years. Gillnets consistently captured chum smaller than the estimated population mean; $\overline{\overline{Wg}}$ increases 0.1 lb. (1% in September).

Pink and sockeye, although comparable in weight ($\overline{Ws}$), differ markedly in $\hat{S}$ (Table XVIII). During August, gillnets selected smaller pinks (reverse selection) and larger sockeye (positive selection). In September, pinks shifted to slight positive selection compared to high positive selection for sockeye. Chum are apparently too large for gillnets in both months (consistent negative $\hat{S}$); degree of selection is most pronounced during August when small mesh gillnets are in use. In September, larger mesh nets cause a reduction in $\hat{S}$ for chum but no change in direction.

TABLE XVIII. Average gillnet selection index, $\hat{S}$, for pink, sockeye and chum.+

	August	September
pink	7.5 (-7.5)*	4.0 (2.2)
sockeye	6.7 (6.6)	23.5 (23.5)
chum	12.3 (-12.3)	7.4 (-7.4)

+Source data in Appendix Table 7B.

*$\hat{S}$, sign considered.

For pink (August only), sockeye and chum, $\hat{S}$ and $\overline{Ws}$ were linearly related over the observed range in $\overline{Ws}$ (Figure 27; Appendix Table 8B).

During August, sockeye seldom exceeded a weight sufficient to produce negative selection. Zero directional $\hat{S}$ occurred between 6 and 7 pounds; 6.5 lb. (2.9 kg.) based on the regression line. Sockeye and coho cover approximately the same weight range in August and as expected, both regressions had similar slope and elevation (Figures 27 and 25; Appendix Table 8B).

Pinks, on the other hand, similar in weight to sockeye and coho, underwent consistent negative $\hat{S}$. Accordingly, different species morphometry is suspect. McCombie and Berst (1969) relate gillnet efficiency for several fish species to a maximum girth-mesh perimeter ratio of 1.0 to 1.2, net efficiency on either side of the ratio falls rapidly. Perhaps pink salmon above the population mean weight

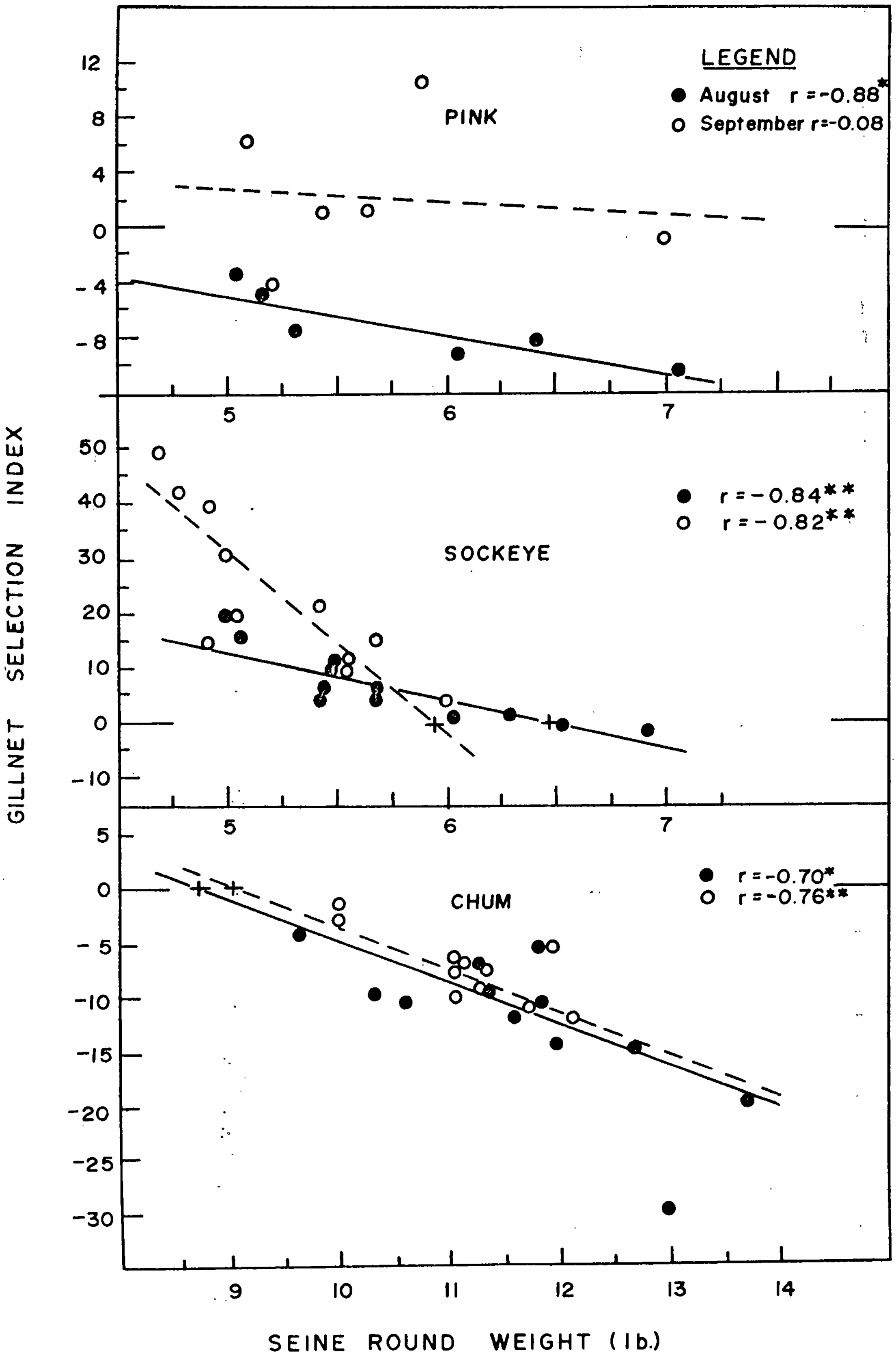

Figure 27. Gillnet selection index, $\hat{S}$, versus mean weight of the seine catch (Area 20) for pink, sockeye and chum caught in August and September, 1958 to 1969.

exceed optimum girth causing a predominance of small pinks in the gillnet catch.

Comparison of condition factor between test troll caught sockeye, pink and coho (Appendix Table 12A) demonstrated pinks were heaviest per unit length ($p \leq 0.01$). This implies pink girth exceeds sockeye and coho girth for fish of the same weight. These data are in agreement with Todd (MS 1969) who found pinks surpassed sockeye in girth by approximately four per cent for fish of the same standard length. Todd points out, however, that differences in mean selection length (sockeye > pink) for a single mesh size (based on experimental fishing and calculated using the normal probability model of Holt, 1963) were not totally explainable on the basis of species differences in girth-length relationships, and that swimming thrust or other behavioural attributes may be more important in explaining species differences in selective properties of gillnets. Perhaps his comment regarding behaviour bears some relevance to the observed low $\hat{S}$ - $\overline{W}$s. correlation for September pinks.

For sockeye, the September regression slope significantly exceeded that of August ($p \leq 0.05$) which may be related to a change in age composition. For instance, four $\hat{S}$ above 30 (upper left, Figure 27) occurred on years preceding large Adams River populations when 3_2 sockeye returns are high, often 50 per cent of the September catch (Killick and Clemens, 1963, Appendix Table A). "Jack" sockeye, generally less than 50 cm. in fork length, are seldom caught by gillnets (Peterson, 1954) but would occur in the seine catch giving rise to high $\hat{S}$. On remaining years, 4_2 sockeye dominate September catches, thus overall size distributions would be similar in shape to those of August and $\hat{S}$ should shift in elevation but not slope as mesh sizes increase.

Chum consistently weigh more than the zero $\hat{S}$ size of approximately 9.0 lb. (4.3 kg.), hence negative $\hat{S}$. (Figure 27, lower). Similar elevation between August and September regressions implies selection is unchanged between months (differences in $\hat{S}$, Table XVIII, perhaps due to increased mesh sizes in September). However, in view of the late season timing of the chum, much of the August chum catch occurs when gillnets are changing to larger mesh nets. This might minimize differences between monthly regressions as August chums would be exposed to a fleet mesh distribution similar to that in September.

There was no obvious relationship between $|\hat{S}|$ and $\hat{C}_{gs}$, for pink, sockeye or chum.

In summary, Juan de Fuca gillnets are selective for all species, but there are considerable differences in degree and direction of selection between species and between months within species. Monthly changes probably reflect altered size distributions and fleet mesh distributions. Intensity and direction of selection appear closely related to salmon weight. From the foregoing it is apparent that fleet mesh distributions are not synchronized between species and, furthermore, when a preferred species (sockeye or coho) is abnormally small, selective removal of stock components intensifies suggesting inefficient utilization of the stock as a whole.

ii) Sequential selection.

To test for sequential selection, random samples of ten coho weights (test troll caught in 1967, Appendix Table 13A) were compared between basic areas for three charter period pairs (Cp 1 and 2; Cp 3 and 4; Cp 5 and 6). Basic area I covers the gantlet entrance fished by approximately 70 per cent of the gillnet fleet plus Swiftsure Bank west of the Bonilla-Tatoosh net line; Ba II includes the remainder of the gillnet fleet; and Ba III is positioned at the exit. Gillnet mesh sizes are assumed homogenous between Ba. Test troll selectivity, if present, is unlikely to vary between Ba in the same direction as sequential selection. During Cp 1 and 2, a small gillnet fleet operated between San Juan Point and the Bonilla-Tatoosh line on three of 25 charter days; during Cp 3 and 4, 11 of 28 charter days followed intense nighttime gillnet operations between "the line" and Sheringham Point; during Cp 5 and 6, 13 of 26 charter days followed gillnet operations.

Basic areas and Cp were compared in a two-way analysis of variance. The analysis included Cp because of possible Ba differences based on other factors, perhaps differences in food availability (thus growth) which, if present, would appear during Cp 1 and 2 when net fishing was minimal.

All calculated F ratios (Table XIX) were significant. To assess which Ba differences were significant, Duncan's new multiple range test was applied to overall mean weights (lb.); means not underlined by the same line are significantly different ($p \leq 0.05$).

TABLE XIX. Analysis of variance for comparison of coho size between paired charter periods and basic areas, 1967.+

Source	SS	DF	MS	F Ratio
Charter periods	184.3	2	92.1	10.26*
Basic areas	62.1	2	31.1	16.36**
Interaction	35.9	4	8.98	4.73**
Error	153.7	81	1.90	
Total	436.0	89		

+Basic areas considered as fixed effect, charter periods as random effect.

	I	II	III
Weight (lb.)	5.92	<u>4.58</u>	<u>3.93</u>

Coho mean weight in Ba I significantly exceeded Ba II and III, but Ba II and III did not differ. Basic area differences were negligible during Cp 1 and 2 (Figure 28) but were fully expressed once the intense fall fishery began, hence significant interaction.

These data strongly suggest that sequential selection operated on Juan de Fuca coho in 1967 causing a successive west to east reduction in mean weight of escaping coho. Skeena sockeye and pink pass

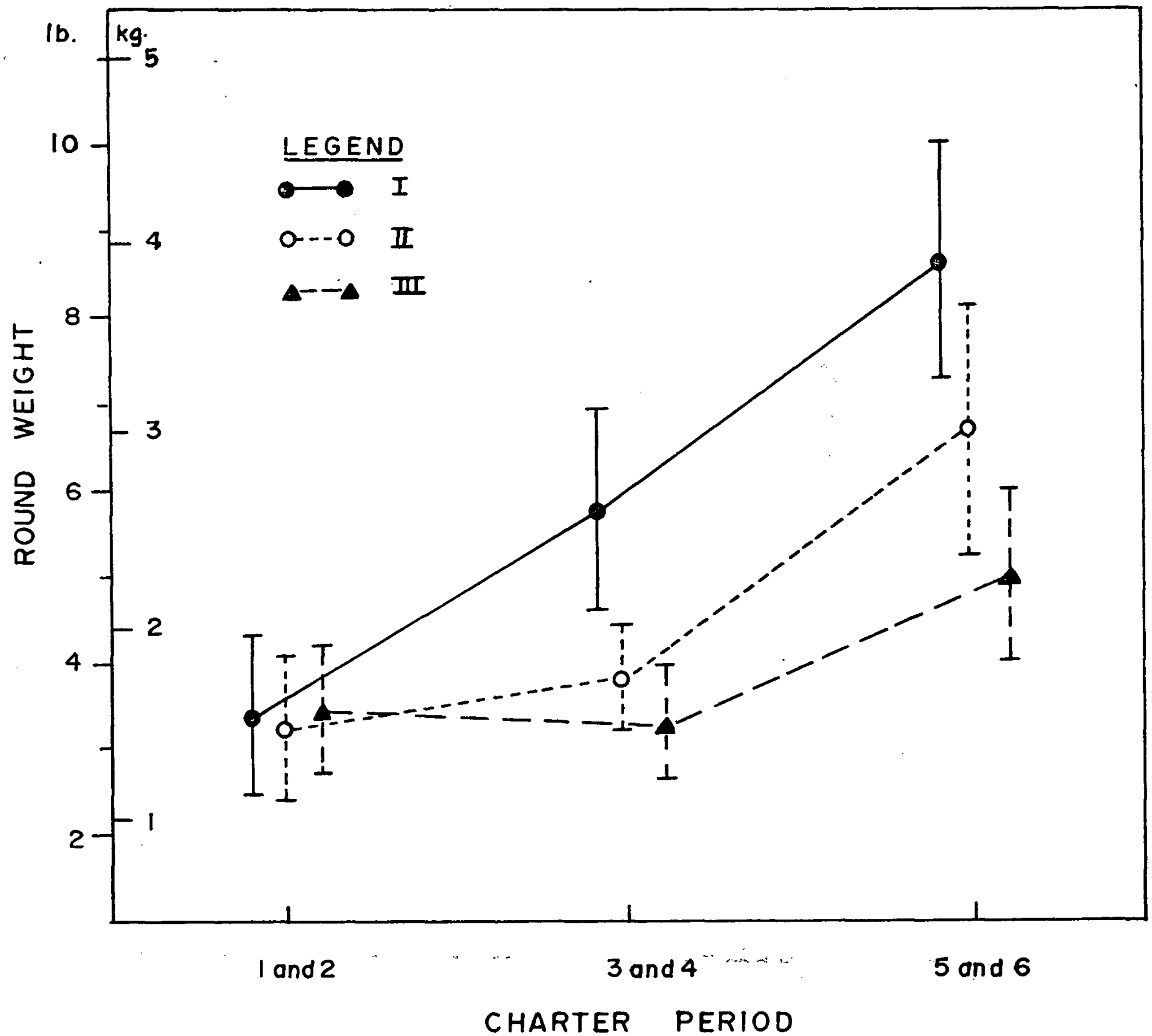

Figure 28. Mean weights of coho salmon by charter period pairs and basic areas, 1967. Vertical lines are 95% confidence limits on the means.

through a similar gantlet arrangement, also apparently experiencing sequential selection (Todd, MS 1969). Killick and Clemens (1963) give passing note to the "compounding effects" of selection on Fraser sockeye as they pass through successive Canadian and American gillnet and seine fisheries.

Gillnetters might overcome sequential selection by decreasing mesh sizes depending on distance from the entrance of the gantlet (increase mesh size under negative selection). In effect, this would increase the vulnerable fraction of the stock resulting in more even distribution of exploitation among the total fleet.

3. Troll selectivity.

a) Introduction and methods

In general, selective action of troll gear, or for that matter, any hook and line gear, relates to fish behaviour rather than mechanical properties of the gear (Allen, 1963). Terminal gear and fishing techniques (lure shape, color, fishing speed, etc.) influence selection insofar as they capitalize on unique behaviour of a species or size class, thus increasing "attack" or retention rates of the favoured group. Relevant behavioural aspects governing size or species selection might include food preference, food competition, struggling behaviour once hooked, and so on.

Presence of size selection for chinook was assessed simply by comparing charter period mean weights of the test troll catch with week-ending mean weights of Area 20 commercial troll, gillnet and seine catches. Test troll gear and fishing techniques were standardized for experimental purposes (Appendix A) and, consequently, differed considerably from commercial troll gear. Commercial trollers deliver gutted chinook (head-on) which reduces weight by approximately ten per cent over round weight. Size selection by test troll gear on 2_2 coho is discussed on page 28 (Figure 4).

Part two investigates species selectivity of trolling lines (bow and deep lines on charter trollers), vessel differences in line selectivity, and the effect of fishing depth on species selectivity of trolling lures (hoochie-dodgers and cerise painted "coho" spoons, Appendix Figure 2A). Lure types were equally replicated at all fishing depths on each line (Appendix Figure 6A).

b) Observations and interpretations

i) Size selectivity.

Test troll chinook weights averaged less than three pounds (1.3 kg.), whereas troll means (dressed weight) generally exceeded seven pounds (2.5 kg.) and seines often averaged over ten pounds (4.5 kg.), particularly during August (Figure 29).

Age analysis of the test troll catch (Appendix Table 5A) indicated 77 per cent were 2_1, 16 per cent 3_1, and less than 5 per cent 4_1. Size analysis (Figure 7) indicated 2_1 chinook ranged from 1 to 4.5 lb., mean approximately 2.2 lb. (1 kg., about 40 cm. fork length); 3_1 chinook ranged from 2.8 to 10 lb., mean approximately 5.6 lb. (2.5 kg. about 58 cm.).

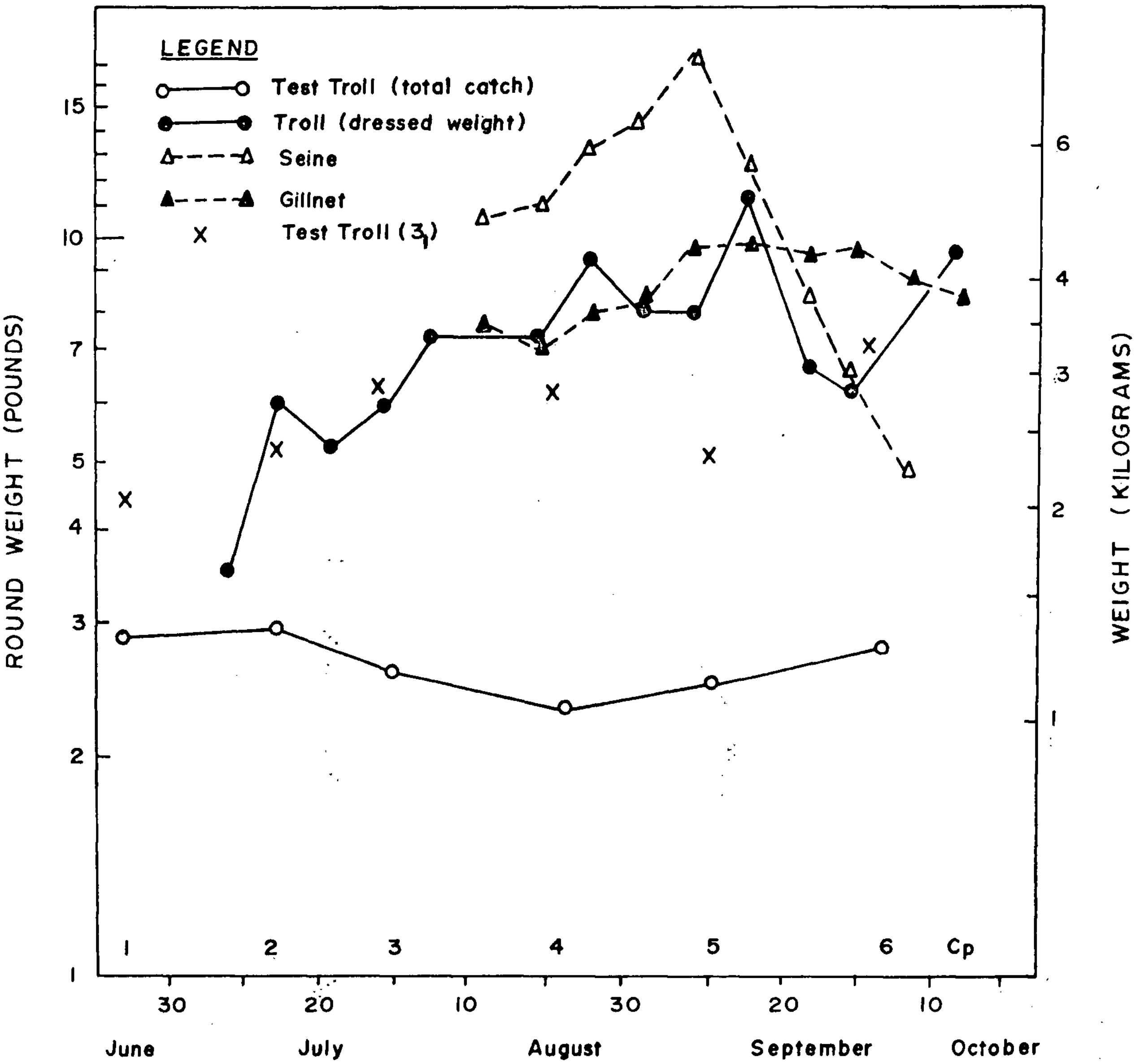

Figure 29. Average weight of chinook caught by test troll gear and by Area 20 commercial troll, gillnet and seine gears, 1967. Commercial weights plotted on mid-week dates.

Stomach content analysis of early season test troll caught chinook demonstrated a marked difference in general composition and volumes between age classes (Table XX). Crustaceans dominated in 2_1 stomachs (53%), whereas the few 3_1 chinook caught contained 70 per cent fish. Furthermore, 3_1 volumes averaged 6.3 times 2_1 volumes; round weights differed by a factor of 2.5.

A recent experiment on the west coast of Vancouver Island (Pitre, 1970) demonstrated that hoochie-dodgers selected smaller chinook than six inch spoons and plugs.

Milne (1955a) found large spoons and plugs (both seven inches long) selected larger chinook than small spoons (egg wobblers) and plugs, average fork lengths 68 cm. and 59 cm. respectively. Stomach contents of chinook caught by large lures had a much higher incidence of fish (herring) than stomach contents of chinook caught by small lures. Small chinook were more readily caught on small lures while feeding on invertebrates or when their stomachs were empty. He suggested lure selectivity might relate to size and type of food eaten at time of capture (lengths of herring in stomachs of large chinook were similar to lure lengths).

Obviously, part of the difference between test troll weights and those of other gears occurred because charter trollers retained chinook below the three pound minimum commercial size. Mean weights of 3_1 chinook, however, are reasonable estimates of mean weight of the "legal" test troll catch. Thus, during August, when an

TABLE XX. Composition of 2_1 and 3_1 chinook stomach contents captured during Cp 1 and 2, 1967, in Basic Area I.+

Age	Volume ml. per 100 stomachs	Per cent Fish	Per cent Crustacean	N
3_1	1046	71	29	36
2_1	165	47	53	67

+Displacement volumes: fish predominately sand lance, *Ammodytes hexapterus*; crustaceans predominately Euphausiid species.

important in-migration of maturing chinook occurs (Section A), most probably aged 3_1 and 4_1, charter trollers demonstrated pronounced selection for smaller (younger) chinook (compare seine and troll means) and also selected smaller chinook than commercial troll gear. Similarity of test troll and commercial troll mean weights in June and July may reflect charter troll sales of "legal" chinook which were approximately 25 per cent of the June-July commercial catch. During August and September, test troll landings were less than ten per cent of the commercial catch.

In brief, test troll gear was selective for small chinook (age class 2_1), a reasonable conclusion considering other studies demonstrate small spoons and hoochie-dodgers to be selective in this direction. Stomach content analysis supports the observation by Milne on importance of diet. It is interesting that the charter fishermen, all experienced at fishing chinook, felt simply lengthening leaders from 12 ft. to perhaps 20 to 30 ft. (such as used by Pitre) would have increased catches of older chinook with existing lures.

ii) Species selection.

Charter trollers were instructed to standardize gear and fishing techniques (Appendix A) so that catch fluctuations between time periods and areas would estimate changes in salmon abundance. However, as the 1967 study progressed, it became apparent to field personnel that even under rigid control, charter vessels differed somewhat in species selection, perhaps arising from vessel differences in line selectivity, and that in the overall, lines might be species selective.

To examine line selectivity total study area catches for each vessel of 3_2 coho, 2_2 coho, chinook, pink and sockeye on bow lines and the top four deep line lures were summed over Cp 3 to 5 (July 26 to September 21) and per cent catch by line type calculated (Appendix Table 14A). Differences between species and vessels in per cent catch on deep line lures was tested by two-way analysis of variance without replication; percentages were rectified using the arcsine transformation (Sokal and Rohlf, 1969, p. 386). The calculated F ratios (Table XXI) for species and vessels were significant ($p \leq 0.01$).

TABLE XXI. Analysis of variance for comparison of transformed (arcsine) per cent catch on deep line lures 6 to 3 between three charter vessels and four salmon species (two coho age classes), Cp 3-5, 1967.

Source	SS	DF	MS	F ratio
Trollers	215.05	2	107.53	10.19**
Species	734.40	4	183.60	17.40**
Error	84.43	8	10.55	
Total	1033.88	14		

To assess which species and vessel differences were significant, Duncan's new multiple range test (Steel and Torrie, 1960, p. 107) was applied to transformed means. Transformed means, converted back to percentages, not underscored by the same line, are significantly different ($p \leq 0.05$).

	Chinook	2_2 Coho	3_2 Coho	Sockeye	Pink
Percentage catch on deep lines	19.3	43.2	46.3	49.0	50.4

Chinook avoided deep line lures (19%) and differed significantly from other species which ranged between 43 and 50 per cent catch on deep lines. Line selectivity did not differ between coho, sockeye and pink salmon. Fishermen claim chinook actively seek the lowest lures on any line and perhaps might have avoided upper deep line lures. Whatever the mechanism, these data imply selective action beyond the simple effects due to differences between lures.

	Trollers		
	A	B	C
Percentage catch on deep lines	32.1	40.8	49.7

All vessel differences were significant. Deep lines were least productive on vessel A and most productive on vessel C. Apparently standardization was not entirely successful. However, without paired fishing experiments, the question of vessel differences in overall productivity could not be assessed.

As coho, pink and sockeye all approached 50 per cent catch on deep lines, it was of interest to isolate these species from chinook and then test each vessel's catch for departure from a 1:1 deep line to bow line catch ratio, using Chi-square (two-tailed, 1 df). Vessel A caught 39 per cent on deep lines, significantly below 50 per cent (χ^2 = 18.6). Vessel B fished bow and comparable deep line lures equally efficiently. Vessel C was more adept on deep lines, 57 per cent (χ^2 = 6.7). Deep line productivity for chinook was similarly ranked between vessels but none exceeded 25 per cent (Appendix Table 14A).

Vessel differences in line selection raised the question of whether lure selection might be similarly affected by variations between fishermen or vessels. Possible factors might include handling of the gear (retrieval of lines, care of gear), fishing speed and so on. To test for vessel differences for coho, the ratio of hoochie-dodger catch (HD) to spoon catch (S) was compared between vessels A and C (Table XXII) using 1968 data.

TABLE XXII. Coho catch by lure type and line for trollers A and C during Cp 1 and 2, 1968.

Troller	C	A	Total
		BOW LURES (χ^2 = 3.95*)+	
Hoochie-dodger	65	68	133
Spoon	46	80	126
	111	148	259
		TOP 4 DEEP LURES (χ^2 = 8.75**)+	
Hoochie-dodger	79	43	122
Spoon	49	61	110
	128	104	232

+Chi-square test for independence in a fourfold contingency table (two-tailed, 1 df).

Results indicated significant vessel differences. Troller C caught more coho on HD than on spoons (60%) for both lines, whereas troller A landed more coho on spoons (56%). Within vessels, differences in HD/S ratios between lines were non-significant but the overall percentages for each vessel (60% and 56%) significantly exceeded 1:1 ratios.

Obviously, if vessels differ in lure selection for a single species, then comparisons of lure selection between that species and others have little meaning unless the "vessel factor" can be isolated. Perhaps, for certain lures, the way they are fished affects species selection more than the lures themselves.

In this regard I assessed the effect of fishing depth on selection (HD catch divided by spoon catch for each deep line depth interval). It is assumed vessel inequalities would not affect direction of the depth effect; i.e., the ratio HD catch/S catch, would change in a similar direction for each vessel. Species catches are summed over all Ba for Cp 1 to 5 in 1967 (Appendix Table 15A) and for the total 1968 study period (Appendix Table 16A); vessels differed somewhat in contributions to species samples (Table XXIII). Results of one-tailed χ^2 tests appear in Appendix Table 17A.

Both coho age classes increased preference for HD at greater depths (Figure 30). The 3_2 coho trend was more pronounced in 1968. For chinook in 1968, HD demonstrated similar increasing productivity relative to spoons with surface values of 0.6 and 0.7 advancing to 4.7 and 3.2 for lures one and two. The 1967 trend was not significant

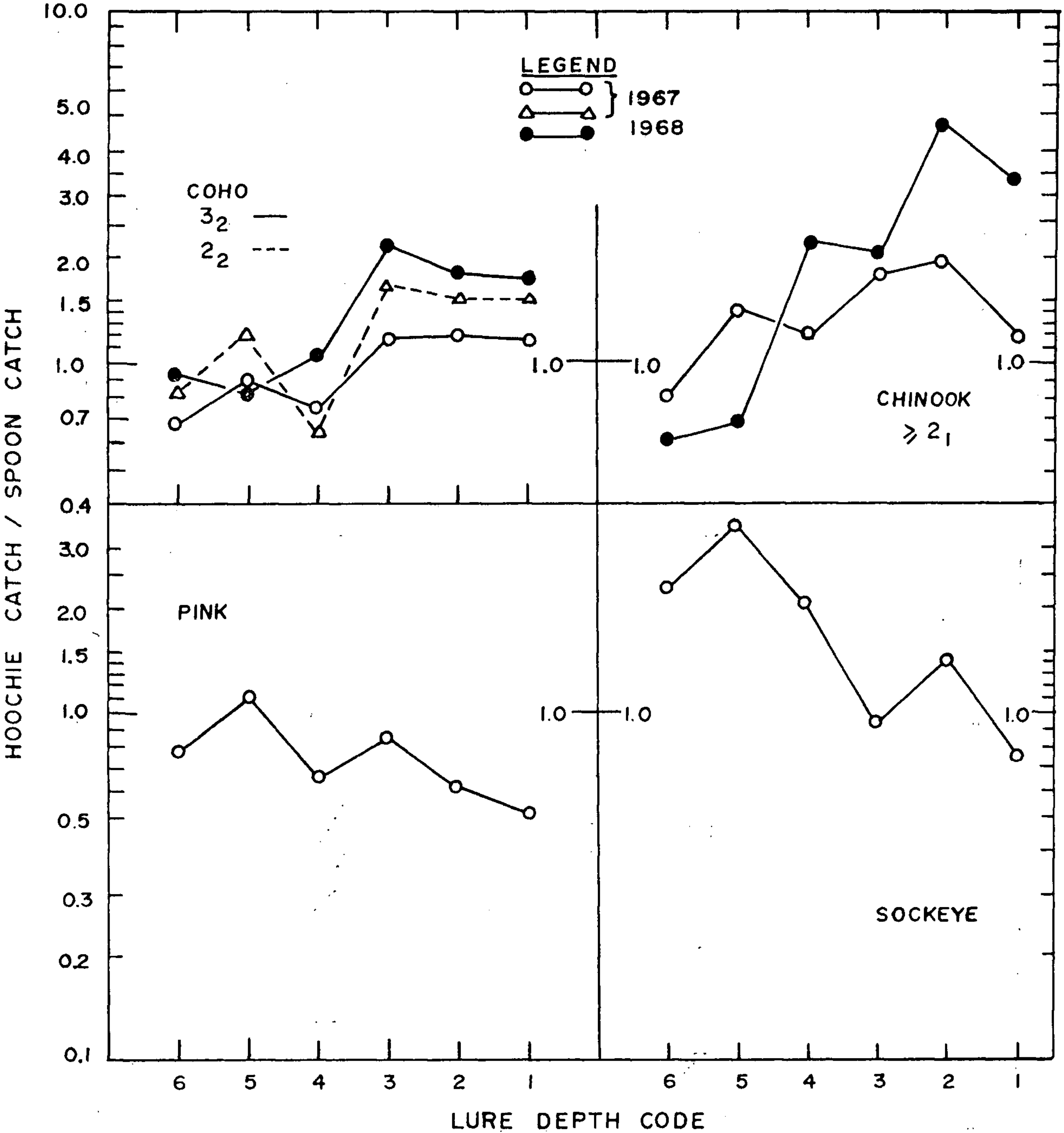

Figure 30. Test troll hoochie-dodger catch divided by spoon catch by deep line lure position (surface = 6) for coho, chinook, pink and sockeye caught between June 19 and September 21, 1967, and coho and chinook caught between May 1 and July 12, 1968.

due to low catches by surface lures. For 1968, generally heightened response to HD likely reflects the large contribution of vessel C to the total 1968 catch (Table XXIII). Vessel C fished HD more effectively than spoons for coho (Table XXII); apparently this also applied for chinooks.

TABLE XXIII. Approximate per cent contribution to deep line catch samples by each troller, 1967 and 1968.

	A	B	C
		1967	
Coho 2_2	50	15	35
Coho 3_2	26	22	52
Chinook	23	31	46
Pink	30	37	33
Sockeye	12	35	53
		1968	
Coho 3_2	36		64
Chinook	29		71

The trend for pinks was reversed compared to coho and chinook; however, statistical significance was not achieved (Figure 30). With the exception of lure position five, spoons outfished HD.

Sockeye demonstrated strong preference for HD at surface positions (>3.0); ratios reduced to approximately 1.0 for deep positions.

Preliminary diet analysis for Cp 1-2 and Cp 3, 1967 (Table XXIV)

TABLE XXIV. Gross composition and volume of salmon stomach contents caught in Ba I during Cp 1-2 and Cp 3, 1967.

		Coho			Chinook[+]			Pink			Sockeye		
	Depth	Fish[++]	Crust.[++]	Vol.[*]	Fish	Crust.	Vol.	Fish	Crust.	Vol.	Fish	Crust.	Vol.
Cp 1-2	6 + 5	35%	65%	1119(122)[**]	52	48	237(17)	1	99	1424(13)			
	4 + 3	32	68	1999(32)	70	30	377(52)	17	83	1005(8)			
	2 + 1	15	85	2611(13)	74	26	439(18)	80	20	156(5)			
	Mean[**]	31	69	1404(167)	69	31	363(87)	7	93	1051(26)			
Cp 3	6 + 5	84	16	341(86)	65	35	20(9)	14	86	236(29)	-	100	80(11)
	4 + 3	81	19	799(66)	71	29	135(54)	4	96	186(54)	3	97	67(32)
	2 + 1	22	78	411(24)	71	29	41(53)	2	98	87(26)	1	99	238(10)
	Mean	70	30	523(176)	71	29	83(116)	7	93	176(109)	1	99	101(53)

[+] Samples weighted to 80%, 2_1; 20%, 3_1; to equate Cp 1 - 2 and Cp 3 age compositions.

[++] Fish, dominant items: sand lance (Ammodytes hexapterus); herring (Clupea pallasii); juvenile rockfish (Sebastodes spp.); Crustacean dominant items: Euphausiids (Euphausia pacifica, Thysanoessa spinifera); Amphipods; Decapod zoea and megalops stages.

[*] Displacement Volume (ml.) per 100 stomachs, per cents based on volumes.

[**] Mean weighted by depth interval sample size, in brackets.

indicated stomach contents varied in amount and composition between depths (fish, crustaceans and their remains accounted for 99 per cent of all stomach volumes). Coho volumes were lowest for surface lures 6 and 5, whereas per cent crustacean content was highest on deep lures 1 and 2. Trends were similar between time periods but overall composition changed from 69 per cent crustacean in Cp 1-2 to 70 per cent fish in Cp 3. Chinook volumes also increased with depth but per cent crustacean content was highest on surface lures. In total, chinooks favoured fish (70%). Pinks fed predominately on crustaceans (93% by volume) but volumes decreased with increasing depth, the reverse of coho and chinook. Sockeye showed greatest reliance on crustaceans (99%) and volumes were highest for deep lures. Changes in diet and feeding intensities (volumes) with depth may relate to changes in lure selection. Until stomach analyses are completed in more detail, speculation on mechanisms is premature.

Previous results, particularly in relation to troller variability, are quite baffling and underline our present scanty knowledge of hook and line selection. Probably one of the few common traits among trollers is their individuality in choice and rigging of terminal gear. Almost without exception trollers can give detailed reasons, based on their deductions of salmon behaviour, as to why a particular lure, lure rigging or fishing technique is successful. Agreement among trollers is uncommon. Moreover, many trollers admit to being unable to profitably fish another fisherman's successful gear arrangement or technique, even though their own fishing procedure places them among the top production trollers. It would seem, therefore, that investigation of effects of fishing techniques on hook and line selectivity might prove a stimulating and profitable direction for future studies, especially considering the necessity for expanded management of hook and line fisheries.

In summary, species selection of lures varies with fishing depth; consequently, studies attempting precise definition of lure selectivities should control fishing depths or at least ensure that depths are representative of normal commercial practices, if results are to be applied for regulatory purposes. Similarly, investigators should be aware of vessel (or fisherman) effects on lure and line selectivity and attempt to choose representative trollers and gear when results are to be extrapolated to the total fleet. Obviously, not knowing why certain lure properties and fishing techniques stimulate "attack" by salmon severely limits management strategies pertaining to hook and line gears. Here there is unlimited scope for experimental and field investigations. Questions might include the importance of lure movement, reflectivity, colour; the effect of changing spectral composition of radiant energy with depth on salmon response to lures; the effect of depth changes in background luminance (Whitney, 1969) on perception and response to lures; or how "immediate" feeding habits conditions response to lures.

4. Coho susceptibility to hook and line gear.

a) Introduction

Hook and line gear, in contrast to other gear types, depends on active response of fish for captures, presumably a feeding response motivated by "mistaken" identification of lures as food. On that premise, physiological factors governing feeding behaviour will affect hook and line exploitation. Understanding these factors is significant for efficient management of hook and line fisheries, particularly those exploiting coho salmon which dominate sport and troll catches in British Columbia and in most other Pacific coast hook and line fisheries.

Several investigators (Smoker, 1954; Anon, 1965; Wright, 1968) note that sport and troll fisheries in coastal approaches and inside waters (Puget Sound, Georgia and Juan de Fuca Straits) take a relatively small catch from fall spawning migrations of coho. This is particularly noticeable for Juan de Fuca Strait and Georgia Strait fall recreational fisheries. Apparently, coho vary seasonally in susceptibility[2] to hook and line gear. The objective of this study was to explore susceptibility changes for coho at the entrance of Juan de Fuca Strait.

Prakash (1962) and Rogers (1959), on observing declines in coho stomach volumes during the fall (west coast of Vancouver Island troll and net samples), speculated that physiological changes associated with

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[2] I prefer the term "susceptibility" (in reference to lures) to "catchability" or "vulnerability" (Ricker, 1958b; Cushing, 1968) as to be susceptible is to be impressionable--to succumb readily (Funk, 1941). After all, don't lures attempt to deceive the salmon and, when salmon respond less readily, are they not therefore less susceptible?

advancing maturity reduced feeding intensity. Other marine fishes cease or reduce feeding activity during spawning; e.g., haddock (Homans and Vladykov, 1954). It is well documented (Greene, 1915; Hoar, 1957; Prakash, MS 1958; Foerster, 1968) that, with few exceptions, Pacific salmon fast during freshwater spawning migrations. Jones (1959) suggests that reduction and cessation of feeding facilitates mobilization of muscle proteins necessary for synthesis of gonadal proteins.

Data of Parker, Black and Larkin (1959) suggested fasting decreased effects of hyperactivity. This led to the hypothesis that cessation of feeding has adaptive survival value in fresh water by effecting "paced" energy release minimizing wastage of critical energy reserves necessary for migration and spawning.

From previous observations and speculations, it is arguable that the process of sexual maturation, at some intermediate stage occurring in salt water, initiates certain physiological mechanisms effecting reductions and later, perhaps, cessation of feeding activity prior to entry into fresh water. As a test it was hypothesized that hook and line gear would select less sexually mature coho from the total population and that this selection would be most evident just prior to and during the inshore spawning migration. A field study was conducted at the entrance of Juan de Fuca Strait to test this hypothesis. Degree of maturity was estimated from gonad weights adjusted for fish size.

Coho are abundant in entrance waters well into the fall (Milne *et al.*, 1958; 1959). The total population probably contains in excess of thirty "major" natural and artificial stocks (Aro and Shepard, 1967; Atkinson, Rose and Duncan, 1967; Informal Committee on Chinook and Coho, 1969). Thus, it was reasonable to expect that a range of maturity levels would be accessible to hook and line gear. By temporarily and spatially synchronizing hook and line and total population samples it was assumed both were obtained from the same overall population.

b) Methods and materials

i) Collection of field data

Hook and line samples were collected by a small commercial troller (Plate 5) chartered for 35 days between July 29 and September 27, 1965. Test trolling was conducted weekly during periods closed to commercial fishing (Figure 31), usually just prior to each week's net opening (net fishing began on the evening of August 1). Weekly trolling attempted capture of at least fifty coho in the vicinity of seine operations (Appendix Table 1D).

Trolling took place between Swiftsure Bank and Sombrio Point within basic area I (see Figure 19 or Appendix Figure 1A). Whenever possible, catches were made in Da IB or just west of the Bonilla-Tatoosh line; after September 1, trolling was often closer to Swiftsure Bank.

The procedure of deciding where to fish within the study area was highly subjective and arbitrary, but it was consistent throughout in simulating the kinds of clues frequently used by trollers (e.g., jumping or finning salmon, water clarity, surface presence of

Plate 5. Troller chartered for 1965 coho susceptibility study (planing hull, 22 feet OAL).

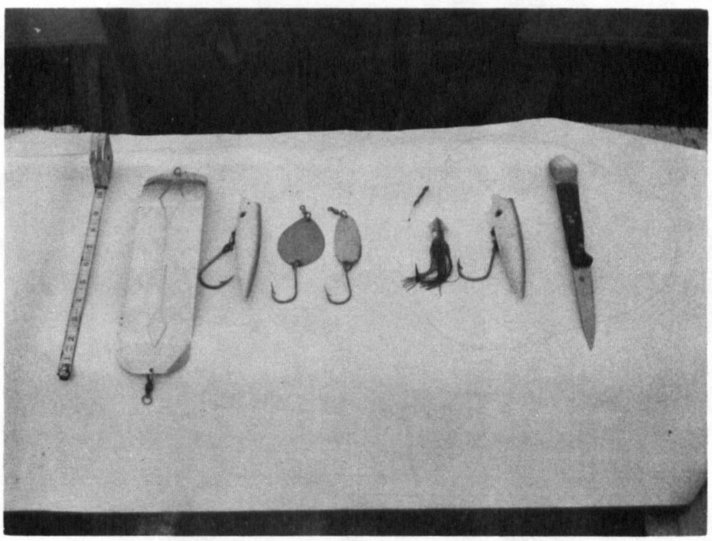

Plate 6. Examples of 1965 trolling lures (left to right): Abe and Al dodger, plastic plug, egg wobbler (brass, nickel or painted), brass or brass and nickel Johnson spoon, plastic cuttle fish hoochie (attaches to dodger).

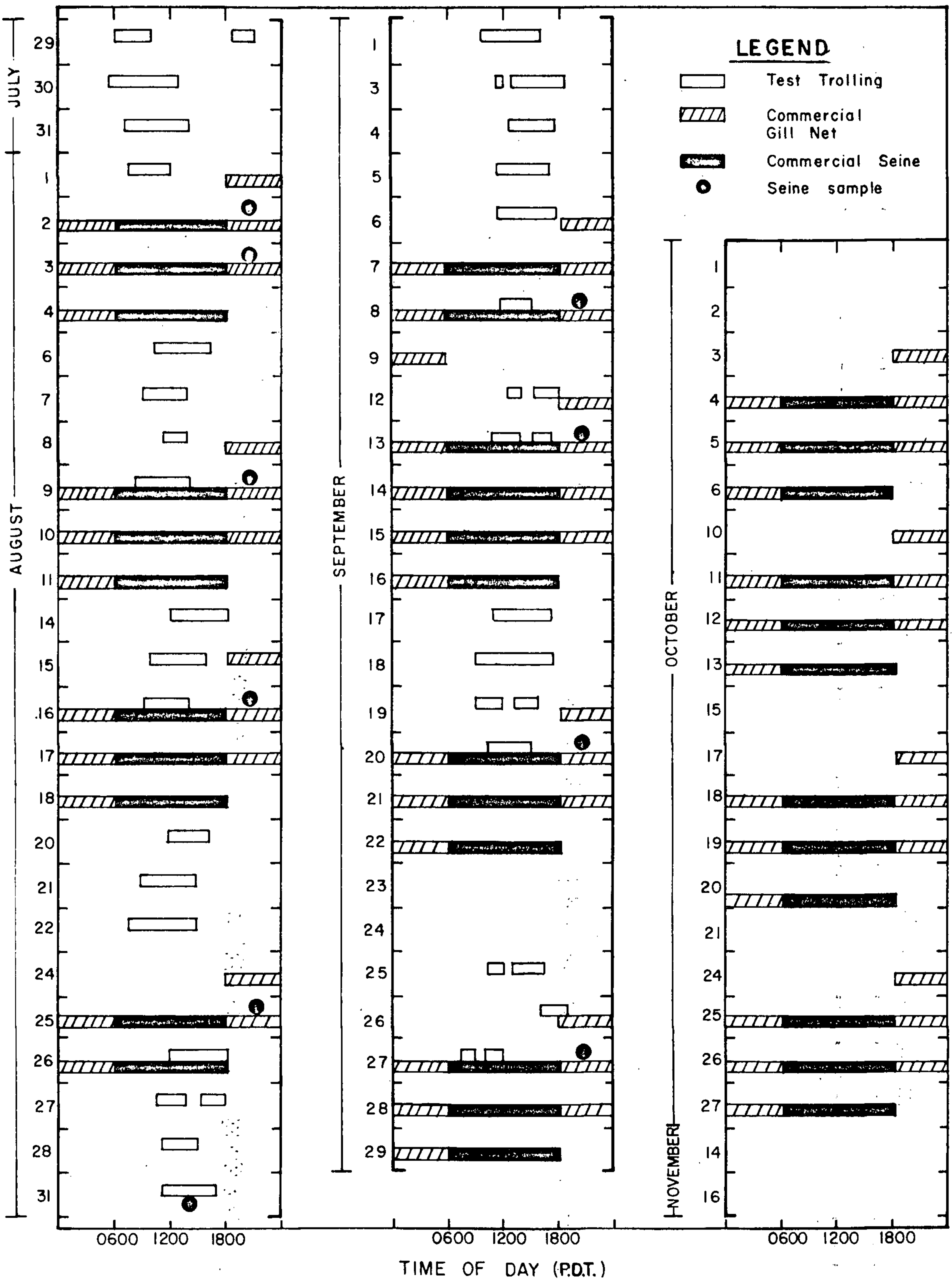

Figure 31. Daily times for test trolling, seine sampling and commercial net fishing, 1965.

salmon feed). In brief, it was a procedure that should have reflected normal trolling techniques.

The operator was experienced at fishing coho and was familiar with the study area; consequently, choice of lures (Plate 6) and fishing techniques (Plate 7) were at his discretion. During the study a wide range of trolling lures was tested. Occasionally, sport rods were fished off the stern using bait or commercial spoons. After the first week in September, about 25 per cent of the lure array (12 to 14 lures) consisted of fresh frozen small herring or herring strip in combination with dodgers. Deep and "pig" lines were used with three to five lures per line spaced every four fathoms (7.3 m.). Fishing depth of pig lines was estimated at 70 ft. (21.3 m.); deep lines 100 ft. (30.5 m.).

Fork lengths (to nearest mm.), round weights (pounds and tenths) and scales (preferred area) were taken; both gonads and digestive tracts (severed at pharynx and anus) were placed in "whirl-pak" plastic bags in a ten per cent formalin solution.

Total population samples were collected from the seine catch; seine gear was assumed to be non-selective. Samples were taken weekly (Figure 31) from seines delivering to packers in Port San Juan (August 31 sample from IPSFC test fishing seine, net fishery closed). On each sampling night (seines deliver in the evening, samples usually from first weekly fishing day) crews randomly obtained a total of 100 coho from an average of five seines that fished

Plate 7. Landing a coho salmon, note styrofoam "pig" in background.

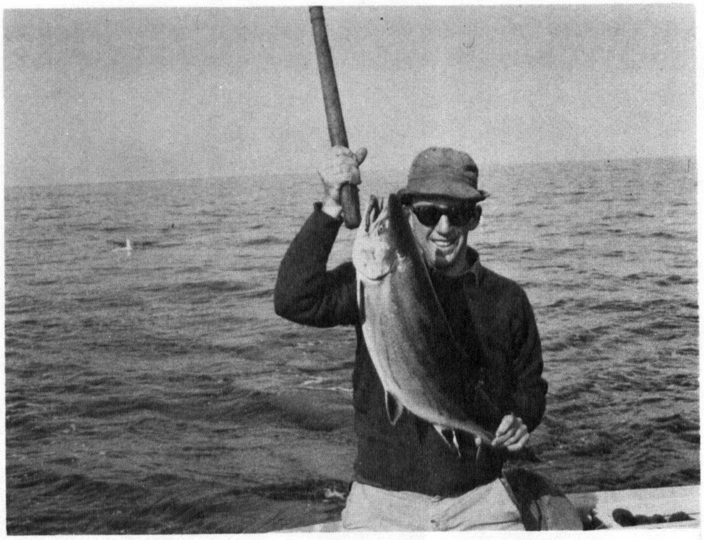

Plate 8. A seventeen pound (7.7 kg.) coho salmon.

within five miles (8 km.) of the net line (Appendix Table 2D). Biological data was identical to that taken for hook and line gear.

ii) Maturity and stomach content analysis

Gonads were weighed (grams) on a triple beam balance after soaking for at least ten hours in circulating fresh water (5°C). Weights stabilized after five to eight hours in fresh water. Prior to weighing, testes were blotted dry on paper towelling; ovaries were shaken, then blotted to remove excess water. Reproductive tracts were removed before weighing. Both gonads were weighed for each coho.

Contents of the digestive tract from pharynx to pyloric sphincter were emptied into a dissecting tray and identified. Fish components were identified to species when possible, numbers were recorded for each stomach when species or genus could be determined. Unidentifiable fish remains were arbitrarily divided into three classes: (1) only bones and vertebrae; (2) vertebral columns with some partially digested muscle (<5 ml.); (3) bones and partially digested muscle (> 5 ml.). Crustaceans were identified to suborder (normally: Euphausiacea; Decapoda, zooea and megalops stages). Numbers in each suborder were estimated visually based on the following classes: 1, 2-10, 11-25, 26-75, 76-150, 151-250, 251-350, 351-750. Class mid-points were assigned to each stomach; for calculating means, counts were transformed by taking square roots (Sokal and Rohlf, 1969, p. 384).

Differences in gonad weight (corrected for fish size) between gear types (seine and test troll), time periods (6) and sexes were assessed by two three-factor analyses of covariance (ANCOVA). In analysis one, fish length (mm.) was the covariate; in analysis two, fish weight (g.) was the covariate. Weekly troll and seine samples were grouped into six time periods (Table XXV) and random sub-samples of nine male and nine female coho were chosen for each gear type (Appendix Table 3D).

Ishida et al., (1961) show for sockeye and chum salmon that gonad weight by itself and gonad weight divided by fish weight (maturity index) increase roughly in relation to advancing sexual maturity as measured by morphological criteria based on microscopic examination of histological sections of testes and individual eggs.

TABLE XXV. Grouped sample dates for analysis of covariance.

Time Period	Grouped Sample Dates			
	Seine	N+	Troll	N+
1	August 2, 3	100	August 1	30
2	August 9	100	August 8, 9	41
3	August 16	100	August 14-16	53
4	August 25	100	August 22, 26, 27	38
5	September 7	100	September 5-7	51
6	September 13	100	September 12, 13, 17, 18	25

+Sample size from which sub-samples of 9 males and 9 females were randomly chosen.

c) Results and interpretations

i) Maturity

For both ANCOVA, gonad weights, corrected for fish size, increased over the total study period (Table XXVI, Figures 32 and 33). This increase was not unexpected considering all coho were in their ultimate ocean year (main effects F ratios calculated by method of Snedecor, 1956, p. 361). Based on first and last week means (Figure 33), testes had a weekly (6) instantaneous growth rate of 0.131; ovaries, 0.172. Gonad growth undoubtedly reflects passage through successive maturity stages (Ishida, et al., 1961). Main effects for sex and gear types were non-significant.

The hypothesis that hook and line gear selects less mature coho as maturity of the total population advances was not adequately supported; although in both analyses, time period-gear type interactions (BC) were significant ($p \leq 0.05$). In Figures 32 and 33 diverging trends (hook and line progressively below total population) only appeared in the last two time periods (tp). Between tp one and five, gonad weights show an inverse relationship between gear types (with exception of Figure 33, female). This probably contributed as much to significance of BC as did terminal divergence. In addition, for females, fish size and maturity index (MI_W)[3] were positively correlated (Figure 34). During the last two tp (particularly tp 6), troll

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[3] MI_W = [gonad weight g./fish weight g.]1000
Commonly used to determine maturity schedules for sockeye and chum salmon on the high seas (Godfrey, 1961; Ishida et al., 1961).

TABLE XXVI. Analysis of covariance for comparison of gonad weights, corrected for fish size, between sexes, time periods and gear types.[+]

Source	SS		DF	MS		F ratio
	Fish length is covariate					
Sex (A)	6.4837	E5[++]	1	6.4837	E5	1.39
Times (B)	3.6539	E7	5	7.3078	E6	15.68**
Gears (C)	1.6373	E6	1	1.6373	E6	3.47
Interactions (first order)						
AB	2.3317	E6	5	4.6634	E5	1.21
AC	8.5172	E4	1	8.5172	E4	1.12
BC	2.0445	E6	5	4.0890	E5	5.38*
Interaction (second order)						
ABC	3.8008	E5	5	7.6016	E4	0.20
Error	7.3317	E7	191	3.8386	E5	
	Fish weight is covariate					
Sex (A)	1.9866	E6	1	1.9866	E6	2.76
Times (B)	2.7553	E7	5	5.5105	E6	7.66**
Gears (C)	6.2989	E5	1	6.2989	E5	1.96
Interactions (first order)						
AB	3.5949	E6	5	7.1899	E5	2.36
AC	2.9050	E2	1	2.9050	E2	0.00
BC	1.7711	E6	5	3.5422	E5	5.43*
Interaction (second order)						
ABC	3.2593	E6	5	6.5185	E4	0.21
Error	5.8290	E8	101	3.0518	E5	

[+] Sex and time periods considered random effects, gear types fixed effects.

[++] Floating point format.

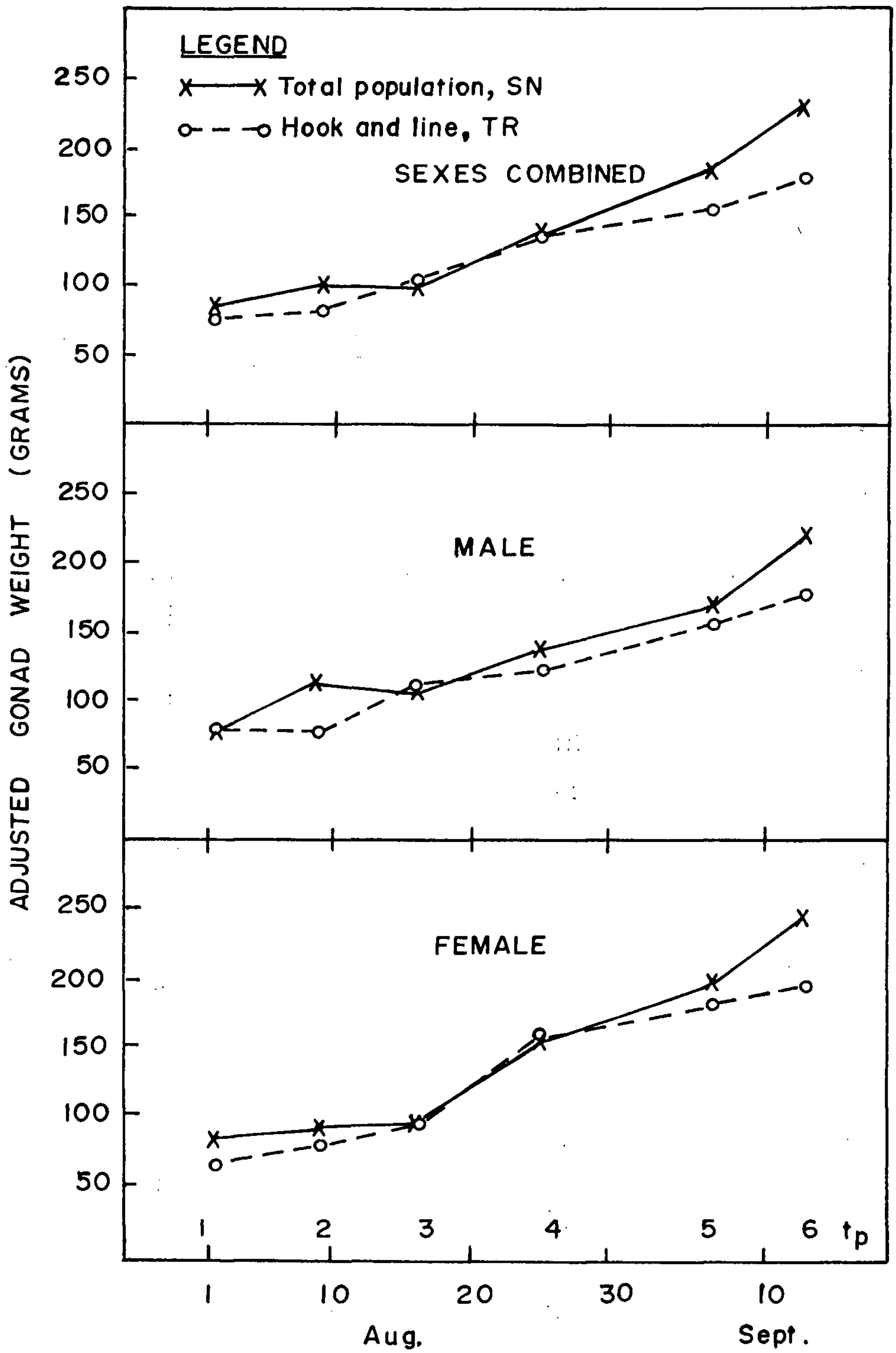

Figure 32. Gonad weight adjusted for fish length for seine (SN) and troll (TR) samples and six ANCOVA dates, 1965.

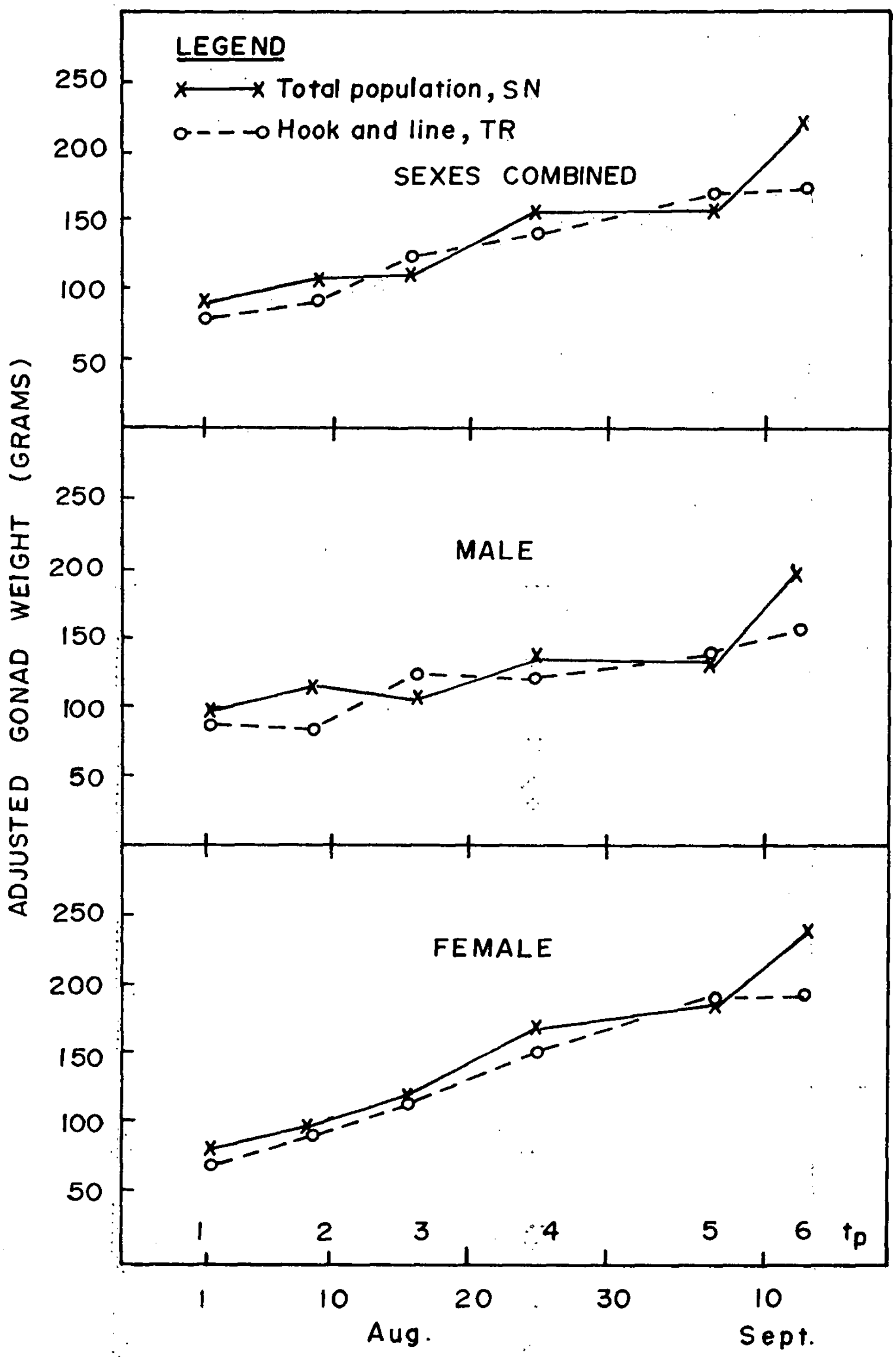

Figure 33. Gonad weight adjusted for fish weight for seine (SN) and troll (TR) gear and six ANCOVA dates, 1965.

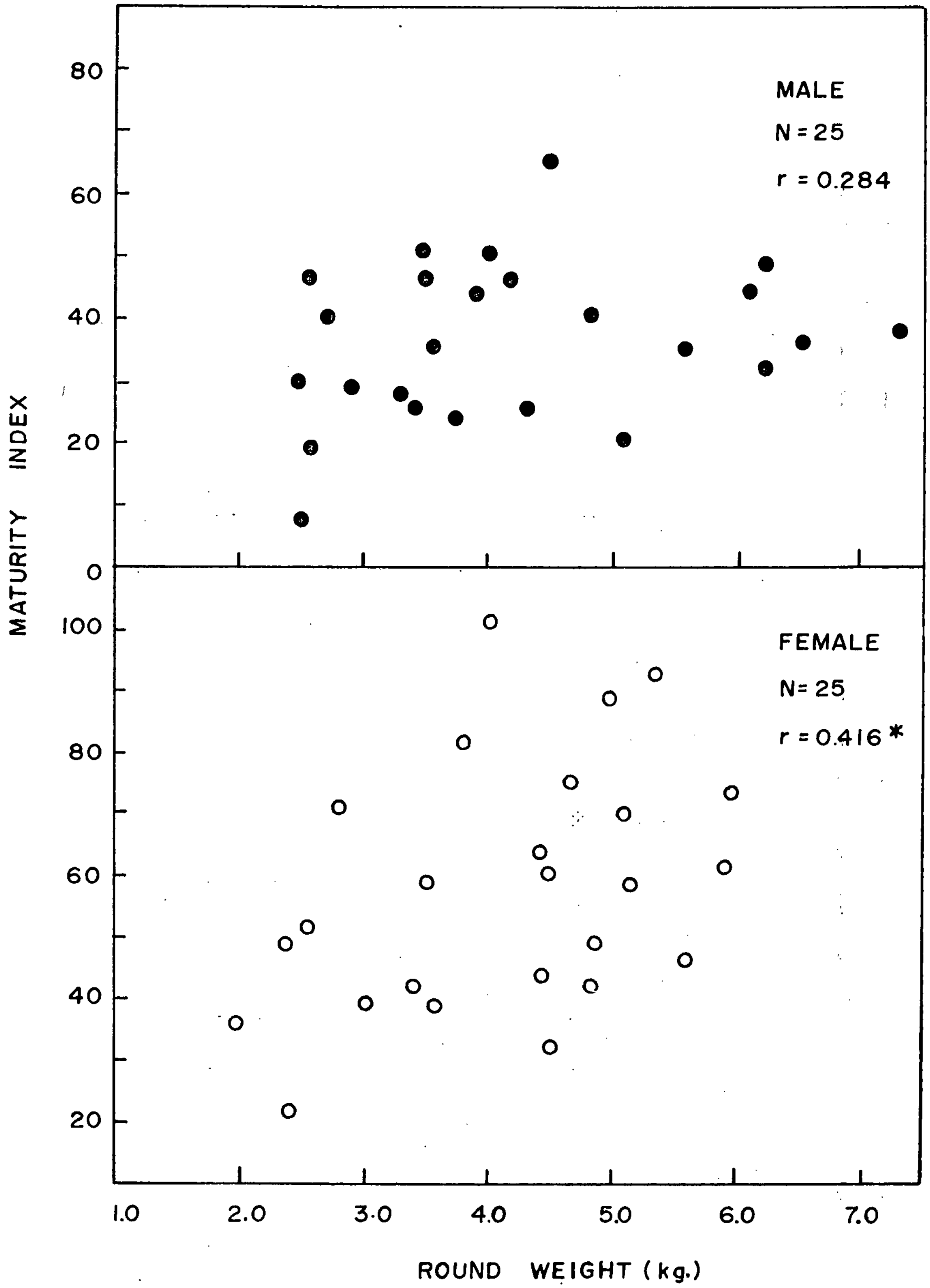

Figure 34. Relationship between maturity index (MI_w) and fish weight for coho caught by seine gear on August 31, 1965 (random sub-sample of 25).

sub-samples were composed of smaller coho than seine sub-samples (Appendix Table 3D), thus the divergence observed may, in part, reflect differences in fish size.

These results conflict with data of Rogers (1959) who compared coho $\overline{MI}_{\ell}$ (fork length equals denominator) between troll and gillnet samples from the entrance of the Strait. For both sexes the difference in $\overline{MI}_{\ell}$ between gears greatly increased after the first week in September (gillnet > troll), implying troll gear selected less mature coho. Fish size was not a factor. Rogers could not show similar divergence over time using egg diameter as a maturity index.

Use of mean maturity indices is perhaps unreliable considering inherent variability of such a measure. Examination of daily MI_w frequency distributions (Figures 35 and 36, means and SD in Appendix Table 4D) demonstrates the wide range of MI_w encountered in 1965 and the considerable overlap between weeks. Similar variability was noted for female sockeye samples at the entrance of Puget Sound (Colgrove, 1966). With regard to the original hypothesis, it is perhaps noteworthy that of the few coho troll-caught after August 16, most MI_w fell to the left of seine MI_w medians.

Growth of testes and ovaries differ considerably over the period of germ-cell development (Figure 37, Appendix Table 4D). Initially, testes underwent fairly rapid increase in size, followed by reduced growth after the first week in September (testes were 5.0 per cent of body weight on September 13 and 6.6 per cent on October 26). Ovaries

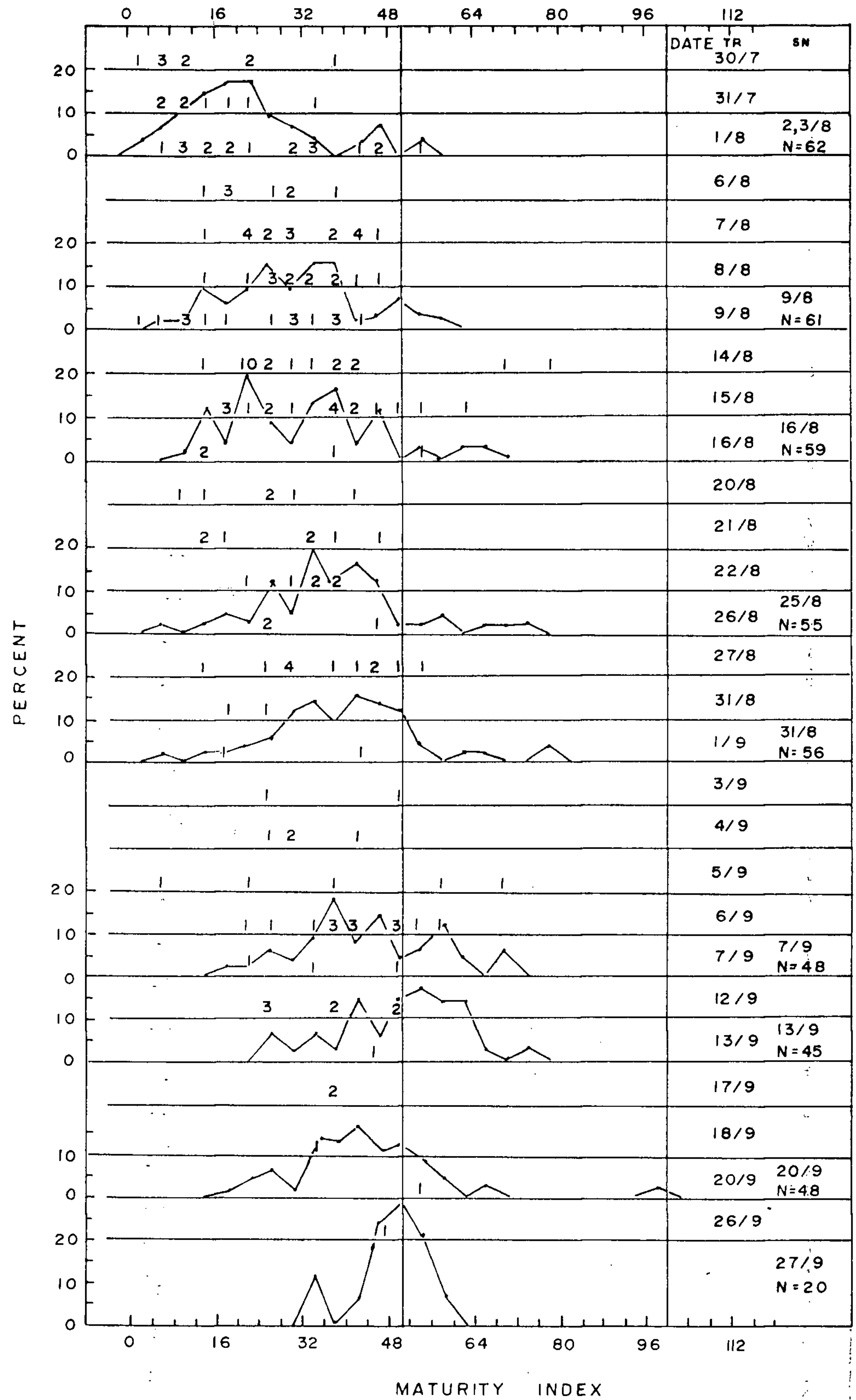

Figure 35. Daily frequency distributions of maturity index (MI_W) for male coho salmon caught by seine and test troll gear in 1965. Numbers represent individual troll MI_W values for each four point interval; seine MI_W distributions as per cent.

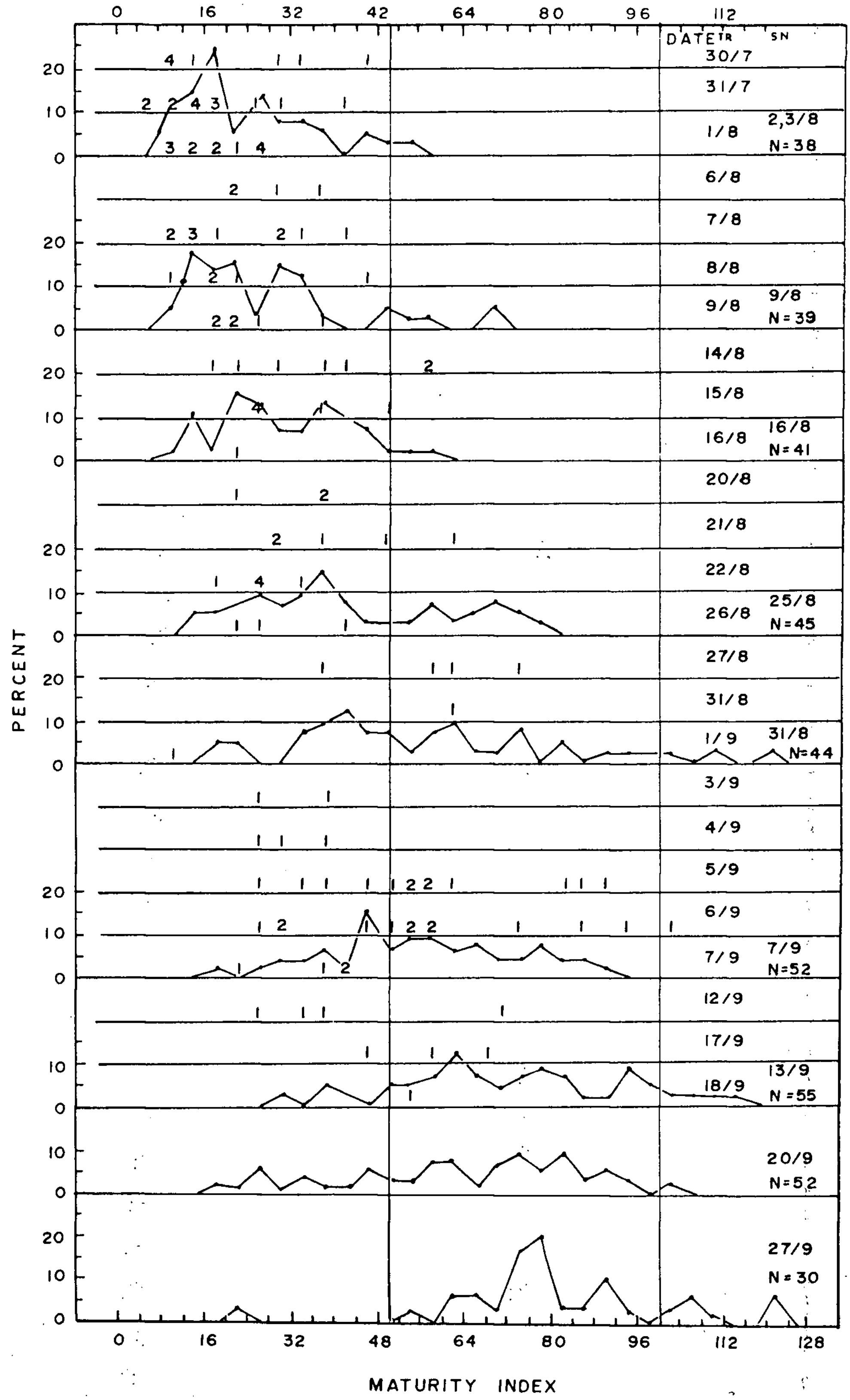

Figure 36. Daily frequency distributions of maturity index (MI_W) for female coho salmon caught by seine and test troll gear in 1965. Numbers represent individual troll MI_W values for each four point interval; seine MI_W given as per cent.

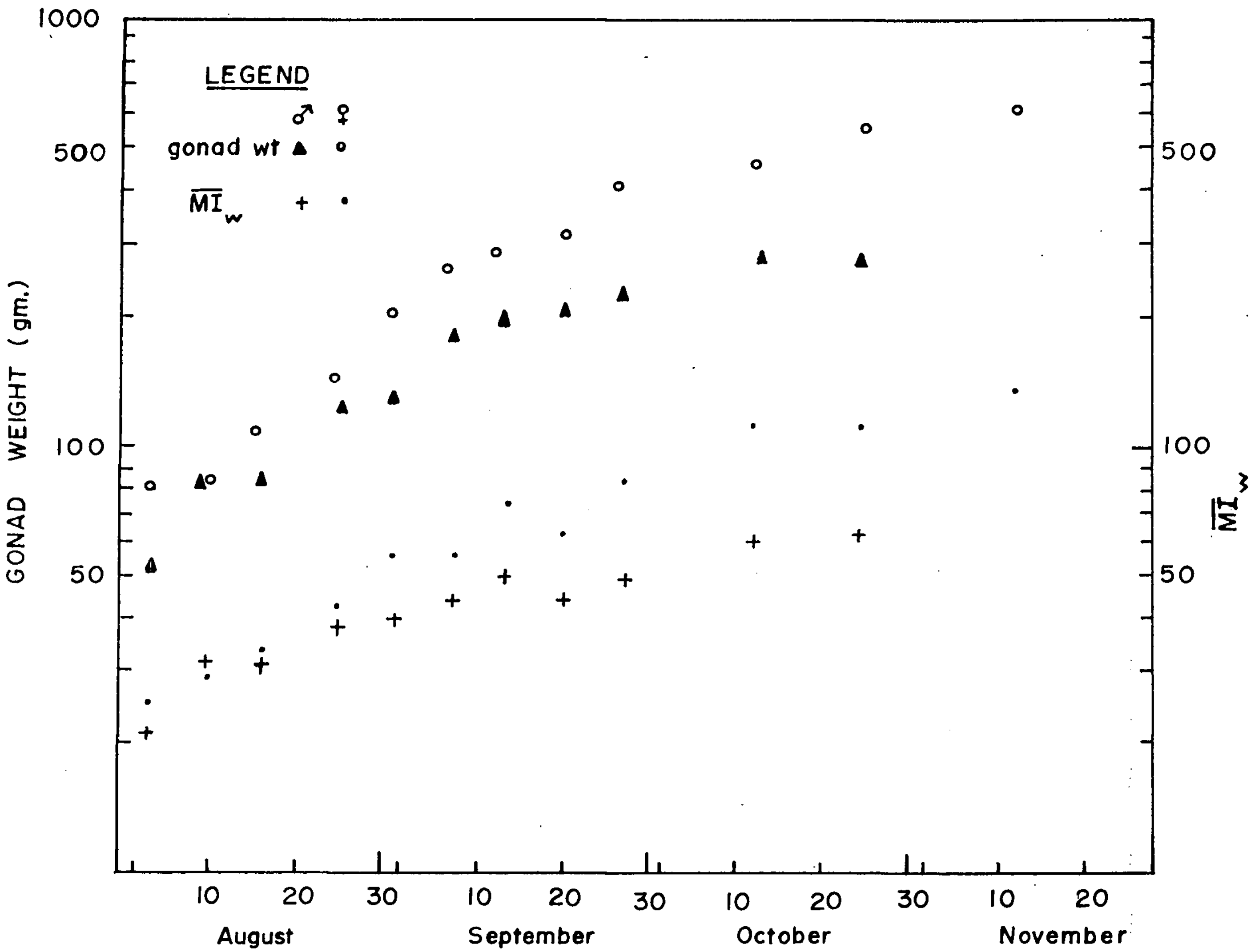

Figure 37. Male and female gonad weights and $\overline{MI}_w$ for coho caught by seine gear in Juan de Fuca Strait (to September 27) and gillnet gear in the Fraser River (October 15-November 16) 1965.

and testes were similar in size and $\overline{MI_w}$ to the last week in August, thereafter ovaries continued fairly even growth through October and reached 13.3% of body weight by mid November. Ishida et al., (1961) followed a single stock of kokanee through a complete maturation cycle and found ovary weights and egg diameters, as well as their ranges, continued to increase through six pre-spawning histological stages (oil globule stage to pre-maturation stage). By comparison, after testes reached the spermatid stage (three months before spawning) there was little change in weight; rapid growth preceeded this stage.

Because of sex differences in the maturation process and the increasingly variable relationship between histological stage and gonad weight (or MI_w) at advanced maturation levels, size of gonads and MI_w appear poor criteria for detecting small differences in stage of maturation, and thus were a poor choice to assess hook and line selection.

ii) Stomach contents

Coho fed most frequently on euphausiids (Table XXVII) which had an average seasonal percentage occurrence of 33 per cent (Appendix Table 5D). Decapod occurrences declined throughout the study period. In the fish component, sand lance dominated during the first two weeks (seasonal average 9 per cent), herring during remaining weeks (seasonal average 9 per cent). Fish seldom occurred as frequently in stomachs as euphausiids. Chapman (1936) showed similar crustacean

TABLE XXVII. Percentage occurrence of diet constituents in the stomachs of seine-caught coho salmon and estimated percentage feeding, by week, 1965.

	August					September			
	2, 3	9	16	25	31	7	13	20	27
Herring	-	6.0	1.0	18.6	16.5	13.1	8.1	8.1	14.9
Sand lance	32.3	16.0	1.0	4.1	4.1	4.0	5.8	3.0	8.5
Other fishes	13.5*	1.0	4.2	4.1	2.1	3.0	1.2	5.1	6.4
Euphausiids	33.3	28.0	28.1	16.4	19.6	30.3	58.6	42.4	57.5
Decapod, zooea and megalops stages	30.2	19.0	5.2	4.1	5.2	4.0	-	-	-
Other crustaceans**	4.2	4.0	5.2	4.1	9.3	11.1	13.7	14.1	10.6
Miscellaneous+	1.0	1.2	1.0	1.3	1.1	-	-	1.2	1.0
Fish remains 1	10.4	3.0	9.4	7.2	17.5	10.1	9.2	14.1	6.4
2	1.0	-	2.1	4.1	5.2	4.0	4.6	9.1	4.3
3	-	-	1.0	-	3.1	1.0	1.2	1.0	2.0
Percentage feeding++	71.0	54.0	38.5	48.5	60.8	56.6	66.7	61.6	72.3
Sample size	96	100	96	97	97	99	87	99	47

* Juvenile rockfish (Sebastodes) and larval fishes (likely herring and sand lance).

** Amphipods, Copepods, mysids, isopods.

\+ Squid, insects, gastropod shells, algae, feathers.

++ > one crustacean or >0.5 ml. fish remains.

dominance for coho caught at the entrance of the Strait and contrasted this with a fish diet for coho captured off Westport. Percentage occurrence of euphausiids increased considerably during September. Prakash (1962) demonstrated similar euphausiid gains in the fall for coho sampled off the east and west coasts of Vancouver Island.

If less mature coho feed more often or more voraciously, an inverse relationship between organism counts per fish and maturity level would be expected. This was explored for September seine samples using crustacean counts for coho arrayed into four 20 point maturity classes. Results did not support an inverse relationship, hardly surprising in view of the variability against which the relationship is measured. Table XXVIII presents a typical example.

TABLE XXVIII. Comparison of crustacean counts between female MI_w classes for September 20, 1965.

MI_w	20 - 40	40 - 60	60 - 80		80 - 100
	24	0	0	18	18
	0	0	6	6	0
	6	0	0	1	0
	0	141	12	0	200
	0	0	18	50	56
	0	24	0	0	12
	50	24	0	6	0
	6	0	50	18	0
		24	0	0	18
		0	1	0	
mean+	2.01	2.81	2.10		3.19
SD+	2.50	3.86	2.22		4.39

+square root transformations (zero values augmented by 0.5)

Prakash (1962) and Rogers (1959) commented that percentage of stomachs containing food indicated feeding intensity; both observed declines in this index between August and September and inferred decreased feeding intensity. My data conflict with these results. Per cent of the seine sample judged feeding was minimal in mid August (29%) then increased to 72 per cent by September 27 (Table XXVII). Obviously, availability of food and many other factors affect this index. Average numbers of herring in stomachs of feeding coho rose slightly at the end of September and average numbers of euphausiids showed marked increases throughout September for samples from both gears (Table XXIX). It appears that food availability was higher in September, perhaps masking a change in feeding intensity.

Euphausiid "food indices" were compared for seine and troll gear to obtain a relative measure of feeding intensity. The food index was the mean number euphausiids per feeding coho per kilogram of fish weight (Appendix Table 6D). Presumably the seine index estimates feeding intensity of the total population. Subtracting seine index from troll index estimates relative change in feeding intensity of the total population. Figure 38 suggests feeding intensity of the total population decreased considerably through mid August. This change coincided with early timing of the main spawning migration. Prakash (1962) inferred a similar feeding intensity change between August and September, 1957, for west coast coho based on stomach volumes

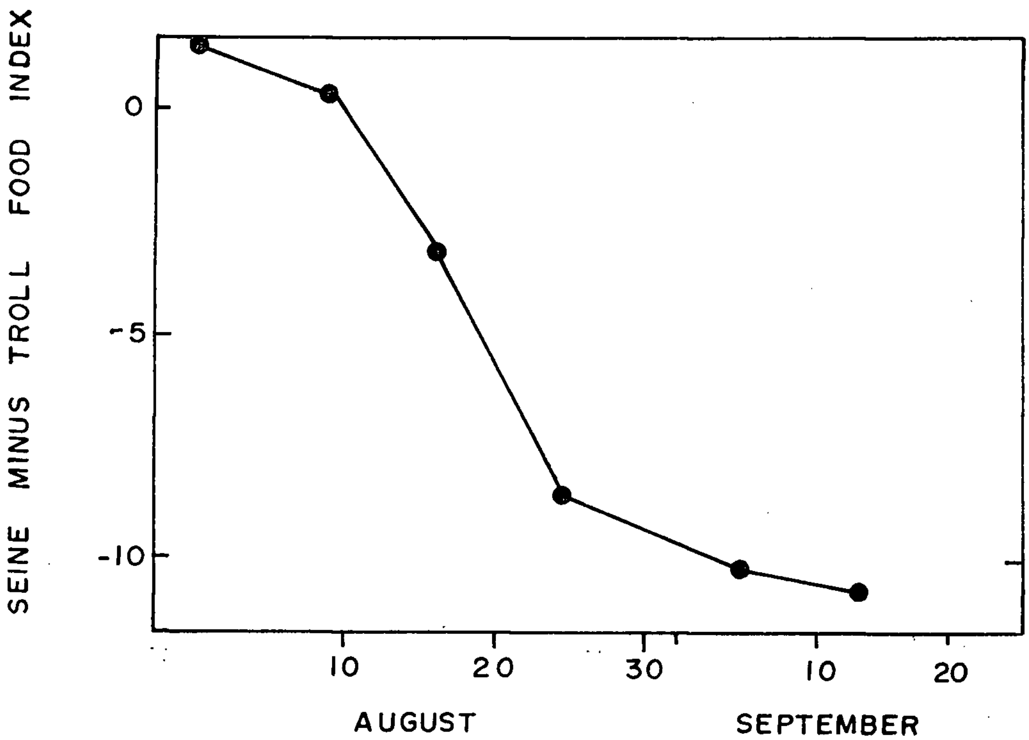

Figure 38. Difference between troll and seine euphausiid food indices (mean euphausiid count per coho per kg. body weight) for coho samples from ANCOVA dates.

and Rogers (1959), using food indices for troll and gillnet samples taken at the entrance to the Strait in 1958, inferred coho reduced feeding intensity at the end of August.

TABLE XXIX. Mean number euphausiids and herring (seine only) per feeding coho and per cent coho classified as feeding for weekly seine samples and ANCOVA troll dates, 1965.+

	August					September			
	2, 3	9	16	25	31	7	13	20	27
					SEINE				
Euphausiids	6.7	6.4	6.2	7.2	4.5	4.9	12.9	17.3	40.4
Herring	-	1.5	3.0	3.0	1.8	2.0	1.3	1.5	2.2
% Feeding	71	54	39	49	61	57	67	62	72
N	96	100	96	97		99	87		
					TROLL				
Euphausiids	1.0	4.9	11.4	39.8		41.9	51.3		
% Feeding	97	90	85	78		90	77		
N	30	41	53	38		51	25		

+Mean counts calculated from square root transformations.

iii) Troll catches

In 1965 the fall in-migration initiated soon after mid-August, earlier than normal, and continued well into September. During this period test troll CPUE (Figure 39) generally declined (excepting September 5, 6, 7, 12). After mid-September, four of seven charter days produced zero catch. In comparison, indices of total population

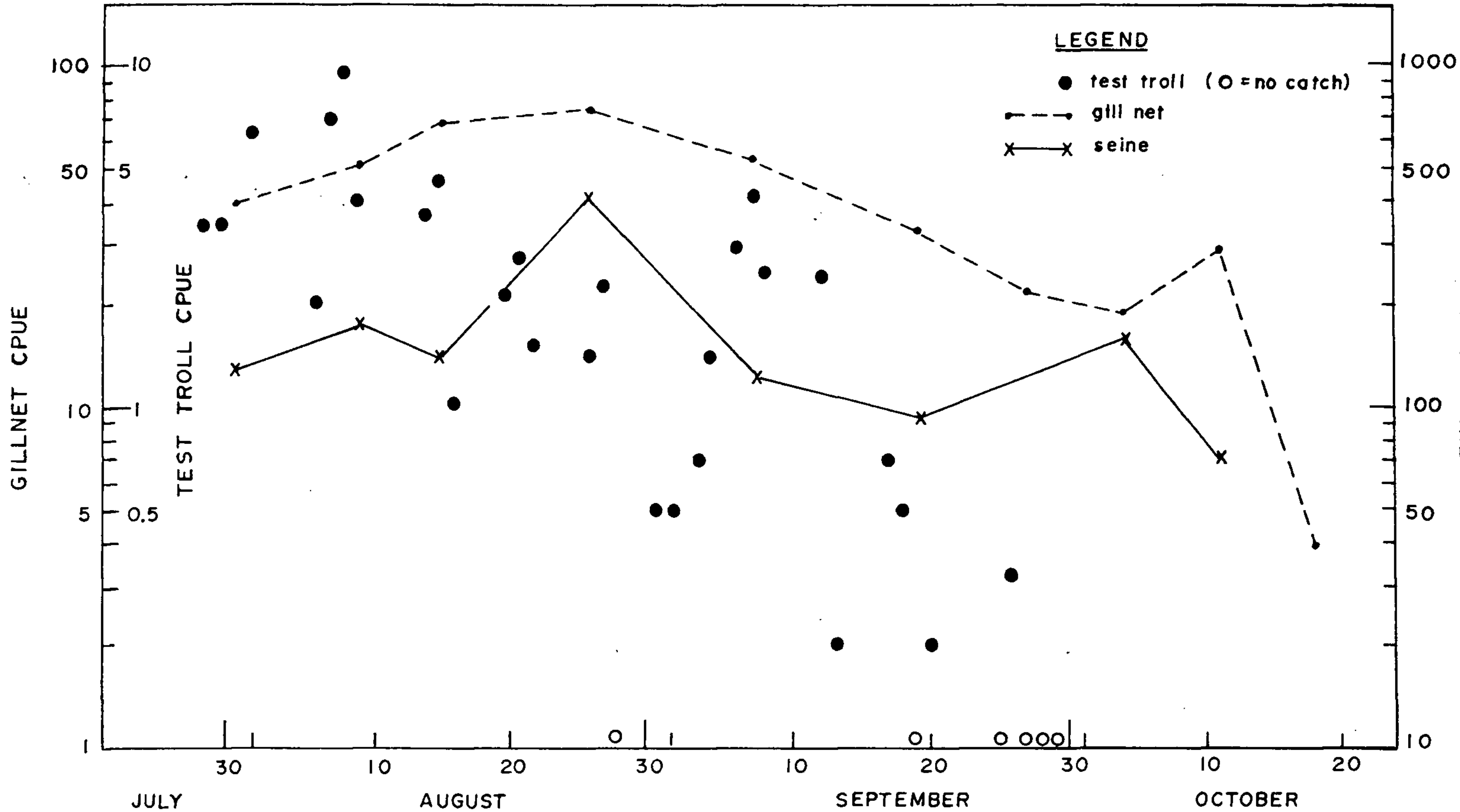

Figure 39. Comparison of daily catch per unit effort (CPUE) between test troll, gillnet and seine gear during the 1965 study period. Test troll effort equals hours fishing; gillnet and seine effort equal deliveries on first weekly fishing days.

abundance (seine CPUE and gillnet CPUE) were close to early August levels.

Throughout the period of declining troll CPUE, fishing techniques were biased toward increasing catches. Bait was fished (supposedly a more efficient lure) and trolling extended further to the west where encounters with surface "shows" of salmon feed increased. On many days repeated trolling through resting or feeding seabirds or in the vicinity of jumping or finning salmon produced negligible catches. Depth range fished should have adequately covered vertical distribution of coho (Section D) so it is unlikely that coho were passing beneath the gear. From the foregoing, it appears that coho altered their response to trolling lures, a decrease in susceptibility.

Perhaps this change relates to feeding behaviour. As suggested, the total population may have decreased feeding intensity between mid-August and September. If responsiveness to food motivates coho to aggregate in areas of feed, and this motivation declined, then continued emphasis on trolling through feed "shows" would expose lures to reduced coho densities compared to earlier time periods (less lure-salmon encounters) and thus reduced CPUE.

iv) Size composition

During most of August, coho size distributions from seine samples were quite stable (Figure 40). On August 25 and 31, incidence of coho above 4.0 kg. (8.8 lb.) increased but the left limb of the size distributions changed little. Based on mean weights, instantaneous rate of

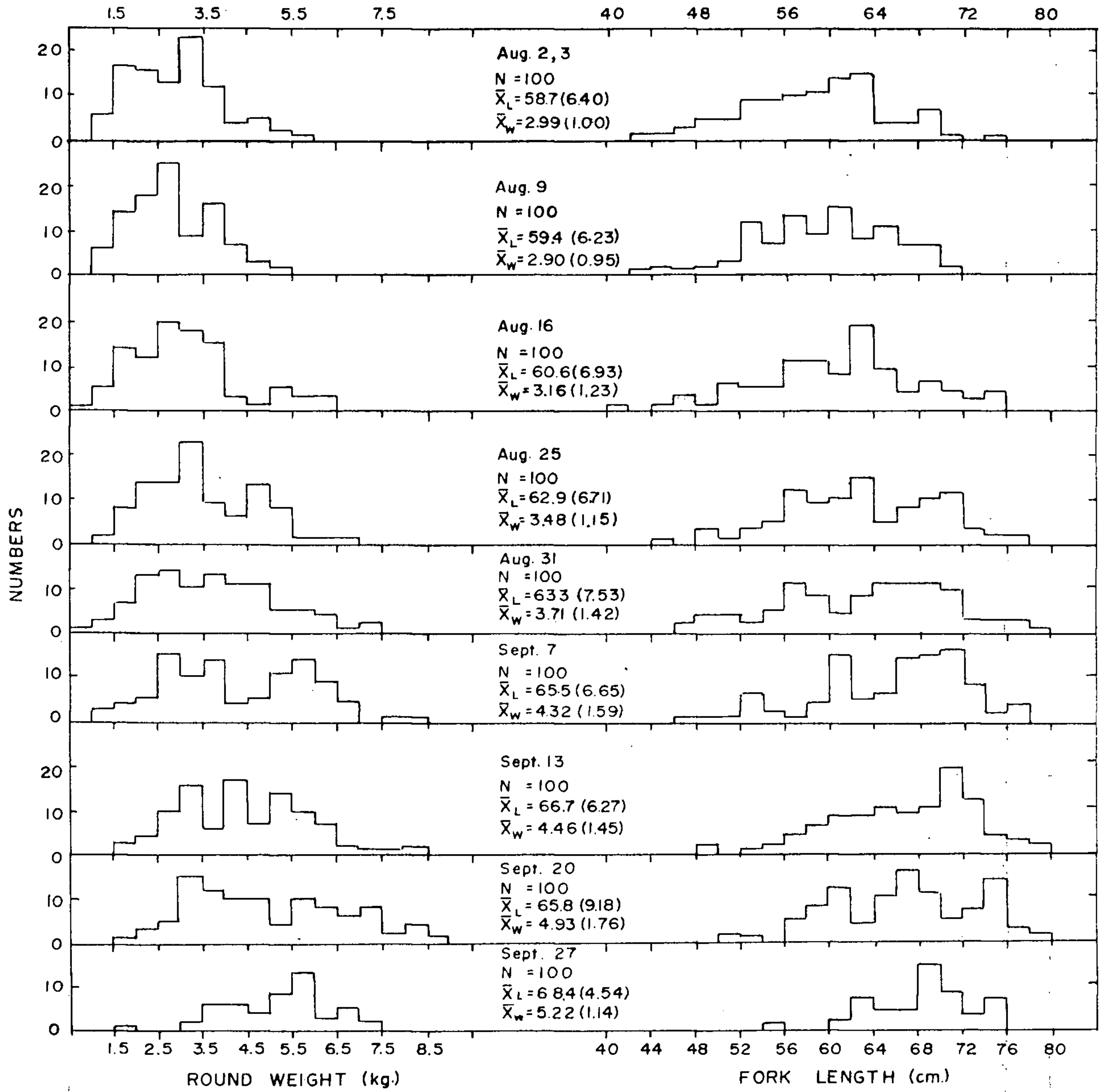

Figure 40. Frequency distributions, means and standard deviations (bracketed) of coho weight and length for weekly seine samples, 1965.

increase in coho size between August 2, 3 and 31 was 0.215 (ℓn 3.71/2.99). On September 7 the weight distribution was bimodal and thereafter coho composing the right limb increased in contributions; by September 27 fewer than 15 per cent were less than 4.0 kg. Rate of increase in coho size between August 31 and September 27 was 0.344 (ℓn 5.22/3.71).

Considering the abrupt change in configuration of size distributions in late August and the high rate of increase in weight during September compared to August, it seems reasonable to surmise that two more or less distinct size groups passed through the Strait fishery during the 1965 fall migration.

Back calculated (from scales)[4] fork lengths at first saltwater annulus give support to this observation (Figure 41). In September coho were approximately 4 cm. longer at time of annulus formation compared to August in-migrants. If time of annulus formation is similar for both coho groups (August and September in-migrants), then these data suggest late in-migrants benefitted from improved growth conditions during their penultimate ocean year, which in turn may be related to earlier out-migration timing (see page 29).

It is perhaps noteworthy that test troll gear was selective against larger coho during September, but not in August (Figure 42). Size

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[4] Back calculations based on the graphical method of Smith (1955) which assumes a proportional relationship between scale radius and fork length. From a sample of 152 coho (1962 to 1966 brood years) evenly distributed into size classes between 6 and 77 cm., log linear regression of scale radius (20° ventral) on fork length gave a slope value of b = 1.012, not significantly different from b = 1.00; thus a proportional relationship is accepted.

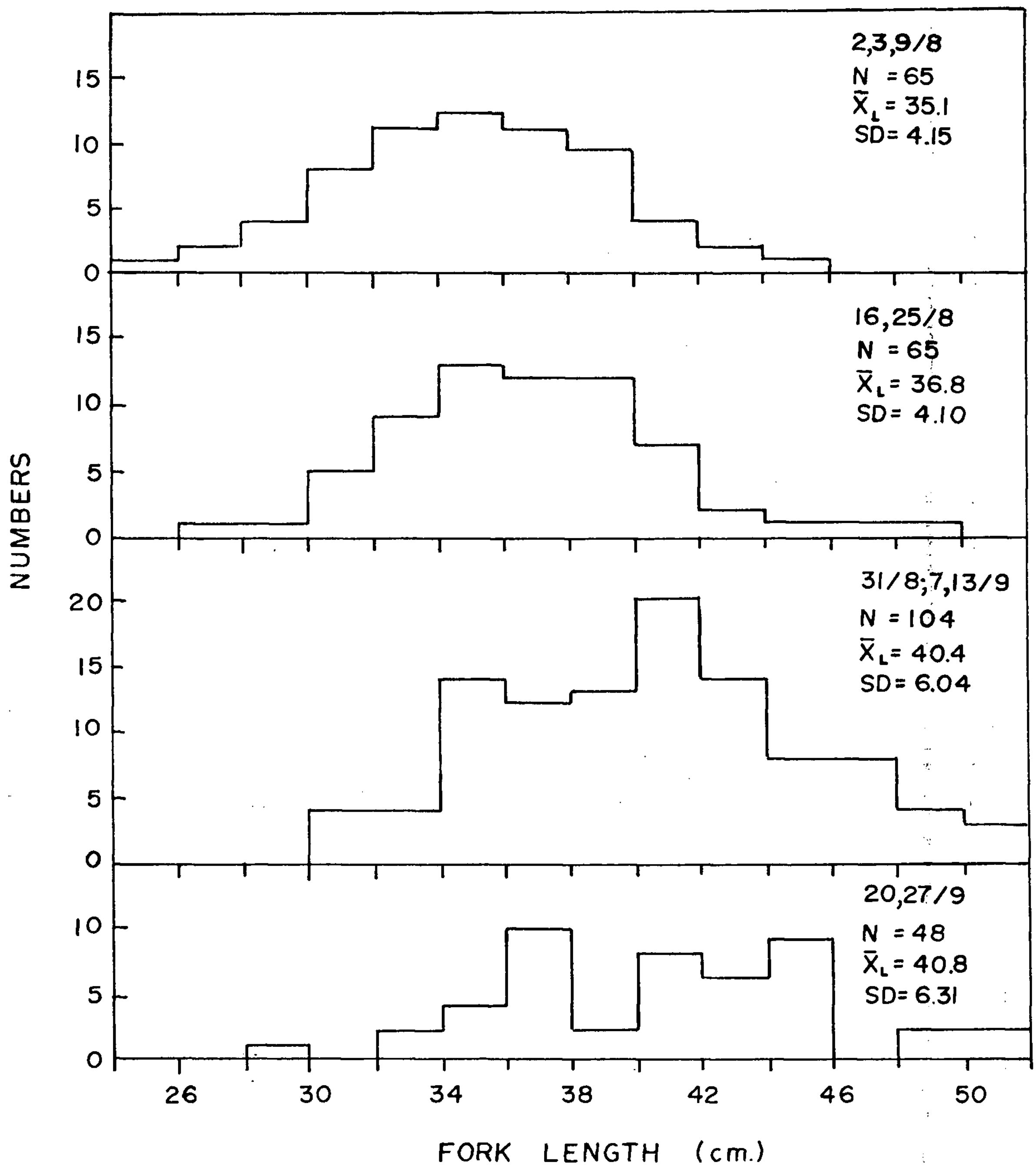

Figure 41. Frequency distributions of back-calculated coho length at time of saltwater annulus formation for combined weekly seine samples, 1965.

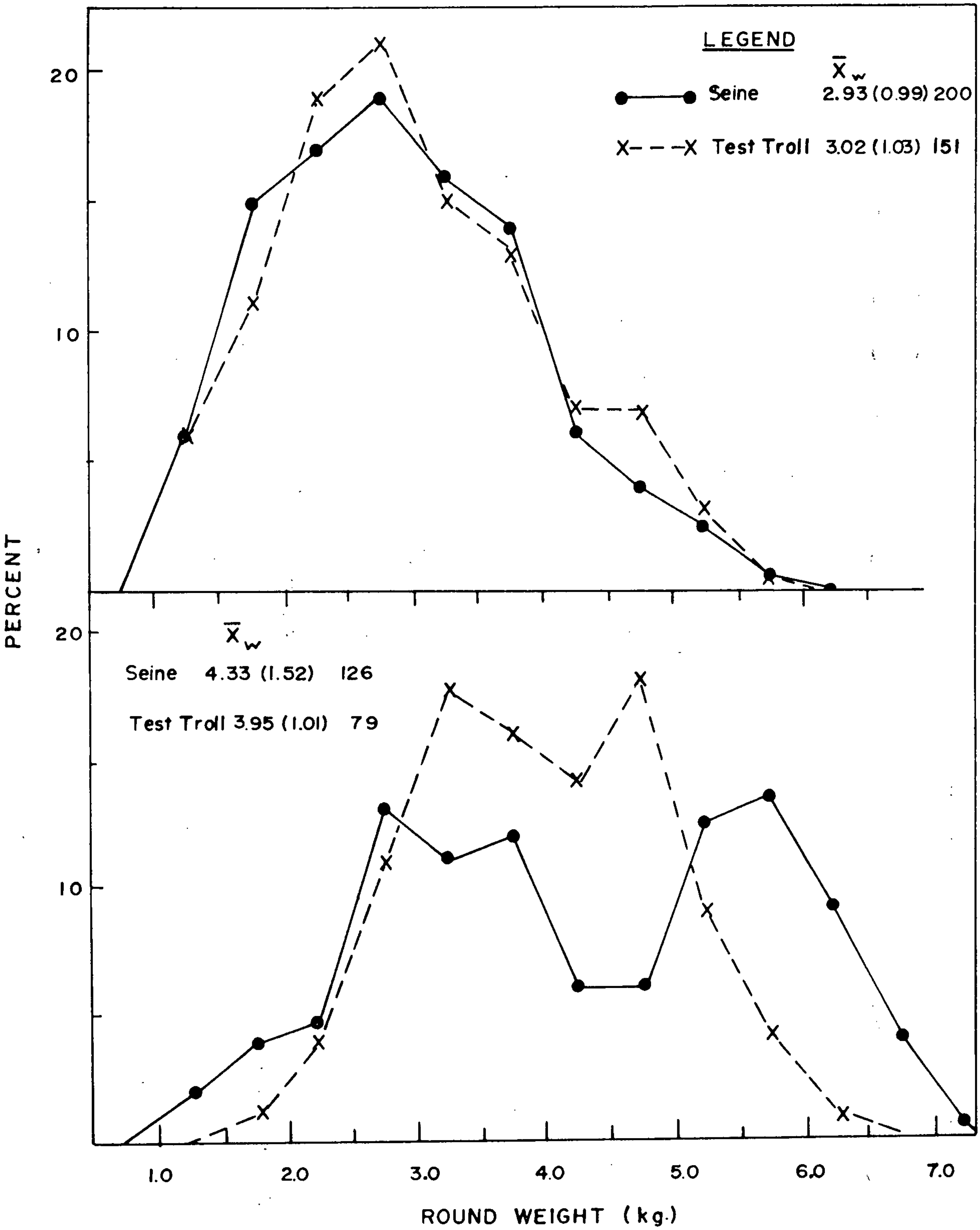

Figure 42. Weight frequency distributions for seine (Aug. 2, 3, 9; Sept. 7, 13) and test troll (July 31 to Aug. 9; Sept. 3 to 13) caught coho, 1965.

selection, in combination with declining troll CPUE, suggests larger September in-migrants are less susceptible to hook and line gear.

d) Summary

Hook and line selection for less sexually mature coho could not be demonstrated through use of analysis of covariance and inspection of daily maturity index frequency distributions. However, criteria for maturity, gonad weight adjusted for fish size and gonad weight divided by fish weight, are likely poor indicators of precise maturation stages and thus provided a poor basis on which to judge whether maturation affects hook and line selectivity.

Declines in troll CPUE suggested decreased coho susceptibility after mid-August. This may be related to reduced feeding intensity. Comparison of seine and troll size distributions infer that larger late migrating coho are less susceptible to hook and line gear.

The field data were inconclusive with regard to maturation and feeding; however, there is no doubt that coho change their responsiveness to lures later in the season, and presumably this is related to feeding behaviour.

5. Vulnerability summary.

Gillnets are directionally selective for all species, but direction and intensity of selection varies between species and between months within species.

Sequential selection was demonstrated for coho salmon and likely occurs for all species, to varying degrees, depending on intensity of selection and exploitation for each species.

Test troll lures and fishing technique were selective for smaller chinook, particularly age class 2_1.

Despite gear standardization, test trollers differed considerably in trolling line productivity and in one instance, selectivity of lures. In general, bow and deep lines (lures 6 to 4) were equally effective on coho, pink and sockeye; chinook catch was highest on bow lines. All species demonstrated changes in lure preference (spoons versus hoochie-dodgers) with increased fishing depth.

The hypothesis that hook and line gear selects less sexually mature coho at later gametogenic stages was not adequately supported; however, migrant coho did decrease in susceptibility to hook and line gear during the fall.

ESTIMATION OF EXPLOITATION

In a gantlet fishery, precise estimates of fishing mortality are complicated by numerous factors affecting availability of salmon to gear. These may relate to behaviour of the fish, characteristics of the gear or "behaviour" of the fishermen. Each species of salmon may present a different relationship. For purposes of intraseasonal managment, each factor varies in relevance to overall management objectives. The following concerns priorities which might be assigned to previously developed factors affecting exploitation, particularly in relation to inclusion in a simulation model for the Juan de Fuca fishery. Gear types are considered separately. Later, catchability coefficients are estimated for Juan de Fuca gear types on coho and pink salmon and a simple analytical technique is presented for assessing effects of gear specific regulations on reallocation of catch among competing users.

Of the four gear types present in the Strait, seines appear least variable in terms of species differences in exploitation. Effective fishing depth (page 18) covers vertical distribution of all species with the possible exception of immature chinook (Section D). Detectability or density of pink schools might give seines higher efficiency on pinks compared to other species. In terms of the gear itself, physical competition (Ricker, 1958b) may occur at higher effort levels due to the seiners' preference for fishing as close as possible to the Bonilla-Tatoosh net line (page 58; Plate 4). Provision for gear interference would appear important for purposes of simulation and was included in the intraseasonal gantlet model (ISGF) of Paulik and Greenough (1966).

Gillnets seem to present the widest variety of problems with regard to exploitation. Perhaps uppermost in importance are differences in mesh selection between and within species (Section E). Annual and monthly changes in size frequency distributions appear a major contributing factor. Todd's (MS 1969) empirical selection curves for the Skeena gillnet fishery on sockeye and pink salmon show variable rates of exploitation, u, for size groupings for each age and sex class. For instance, pink salmon between 300 and 375 mm. postorbital-hypural length had $u < 0.1$ whereas $u > 0.3$ characterized pinks over 400 mm. Clearly gillnet catchability coefficients, q, for each species (or stock) will fluctuate depending on intensity of selection.

Some correction for sequential selection (Section E) appears necessary. If mesh sizes are evenly distributed throughout the gantlet, then sequential selection will progressively reduce q moving away from the gantlet entrance (by reducing the vulnerable fraction), causing the overall rate of exploitation to be overestimated if q is assumed constant. For purposes of simulation, allowance might include area specific q values depending on intensity of selection and distance from the entrance. In addition, it might be interesting to study how compensating changes in mesh size alters overall gillnet exploitation.

Gillnets, due to shallow operating depth, could be affected by changes in species vertical distributions (Section D). Prior to spawning migrations, coho and pink during daylight hours were abundant within the top 18 meters, the approximate effective gillnet operating depth; chinook were concentrated below 27 meters. During in-migrations all species assumed similar but deeper depth distributions. Some allowance for depth effects would seem appropriate; for instance, it makes no sense to model complicated mesh selection factors if 80 per cent of a run travels below the depth range of gillnets.

For the Juan de Fuca fishery, hook and line gears have little influence on total exploitation. Therefore, management objectives regarding interseasonal escapement goals are not seriously upset by factors affecting hook and line exploitation, or, for that matter, hook and line exploitation in total. However, intraseasonal management must recognize the "value" of recreational fishing (Crutchfield, 1962; Stevens, 1969) and the need for a rational system of management strategies for decision-making models (see McFadden, 1969, for philosophical treatment of this subject). For example, one strategy might involve manipulation of commercial exploitation to attain a preset sport CPUE level based on generating greater angler participation (Stevens, 1966) in anticipation of "attainment of a tangible reward for effort...a fish-in-hand...." (McFadden, 1969).

In Juan de Fuca Strait abundance (density) of salmon escaping prior net operations, in combination with sport q, will determine CPUE. Because of the sport fisheries' location, factors affecting net exploitation indirectly affect hook and line exploitation; in addition, changes in susceptibility, such as demonstrated for coho (Section E), should be included in model formulations.

Basic input for the ISGF model were catchability coefficients from which expectations of capture (exploitation rates) for each gear type and area were calculated. In lieu of a simulation model, estimates of q are still appropriate for purposes of empirical management; for instance, in predicting gross effects of regulation changes to redistribute catch among competing users through changes in fishing intensity (e.g., Mathews and Wendler, 1968).

For pink salmon, tagging in 1959 (Vernon, et al., 1964) provided weekly estimates of initial population, N, available to Juan de Fuca gear types and weekly exploitation rates (Table XXX, cols. 4 and 5). Using N and weekly seine, Sn, and gillnet, Gn, catches, instantaneous weekly fishing mortalities are calculated (Table XXX, cols. 12 and 13) for seines,

$$F_s = Sn(-\ell n(1-u))/C \qquad (1)$$

and for gillnets,

$$F_g = Gn(-\ell n(1-u))/C \qquad (2)$$

where C equals total catch and u equals arithmetic exploitation rate.

Assuming the initial population enters at a constant rate throughout the week and assuming daily fleet sizes, f_s and f_g, are similar each weekly fishing day, d, then estimates of mortality coefficients, based on one day's fishing time, are for seines,

$$F_s^1 = (7/0.5d)F_s \qquad (3)$$

and for gillnets,

$$F_g^1 = (7/0.5d)F_g \qquad (4)$$

where 7/0.5d adjusts F to a 12 hour fishing day (Table XXX, cols. 14 and 15).

Catchability coefficients for seines and gillnets may be estimated by dividing (3) and (4) by f_s and f_g respectively (Table XXX, cols. 16 and 17). Relative gear efficiency is simply:

$$\hat{C}_{gs} = q_s/q_g \qquad (5)$$

TABLE XXX. Calculation of seine and gillnet catchability coefficients for pink salmon based on IPSFC estimates of initial population size from tagging in 1959*

Column	1	2	3	4	5	6	7	8	9	10
	Catch			Initial Weekly	Total Exploitation	Days	Weekly Deliveries		Vessels per Fishing Day	
Week ending	Seine	Gillnet	Total+	Population	Rate (3/4)	Fishing	Seine	Gillnet	(7/6)	(8/6)
July 25 (1)	4, 200	2, 000	7, 200	17, 300	0.416	3	117	357	39	119
Aug. 15 (2)	89, 750	14, 900	109, 650	386, 650	0.284	4	265	523	66	131
22 (3)	46, 550	16, 750	72, 600	1, 117, 600	0.065	2	147	23	74	162
29 (4)	583, 200	60, 800	670, 900	1, 322, 550	0.507	4	347	672	87	168
Sept. 5 (5)	321, 600	71, 100	409, 750	1, 289, 450	0.318	5	465	770	93	154
12 (6)	244, 700	27, 700	283, 400	505, 100	0.561	6	505	684	84	114
19 (7)	24, 250	5, 900	32, 950	105, 450	0.312	5	140	614	28	123

Column	11	12	13	14	15	16	17	18
	Total Instantaneous Weekly Fishing Mortality	Instantaneous Mortality by Gear Type		Instantaneous Mortality per weekly fishing day		Catchability Coefficients		Relative Gear Efficiency
		Seine (1/3·11)	Gillnet (2/3·11)	Seine	Gillnet	Seine (14/9)	Gillnet (15/10)	(16/17)
(1)	0.5379	0.3137	0.1494	1.4639	0.6972	0.03754	0.00585	6.4
(2)	0.3341	0.2735	0.0454	0.9573	0.1589	0.01450	0.00121	12.0
(3)	0.0672	0.0431	0.0155	0.3017	0.0543	0.00408	0.00034	12.0
(4)	0.7072	0.6147	0.0641	2.1508	0.2244	0.02472	0.00134	18.5
(5)	0.3827	0.0664	0.0664	0.8411	0.1859	0.00904	0.00121	7.5
(6)	0.8233	0.0805	0.0805	1.6588	0.1878	0.01975	0.00165	12.0
(7)	0.3740	0.0670	0.0670	0.7708	0.1876	0.02753	0.00153	18.0
					means	0.01959	0.00188	12.3
				excluding weeks 1 and 3		0.01911	0.00139	13.6

*Source: Vernon et al., (1964)-Cols. 1-5 from Table L-8; Cols. 7 and 8 from Table A-14.

+Totals rounded; troll catch included.

Catchabilities for seines suggest physical competition may occur at high f_s (Figure 43); q_g are relatively stable, excepting weeks 1 and 3. One seine generates approximately 0.01911 F, from $\overline{q}_s$ values excluding extremes (weeks 1 and 3). Obviously it doesn't take much of a seine fleet to effect a high removal rate. It is perhaps noteworthy that $\hat{\overline{C}}_{gs}$ of Table XXX is quite similar to $\hat{\overline{C}}_{gs}$ of Table IX calculated using daily seine and gillnet catch and effort statistics (expression (1), Section C).

Suitable tagging data were not available for coho salmon. Instead, a rough estimate of q_s was obtained by direct comparison of average daily seine catch and effort during September for 1961 to 1968, (Figure 44) using the method of Ricker (1940; 1958b, p. 158) to first estimate u, and from expression (1) and f_s, to estimate q_s. This technique assumes abundance[1] has remained fairly constant over successive years (Figure 45), there is a uniform within season pattern of recruitment and effort between years, and assumptions with regard to Type IA fisheries (Ricker, 1958b) are applicable. From Figure 44 ratios of maximum and minimum vessel counts (90/20) and their adjusted catches (from the line) are used in Ricker's expressions 7.1 and 7.2 to give for f_s of 20, u equals 0.26, F_s equals 0.3011 and q_s equals 0.01505 (F_s/f_s).

Catchability coefficients for troll and sport gear for pinks and for gillnet, troll and sport gear for coho (Table XXXI) may be estimated by dividing q_g or

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[1] Abundance calculated using the method of Hourston, et al., (1965, p. 35) but substituting gillnet catch per delivery on first weekly fishing days for their weekly seine catch per delivery and summing four weekly relative abundance estimates to obtain a monthly estimate of relative abundance.

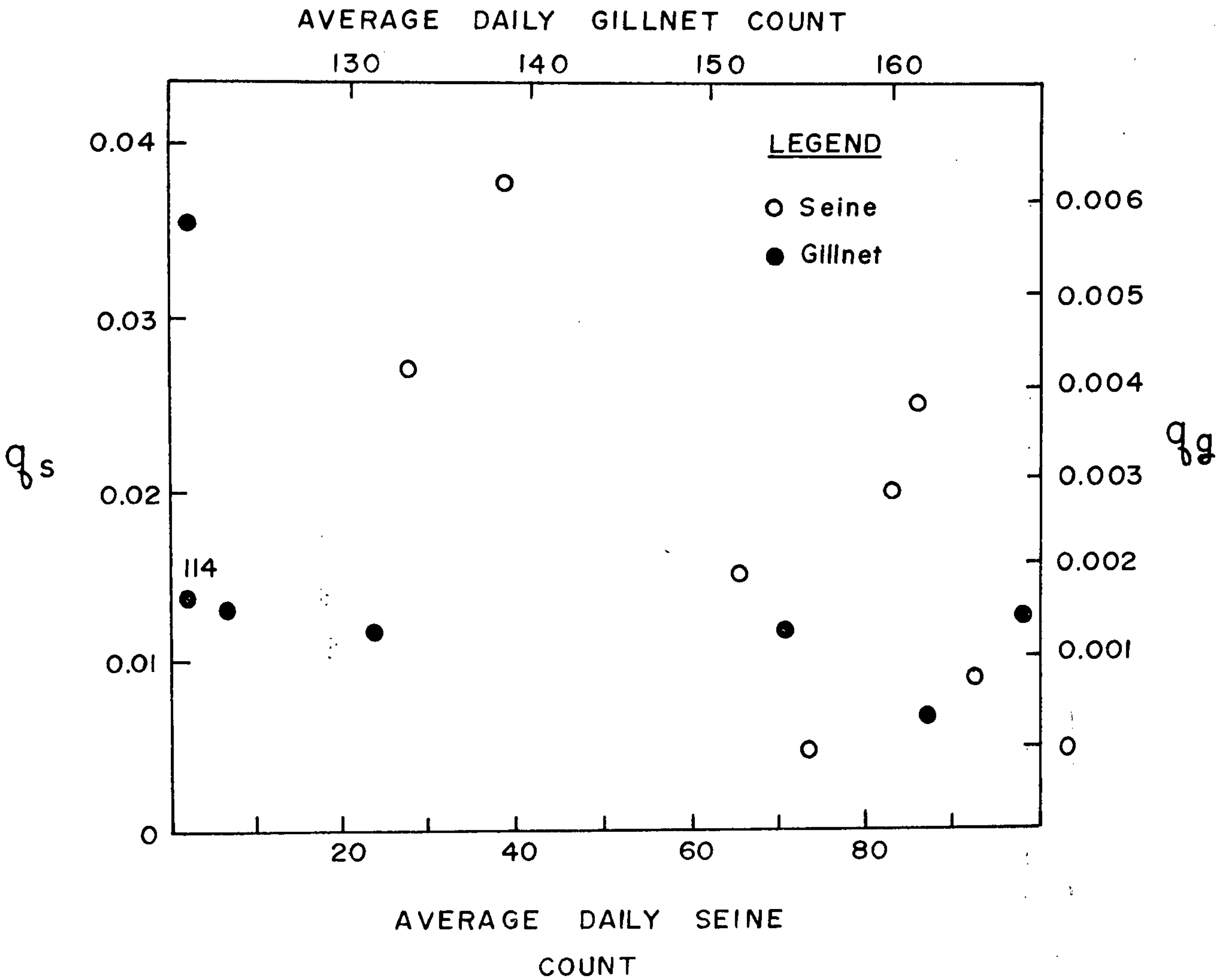

Figure 43. Estimated weekly catchability coefficients on pink salmon for seine, q_s, and gillnets, q_g, in Area 20, 1959.

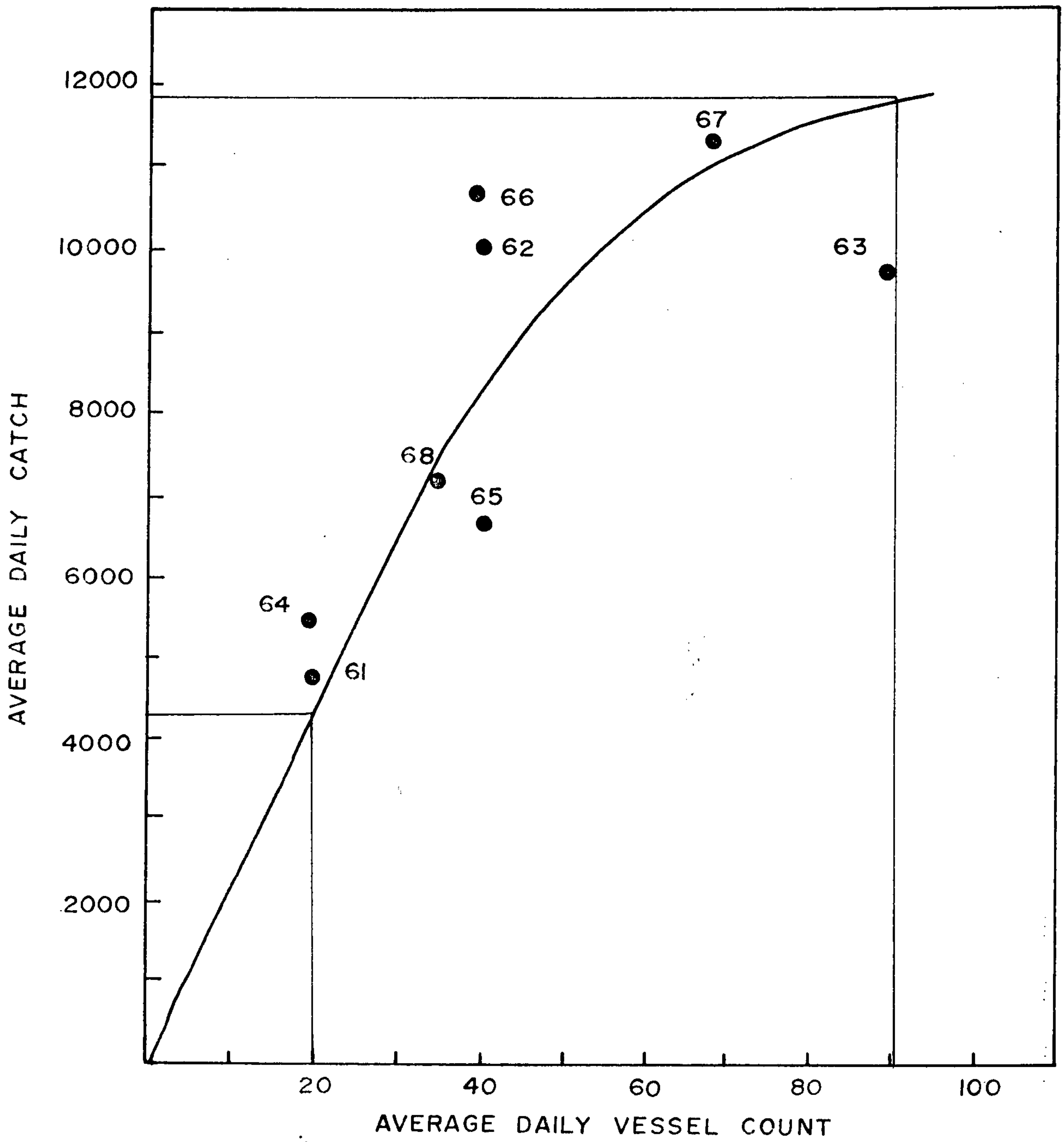

Figure 44. Average daily seine catch of coho versus daily seine count for September, Area 20, 1961 to 1968. Line fitted by eye.

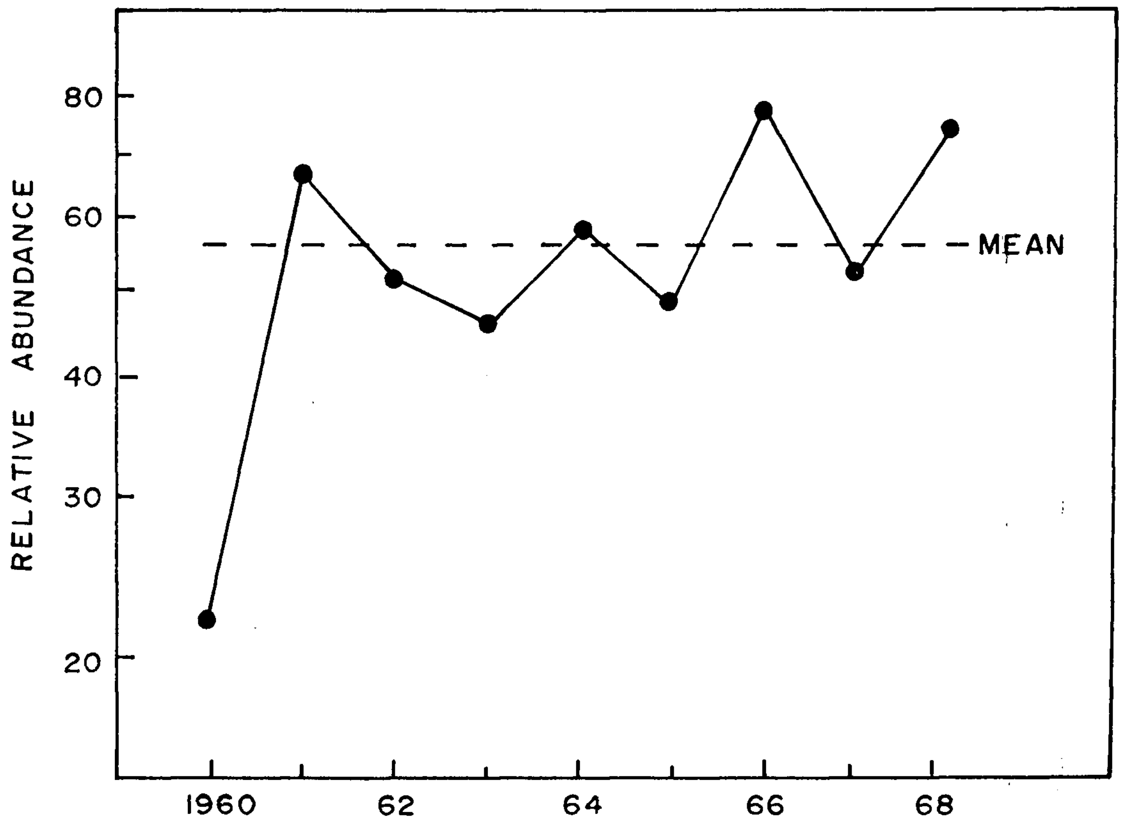

Figure 45. Estimated relative abundance of coho salmon for September in Juan de Fuca Strait (Area 20), 1960 to 1968. Based on gillnet catch per delivery on first weekly fishing days.

q_s by the appropriate relative gear efficiencies, $\hat{C}$, from Appendix Tables 1C, 3C and 4C (coho $\hat{C}_{gs}$ equals 4.1, August-September mean).

TABLE XXXI. Estimated catchability coefficients by gear type for coho and pink salmon.

	Pink	Coho
Seine	0.01911*	0.01505
Gillnet	0.00139*	0.00367
Troll	0.00058	0.00044
Sport	0.000040	0.000058

*From Table XXX, means.

Shepard and Withler (1958) estimated sockeye q_g for Skeena gillnets when linen nets were in vogue. Their average value was 0.00079 (1946 to 1950) and, when corrected for a two-day weekend closure, 0.00111. Based on estimates of relative efficiency between nylon and linen gillnets (nylon > linen) averaging approximately 2.7 (Pycha, 1962; Todd, MS 1969) Skeena q_g for nylon gillnets would be 0.00300, not too dissimilar from my estimate for coho q_g of 0.00367 for Juan de Fuca nylon gillnets.

Situations often arise where catch from a finite population must be redistributed among competing users. In many instances management is under pressure to enact "immediate" inter or intraseasonal changes and there is thus little time for sophisticated analyses to assess the relative value of particular strategies. In some cases, however, existing data may be adequate for a "ball park" judgment, particularly when reasonably accurate data on effective effort (and its distribution) and catchability coefficients are available, when natural mortality can be considered negligible and when the kind of competition between gear types is known or can be reasonably assumed (Beverton and Holt, 1957, section 8.3, discuss gear competition in relation to a gantlet fishery). The following symbols are used:

C_1 catch by gear type benefitting from regulation change (the recipient gear type)

C catch by other gear(s)

N initial population

F_1 fishing mortality coefficient corresponding to recipient gear

F fishing mortality coefficient corresponding to other gear(s)

F_t equals $F_1 + F$

f_1 effective effort units of recipient gear

$f_2 \ldots f_n$ effective effort units of other gears

q_1 catchability coefficient for recipient gear

$q_2 \ldots q_n$ catchability coefficients for other gears.

Assuming,

$$F_1 = q_1 f_1 \qquad (6)$$

$$F = q_2 f_2 + \ldots . q_n f_n \qquad (7)$$

then,

$$u_1 = -\ell n\ (1 - e^{-q_1 f_1}) \qquad (8)$$

$$u = -\ell n\ (1 - e^{-(q_2 f_2 + \ldots . q_n f_n)}) \qquad (9)$$

$$u_t = -\ell n\ (1 - e^{-F_t}) \qquad (10)$$

where u_1, u and u_t are respectively, arithmetic exploitation rates for: recipient gear, other gear(s), all gears.

Let us assume that effort by the other gear(s) is to be eliminated by regulation and that previous to the change all gears were competitive in time and space. Catch by the recipient gear before the change is,

$$C_1 = Nu_tF_1/F_t \tag{11}$$

and after,

$$C_1^1 = Nu_1 \tag{12}$$

Proportional increase in recipient gear catch is obviously,

$$P = (C_1^1 - C_1)/C_1 \tag{13}$$

Instead of enacting the change to measure P, it seems logical to estimate P, if f and q values are available, by using previous relationships with F and u, letting N = 1, and substituting (11) and (12) into (13),

$$\hat{P} = \frac{u_1 - u_tF_1/F_t}{u_tF_1/F_t} \tag{14}$$

$$\hat{P} = \frac{u_1 F_t}{u_tF_1} - 1 \tag{15}$$

For example, if F_1 is estimated to equal 0.4 and one hundred units of competing gear of average q equal to 0.004 are to be eliminated by regulation (F = 0.4 and F_t = 0.8), then by entering F on the abscissa of Figure 46 and by following the F intersect with the F_1 isopleth of 0.4 to the ordinate, read $\hat{P}$ = 0.20. In this case the recipient gear would increase its catch by 20 per

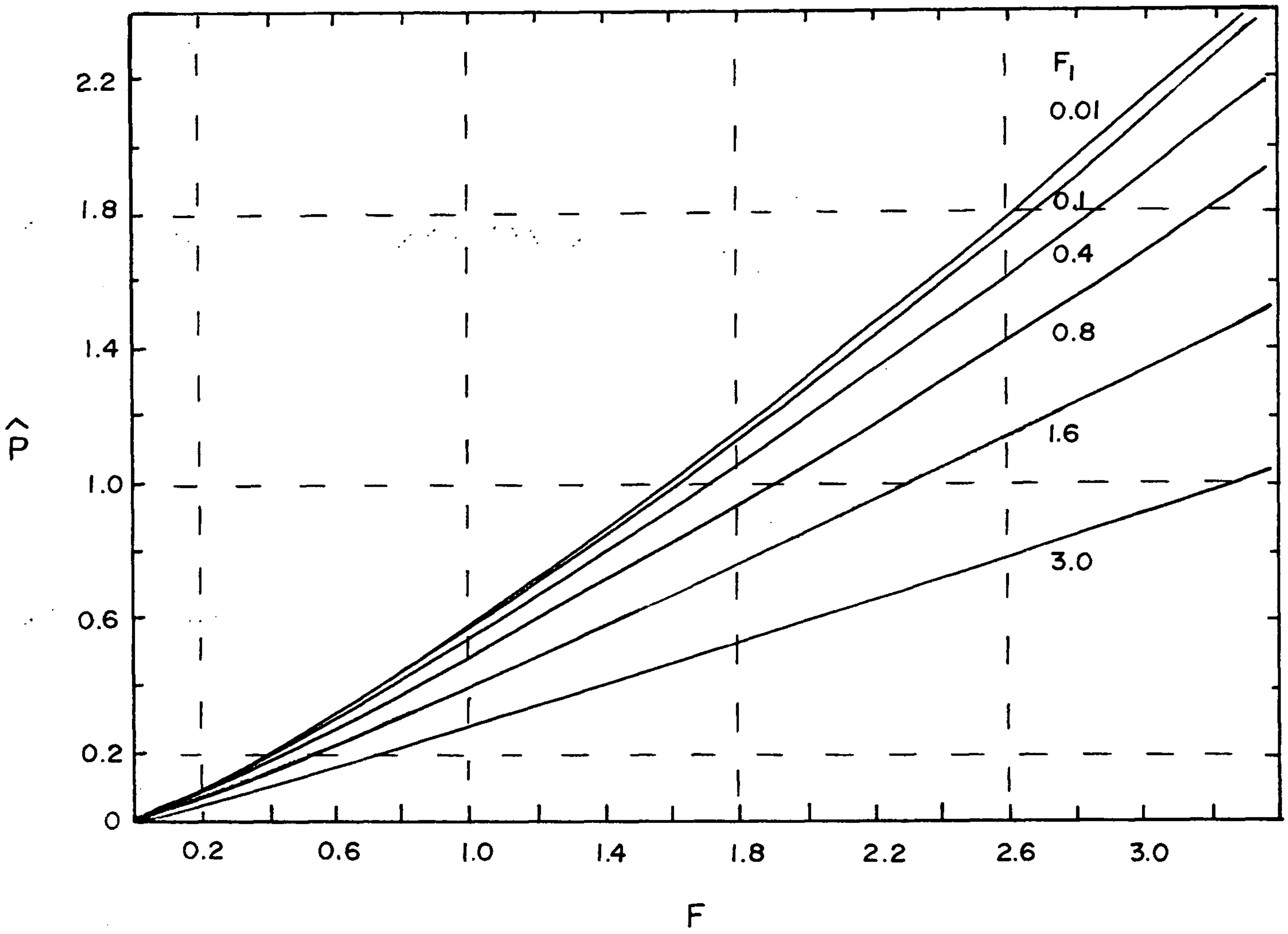

Figure 46. Graphical estimation of proportional change in catch of recipient gear, $\hat{P}$, given fishing mortality coefficient of recipient gear, F_1, and change in fishing mortality coefficient, F, of competing gear(s).

cent. If the competing gear is only partially reduced, enter the change in F on the abscissa to obtain $\hat{P}$.

In a gantlet situation some of the regulated gear might be ahead of the recipient gear. Thus, N available to the recipient gear, after a regulation change, would be higher and additionally F would be reduced in the region of competition. Conversely, elimination of one gear type from direct spatial competition might result in its relocation ahead of the recipient gear. Here $\hat{P}$ might be reduced to zero or be negative depending on numbers of units taking this strategy. Finally, in many gantlet situations the assumption of perfect spatial and temporal competition is invalid. For instance, consider Juan de Fuca spatial distributions of gillnet and sport gear (Figure 14, sport inshore, gillnet offshore) and also weekly timing of these gears (sport primarily on weekends, gillnets on weekdays). Here $\hat{P}$ will obviously be maximal. This is not to say, however, that calculation of $\hat{P}$ maximum is unnecessary, for at least a bench mark is established and the fishery manager knows an upper limit to his proposed regulation change, often a useful statistic in the politics of bargaining.

IMPLICATIONS FOR MANAGEMENT

An important point arising from this study is the need to consider sport fisheries in the design of inter and intraseasonal fishing strategies. For example, after 1960 Sooke-Victoria sport effort increased at a rate of 21 per cent compounded annually, clear indication of latent recreation demand. An unfortunate corollary of this development was increased political pressure by sports representatives for a "fair share" of the total catch, culminating in the 1967 closure to commercial fishing of eastern Area 20 and all of Area 19. This caused displacement of perhaps 50 gillnets and 10 to 20 trollers; but displacement was ahead of the closed area, thus abundance to sport gear was, if anything, lowered rather than enhanced. Perhaps prior reflection on probable exploitation rates, gear distributions, and fish and fishery timing might have changed this decision. Based on catchability coefficients of the previous section and probable gear levels, the competing gears' exploitation coefficient would be less than 0.2. Assuming <u>all</u> competing commercial gear left Area 20 (instead of relocating to the west), the most optimistic sport catch improvement would be less than 10 per cent (Figure 46). Clearly we cannot afford to develop recreational policies out of uninformed political pressure.

However, as recreational managers, we are seriously handicapped in solving political situations, for we currently lack defined objectives. Some stress economic valuation, a cost-benefit approach (Crutchfield, 1962; Pearse and Laub, 1968; Stevens, 1969); others, on the recreational side, validly stress quality intangibles, "The room it [sport fishing] offers for personal growth, a gradual development of skill and keeness of perception...." (Haig-Brown, 1956).

Questions arise from all sides. What is the importance of accessibility, sport fishing facilities, species mix, fish size? How important are fish, or their capture, in the total recreational experience? In situations of competition, how do we weigh the quality of sport fishing against a man's livelihood, what magnitudes of sacrifice and gain suffice, does the highest net economic value decide? These are questions facing economists, biologists and politicians; their decisions must be based on a sound philosophy, a philosophy which must now be developed.

DISCUSSION

There is no doubt that gantlet fisheries qualify as systems problems (Paulik and Greenough, 1966; Greenough, MS 1967; Paulik, 1969), and the Canadian Juan de Fuca fishery is certainly a complex example. At present, three commercial gears, seine, gillnet and troll, annually harvest 1.88 million of all salmon species (Table I); sport effort exceeds 35,000 boat days, one of the province's largest recreational fisheries.

Considering the complexity of gear, gear distribution and salmon species involved, it is not unexpected that many variables affecting exploitation must be clarified for purposes of intra and interseasonal management (Paulik and Greenough, 1966). This study investigated distribution of fishing gears, seasonal timing of exploitable salmon, accessibility of salmon to the gears (horizontal and vertical distributions; migration rates), vulnerability of salmon to the gears (gillnet and troll selectivity; susceptibility to hook and line gear), and relative gear efficiency.

Management and Salmon Availability

Fishing gears extend 90 miles along the Vancouver Island shore, from the Bonilla-Tatoosh net line to Victoria (Figure 14). Seines head the gantlet followed by a loose offshore distribution of gillnets and trollers and, finally, the inshore sport fishery in eastern Strait waters now closed to commercial fishing.

When stock or run timing overlaps, problems of intraseasonal management are compounded. Juan de Fuca chinook timing overlaps with all species, although distinct peaks may occur; stock timing and definition for chinook is essentially undocumented. Some coho, by milling at the entrance in August (Milne, et al., 1958; 1959), undergo repetitive exploitation during peak and declining Horsefly-Chilko-late Stuart sockeye runs, and during building Adams River and odd year pink runs. Peak coho in-migration normally occurs after the pink run declines. The latter portion of the coho run and on non-pink and "off" Adams River years, the whole run are generally distinct from timing of other species. Annual fluctuations in coho timing, which are poorly documented, probably reflect mixture and changing proportions of many stocks both artificial and natural. In some years pink and sockeye timing overlap. This seriously complicates IPSFC management, particularly in relation to escapement requirements and division of catch between Canadian and American fishermen. Sockeye division was impossible in 1967 (IPSFC, 1968). Finally, coho and perhaps chinook out-migrations coincide with the fall net fishery. In some years incidental catch (gilling) of immature coho by seines is high.

Overlapping of the timing of chinook, coho, pink and sockeye runs, as well as intermingling of stocks within runs, presents substantial management problems. Chum are the only species with relatively unique timing, but most major chum stocks are thought to favour Johnstone Strait (Neave, 1966b; Aro and Shepard, 1967). When intermingling of species and stocks within species occurs, optimum interseasonal strategies for each component are seldom compatible; therefore, compromise is a necessity (Paulik and Greenough, 1966).

On interseasonal strategies, Royal (1953) stresses that maximum productivity from salmon runs is achieved by favouring the most productive stocks. Paulik et al., 1967, gives analytical support showing that maximum total sustained yield from three stocks whose reproductive potentials and replacement sizes were variable (modification of the example given by Ricker, 1958a) was highest using a common exploitation rate that gave total escapement equal to the sum of optimum escapements for each stock. The weakest stock was driven to extinction and the common exploitation rate was only slightly below the rate which would maximize total equilibrium catch of the most productive stock. Thompson (1959; 1962), on the other hand, favours regulation to maintain a wide diversity of genotypes, so the total run remains adaptable in the face of environmental variability.

For Fraser sockeye, the Salmon Commission stresses "uniform fishing mortalities for each annual population..." (IPSFC, 1964) for minimum interference with cyclical dominance, thought to be maintained by depensatory predation in the lacustrine environment (Ward and Larkin, 1964).

Long term yields based on other strategies (and effects of environmental variability on yields) for single stock and multiple stock situations have been analyzed through deterministic and simulation procedures by many authors (Ricker, 1958a; Larkin and Hourston, 1964; Paulik et al., 1967; Larkin and McDonald, 1968; Tautz et al., 1969). In general, best extended catches occurred when escapements were completely stabilized at an escapement associated with maximum equilibrium catch.

Ideally, a unique annual fishing mortality exists for each species and component stock (Paulik and Greenough, 1966) based on stock or species specific empirical (e.g., Shepard and Withler, 1958) or analytical stock-recruitment considerations. In practice, appropriate intraseasonal strategies are difficult, at times impossible, to execute due to intermingled timing, limited regulatory options available to the manager (basically time period and area closures), and economic pressure for a relatively stable annual catch. It would seem, therefore, that further interseasonal studies might attempt analyses on multiple species and stock tolerances to sub-optional strategies, with the overview of optimizing total production commensurate with the constraints of intraseasonal management alternatives.

For coho and chinook passing through the Strait we lack necessary data for inter and intraseasonal management. Initially, stock definition and timing are required. In this respect the Informal Committee on Chinook and Coho has planned a comprehensive coast-wide juvenile marking program which, if implemented, would provide necessary information. Of equal importance, however, is examination of stock-recruitment relationships for natural stocks of these species. For instance, certain data (Lister and Walker, 1966; Mundie, 1969) suggest coho smolt production may be tied to available stream habitat, rather than escapement, and that environmental factors such as summer stream flow have the most pronounced effect on production (McKernan et al., 1950; Wickett, 1951; Smoker, 1953; Anon. 1965). Because of this, many coho stocks may presently be characterized by overescapement (D.B. Lister, personal communication) and coho stock-recruitment may be asymptotic, such as Ricker's (1958a) curve F. Certainly these theories should be pursued.

Horizontal distributions (Figures 15 and 17) provided a rough indication of migration route through Canadian waters. Salmon on spawning migrations and out-migrations (coho) favoured offshore Canadian waters, perhaps related to directionality and consistency of offshore current patterns. Immature chinook were higher in abundance near shore. Adjacent to Sooke, all species favoured inshore waters, providing reasonable explanation for past success of Sooke traps and relatively high catch success of Sooke sport gear. All species avoided Canadian waters east of Race Rocks.

Migration rates, based on past tagging studies (Vernon et al., 1964; Verhoeven and Davidoff, 1962; Milne et al., 1958; 1959) are not totally adequate. With exception of pink salmon (Vernon et al., 1964) data on within-season changes in migration rate are incomplete. Wood (MS 1966) noted Rivers Inlet sockeye considerably accelerated migration as the spawning run progressed. Juan de Fuca data of Milne and co-authors suggests coho may behave similarly and, in addition, pass through a milling phase at the entrance during August. Therefore, generalizing to a single seasonal migration rate may be an over simplification which could lead to serious management complications, particularly in relation to "pulsing" salmon[1] through to the Sooke sport fishery or to subsequent commercial fisheries (San Juan Islands, West Beach, Point Roberts) and in estimating exploitation. For the Victoria (Area 19B) sport fishery, significantly increasing abundance to sport gear through manipulation of commercial exploitation seems fruitless as it appears there are oceanographic barriers to migration through these waters. To refine migration rate and route information, ultrasonic tracking methods (Johnson, 1963) might prove rewarding.

From daytime vertical distributions (Figures 18, 19, 21) estimated from test troll depth of capture data, it is apparent that species differ in depth relationships and that accessibility to surface operating gillnet (14 m.) and sport gear (9 m.) is by no means total.

Coho, for the most part, were surface oriented (above 27 m.) in contrast to the depth orientation of chinook (below 36 m.). Pinks, in June and July, favoured the surface but during the main in-migration changed to a mid-depth level (18-36 m.) as did sockeye and also coho during their spawning migrations; maturing chinook were similarly distributed. From these observations it was postulated that mid-depth preferences might relate to certain migration "cues" necessary for directed spawning movements.

Daytime vertical shifts were not extreme, certainly not as pronounced as nighttime surfaceward movements exhibited by sockeye and chum on the high

[1] Here, I mean timing the commercial fishery so that escaping daily cohorts present off Sooke on weekends, when sport effort peaks, would have had minimum commercial exploitation. Clearly this depends on accurate estimates of migration rates.

seas (Manzer, 1964). Little is known of diurnal vertical shifts in coastal waters, particularly on migration routes. This seems a useful direction for future studies because many coastal gillnet fisheries (Skeena, Rivers Inlet) operate both night and day. Vertical shifts, if present, might have considerable impact on exploitation.

Chinook appeared to be vertically stratified on the basis of maturity (Table XV). Conceivably, maturity level varies between stocks in chinook and other species. Hence vertical distributions might differ between stocks giving rise to uneven stock exploitation from constant fishing effort.

Net operation apparently depressed depth distributions of coho and pink salmon on commercial fishing days (Figure 22). However, it could not be determined whether differences were caused by salmon actively avoiding seines or by selective nighttime gillnet removals of surface salmon without subsequent daytime replacement.

Of factors affecting vulnerability of salmon to gear, selective action of gillnets has long been suspected of affecting population structure (Milne, 1955b; Killick and Clemens, 1963; Larkin and McDonald, 1968; Todd, MS 1969) perhaps through inheritance of age of return within age classes (Godfrey, 1958) or between age classes (Peterson, 1954; Larkin and McDonald, 1968). Juan de Fuca gillnets were size selective on all salmon species, but there were considerable differences in degree and direction of selection between species and between months within species (Figures 25 and 27).

Sockeye and coho underwent consistent positive selection, although during

August, in years when mean weights were over six pounds, directional selection fell to near zero or was slightly negative. September coho in-migrants were 1.5 pounds heavier than in August (6.2 lb. versus 7.8 lb.). Selection, however, remained positive and of the same intensity as in August, reflecting change to fall mesh nets, about one inch larger (stretched measure) than those used during August.

Chinook selection ranged widely from high positive to high negative probably due to changing age compositions. Van Hyning (MS 1968, p. 274), using marked chinook recovered in the Columbia gillnet fishery and at various hatcheries, showed positive selection on two and three-year fish and negative selection on four-year chinook; he makes no reference to mesh sizes. In summing up, he comments that Columbia gillnets tend to select medium sized chinook and thus have not inflicted damaging trends in fecundity.

Smaller pink salmon were exploited at a higher rate (negative selection) in August, which at first seemed odd considering similarity of pink (5.9 lb.), sockeye (5.8 lb.) and coho (6.2 lb.) mean weights. Pinks were heavier per unit length than either sockeye or coho which suggested greater girth. Direct girth measurements of pink and sockeye by Todd supported this observation. It is possible that pinks above the population mean weight exceeded the optimum girth-mesh perimeter ratio (McCombie and Berst, 1964) causing a predominance of small pinks in the gillnet catch.

Chum, averaging 11.5 pounds, were consistently too large for gillnets.

For all species, high correlations between selection index and fish weight suggest that fleet mesh distributions have remained relatively constant since 1958.

Thus, gillnetters fail to compensate for yearly fluctuations in fish size (Figures 24 and 26) and annual changes in size distributions will have a significant effect on gillnet exploitation.

Clearly, for all species, samples from the gillnet catch will be biased with respect to size and age composition. This bias may extend to sex composition if sexual dimorphism occurs (Todd, MS 1969).

Long term effects of selection on fecundity, production and so on are unclear. Todd suggests, for the Skeena gillnet fishery on sockeye, that periodic closures (with accompanying high escapement), constant fleet mesh distributions and yearly fluctuations in size and age composition would soften the impact of selectivity upon characteristics of the escapement. Killick and Clemens (1963) reach essentially the same conclusion for Fraser sockeye and point out that through eleven to twelve generations, races of the four major cycles have maintained consistent mean sizes. Larkin and McDonald (1968) included selection factors for four, five and six-year old sockeye as well as direct inheritance of age of return (jack proportion held constant) in their simulation of Skeena sockeye population biology. Based on these precepts it was not unexpected when, after fifty simulated years, six-year sockeye were eliminated and five-year sockeye were reduced to about two per cent of the total run. By contrast, the natural population did not show such a gross change in age structure although simulated gillnet selection was realistic. Larkin and McDonald speculated that "there are factors of inheritance of age of return, or environmental determinants of age of return that sustain the proportion of fives in the natural populations." Of a perhaps departing view are preliminary data of Ricker (1968 MS), which show the incidence of jack sockeye has significantly increased for some Fraser stocks, in particular on the Birkenhead. Gillnet exploitation of jacks is negligible (Peterson, 1954; Verhoeven and Davidoff, 1962). Ricker comments that long term effects on age composition are certainly plausible and bear further investigation.

Because coho stocks are composed of a single dominant age class, we perhaps shouldn't be as comfortable in our assessments of gillnet selectivity. For example, Juan de Fuca gillnets consistently select larger coho and large size of returning coho appears correlated with earlier out-migration timing (pages 29 and 156 ; Figure 41). Thus, it is conceivable that gillnet selection over the long term may favour late out-migrating coho because they return at a smaller size, thus indirectly extending the period of residence in Gulf of Georgia waters, to the detriment of west coast troll productivity.

It seems appropriate that we give further study to the problem of gillnet selectivity. The Juan de Fuca fishery provides a unique opportunity to collect both unselected and selected samples by sampling seine catches from the entrance and gillnet catches either from the entrance or from Sooke, depending on how the problem of sequential selection is to be treated. Experimental nets could easily be operated west of the Bonilla-Tatoosh line on unexploited (by gillnets) salmon. Todd (MS 1969) provides an excellent review of such a field experiment on selective action of the Skeena gillnet fishery for sockeye (he substituted escapement sampling for the pre-exploitation sampling).

Hook and Line Selection

In retrospect, demonstrating species and size selection of hook and line gear can scarcely be considered profound, rather it is the mechanisms of selection that demand investigation. However, for interseasonal management, it is important to demonstrate hook and line selectivity; it is relevant to ascertain effects of fishing techniques on selectivity; and conceivably the better studies (Pitre, 1970) will provide sufficient information to alleviate certain troublesome problems such as capture and release of pre-season coho and sub-legal sized chinook. Furthermore, there are certain management implications with respect to changes in susceptibility. For example, to enhance sport catch success on coho in the Juan de Fuca fishery, best success per unit increase in abundance would accrue through development of early (July-August) in-migrating stocks, as they appear considerably more susceptible to hook and line gear. For Columbia River chinook Mathews and Wendler (1968) noted hook and line susceptibility was five times higher on spring run chinook compared to the fall run. This, combined with fishing intensities and certain cost and price data suggested spring run chinook would produce a higher net economic yield if harvested by sport gear, whereas less catchable fall chinook were best (economically) harvested by commercial gear.

Anyone who has viewed the weird variety of lures available to sports enthusiasts must surely wonder who is being "hooked". Until we know what properties of lures, or their operation, stimulate attack and how changes in internal motivation affect behaviour towards lures, we will not understand hook and line selection and will be severely limited in our management capabilities.

Clearly, the mechanisms of lure selection represent an unexplored and most certainly challenging field.

A Simulation Approach

Systems analysis first involves determination of those variables which are important in the system. Ross (1967) adds the following phases applicable to systems study; definition of functional relationships between selected entities (parsing phase), specification of mechanisms of change within the system (modelling phase), and finally analysis involving some solution of the model for specified objectives and validation of model outputs against those of the real world. Dale (1970) discusses fidelity in modelling, where high fidelity (generality "implies that the model resembles the real system for a wide range of states and changes in state...".

Existing intraseasonal simulation models (Royce et al., 1963; Paulik and Greenough, 1966, detailed in Greenough, MS 1967) lack certain basic components shown to be important in the Juan de Fuca situation. However, in fairness it should be noted that the model of Royce et al., (1963) was intended primarily to assess economic consequences of gear limitation in American waters and how this would affect rate of exploitation and division of sockeye and pink catch between Canada and the United States; and the purpose of Paulik and Greenough's intraseasonal gantlet fishery model (ISGF) "was not to study any specific fishery, but rather to study how different types of management policies, particularly management decision rules, data collection subsystems and information transmission subsystems affect biological and economic [sic] performance of a fishery." (Paulik, 1969).

Neither simulation provided for a sport fishery although most gantlet fisheries have or soon will have large numbers of vocal sports enthusiasts whose demands will place considerable pressure on standard management procedures.

Second, no provision was made for seasonal changes in availability to gear, particularly gillnet selectivity. In principle, the ISGF model seems well suited to such an addition. Perhaps through modification of the management sector the hypothetical management agency could input appropriate factors of selectivity to adjust catchability values used in the fishery sector, based on catch sampling for species size distributions. Additionally, it might be valuable to modify the gear-decision-making sector so gillnet fishermen could vary mesh sizes based on size of incoming salmon and known mesh selection factors, information on size coming from the management sector.

A third problem, noted by Greenough (MS 1967) is that the three target species stocks are assumed to enter simultaneously; thus, if stocks entered separately (which occurs in the Juan de Fuca fishery), each group would be divided into catch and escapement as if it was composed of three stocks. Considerable modification would be necessary to correct this problem. Greenough notes several related problems as well as the difficulty of validation, as the model is hypothetical thus negating testing against historical data or future real-system behaviour.

Because the ISGF model omits certain important features of gantlet fisheries, (sports fishing, changing availability, multiple species and stocks) there is reason to question its generality in terms of aiding management in finding optimum regulatory strategies. However, as a teaching tool its potential is invaluable and the concepts it embodies would certainly be applicable in designing a model for a specific fishery.

In conclusion, study of the Juan de Fuca fishery revealed a high degree of complexity in the harvest of salmon. To increase our management capabilities particularly with regard to conflicting strategies arising from recreational and commercial users, a simulation approach seems appropriate. However, before embarking in this direction, it would be advisable to consider the cost of achieving sufficient fidelity for realistic simulation and to weigh this against the more empirical approaches, particularly considering the relative high success of present commercial management.

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APPENDIX A

DETAILED FIELD METHODS FOR 1967 AND 1968 TEST TROLLING AND BASIC DATA TABLES AND FIGURES

A. DETAILED FIELD METHODS FOR 1967 and 1968 TEST TROLLING.

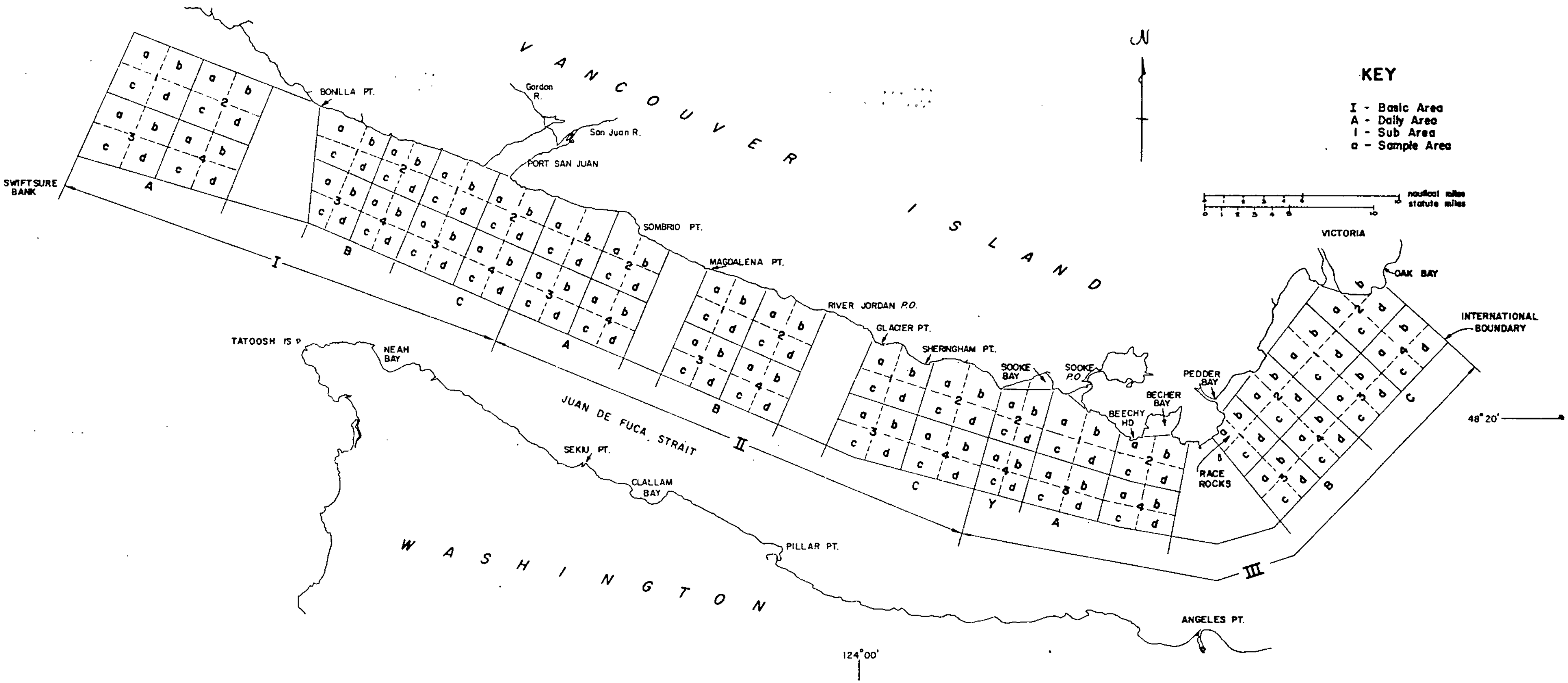
In 1967 three commercial trollers were chartered (Phaedra, Valiant I, Tide Water III) to test troll in the Canadian waters of Juan de Fuca Strait from Swiftsure Bank to Oak Bay (Appendix Figure IA). Each troller was equipped with radar (Decca 101, accurate to 50 yd.^{2}, 55 m.^{2} on long range). For readers not familiar with troller design, see Appendix Figure 2A. Period of operation was June 19 to October 11 and was divided into six charter periods of about 14 days each (Appendix Table 1A).

APPENDIX TABLE IA. Charter Period Dates for 1967 Test Trolling.

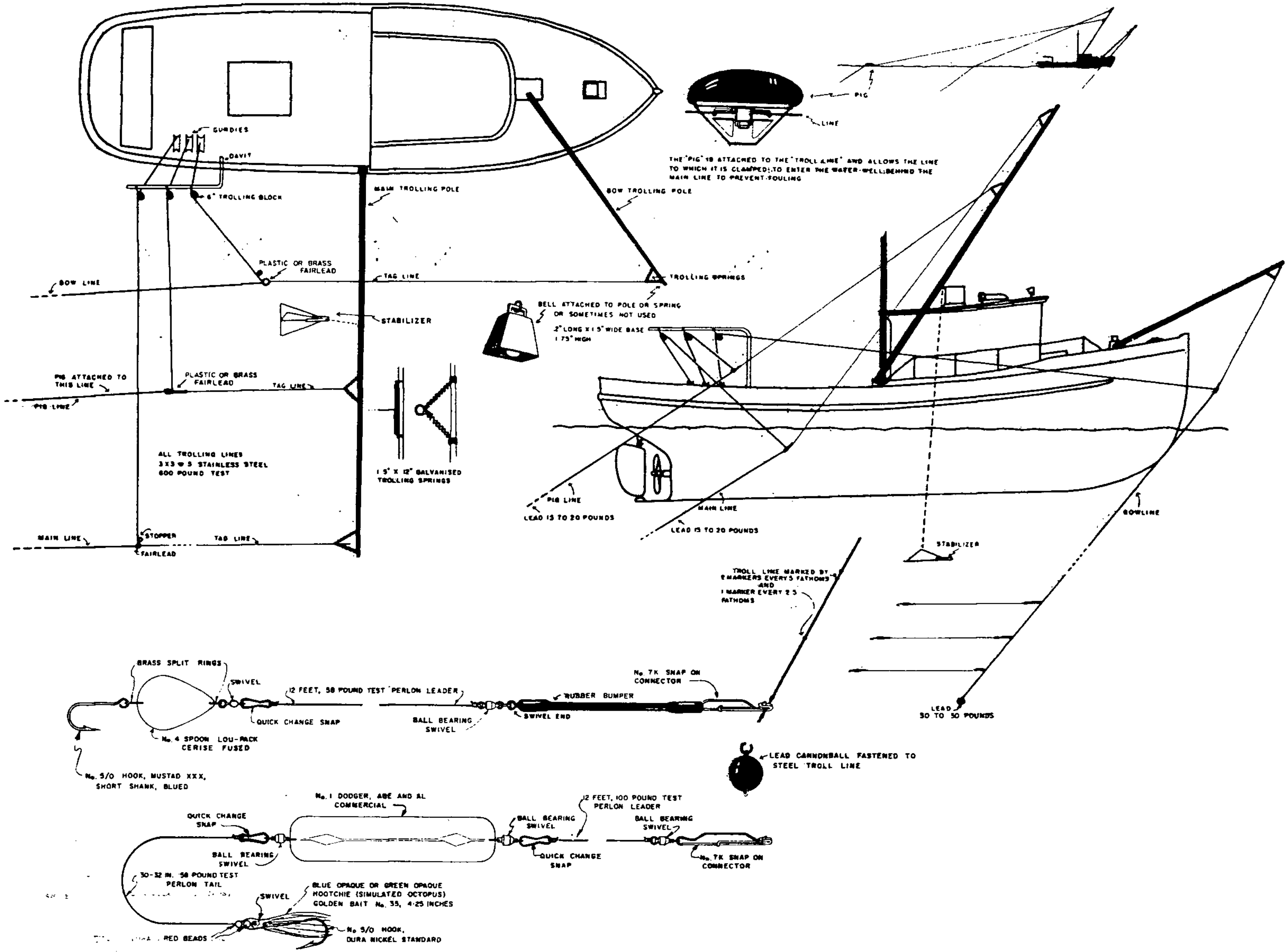
Charter Period	Date	Fishing Days During Charter Period	Location Trollers I	II	III
1	June 19 - 29	11	T	V	P
2	July 6 - 19	14	V	T	P
3	July 26 - August 8	14	V	P	T
4	August 15 - 28	14	P	V	T
5	September 4 - 21	14	P	T	V
6	September 26 - October 11	12	T	T, P	P, V

In 1968 two trollers were chartered (Valiant I and Tide Water III) to test troll off Port San Juan and Sooke. Period of operation was from May 1 to July 12, and was divided into seven charter periods of about eight days each (Appendix Table 2A).

The study area was gridded (Appendix Figure 1A), into three basic areas (I, II, III), three daily areas (A, B, C) per basic area, four sample areas (1-4) per daily area and four sub-areas (a, b, c, d) per sample area. Appendix



Appendix Figure 1A. Juan de Fuca Strait study area grid system, 1967 and 1968.



Appendix Figure 2A. Standard troller design from Milne (1964) and 1967-1968 test trolling lures and lure rigging.

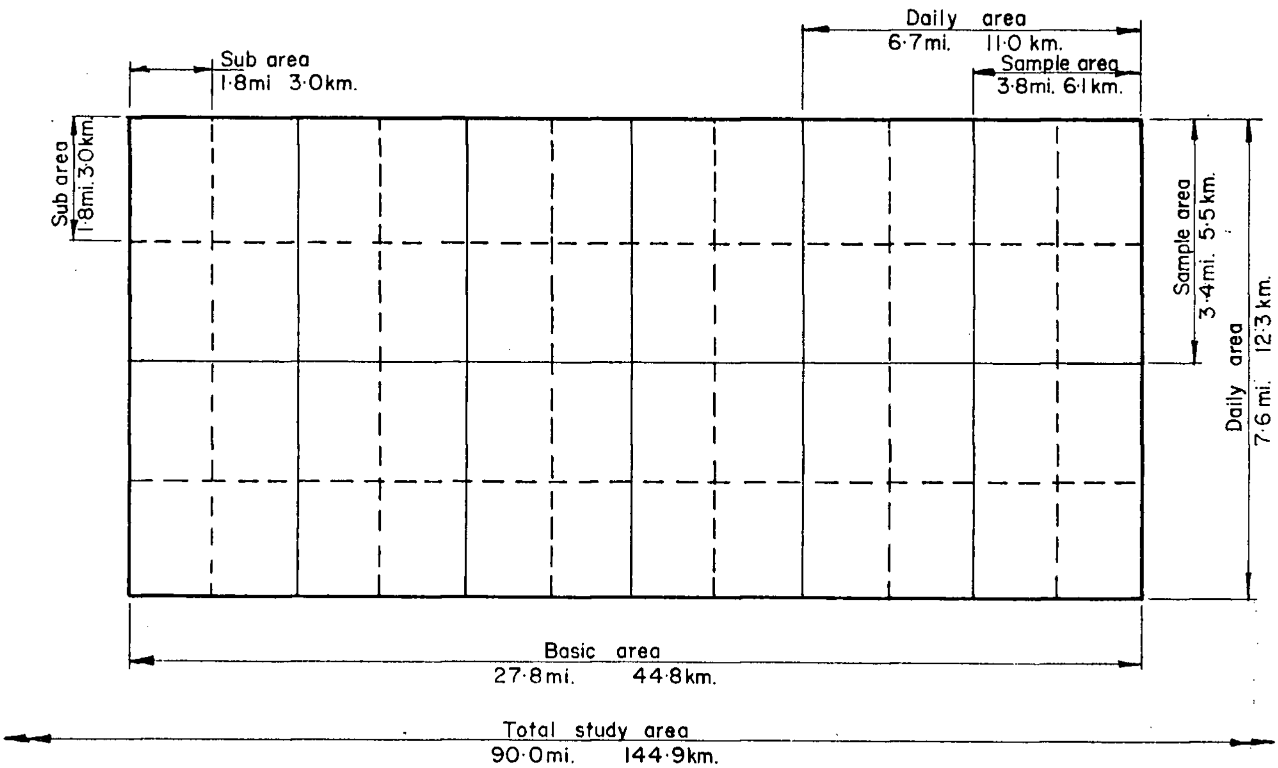
Figure 3A details average grid dimensions.

APPENDIX TABLE 2A. Charter period dates for 1968 test trolling.

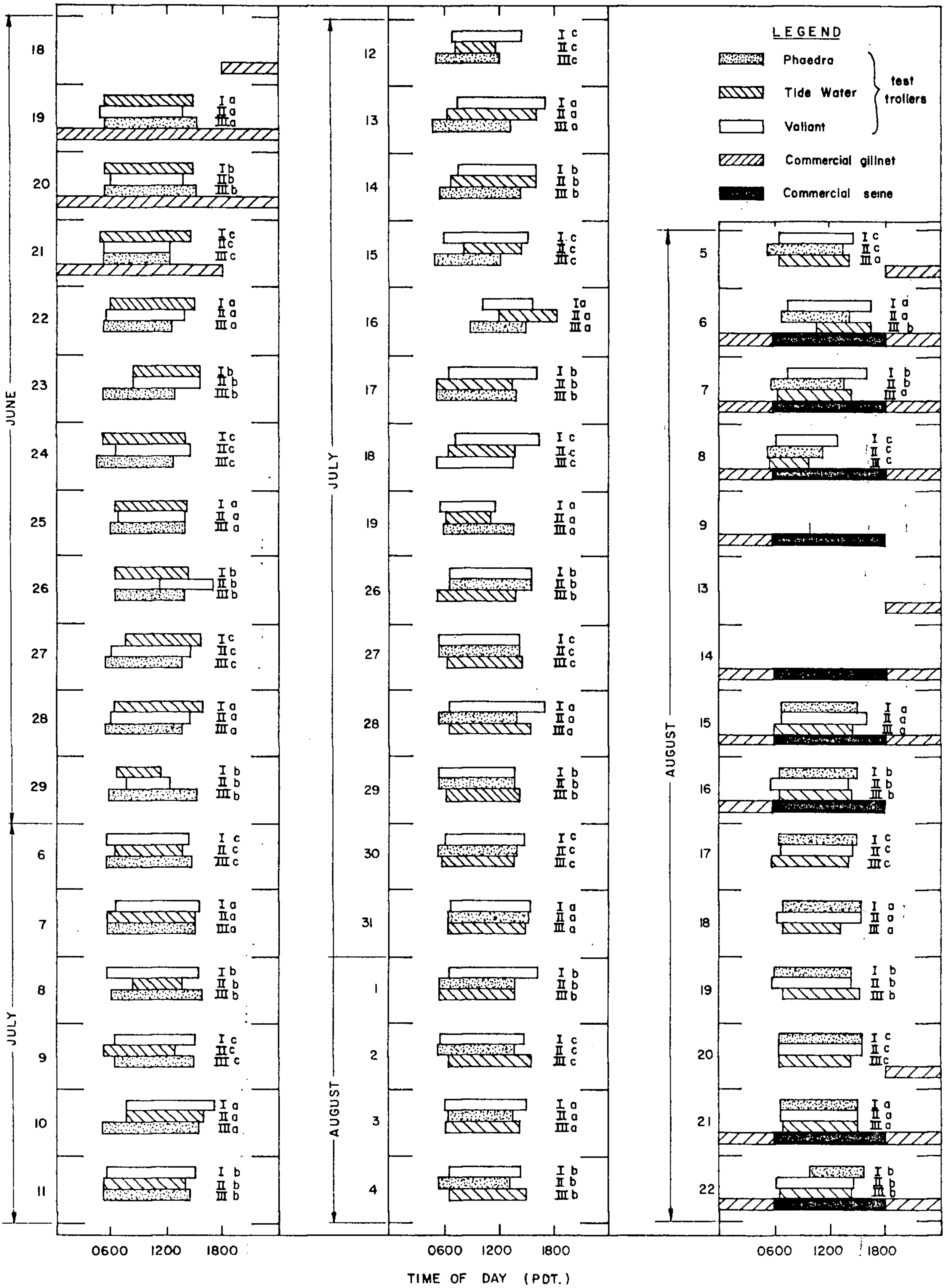
Charter Period	Date	Fishing Days during Charter Period	Location Trollers San Juan	Sooke
1	May 1 - 8	8	T	V
2	May 12 - 19	8	T	V
3	May 23 - 30	8	V	T
4	June 3 - 10	8	V	T
5	June 14 - 21	8	T	V
6	June 25 - July 2	8	T	V
7	July 6 - 12	7	V	T

During each charter period, in 1967, charter trollers operated in separate basic areas (Ba) except for part of the last charter period when weather forced exclusion of Ba I. Trollers changed basic areas after each charter period. A single day's trolling was carried out within one daily area (Da) and each day trollers altered daily areas alphabetically, from A to C. Trollers were instructed to fish for seven to eight hours per day, weather and sea conditions permitting. Appendix Figures 4A and 4B list, for 1967, location of trollers by date, Ba and Da; approximate time of day fished for each troller; and dates and daily fishing times for commercial gillnet and seine gear operating during the test fishing period.

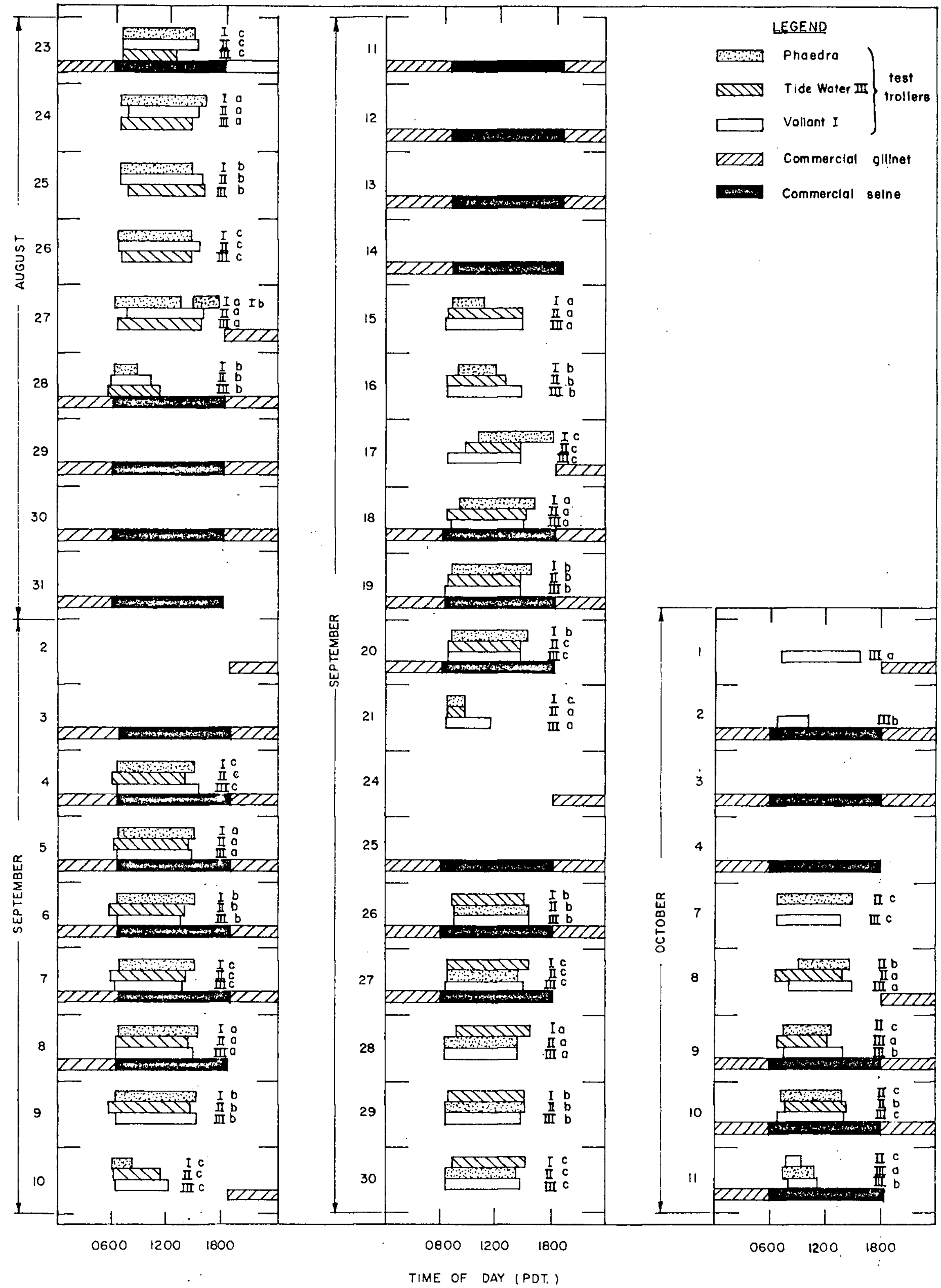
Because the 1968 test trolling program was reduced to two trollers, areas fished and daily area rotation were altered. There were two operating areas: the Sooke area consisting of Ba II Da C, Ba III Da A, and a new daily area Ba III Da Y, to cover waters of Sooke Bay; and the San Juan area consisting of Ba I



Appendix Figure 3A. Average dimensions 1967 and 1968 test trolling grids (excluding III Y).



Appendix Figure 4A. Daily times and locations for test trolling and times for commercial net fishing in Area 20, 1967.



Appendix Figure 4A. (continued) Daily times and locations for test trolling and times for commercial net fishing in Area 20, 1967.

Da C and Ba II Da A. Vessels alternately fished San Juan and Sooke areas each charter period. Within each charter period daily trolling was conducted in a predetermined daily area. During most charter periods all daily areas, except Da Y, were fished for at least two days. Daily area Y was trolled by the Sooke vessel for one-half day on the first day of each charter period and thereafter only on days when the other Sooke daily areas were adequately covered. Appendix Figure 5A presents 1968 location of trollers by date, Ba and Da, approximate time of day fished for each troller, and dates and daily fishing times for commercial gillnet gear.

The following methods are common to both the 1967 and 1968 test trolling programs.[1]

(a) Troll gear

To minimize differences in fishing efficiency between trollers, troll gear was standardized as follows. Trollers used two bow lines with 40 lb. (18 kg.) lead weights (cannonballs) and two deep (main) lines (located amidship) with 20 lb. (9 kg.) lead weights. The bottom lure on the deep lines was estimated to be fishing at approximately 170 ft. (52 m.); bow lines approximately 110 ft. (34 m.). The number of lures per troller was 20, ten spoons and ten hoochie-dodger combinations (5 blue and 5 green hoochies); a hoochie refers to a simulated squid or octopus). The two basic lure types, spoons and hoochie dodgers, were arrayed alternatively at 30 ft. (9.1 m.) intervals, four lures

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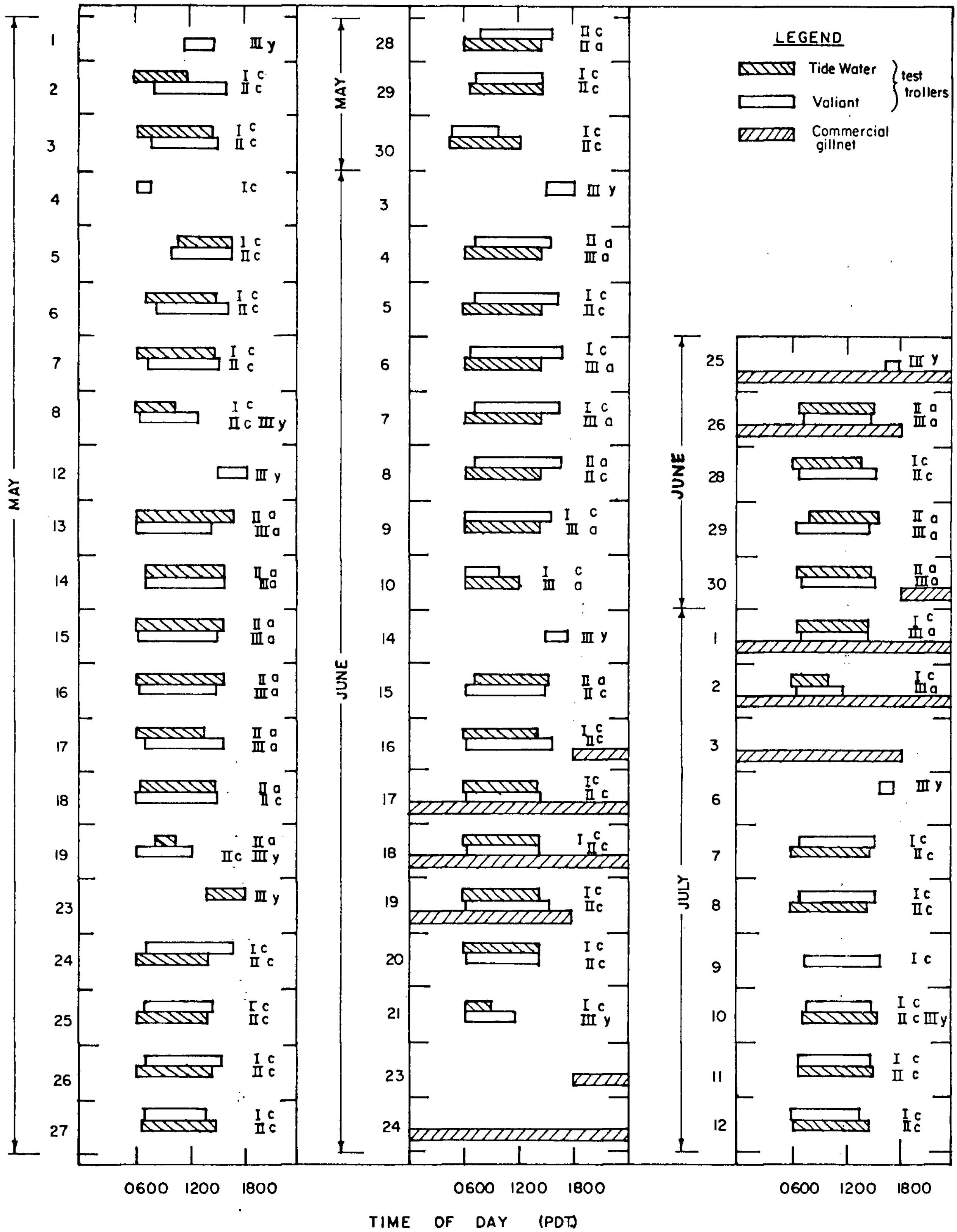
[1] During the last four charter periods in 1968 (May 23-July 12) 268 coho and 291 chinook were tagged with Floy spaghetti-anchor tags (about 60% of the coho and chinook catch); tagging took precedence over biological sampling. Fork lengths and scales were taken for tagged salmon.



Appendix Figure 5A. Daily times and locations for test trolling and times for commercial net fishing in Area 20, 1968.

per bow line and six lures per deep line. For a line pair each lure type was represented at a given depth. Lines were adjusted so that the top four lures on each line fished approximately the same depths. Appendix Figure 2A presents lure types used and method of attachment; Appendix Figure 6A presents lure placement on trolling lines. Bait (frozen herring) was added to hoochie-dodger combination lures for charter period 6, 1967, only.

(b) Daily trolling pattern

Trolling pattern was based on maximum coverage of daily areas, not on locating and operating on salmon concentrations (salmon schools were neither sought nor avoided). On most days seven to eight hours fishing time allowed for one and sometimes two complete passes through a daily area, covering some segment of each sample area. Occasionally strong tidal currents necessitated hauling gear and running to a different location to provide adequate coverage.[2] The large size of daily areas prevented multipl passes through salmon concentrations. Appendix Figure 7A shows a sample daily trolling path.

(c) Data collected

A portion of each day's salmon catch was sampled as soon as possible after capture to a maximum of 40 coho (daily catch was seldom greater than 20 coho), and 10 each for the remaining salmon species including coho and chinook grilse (in their first ocean year). For each sampled salmon fork

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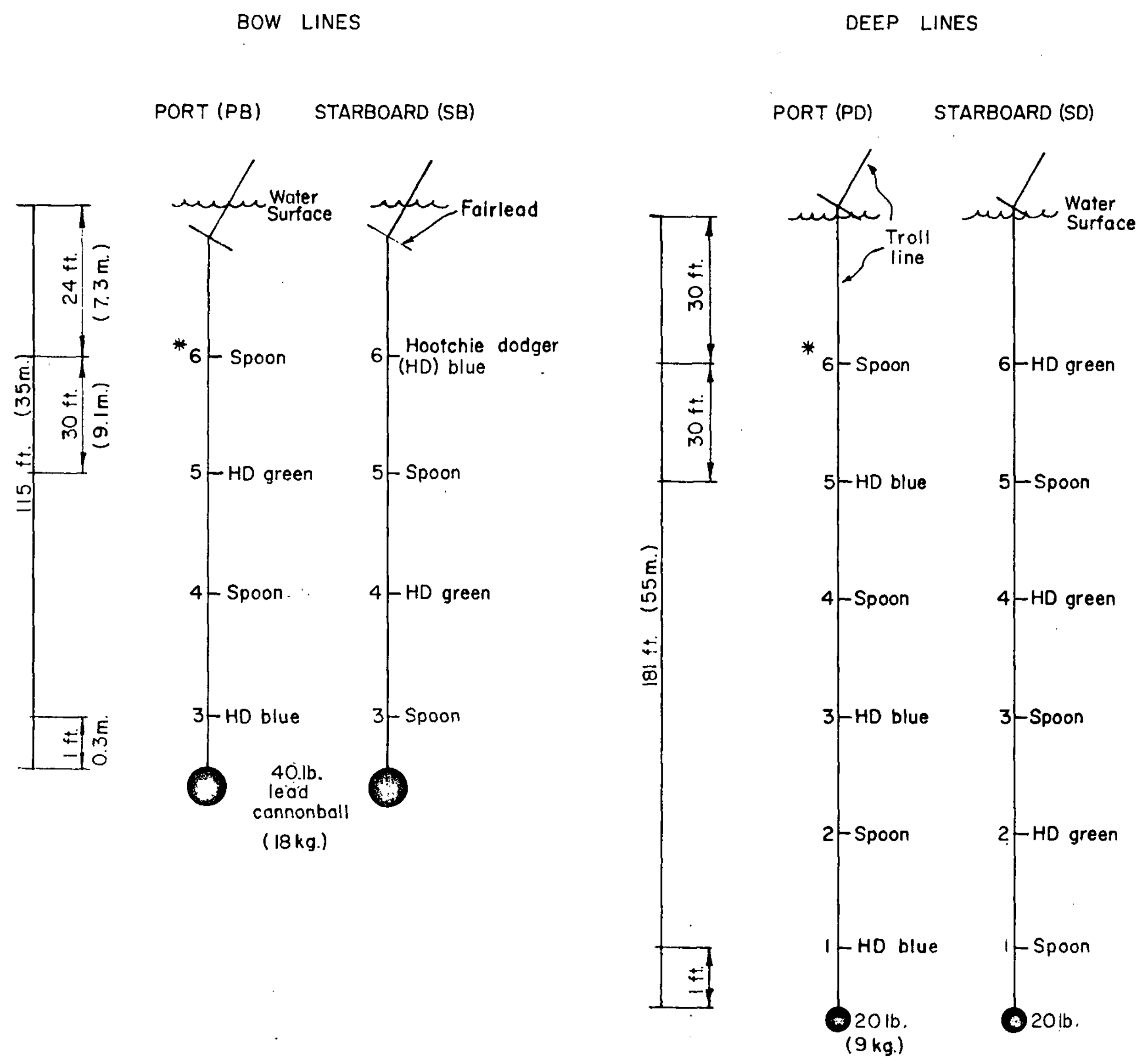
[2] Radar positions were taken at 10 to 30 minute intervals, when crossing sample area boundaries and when lines were pulled or set. Times and locations (entered on special charts) provided necessary data for calculating sample area effort.

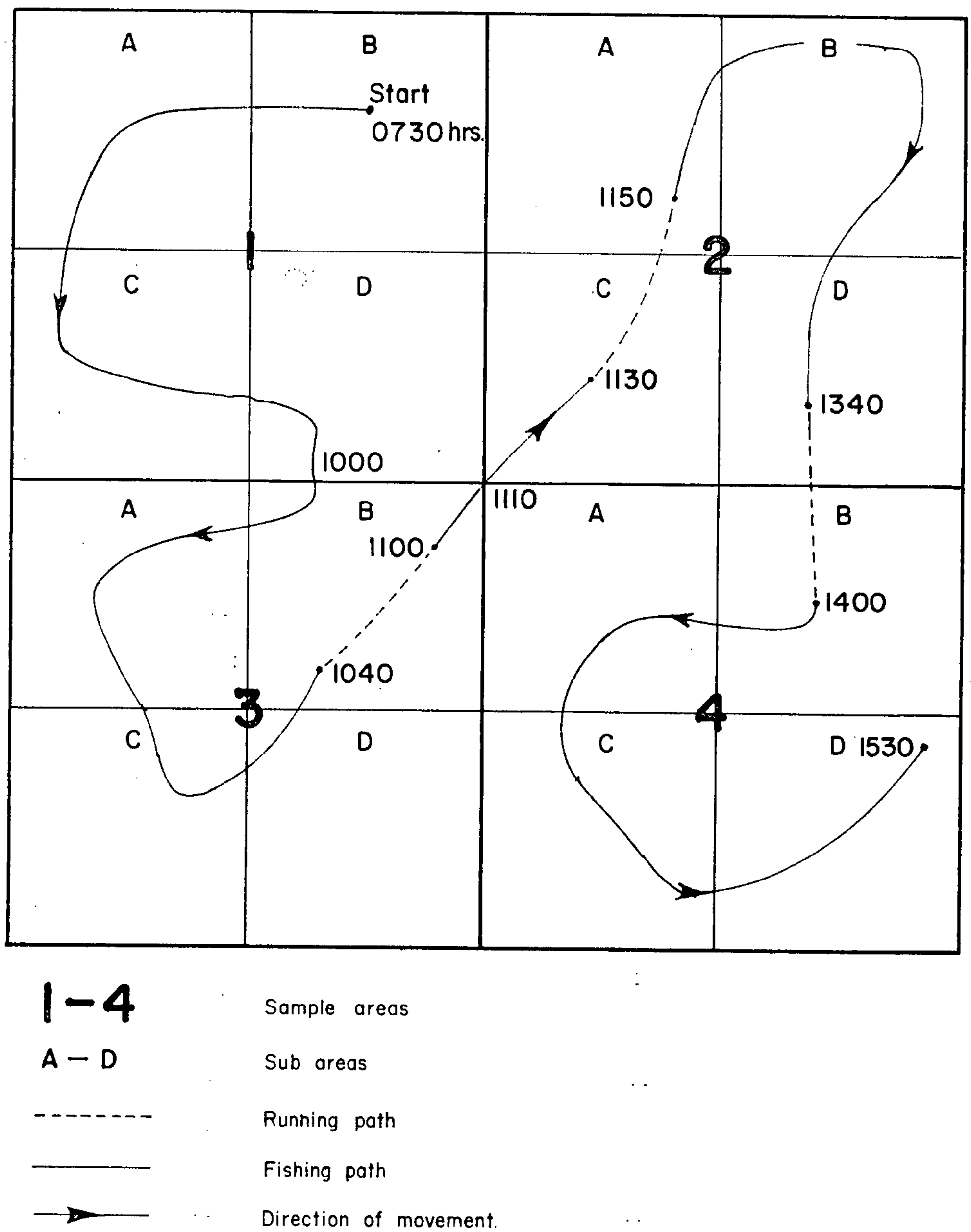


Note 1. Measurements represent length of trolling line starting at the water surface

Note 2. Rubber bumpers used only on four deepest lures

Note 3. * Denotes lure depth code number.

Appendix Figure 6A. Lure placement on trolling lines for 1967 and 1968 test trolling.



Appendix Figure 7A. Example of daily test trolling path.

length (mm.), round weight (0.1 lb.) and sex were recorded, a scale sample was taken from the left preferred area (Koo, 1962), and stomach and both gonads were preserved in a ten per cent formalin solution.

Time, depth, lure, trolling line, sub-area and how hooked was recorded for salmon that were (a) sampled, (b) caught, identified and released (over daily sample size), and (c) caught, identified and subsequently lost while being landed.

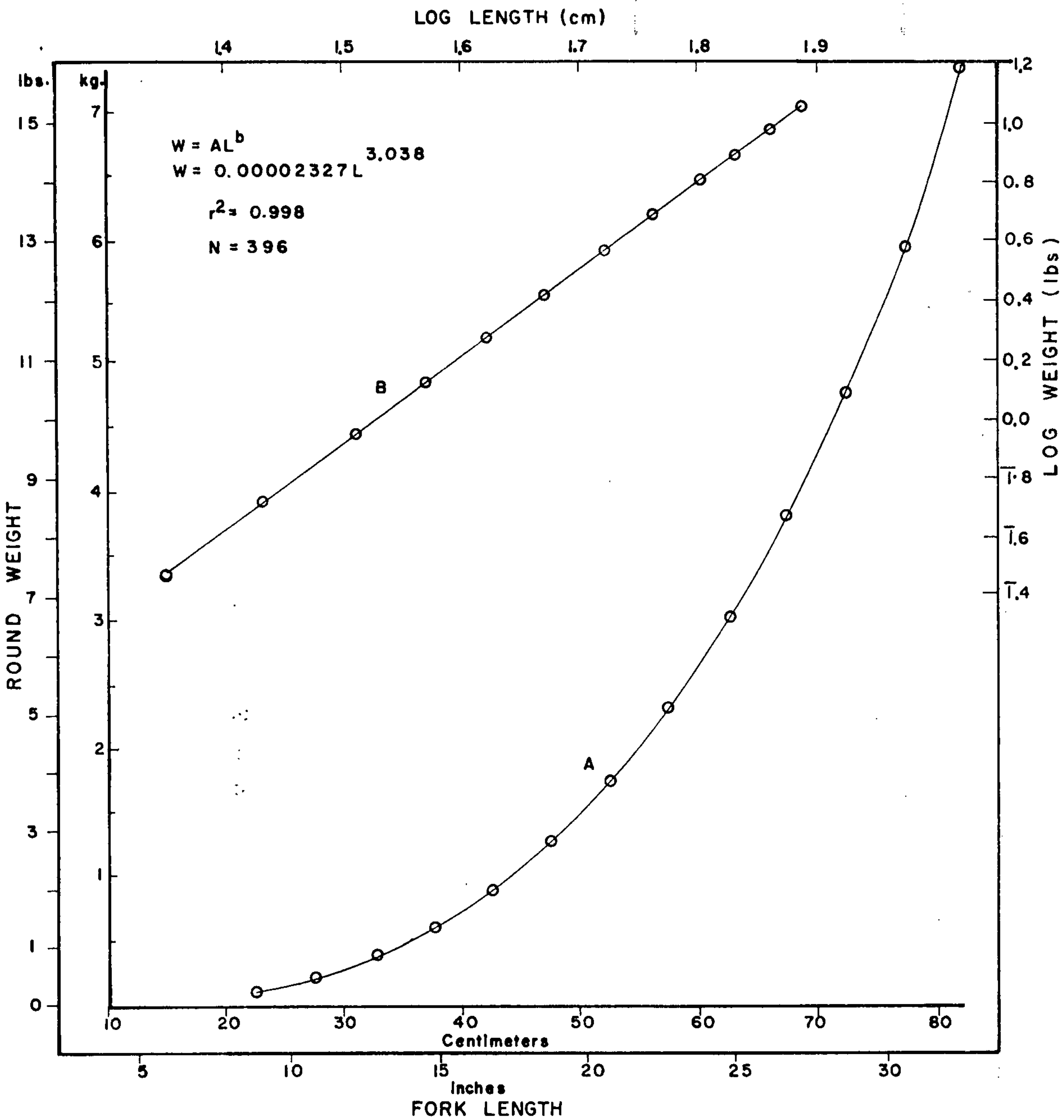
The daily effort for each troller was measured in hook hours, the number of lures fished (normally 20) multiplied by hours fished, and was recorded for each sample area. Effort was corrected for occasional lure removals when lines were shortened for shallow water trolling, less than 170 ft. (52 m., 28 fm.).

Daily catch, effort and biological sampling data are on file at the Department of Fisheries and Forestry, Vancouver, Canada.

Appendix Tables 3A and 4A summarize basic area catch (includes salmon lost while being landed) by species and basic area effort for charter period divisions for 1967 and 1968 programs respectively.

Appendix Figure 8A presents a length-weight relationship for coho salmon.

Remaining Appendix A tables are referred to in appropriate text sections.



Appendix Figure 8A. Length-weight relationship for coho salmon. Curve A shows absolute values. Curve B shows the log-log transformation. Coho from 1964 and 1965 brood years (test troll caught in 1967) were equally distributed into 11 five centimetre length classes, 20 to 75 cm. Mean round weight of each length class was regressed against the class mark for length. Points are calculated means.

APPENDIX TABLE 3A. Summary of catch and effort, 1967 test trolling.

Charter Period	Salmon Catch: Coho	Chinook	Pink	Sockeye	Total Adult	Coho[C] Grilse	Chinook[C] Grilse	Total Grilse	Total Salmon	Coarse[A] Fish Catch	Effort: Total Hook Hours	Avg. Hook Hours per Charter Day	Avg. Time Fished Per Day: Hrs.	Min.	Troller[D]
BASIC AREA I															
(1) June 19-29	162	45	13	1	221	0	0	0	221	449	1751	159 (11)[B]	7	54	T
(2) July 6-19	66	114	12	6	198	0	0	0	198	529	2196	157 (14)	7	51	V
(3) July 26 - Aug. 8	183	124	163	57	527	17	9	26	553	125	2326	167 (14)	8	20	V
(4) Aug. 15-28	51	63	631	17	762	8	2	10	772	44	2196	157 (14)	7	51	P
(5) Sept. 4-21	34	55	154	0	243	21	0	21	264	60	1936	138 (14)	6	55	P
(6) Sept. 26 - Oct. 11	35	17	15	0	67	42	0	42	109	35	832	166 (5)	8	24	T
Total	531	418	988	81	2018	88	11	99	2117	1242	11239	157	7	51	
BASIC AREA II															
(1)	190	99	12	3	304	0	0	0	304	329	1430	130 (11)	6	30	V
(2)	22	49	4	1	76	0	0	0	76	513	1780	127 (14)	6	18	T
(3)	84	146	87	32	349	59	2	61	410	112	2250	161 (14)	8	2	P
(4)	46	94	368	11	519	52	0	52	571	67	2216	158 (14)	7	55	V
(5)	8	33	94	0	135	148	4	152	287	55	1932	138 (14)	6	54	T
(6)	17	36	2	0	55	211	12	223	378	21	1626	126 (13)	6	17	T, P
Total	367	457	567	47	1438	470	18	488	1926	1097	11234	140	7	0	
BASIC AREA III															
(1)	21	23	6	1	51	0	0	0	51	115	1725	156 (11)	7	50	P
(2)	7	17	2	0	26	0	0	0	26	59	2058	147 (14)	7	21	P
(3)	15	61	20	11	107	22	1	23	130	45	2067	148 (14)	7	23	T
(4)	31	40	185	5	261	224	5	229	490	48	2124	152 (14)	7	35	T
(5)	13	41	25	0	79	287	17	304	383	19	2085	149 (14)	7	26	V
(6)	16	53	4	0	73	340	44	384	457	25	1766	126 (14)	6	35	P, V
Total	103	235	242	17	597	873	67	940	1537	311	11825	146	7	30	
Grand Total	1001	1110	1797	145	4053	1431	96	1527	5586	2650	34296	148	7	24	

[A] Rockfish species, ling-cod, dogfish, hake, sablefish, grey cod.
[B] Charter days fished in brackets.
[C] Coho aged 2_2, chinook aged 1_1 or 2_2; in other words, coho and chinook in their first ocean year.
[D] T = Tide water; V = Valiant; P = Phaedra.

APPENDIX TABLE 4A. Summary of catch and effort, 1968 test trolling.

Charter Period	Coho	Chinook	Total	Coarse Fish Catch[A]	Total Hook Hours	Avg. Hook Hours Per Charter Day	Avg. Time Fished Per Day Hrs.	Avg. Time Fished Per Day Min.	Troller[C]
SAN JUAN (I C, II A)									
(1) May 1-8	89	38	127	14	905	129 (7)[B]	6	28	T
(2) May 12-19	185	72	257	51	1007	145 (7)	7	14	T
(3) May 23-30	182	112	294	29	1004	143 (7)	7	10	V
(4) June 3-10	114	170	284	15	1150	164 (7)	8	13	V
(5) June 14-21	60	29	89	29	1030	147 (7)	7	21	T
(6) June 25-July 2	8	8	16	50	829	138 (6)	6	54	T
(7) July 6-12	10	24	34	27	931	154 (6)	7	43	V
Total	648	453	1101	215	6856	146	7	50	
SOOKE (II C, III Y, III A)									
(1)	245	57	302	0	1037	149 (7)	7	26	V
(2)	70	28	98	2	1137	142(8)	7	7	V
(3)	22	18	40	3	1175	147 (8)	7	20	T
(4)	8	18	26	4	1141	143 (8)	7	8	T
(5)	23	57	80	1	1173	147 (8)	8	23	V
(6)	23	44	67	0	866	124 (7)	6	11	V
(7)	4	21	25	41	846	141 (6)	7	2	T
Total	395	243	638	51	7375	142	7	6	
Grand Total	1043	696	1739	266	14231	144	7	12	

[A] Rockfish species, ling cod, dogfish, hake, sablefish.
[B] Charter days fished in brackets.
[C] T = Tide Water; V = Valiant

APPENDIX TABLE 5A. Age of test troll caught chinook salmon, 1967 and 1968[a].

Basic Area		I								II								III								TOTAL							
Age Group / Charter Period		1_1	2_1	3_1	4_1	2_2	3_2	4_2	N	1_1	2_1	3_1	4_1	2_2	3_2	4_2	N	1_1	2_1	3_1	4_1	2_2	3_2	4_2	N	1_1	2_1	3_1	4_1	2_2	3_2	4_2	N
																	1967																
1 and 2	No.	-	61	36	1	-	4	3	105	-	72	28	3	-	4	2	109	-	11	9	1	-	-	-	21	-	144	73	5	-	8	5	235
June 19-July 19	%	-	58	34	1	-	4	3		-	66	26	3	-	4	1		-	52	43	5	-	-	-		-	62	31	2	-	3	2	
3 and 4	No.	-	92	16	2	-	4	-	114	-	144	4	1	-	-	-	149	-	52	8	4	-	2	-	66	-	288	28	7	-	6	-	329
July 26-Aug. 28	%	-	81	14	2	-	3	-		-	97	3	<1	-	-	-		-	79	12	6	-	3	-		-	87	9	2	-	2	-	
5 and 6	No.	-	27	5	2	1	-	-	35	1	40	3	-	1	1	-	46	4	50	8	-	8	-	-	70	5	117	16	2	10[b]	1	-	151
Sept. 4-Oct. 11	%	-	77	14	6	3	-	-		3	84	7	-	3	3	-		6	70	12	-	12	-	-		3	79	11	-	7	<1	-	
Total	No.	-	180	57	5	1	8	3	254	1	256	35	4	1	5	2	304	4	113	25	5	8	2	-	157	5	549	117	12	10	16	4	715
	%		71	22	2	<1	3	1		<1	84	12	1	<1	2	1		3	72	16	3	5	1	-		1	77	16	2	1	2	1	
																	1968																
		San Juan																Sooke															
1 and 2	No.	-	47	19	-	-	2	-	68									1	32	14	-	-	3	-	50	1	79	33	-	-	5	-	118
May 1-19	%	-	69	28	-	-	3	-										2	64	28	-	-	6	-		<1	67	28	-	-	4	-	
3 and 4	No.	-	128	47	-	-	1	1	177									-	13	5	-	-	-	1	19	-	141	52	-	-	1	2	196
May 23-June 10	%	-	72	27	-	-	<1	<1										-	68	26	-	-	-	5		-	72	27	-	-	<1	1	
5, 6 and 7	No.	-	29	5	-	-	-	1	35									-	77	5	-	-	-	-	82	-	106	10	-	-	-	1	117
June 14-July 12	%	-	83	14	-	-	-	3										-	94	6	-	-	-	-		-	91	9	-	-	-	<1	
Total	No.	-	204	71	-	-	3	2	280									1	122	24	-	-	3	1	151	1	326	95	-	-	6	3	431
	%	-	73	25	-	-	1	<1										<1	81	16	-	-	2	<1		<1	76	22	-	-	1	<1	

[a] Age Notation - The total age of the salmon is determined from the moment the fertilized egg is deposited by the parent; the corresponding year is termed the brood year. A superscript-subscript system of notation is used with the superscript indicating the fishes' total age, and the subscript denoting the year of life in which the fish migrated to sea. For example consider chinook aged:

(1) 4_2 - an egg deposited in the fall of calendar year "n"; emerged as a fry in the spring of year n + 1; migrated to sea during year n + 2 (therefore a stream type) probably in the spring; and returned to spawn, or was caught, in year n + 4, its fourth year of life. If this fish had been sampled on the spawning grounds we would conclude that it had spent more than one but less than two full years in fresh water and approximately 2 1/2 years in salt water.

(2) 2_1 - This fish is an ocean type as it has spent less than one year in fresh water (therefore no fresh water annulus) and is in its second year of life after spending one winter in salt water. Chinook of this total age are unlikely to spawn and consequently will spend one to three more winters in salt water eventually spawning as either a 3_1, 4_1 or 5_1. ~~It~~ should be obvious that for any age notation the number of winters in salt water is equal to the superscript minus the subscript.

[b] Possibly 1_1

APPENDIX TABLE 6A. Daily area (A, B, C) effort in hook hours for 1967 test trolling.+

	Basic Area	I			II			III			
Charter Period	Sample Area	A	B	C	A	B	C	A	B	C	Total
1 and 2	1, 2	713	558	720	592	410	409	828	633	528	5391
	3, 4	665	682	609	695	568	536	587	653	554	5549
3 and 4	1, 2	727	673	702	627	613	611	999	927	520	6399
	3, 4	805	848	769	899	955	761	616	543	586	6782
5 and 6	1, 2	351	535	381	439	453	685	657	705	609	4815
	3, 4	420	551	529	501	741	737	637	538	705	5359
	Total	3681	3847	3710	3753	3740	3739	4324	3999	3502	34295
											$\bar{\bar{X}}$ 635

+ For hours fishing divide hook hours by 20.

APPENDIX TABLE 7A. Daily area (A, B. C) effort in hook hours for 1968 test trolling.+

	Basic Area	I			II			III			
Charter Period	Sample Area	A	B	C	A	B	C	A	B	C	Total
1 and 2	1, 2			438	416		581	586			2021
	3, 4			467	591		595	412			2065
3 and 4	1, 2			909	241		752	600			2502
	3, 4			754	250		676	288			1968
5, 6 and 7	1, 2			1153	327		1964	517			2961
	3, 4			1031	279		981	423			2714
	Total			4752	2104		5168	2207			14231

+For hours fishing divide hook hours by 20.

APPENDIX TABLE 8A. Salmon catch by lure depth and basic area for charter period three (July 26-August 8), 1967.

		Coho 3_2							Coho 2_2							Chinook							Pink							Sockeye						
Lure-Depth	Code+	6	5	4	3	2	1	N	6	5	4	3	2	1	N	6	5	4	3	2	1	N	6	5	4	3	2	1	N	6	5	4	3	2	1	N
Ba I	No.	10	15	9	6	4	6	50	6	4	3	4	2	0	19	3	3	4	9	3	28	50	4	10	9	7	16	4	50	2	5	12	15	14	22	50
	%	20	30	18	12	8	12		32	21	16	21	11	-		6	6	8	18	6	56		8	20	18	14	32	8		4	10	24	20	18	4	
Ba II	No.	12	9	14	9	4	2	50	7	14	10	11	4	4	50	1	1	4	12	6	26	50	1	7	11	9	9	13	50	1	5	8	9	0	2	25
	%	24	18	28	18	8	4		14	28	20	22	8	8		2	2	8	24	12	52		2	14	22	18	18	26		4	20	32	36	-	8	
Ba III	No.	4	4	3	2	2	0	15	6	3	4	5	2	0	20	1	1	3	5	15	25	50	6	7	3	2	2	2	22	4	1	1	3	4	0	13
	%	27	27	20	13	13	-		30	15	20	25	10	-		2	2	6	10	30	50		27	32	14	9	9	9		31	8	7	23	31		
Total	No.	26	28	26	17	10	8	115	19	21	17	20	8	4	89	5	5	11	26	24	79	150	11	24	23	18	27	19	122	7	11	21	27	18	4	88
	%	23	24	23	15	9	7		21	24	19	23	9	5		3	3	7	17	16	53		9	20	19	15	22	16		8	13	24	31	21	5	

+See Appendix Figure 5A.

APPENDIX TABLE 9A. Salmon catch by lure depth, area and charter period for 1968.

		Coho							Chinook						
Lure-depth Code[+]		6	5	4	3	2	1	N	6	5	4	3	2	1	N
								SAN JUAN							
Cp 1 and 2	No.	18	11	6	11	1	3	50	2	0	5	5	15	23	50
	%	36	22	12	22	2	6		4	-	10	10	30	46	
Cp 3 and 4	No.	14	20	9	1	2	4	50	1	1	6	9	8	25	50
	%	28	40	18	2	4	8		2	2	12	18	16	50	
Cp 5, 6 and 7	No.	21	13	7	5	2	2	50	0	2	3	10	12	23	50
	%	42	26	14	10	4	4		-	4	6	20	24	46	
Total	No.	53	44	22	17	5	9	150	3	3	14	24	35	71	150
	%	35	29	15	11	3	6		2	2	9	16	23	47	
								SOOKE							
Cp 1 and 2	No.	13	15	8	4	6	4	50	1	0	4	5	8	32	50
	%	26	30	16	8	12	8		2	-	8	10	16	64	
Cp 3 and 4	No.	21	2	2	3	0	4	32	2	0	7	13	12	16	50
	%	66	6	6	10	-	13		4	-	14	26	24	32	
Cp 5, 6 and 7	No.	7	9	13	5	6	10	50	0	0	3	12	13	22	50
	%	14	18	26	10	12	20		-	-	6	24	26	44	
Total	No.	41	26	23	12	12	18	132	3	0	14	30	33	70	150
	%	31	20	17	9	9	14		2	-	9	20	22	47	

[+]See Appendix Figure 5A.

APPENDIX TABLE 10A. Summary of Chi-square tests for vertical distribution of salmon.+

Test		N Feet <90	>90	χ^2	Conclusion*
1. Proportions of 1_1-2_2 and $\geq 2_1$ chinook	1_1-2_2 $\geq 2_1$	11 4	39 46	2.82	accept H_i that 1_1-2_2 shallower
2. Proportions of maturing (M) and immature (IM) 3_1 chinook	M IM	14 20	5 51	11.47	accept H_i that IM shallower
3. Proportions of 2_1 and 3_1 chinook	2_1 3_1	31 20	45 51	2.06	accept H_o
4. Proportions of NF and CF caught pink for I BC, II AB.	NF CF	207 75	250 208	26.2	accept H_i that NF shallower
5. Proportions of NF and CF caught pink for I A.	NF CF	59 55	86 74	<1.0	accept H_o
6. Proportions of NF and CF caught coho for I BC, II AB.	NF CF	22 11	14 19	3.00	accept H_i that NF shallower
7. Proportions of NF and CF caught coho for I A.	NF CF	31 22	17 18	<1.0	accept H_o

+ Test for independence, fourfold contingency table, correction for continuity omitted when N > 200 (Snedecor, 1956).

* $\chi^2_{0.05} = 2.71$, one-tailed, one degree of freedom.

NF = caught on non-fishing days.

CF = caught on commercial fishing days.

APPENDIX TABLE 11A. Capture data for pink and coho salmon test troll caught on commercial net fishing and closed days in daily areas on either side of the Bonilla-Tatoosh net line, 1967.

Commercial Fishing Days (CF)					Non-commercial Fishing Days (NF)				
Date	Area	Fishing Time (PDT)	Pink	Coho	Date	Area	Fishing Time	Pink	Coho
Aug. 7	IB	0730-1615	7	2	Aug. 4	IB	0650-1450	5	13
8	IC	0605-1305	4	3	5	IC	0700-1550	3	1
16	IB	0620-1500	51	2	19	IB	0600-1435	44	4
22	IB	1000-1605	47	2	25	IB	0630-1440	90	3
23	IC	0620-1440	46	1	26	IC	0615-1435	39	1
Totals			155	10	Totals			181	22
6	IA	0730-1630	7	23	3	IA	0605-1515	23	38
15	IA	0700-1500	118	10	18	IA	0700-1540	84	9
21	IA	0650-1505	29	7	27	IA	0600-1635	38	1
Totals			154	40	Totals			145	48
6	IIA	0650-1415	-	6	3	IIA	0605-1345	2	2
7	IIB	0550-1335	2	4	4	IIB	0555-1330	7	2
15	IIA	0650-1605	24	7	18	IIA	0620-1520	57	3
16	IIB	0540-1405	30	1	19	IIB	0545-1425	42	2
21	IIA	0710-1515	5	1	25	IIB	0635-1520	51	2
22	IIB	0610-1445	29	1	27	IIA	0620-1515	33	3
Totals			128	20	Totals			278	14

APPENDIX TABLE 12A. Comparison of coho, pink and sockeye coefficients of condition, K, caught by test troll gear in basic area I during charter period three, 1967.*

	Sockeye			Pink			Coho		
	Male	Female	Combined	Male	Female	Combined	Male	Female	Combined
	1.151	1.218		1.355	1.285		1.281	1.258	
	1.126	1.025	$\bar{X}_L$ +	1.281	1.472	$\bar{X}_L$	1.271	1.112	$\bar{X}_L$
	1.181	1.137		1.440	1.417		1.225	1.384	
	1.155	1.257	56.1	1.440	1.345	53.3	1.212	1.158	53.5
	1.333	1.223		1.157	1.367		1.123	1.218	
	1.265	1.030		1.401	1.355		1.343	1.192	
	1.248	1.237		1.275	1.501		1.226	1.219	
	1.319	1.362		1.358	1.295		1.202	1.190	
	1.339	1.213		1.372	1.418		1.299	1.260	
	1.213	1.169	$\bar{X}_1$	1.418	1.128	$\bar{X}_2$	1.233	1.346	$\bar{X}_3$
Mean	1.233	1.187	1.210	1.340	1.358	1.344	1.242	1.234	1.238
SD	0.079	0.102	0.092	0.093	0.106	0.023	1.061	1.082	1.071
CV	34%	55	44	28	30	7	25	35	30

$t = \frac{\bar{X}_1 - \bar{X}_2}{S\bar{d}}$ where: $S\bar{d} = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}$ (Steel and Torrie, 1960, p. 81) $t = \frac{\bar{X}_1 - \bar{X}_3}{S\bar{d}}$

$t = 4.47^{**}$ $\quad S_1^2 \neq S_2^2$ $\quad t = 0.55$

* $K = \left[\frac{\text{Weight (g.)}}{(\text{Fork length, cm.})^3}\right] 10^2$, random samples.

\+ $\bar{X}_L$ = mean fork length.

APPENDIX TABLE 13A. Random samples of coho round weights (lb.) for basic areas and charter periods, 1967.

Ba	I			II			III		
Cp	1 - 2	3 - 4	5 - 6	1 - 2	3 - 4	5 - 6	1 - 2	3 - 4	5 - 6
	4.2	3.5	10.5	2.8	2.2	3.6	3.6	3.9	3.8
	2.6	6.1	10.5	3.7	4.3	8.2	3.1	2.3	5.2
	1.5	5.6	9.8	3.3	3.5	6.7	2.3	3.6	3.8
	2.4	3.7	5.0	2.4	3.6	6.3	3.7	3.1	6.1
	2.8	4.0	7.6	4.8	5.0	7.8	5.0	4.1	3.6
	3.6	6.6	7.9	2.5	4.0	8.5	2.5	4.7	5.2
	3.4	8.5	6.9	5.4	2.9	8.8	3.4	3.0	5.1
	3.3	8.7	10.2	3.7	4.3	5.2	4.8	3.0	6.2
	6.0	7.0	7.8	2.2	4.3	3.6	2.6	2.1	7.8
	4.5	6.8	9.6	1.7	3.8	8.2	3.9	2.8	3.5
Mean	3.43	5.75	8.58	3.25	3.79	6.69	3.49	3.26	5.03
SD	(1.26)	(1.65)	(1.83)	(1.17)	(0.80)	(1.97)	(0.92)	(0.81)	(1.40)
Grand mean		5.92			4.58			3.93	

Test for homogeniety of variance: $F_{max} = \frac{\max S^2}{\min S^2}$ (Rohlf and Sokal, 1969, Table T).

$F_{max}\ (8,\ 9) = \frac{(1.97)^2}{(0.80)^2} = 6.06 < \text{tab } F_{max(0.5)} = 8.95$, therefore, accept H_o.

APPENDIX TABLE 14A. Per cent catch at comparable bow and deep line lure depths for each test troller, July 26 to September 21, 1967.

	Troller A			Troller B			Troller C		
	Deep+	Bow+	N	Deep	Bow	N	Deep	Bow	N
Sockeye	33%	67%	21	52	48	38	62	38	56
Chinook	16	84	50	19	81	109	24	76	123
Coho 3_2	44	56	45	38	62	99	57	43	187
Coho 2_2	35	65	176	47	53	144	48	52	144
Pink	43	57	163	50	50	161	58	42	161

+lures 6 to 3 on Appendix Figure 6A.

APPENDIX TABLE 15A. Test troll salmon catch by lure type and depth interval (deep lines) between June 19 and September 21, 1967.

Lure Depth	Coho 3_2			Coho 2_2			Chinook $\geq 2_1$			Pink			Sockeye		
	HD*	S+	HD/S	HD	S	HD/S	HD	S	HD/S	HD	S	HD/S	HD	S	HD/S
6	43	63	0.68	15	18	0.83	4	5	0.80	14	18	0.78	7	3	2.33
5	55	62	0.89	24	20	1.20	7	5	1.40	34	31	1.10	7	2	3.50
4	38	54	0.70	12	19	0.63	16	13	1.23	39	60	0.65	13	6	2.17
3	41	36	1.14	25	15	1.67	40	23	1.74	46	54	0.85	14	15	0.93
2	24	21	1.14	6	4	1.50	63	32	1.97	34	57	0.60	10	7	1.43
1	19	17	1.12	3	2	1.50	162	138	1.17	23	42	0.55	3	4	0.75
Total	220	253		85	78		292	216		190	262		54	37	

* HD = Hoochie-dodger.

+ S = Spoon

APPENDIX TABLE 16A. Chinook and coho test troll catch by lure type and depth interval (deep lines) for the 1968 study period, May 1 to July 12.

Lure Depth	Coho 3_2			Chinook $\geq 2_1$		
	Hoochie-dodger	Spoon	HD/S	Hoochie-dodger	Spoon	HD/S
6	68	77	0.88	3	5	0.60
5	57	66	0.86	2	3	0.67
4	68	66	1.03	13	6	2.17
3	40	19	2.11	24	12	2.00
2	28	16	1.75	80	17	4.71
1	22	13	1.69	168	53	3.17
Total	283	257		290	96	

APPENDIX TABLE 17A. Values for 2x2 independence Chi-square for changes in lure selectivity with depth (deep line catches divided into two categories: shallow, lures 6 to 4; deep, lures 3 to 1)+

1967

Coho 3_2	Coho 2_2	Chinook $\geq 2_1$	Pink	Sockeye
17.30**	3.11*	1.0	1.0	2.92*

1968

Coho 3_2	Chinook $\geq 2_1$
6.66**	12.20**

One-tailed significance levels, $\chi^2_{0.05} = 2.71$

$\chi^2_{0.01} = 5.02$; correction for continuity omitted when N > 200.

+Source data in Appendix Tables 15A and 16A.

APPENDIX B

BRIEF HISTORY OF THE JUAN DE FUCA FISHERY AND TABLES OF CATCH STATISTICS

APPENDIX B

Brief History of the Juan de Fuca Fishery

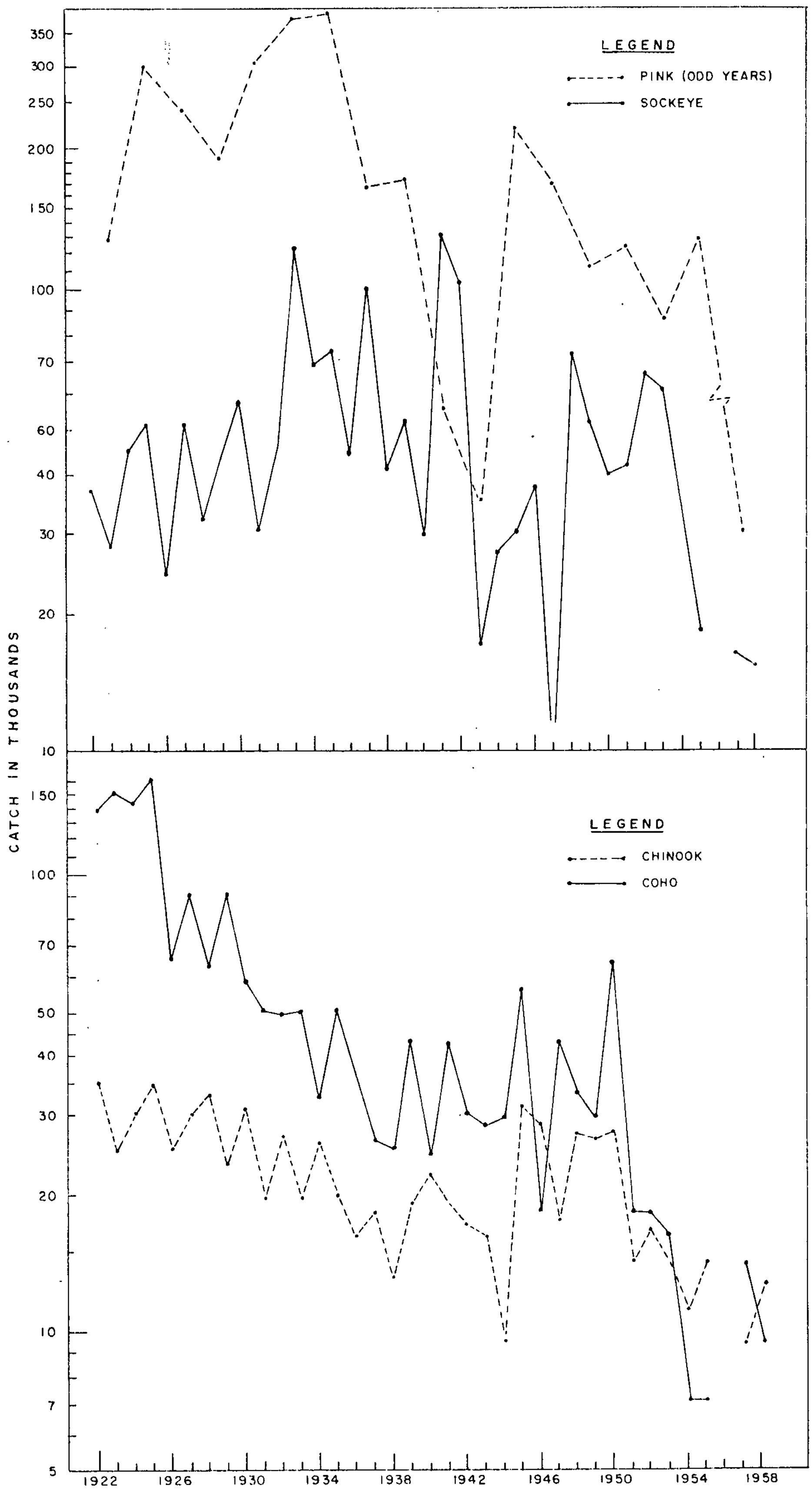
Salmon were purse-seined in outer Juan de Fuca Strait as early as 1910. Between 1910 and the mid-1920's, the Strait was almost exclusively an American seine fishery harvesting immature salmon during June and July (Gilbert, 1913; Smith, 1921). In 1921 over one hundred American purse seines fished the entrance and nearby oceanic waters (Jensen, 1954). A sizeable Canadian purse seine fleet developed after 1920 and by the end of the decade some began fishing outer Strait waters (Areas 20 and 21), although it was not until the mid-1940's that Canadian seine effort approached American levels.

About 1908 American trollers operated in the Strait and by 1912 most of the fleet fished the outer Strait (Rounsefell and Kelez, 1938). Canada had small power trollers fishing the open ocean off Cape Flattery by 1910 (Milne, 1964). Because trollers relied almost entirely on chinook and coho they shunned the Strait itself and tended to fish near Swiftsure Bank and on other continental shelf locations where rearing populations of chinook and coho were more abundant.

The Sooke traps, now inoperative, were the dominant Canadian fishing gear (in terms of catch) in Juan de Fuca Strait prior to 1947. They began operation in 1904 apparently to counteract a similar development on the American side of the Strait (McKervil, 1967) as at this time the Canadian salmon industry was becoming increasingly concerned about American harvest of Fraser River salmon. At one time twenty traps were licensed. As various sites were found unprofitable, the number dropped and from 1922 to 1958 three to six operated annually (Appendix Table 3B). General boundaries set by the Canada Department of Fisheries and Forestry (CDFF) extended from Beechy Head to Sombrio Point, although Brooks (1968) notes that most traps operated from Trial Island off Victoria to Boulder Beach just west of Sheringham Point. Trap locations are still noted on certain Canadian Hydrographic Service charts. For descriptions of trap design refer to Brooks (1968) and Rounsefell and Kelez, (1938); for floating traps refer to Hipkins (1968).

Trap catches (Appendix Figure 1B, Appendix Table 3B) were often over 200,000 for pinks and 70,000 for sockeye. Catches varied considerably between years and for pinks trended downwards after 1937; sockeye catch maintained until the last four years of trap operation. Catches of coho and chinook declined between 1922 and 1932, coinciding with development of Canadian and American troll fisheries, plateaued until 1950, then declined sharply as west coast troll exploitation again increased and Canadian net fisheries intensified off the entrance of the Strait.

The traps did not operate in 1956 because the owners felt prospects for sockeye and other species did not warrant the expense of construction and maintenance (traps were dismantled each year in August or September). In 1957 the International Pacific Salmon Fisheries Commission (IPSFC) closed Juan de Fuca Strait to net fishing, including trap operation, until August 10 for protection of early migrating Fraser sockeye stocks. The trap owners claimed these sockeye were the mainstay of trap operations as the majority of late sockeye purportedly migrated offshore and thus were not as accessible to trap gear. In 1958 Sooke traps were allowed only three days fishing per week prior to August

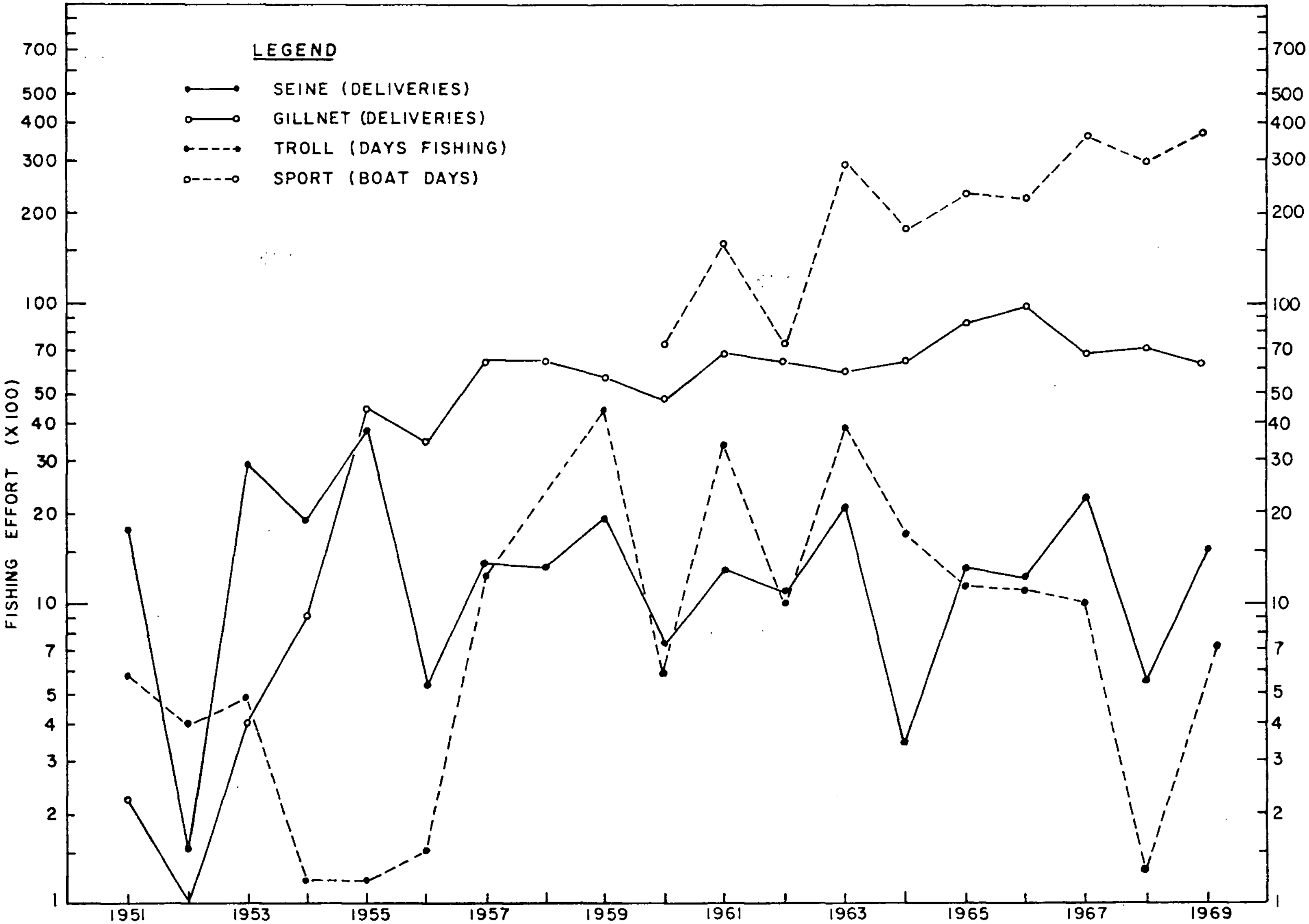


Appendix Figure 1B. Annual catches of pink, sockeye, chinook and coho by Canadian salmon traps located at Sooke, 1922-1958.

20, the opening date for gillnet and seine gear. This arrangement proved unsatisfactory and in 1959 the owners decided that proposed regulations and poor pink and early sockeye prospects mitigated against further trap operation for the foreseeable future. The Sooke traps have remained closed since 1958.

Between 1940 and 1950, the Canadian seine fleet increased considerably; however, since 1950 annual seine effort has shown little trend (Appendix Figure 2B). Gillnets avoided the Strait and outside waters until 1953 after which there was a rapid increase in gillnet effort (primarily Area 21) which, by 1957, had almost doubled net catches of coho and sockeye salmon. Since 1957 little change in gillnet effort has occurred.

Intensification of exploitation between 1940 and 1957, particularly development of the gillnet fishery, greatly increased the proportion of sockeye harvested in offshore waters where identification of particular stocks was virtually impossible. Furthermore, outside fishing worsened an already complicated management system involving all species. Consequently, at the February 1957 "Conference on Coordination of Fisheries Regulations between Canada and the United States" the Canadian proposal for a net line across the entrance of Juan de Fuca Strait (Bonilla Point to Tatoosh Island, part of a total coast surfline) was provisionally adopted and was in effect for the 1957 net season. Net fishing was now limited to waters east of the line. This change greatly reduced American net catch in Juan de Fuca Strait as few entrance locations had suitable tidal conditions for operation of gillnet and seine gear (Milne, et al., 1958). In addition, net fishing was not allowed in a three mile wide sport preserve extending



Appendix Figure 2B. Annual fishing effort by gear type for the Canadian fishery of Juan de Fuca Strait, 1951 to 1969.

along the U.S. shore from Sekiu Point, east of Neah Bay, to Angeles Point opposite Victoria.

There was some doubt at the 1957 conference as to whether the Bonilla-Tatoosh line would adequately separate coho stocks of inside and coastal origin, and minimize capture of immature feeding coho. However, results of a joint study in 1957 and 1958 concluded (Anon., 1959) that waters east of the Bonilla-Tatoosh line did not constitute an important rearing area for immature coho and that the vast majority of coho between Swiftsure Bank and Sooke were destined for spawning streams in Georgia Strait and Puget Sound. Therefore, the Bonilla-Tatoosh line was formally adopted as the seaward limit of net fishing in Juan de Fuca Strait.

In 1957 Canada and the United States ratified a Protocol to the existing Fraser River salmon treaty to bring management of pink salmon fisheries in Fraser Convention waters, which include Juan de Fuca Strait, under internationa control (Vernon, et al., 1964). Terms of the original Fraser River salmon treaty, ratified in 1937, required the United States and Canada to restore and maintain the fishery for Fraser River sockeye salmon and divide the allowable catch equally between fishermen of the two nations. The same requirements applied to the pink Protocol. In terms of management, the Fraser River salmon treaty empowers the IPSFC to regulate all Convention water fisheries involving pink and sockeye stocks of the Convention area. The Commission's objectives are to ensure adequate pink and sockeye spawning escapements, to divide the Convention area catch between both countries and to conduct scientific investigations necessary for management, maintenance and development of Convention stocks.

Little factual information is available on development of the Victoria-Sooke sport fishery) Sport Areas 19B and 20). However, as annual effort exceeded 7, 000 boat days (Appendix Figure 2B) in 1960, the earliest accurate records available, it is reasonable that sport fishing activity was common well before 1960. Residents of Sooke and certain Departmental employees recall considerable sport fishing activity prior to 1960, particularly in the vicinity of traps at Gordons Beach, just west of Otter Point, and at the entrance to Sooke Harbour. Indeed, there are several references in CDFF files to operational problems encourntered by trap owners from sports fishermen fishing alongside the leads and at the entrance to the outer "heart" where schooled salmon were easily accessible to sport gear.

Since 1960 sport effort has increased fourfold (30, 000 boat days, 1967), partly a response to increased marina facilities and launching ramps. Note the odd-even year fluctuations undoubtedly caused by cycling pink abundance. In recent years (1967 and 1968) Sooke-Victoria angler participation has ranked fourth in British Columbia behind District I (Vancouver-Howe Sound), Area 13 (Campbell River) and Area 14 (Comox-Courtenay). In terms of total catch Sooke-Victoria ranked second in 1968 and first in 1967 due to high pink abundance Clearly this is an important sport fishing area.

A small Strait troll fleet developed soon after gillnet effort increased; however, trolling effort never approached levels of west coast or Georgia Strait troll fleets and, consequently, was unimportant on a provincial basis. Effort remained relatively high through 1966 (Appendix Figure 2B) although odd-even year fluctuations are present indicating importance of pink salmon. Effort dropped after 1967, mainly due to a partial area closure enacted in 1967 (see below). Based on a CDFF study in 1967 (Unpublished), the majority of trollers fishing Area 20 (and Area 19) were based at local ports, were under 30 ft. (11.7 m.) in length, and apparently relied on sources other than commercial fishing for the major portion of their income.

In May, 1967, the Department of Fisheries and Forestry announced that beginning July 1, 1967, all commercial fishing would be prohibited until further notice in Area 20 east of a line drawn true south from Sheringham Point (a distance of 15.5 nautical miles, 17.8 statute miles, 28.7 km.) and Area 19 in total (William Head to Curtis Point). The closure was promulgated to increase numbers of coho accessible to sport gear and to prevent physical interaction between sport and commercial gear.

Previous to the closure, sports representatives had asked for Departmental action to specifically improve coho sport fishing as they felt sport fishermen were not achieving a "fair share" of the total Strait coho catch. As a possible solution they had proposed, on a trial basis in 1967, a "two mile wide net-free salmon reserve" to extend along the Vancouver Island shore from the Bonilla-Tatoosh line eastward to Area 18 so that coho would pass to the sport area untouched by net gear. The Department favoured the enacted regulation because, it was argued, a corridor would be of considerable hardship to commercial fishermen and management agencies (enforcement). Secondly, there was no assurance that coho would remain within the corridor for the full length of the Strait. In conjunction with the closure the Department began an extensive two year marine study of salmon (particularly coho) and fishing gears of Juan de Fuca Strait; results of this study provided much of the data reported in the text.

APPENDIX TABLE 1B. Annual commercial salmon catch (pieces) for Statistical Area 20, 1958 - 1968.*

Year	Coho				Pink				Sockeye			
	Gillnet	Seine	Troll	Total	Gillnet	Seine	Troll	Total	Gillnet	Seine	Troll	Total
1958	147, 239	100, 644	8, 383	256, 266	262	310	104	676	425, 913	2, 369, 547	NR	2, 809, 578
1959	205, 189	195, 578	16, 424	417, 191	186, 520	1, 298, 522	52, 997	1, 538, 039	115, 394	489, 133	NR	604, 527
1960	64, 775	17, 235	693	82, 703	893	676	12	1, 581	200, 258	350, 002	NR	550, 260
1961	246, 870	209, 531	7, 085	463, 486	32, 179	308, 620	8, 274	349, 073	274, 789	343, 338	418	618, 545
1962	186, 812	203, 475	18, 400	408, 687	366	630	174	1, 170	128, 488	158, 923	96	287, 507
1963	141, 503	203, 433	10, 810	355, 746	373, 835	2, 912, 091	70, 098	3, 356, 024	44, 611	98, 325	528	143, 464
1964	214, 026	89, 077	12, 396	315, 499	616	56	44	716	26, 692	7, 334	66	34, 092
1965	241, 906	211, 483	6, 362	459, 751	74, 419	335, 094	4, 426	413, 938	86, 000	83, 828	172	170, 000
1966	359, 902	204, 267	7, 873	572, 042	3, 474	1, 792	216	5, 482	289, 512	407, 443	51	697, 006
1967	199, 826	260, 150	2, 659	462, 635	375, 652	2, 247, 367	44, 898	2, 667, 917	261, 268	592, 482	3, 685	857, 435
1968	259, 522	139, 424	1, 825	400, 771	748	214	2	964	43, 059	13, 641	7	56, 707
Means												
1958-1968	206, 141	166, 754	8, 446	381, 354	95, 360	645, 942	16, 477	757, 779	172, 362	446, 728	627	619, 546
Odd Years					208, 521	1, 420, 339	36, 139	1, 664, 998				
1963-1968	236, 114	184, 639	6, 987	427, 741	138, 124	916, 102	19, 947	1, 074, 173	125, 190	200, 509	752	326, 450

Year	Chinook+				Chum				Total by Gear			Grand Total
	Gillnet	Seine	Troll	Total	Gillnet	Seine	Troll	Total	Gillnet	Seine	Troll	
1958	5, 083	3, 221	1, 871	10, 175	26, 019	2, 493	4	29, 445	604, 516	2, 476, 215	10, 362	3, 091, 093
1959	5, 973	10, 593	1, 366	16, 932	27, 355	8, 589	246	36, 190	539, 431	2, 002, 415	71, 538	2, 612, 879
1960	7, 378	6, 042	1, 540	14, 960	14, 669	1, 114	27	15, 810	287, 973	375, 069	2, 272	655, 314
1961	13, 142	17, 516	2, 960	33, 618	10, 985	2, 212	75	13, 272	577, 965	881, 217	18, 812	1, 477, 994
1962	7, 612	7, 781	5, 492	20, 885	11, 192	2, 479	8	13, 679	334, 470	373, 288	24, 170	731, 928
1963	5, 818	7, 675	10, 845	24, 338	14, 635	4, 799	204	19, 638	580, 402	3, 226, 323	92, 485	3, 899, 210
1964	8, 198	3, 575	9, 549	21, 322	35, 737	1, 500	21	37, 258	285, 269	101, 542	22, 076	408, 887
1965	13, 082	12, 880	3, 038	29, 010	20, 111	3, 463	10	23, 584	435, 518	646, 748	14, 008	1, 096, 283
1966	14, 524	10, 622	3, 904	29, 050	22, 878	3, 963	14	26, 855	690, 290	628, 087	12, 058	1, 330, 435
1967	10, 939	8, 304	1, 384	20, 627	13, 725	6, 850	27	20, 602	861, 418	3, 115, 153	52, 653	4, 026, 652
1968	13, 617	8, 054	518	22, 189	22, 708	4, 042	2	26, 752	339, 654	165, 375	2, 354	507, 383
Means												
1958-1968	9, 488	8, 752	3, 859	22, 101	20, 000	3, 864	58	23, 917	503, 355	1, 256, 914	29, 343	1, 803, 460
1963-1968	11, 030	8, 570	4, 873	24, 423	21, 632	4, 103	46	25, 782	532, 092	1, 313, 871	32, 606	1, 878, 142

* Source: CDFF annual publications of B. C. Catch Statistics.

+ Red, white and jack categories included.

NR - No recorded catch.

APPENDIX TABLE 2B. Annual sport salmon catch (pieces) for Sport Statistical Area 19B-20, 1960-1968*

Year	Coho**	Coho° ≤ 3 lb.	Chinook+	Pink	Total
1960	1,805	5,150	5,775	-	12,630
1961	5,625	1,700	5,725	3,750	16,800
1962	2,700	1,575	3,125	25	7,425
1963	16,420	5,355	7,245	67,225	96,245
1964	7,330	1,751	4,475	350	13,906
1965	5,784	2,248	7,425	5,800	21,275
1966	6,771	1,704	6,175	175	14,825
1967	26,175	1,206	9,550	18,950	55,881
1968	27,170	1,584	11,130	-	39,884
Mean 1963-1968	14,942	2,308	7,666	15,417 (30,658)++	40,336

* Source: CDFF Economics Branch base files.

** Includes coho classified as "grilse" between January and July.

o "Grilse" coho (≤ 3 lb. round weight) caught from August to December, primarily aged 2_2.

\+ Includes chinook classified as "grilse" (most would be 1.5 to 3.0 lb. fish and in their second ocean year).

++ Odd-year mean.

APPENDIX TABLE 3B. Annual Sooke trap catch (pieces), 1922 to 1958[a]

Year	Chinook			Steelhead	Sockeye	Pink	Chum	Coho	Traps[b]
	Red	White	Total						
1922	26873	7684	34557	1152	37051	5300	3598	137370	4
1923	19417	5548	24965	1663	27842	128322	6713	150439	6
1924	20507	9036	29543	2427	45345	21581	10640	142876	4
1925	27248	8052	35300	1304	51118	300755	8482	160944	5
1926	20030	4877	24907	1382	24631	5036	20816	64698	6
1927	24503	5645	30148	1268	51383	240261	8491	91439	5
1928	27579	5441	33020	1515	32345	2926	6928	61724	5
1929	18429	4107	22536	1358	44462	185861	6926	90261	5
1930	24659	7115	31774	1536	57132	6499	3748	58761	6
1931	14977	4059	19036	1588	30167	304188	7072	49600	6
1932	20818	5633	26451	1097	48349	2739	17828	48794	4
1933	15532	3915	19447	1317	121633	377828	2901	50480	4
1934	20734	5976	26710	1134	68833	546	6687	32310	5
1935	15582	4228	19810	958	73244	397595	4583	50117	5
1936	12505	3792	16297	1052	44719	209	4749	36391	4
1937	14978	4434	19412	449	99506	164294	1642	26555	5
1938	9205	3442	12647	873	40925	1472	953	24703	5
1939	14145	4856	19001	932	52693	169018	1626	43091	5
1940	17388	4527	21915	1720	28756	328	3367	24648	5
1941	15051	3888	18939	1264	129812	55503	2360	42742	5
1942	12479	4943	17422	1561	100432	116	2834	30522	5
1943	12761	3302	16063	1105	16926	33699	1263	27843	4
1944	6321	2581	8902	1097	27457	605	697	29721	4
1945	22639	8585	31224	1807	30444	221871	2179	55115	5
1946	21298	6732	28030	2283	37006	42	7758	16588	5
1947	13765	3451	17216	1086	3624	168284	2646	43091	5
1948	22766	4926	27692	1649	74478	214	1930	33032	5
1949	20700	5920	26620	829	51018	109304	2158	29930	5
1950	20282	7252	27534	1215	39460	6782	5226	62678	5
1951	11784	2662	14446	1399	42040	123084	1522	18461	5
1952	13880	3011	16891	1840	65426	839	867	18446	5
1953	11328	3260	14588	1180	60071	86280	1249	15803	4
1954			11166		32903	88	503	7375	3
1955			14264		18557	124750	942	7300	5
1956[c]									
1957			8939		15761	31296	190	15323	5
1958			13476		14118	648	929	10298	3

[a]Source: (1) 1922-1953, Canada Department of Fisheries files, Vancouver, B. C.
(2) 1954-1958, Canada Department of Fisheries, Review of Salmon Catches in British Columbia (1951-1960).

[b]Maximum number of traps in operation.

[c]Traps did not operate in 1956 and were permanently closed after the 1958 season.

APPENDIX TABLE 4B. Numbers of commercial fishing days for the June and Fall fisheries of Statistical Area 20, 1958 to 1968[a].

Year	June Fishery			Fall Fishery										Strike Dates
				Total				August			September			
	Time Period	No. Days	No. Weeks	Time Period	No. Days	No. Weeks	Avg. Days Per Week	No. Days	No. Weeks	Avg. Days Per Week	No. Days	No. Weeks	Avg. Days Per Week	
1958	June 16-21	5	1	Aug. 20-Oct. 31	46	10	4.6	7	2	3.5	14	3	4.7	- -
1959	No fishery	-	-	July 22-Oct. 22	48	12	4.0	9	3	3.0	20	4	5.0	July 25-Aug. 9
1960	No fishery	-	-	July 17-Oct. 20	37	11	3.4	9	3	3.0	10	3	3.3	- -
1961	June 15-24	7	2	July 16-Oct. 22	30	13	2.3	8	4	2.0	10	4	2.5	- -
1962	June 15-23	6	2	Aug. 6-Oct. 3	27	9	3.0	9	4	2.3	15	4	3.8	- -
1963	June 17-22	5	1	Aug. 4-Oct. 22	34	12	2.8	16	4	4.0	9	4	2.3	July 13-Aug. 3
1964	June 15-27	9	2	Aug. 15-Nov. 10	38	13	2.9	6	2	3.0	11	4	2.8	- -
1965	June 14-26	7	2	Aug. 1-Oct. 27	36	12	3.0	11	4	2.8	10	3	3.3	- -
1966	June 15-23	6	2	Aug. 1-Oct. 19	38	12	3.2	14	4	3.5	12	4	3.0	- -
1967	June 18-21	3	1	Aug. 5-Oct. 11	36	10	3.6	14	4	3.5	16	4	4.0	- -
1968	June 16-July 3	9	3	Aug. 11-Oct. 22	29	11	2.6	9	3	3.0	12	4	3.0	- -
Means	1958-1968	5.1	1.4		36.3	11.4	3.2	10.2	3.3	3.1	12.6	3.7	3.4	
	1963-1968	6.5	1.8		35.2	11.7	3.0	11.8	3.5	3.4	11.7	3.8	3.1	

[a] Source: Conservation and Protection Branch records from the Vancouver and Victoria offices, CDFF.

APPENDIX TABLE 5B. Annual period during which the International Pacific Salmon Fisheries Commission has regulated Statistical Area 20 and the gear type initiating weekly fishing.[a]

Year	Date IPSFC Assumed Control	Date IPSFC Relinquished Control	Gear Type Initiating Weekly Fishing[b]
1958	June 23	October 6	Gillnet
1959	June 21	October 7	Gillnet
1960	June 20	August 28	Gillnet
1961	June 24	September 17	Seine
1962	June 24	September 2	Seine
1963	June 23	September 22	Gillnet
1964	June 28	August 15	Gillnet
1965	June 25	September 1	Gillnet
1966	June 25	September 4	Seine
1967	June 25	September 16	Gillnet
1968	July 4	August 11	Gillnet

[a] Source: IPSFC Annual Reports and CDFF Vancouver files.

[b] Fall fishery, by regulation during IPSFC control.

APPENDIX TABLE 6B. Mean round weight (lb.) of salmon caught by gillnet and seine gear in August and September for Area 20, 1958 to 1969.

	Coho				Chinook*				Pink				Sockeye				Chum			
	Aug.		Sept.		Aug.		Sept.		Aug.		Sept.		Aug.		Sept.		Aug.		Sept.	
Year	GN	SN	GN	SN	GN	SN	GN	SN	GN	SN	GN	SN	GN	SN	GN	SN	GN	SN	GN	SN
1958	7.49	7.54	8.93	8.65									6.43	6.28	6.26	6.01	10.45	11.26	9.96	11.09
1959	5.74	4.86	7.22	6.17					4.99	5.26	5.00	5.23	5.66	5.35	5.59	4.88	10.06	11.55	10.20	11.08
1960	6.57	6.76	8.92	8.32									5.68	5.42	5.75		11.11	13.73	9.52	
1961	6.51	6.38	9.49	9.22					6.40	7.17	6.88	6.95	5.97	4.99	6.96	5.00	9.09	13.00	10.78	12.26
1962	7.22	7.25	9.54	8.64									6.63	6.62	6.59	5.38	10.29	11.42	10.44	11.07
1963	6.22	5.23	7.66	6.27	8.54	11.90	10.88	9.06	4.88	5.06	5.44	5.11	5.98	5.74	6.18	5.56	10.61	11.88	10.53	11.43
1964	7.01	6.97	9.26	8.99	7.48	7.42	10.30	6.46					6.06	5.52	6.55	5.65	9.26	10.26	10.25	11.38
1965	6.98	6.55	9.43	8.88	7.11	7.18	11.22	7.41	5.85	6.39	6.49	5.86	5.92	5.12	7.00	4.70	9.21	9.59	9.77	9.96
1966	5.95	5.11	7.85	7.45	7.65	12.56	9.30	12.45					6.84	6.88	6.91	4.84	10.84	12.74	10.49	11.26
1967	6.14	5.36	7.89	6.89	7.48	11.73	9.81	11.11	4.87	5.27	5.43	5.40	6.06	6.01	6.12	5.60	9.43	10.56	9.72	10.04
1968	6.26	5.28	7.02	6.22	6.67	5.75	8.41	7.43					6.07	5.73	6.13	5.13	11.41	11.95	11.34	12.00
1969	6.85	6.93	8.39	8.34	6.61	6.92	8.55	6.03	5.53	6.11	5.70	5.65	6.06	5.46	6.59	5.05	10.30	12.00	10.51	11.65
Mean	6.58	6.21	8.47	7.84	7.36	9.07	9.78	8.56	5.42	5.88	5.82	5.70	6.11	5.76	6.39	5.25	10.17	11.66	10.29	11.20
SD	0.53	0.94	0.91	1.17	0.66	2.86	1.09	2.42	0.62	0.83	0.71	0.67	0.35	0.58	0.46	0.41	0.78	1.17	0.51	0.71
CV+	8%	15%	11%	15%	9%	32%	11%	28%	11%	14%	12%	12%	6%	10%	7%	8%	8%	10%	5%	6%

* Includes red, white and jack categories.

\+ CV = (SD/mean) 100.

APPENDIX TABLE 7B. Gillnet selection index, $\hat{S}$, in August and September for Area 20, 1958 to 1969.

	Coho		Chinook		Pink		Sockeye		Chum	
Year	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.
1958	-0.7	3.2					2.4	4.2	- 7.2	-10.2
1959	18.1	17.0			- 5.1	-4.4	5.8	14.6	-12.9	- 7.9
1960	-2.8	7.2					4.8	-	-19.1	-
1961	2.0	2.9			-10.7	-1.0	19.6	39.2	-30.1	-12.1
1962	-0.4	10.4					0.2	22.5	- 9.9	- 5.7
1963	18.9	22.2	-28.2	20.1	- 3.6	6.5	4.2	11.2	-10.7	- 7.9
1964	0.6	3.0	0.8	59.4			9.8	15.9	- 9.8	- 9.9
1965	6.6	6.2	- 1.0	51.4	- 8.5	10.8	15.6	48.9	- 4.0	- 1.9
1966	16.4	5.4	-39.1	-25.3			-0.6	42.8	-14.9	- 6.8
1967	14.6	14.5	-56.8	-11.7	- 7.6	0.6	0.8	9.3	-10.7	- 3.2
1968	18.6	12.9	13.8	13.2			5.9	19.5	- 4.5	- 5.5
1969	-1.2	0.6	4.5	41.8	- 9.5	0.9	11.0	30.5	-14.2	- 9.8
Mean	8.41 (7.5)[+]	8.89	20.60 (-15.2)	31.81 (21.3)	7.50 (-7.5)	4.03 (2.2)	6.73 (6.6)	23.51	12.33 (-12.3)	7.35 (-7.4)
SD	8.1	6.7	21.6	19.0	2.7	4.1	6.2	14.8	7.0	3.12
CV[++]	96.4%	75.7	104.7	59.9	35.9	101.7	91.6	63.0	57.2	42.4

[+] Unbracketed equals absolute mean; bracketed equals mean sign, considered.

[++] CV = (SD/mean) 100.

APPENDIX TABLE 8B. Regression analysis for gillnet selection index, $\hat{S}$, versus seine mean weight, $\overline{W}_s$.+

		N	t	Equation	$H_o: b_{August} = b_{September}$
Coho	Aug.	12	9.53^{**}	Y = 62.8 - 8.9X	$t = 3.07^{**}$, Accept H_i
	Sept.	12	4.73^{**}	Y = 4.59 - 4.7X	
Chinook	Aug.	7	5.88^{**}	Y = 62.7 - 8.6X	Accept H_o
	Sept.	7	4.97^{**}	Y = 124.0 - 12.0X	
Pink	Aug.	6	3.62^{*}	Y = 9.3 - 2.9X	
	Sept.	6	NS		
Sockeye	Aug.	12	4.95^{**}	Y = 58.8 - 9.1X	$t = 2.83^{*}$, Accept H_i
	Sept.	11	4.31^{**}	Y = 178.5 - 29.5X	
Chum	Aug.	12	3.09^{*}	Y = 36.6 - 4.2X	Accept H_o
	Sept.	11	3.46^{*}	Y = 30.0 - 3.3X	

+ $\hat{S}$ were coded, by addition, to positive values for regression computations. Codes were then subtracted from the intercept. To calculate $\hat{Y}$ ($Y=\hat{S}$) for negative selection change to positive $\hat{b}$

APPENDIX C

TABLES FOR RELATIVE GEAR EFFICIENCY SECTION

APPENDIX TABLE 1C. Monthly gillnet to seine relative gear efficiency (in numbers of gillnet units) 1963 to 1968.*

Species	Month	1963	1964	1965	1966	1967	1968	N	$\hat{C}_{gs}$	CV***
Coho	August	4.4	4.7	3.6	-**	3.2	5.2	5	4.2	19%
	September	4.2	4.9	2.3	5.3	4.0	3.2	6	4.0	28
	October	2.9	3.2	6.4	5.8			4	4.6	39
								15	4.2	28
Chinook	August	5.1	8.4	3.7	-	3.2	10.7	5	6.1	49
	September	9.5	11.4	2.1	1.2	2.0	1.8	6	4.7	96
	October	18.8	7.9	5.8	1.0			4	8.4	90
								15	6.2	80
Pink	August	7.2		10.8		10.9		3	9.6	22
	September	17.6		7.2		13.3		3	12.7	41
								6	11.2	35
Sockeye	August	3.7	5.1	4.9	-	5.2	2.4	5	4.3	28
	September	4.9		5.3+		5.6	4.3	3	4.9	13
								8	4.5	23
Chum	August	2.2	1.0	1.0	-	1.2	2.7	5	1.6	49
	September	1.7	1.1	1.6	0.7	3.2	1.3	6	1.6	54
	October	5.7	1.4	4.0	4.0			4	3.8	49
								15	2.2	66

* Source statistics: Daily delivery statistics collected at Port San Juan by personnel of the Conservation and Protection Branch, CDFF, unpublished.

** Seines initiated weekly fishing, computations omitted.

\+ Average of 1963 and 1967

*** CV = 100SD/mean.

Blanks equal insufficient catch or effort.

APPENDIX TABLE 2C. Catch and effort statistics used to calculate troll to gillnet and sport to gillnet relative gear efficiencies, 1965-1966.*

Sport, Area 19B-20				Sport, Area 20			Troll					Gillnet				
Date	Effort	Catch		Date	Effort	Catch	Date	Effort	Catch			Date	Effort	Catch		
		Chinook	Pink			Coho			Coho	Chinook	Pink			Coho	Chinook	Pink
								1965								
Aug.	5,355	451	2,858	Aug. 22	700	805	Aug. 21	55**	172	51	201	Aug. 16, 17, 25	184**	4,566	210	5,393
Sept.	7,513	928	2,558	29	1,650	530	28	115**	781	65	1,045	Aug. 25, Sept. 7	222**	7,750	63	3,670
Oct.	1,300	286	-	Sept. 12	1,433	520	Sept. 11	139**	361	46	641	Sept. 7, 8, 20	369**	8,240	126	2,321
				Oct. 9	50	20	Oct. 8	18	24	44	-	Oct. 4, 5, 11	327	5,506	32	-
Total	14,168 12,868**	1,665	5,416										1,102 775**		431	11,384
								1966								
				Sept. 11	491	594	Sept. 10	53	231	77	-	Sept. 6, 7, 12	348	12,586	410	-
Sept.	5,701	545	-	18	481	435	17	31	138	35	-	12, 13, 19	383	16,305	180	-
Oct.	1,974	309	-	25	505	310	24	43	227	15	-	19, 20, 26	410	18,600	41	-
				Oct. 2	470	100	Oct. 1	74	316	18	-	26, 27, Oct. 1	493	14,038	44	-
Total	7,676	854											1,634		675	

*Source statistics: Sport Area 19B-20 from Economics Branch, CDFF, base files, unpublished;
Sport Area 20 from Conservation and Protection Branch, CDFF, weekly field records, unpublished;
Troll from CDFF publications of British Columbia Catch Statistics;
Gillnet from Conservation and Protection Branch, CDFF, daily delivery statistics collected at Sooke, unpublished.

**Effort used to calculate pink salmon relative gear efficiencies.

APPENDIX TABLE 3C. Troll to gillnet relative gear efficiency, (in numbers of troll units) 1965 and 1966.*

Species	1965	1966	$\hat{C}_{tg}$
Coho	8.6	8.2	8.4
Chinook	0.7	0.5	0.6
Pink	2.4	-	2.4

*Source statistics in Appendix Table 2C.

APPENDIX TABLE 4C. Sport to gillnet relative gear efficiency (in numbers of sport units), 1965 and 1966.

Species	1965	1966	$\hat{C}_{spg}$
Coho	50.1	76.3	63.2
Chinook	3.3	3.7	3.5
Pink	34.8	-	34.8

*Source Statistics in Appendix Table 2C.

APPENDIX D

TABLES FOR COHO SUSCEPTIBILITY EXPERIMENT

APPENDIX TABLE 1D. Daily coho sample size during 1965 test trolling.

Date	Trolling Time (PDT)++	Sample Size ♂	Sample Size ♀	Sample Size Total	
July 29	0600-1000	-	1	1	*
30	0545-1245	9	8	17	*
31	0715-1340	8	14	22	*
August 1	0745-1200	18	12	30	*
6	1030-1630	8	4	12	*
7	0905-1305	18	10	28	*
8	1125-1325	13	6	19	*
9	0800-1330	16	6	22	*
14	1145-1830	18	7	25	*
15	1045-1545	17	6	23	*
16	0930-1430	4	1	5	*
20	1145-1600	6	3	9	*
21	0915-1445	8	7	15	*
22	0800-1600	6	6	12	*
26	1200-1815	5	4	9	*o
27	1030-1750	13	4	17	*o
28	1145-1430	-	-	-	+
31	1000-1600	2	1	3	*
September 1	1000-1600	2	1	3	+*
3	1130-1845	2	3	5	*
4	1230-1730	4	3	7	o
5	1120-1700	5	12	17	*
6	1125-1730	14	13	27	*o
7	1145-1430	3	4	7	o
12	1240-1800	8	5	13	*
13	1050-1645	1	-	1	+
17	1055-1640	2	2	4	o
18	0915-1640	2	2	4	+
19	0930-1600	-	-	-	*
20	1015-1500	1	-	1	o
25	1030-1630	-	-	-	*
26	1600-1900	1	-	1	+
27	0745-1200	-	-	-	+
28	0900-1830	-	-	-	+
29	0730-1230	-	-	-	+
Total 35 days 168 hours		214	145	359	

* Catches within 5 miles of Bonilla-Tatoosh line

o Catches > 5 miles west of the line

\+ Catches > 5 miles east of the line

++Occasionally includes running time.

APPENDIX TABLE 2D. Weekly seine sample size, 1965.

Date	Number seines sampled	Sample Size ♂	♀	Total
August 2, 3	9	62	38	100
9	7	61	39	100
16	5	59	41	100
25	4	55	45	100
31[+]	1	56	44	100
September 7	5	48	52	100
13	4	45	55	100
20	5	48	52	100
27	5	20	30	50
Total	45	454	396	850

[+] From IPSFC test fishing, fishery closed.

APPENDIX TABLE 3D. Length (mm.), fish weight (g.), and gonad weight (g.) for troll and seine coho sub-samples for ANCOVA analysis.

SEINE

Sex (Male = 1)	Week No. Code	Seine Code	,	,	Length (mm.)	Weight (g.)	Sex	Gonad Weight (g.) 0.1	Sex (Male = 1)	Week No. Code	Seine Code	,	,	Length (mm.)	Weight (g.)	Sex	Gonad Weight (g.) 0.1
1	1	2	1	1	565	3119	1	1117	1	4	2	1	1	600	3175	1	1215
1	1	2	2	2	571	2381	1	417	1	4	2	2	2	592	2948	1	1214
1	1	2	3	3	529	2041	1	903	1	4	2	3	3	681	4309	1	1571
1	1	2	4	4	472	1361	1	384	1	4	2	4	4	722	6350	1	2257
1	1	2	5	5	615	3402	1	742	1	4	2	5	5	491	1814	1	1252
1	1	2	6	6	662	3493	1	374	1	4	2	6	6	637	3572	1	1512
1	1	2	7	7	581	1542	1	176	1	4	2	7	7	651	3714	1	1592
1	1	2	8	8	535	2132	1	346	1	4	2	8	8	745	4990	1	1326
1	1	2	9	9	645	3538	1	678	1	4	2	9	9	495	1588	1	760
2	1	2	1	10	590	3062	2	502	2	4	2	1	10	702	4763	2	3364
2	1	2	2	11	583	2438	2	436	2	4	2	2	11	656	3289	2	1726
2	1	2	3	12	695	5443	2	943	2	4	2	3	12	600	2552	2	750
2	1	2	4	13	577	2495	2	297	2	4	2	4	13	442	1247	2	220
2	1	2	5	14	554	4139	2	1034	2	4	2	5	14	590	2495	2	1898
2	1	2	6	15	557	1701	2	426	2	4	2	6	15	570	2608	2	1064
2	1	2	7	16	636	4173	2	1607	2	4	2	7	16	623	3147	2	1250
2	1	2	8	17	622	3357	2	618	2	4	2	8	17	568	2296	2	535
2	1	2	9	18	615	3583	2	1081	2	4	2	9	18	567	2268	2	1637
1	2	2	1	1	527	2449	1	1158	1	5	2	1	1	531	2325	1	1182
1	2	2	2	2	644	3674	1	1344	1	5	2	2	2	688	5216	1	2359
1	2	2	3	3	545	2268	1	1217	1	5	2	3	3	734	6180	1	2323
1	2	2	4	4	650	3992	1	670	1	5	2	4	4	778	7711	1	3549
1	2	2	5	5	500	1814	1	869	1	5	2	5	5	706	5783	1	2703
1	2	2	6	6	675	3992	1	869	1	5	2	6	6	715	5783	1	2273
1	2	2	7	7	624	3175	1	1188	1	5	2	7	7	705	6237	1	1702
1	2	2	8	8	530	2313	1	318	1	5	2	8	8	688	5443	1	1513
1	2	2	9	9	570	2903	1	974	1	5	2	9	9	603	2977	1	845
2	2	2	1	10	643	4082	2	828	2	5	2	1	10	689	3629	2	947
2	2	2	2	11	520	1588	2	161	2	5	2	2	11	602	3175	2	1800
2	2	2	3	12	687	3765	2	1307	2	5	2	3	12	675	5216	2	3528
2	2	2	4	13	681	4672	2	1486	2	5	2	4	13	586	3005	2	1442
2	2	2	5	14	665	3856	2	520	2	5	2	5	14	705	5557	2	3254
2	2	2	6	15	414	1769	2	516	2	5	2	6	15	611	2552	2	1604
2	2	2	7	16	656	3992	2	490	2	5	2	7	16	732	6464	2	2276
2	2	2	8	17	541	1905	2	593	2	5	2	8	17	698	5443	2	2862
2	2	2	9	18	630	3266	2	1576	2	5	2	9	18	668	3856	2	2349
1	3	2	1	1	502	1724	1	610	1	6	2	1	1	752	6407	1	3094
1	3	2	2	2	686	5035	1	2030	1	6	2	2	2	585	2807	1	1657
1	3	2	3	3	620	3266	1	407	1	6	2	3	3	700	4224	1	2781
1	3	2	4	4	639	3447	1	788	1	6	2	4	4	613	3260	1	1938
1	3	2	5	5	641	3901	1	864	1	6	2	5	5	765	7881	1	4345
1	3	2	6	6	746	6124	1	2223	1	6	2	6	6	760	6691	1	3043
1	3	2	7	7	630	3629	1	733	1	6	2	7	7	606	3090	1	1942
1	3	2	8	8	532	1928	1	631	1	6	2	8	8	762	7428	1	2804
1	3	2	9	9	575	2722	1	953	1	6	2	9	9	560	2552	1	1554
2	3	2	1	10	701	5171	2	1228	2	6	2	1	10	640	3969	2	2584
2	3	2	2	11	584	1497	2	441	2	6	2	2	11	715	5472	2	3384
2	3	2	3	12	591	2676	2	635	2	6	2	3	12	718	5528	2	4272
2	3	2	4	13	694	3538	2	1874	2	6	2	4	13	740	6691	2	5419
2	3	2	5	14	580	2041	2	735	2	6	2	5	14	702	4338	2	1619
2	3	2	6	15	560	1701	2	186	2	6	2	6	15	620	3601	2	2866
2	3	2	7	16	620	3402	2	818	2	6	2	7	16	605	2693	2	986
2	3	2	8	17	615	2722	2	1216	2	6	2	8	17	680	4281	2	2528
2	3	2	9	18	565	2155	2	1233	2	6	2	9	18	648	3119	2	1294

TROLL

Sex (Male = 1)	Week No. Code	Troll Code	,	,	Length (mm.)	Weight (g.)	Sex	Gonad Weight (g.) 0.1	Sex (Male = 1)	Week No. Code	Troll Code	,	,	Length (mm.)	Weight (g.)	Sex	Gonad Weight (g.) 0.1
1	1	1	1	1	554	2359	1	274	.	4	1	1	1	715	5557	1	1961
1	1	1	2	2	583	2858	1	498	1	4	1	2	2	682	4649	1	1562
1	1	1	3	3	560	2586	1	1045	1	4	1	3	3	520	1928	1	762
1	1	1	4	4	510	2041	1	289	1	4	1	4	4	574	2665	1	1382
1	1	1	5	5	591	3039	1	383	1	4	1	5	5	700	4876	1	1462
1	1	1	6	6	559	2449	1	805	1	4	1	6	6	678	4309	1	1696
1	1	1	7	7	588	2903	1	491	1	4	1	7	7	605	2835	1	906
1	1	1	8	8	572	2404	1	776	1	4	1	8	8	594	2693	1	405
1	1	1	9	9	684	4854	1	1064	1	4	1	9	9	506	1758	1	896
2	1	1	1	10	654	3674	2	967	2	4	1	1	10	670	4082	2	1006
2	1	1	2	11	588	2858	2	539	2	4	1	2	11	648	3175	2	876
2	1	1	3	12	555	2223	2	309	2	4	1	3	12	625	3289	2	1180
2	1	1	4	13	623	3538	2	928	2	4	1	4	13	700	4990	2	3823
2	1	1	5	14	558	3901	2	1083	2	4	1	5	14	610	2750	2	664
2	1	1	6	15	630	3039	2	501	2	4	1	6	15	700	5103	2	1200
2	1	1	7	16	590	2903	2	319	2	4	1	7	16	687	4763	2	1764
2	1	1	8	17	618	3538	2	429	2	4	1	8	17	724	5783	2	3294
2	1	1	9	18	609	3085	2	306	2	4	1	9	18	662	4508	2	3268
1	2	1	1	1	548	2540	1	627	1	5	1	1	1	583	2750	1	1090
1	2	1	2	2	628	3810	1	962	1	5	1	2	2	612	3345	1	722
1	2	1	3	3	563	2495	1	857	1	5	1	3	3	608	3175	1	2227
1	2	1	4	4	621	3085	1	694	1	5	1	4	4	606	2948	1	205
1	2	1	5	5	512	1814	1	713	1	5	1	5	5	656	3969	1	2267
1	2	1	6	6	628	3357	1	292	1	5	1	6	6	514	1985	1	761
1	2	1	7	7	678	4854	1	548	1	5	1	7	7	697	4593	1	1477
1	2	1	8	8	549	2359	1	303	1	5	1	8	8	730	6124	1	2961
1	2	1	9	9	520	2087	1	695	1	5	1	9	9	598	2920	1	690
2	2	1	1	10	664	4445	2	982	2	5	1	1	10	608	3062	2	1779
2	2	1	2	11	619	3221	2	385	2	5	1	2	11	609	3119	2	1769
2	2	1	3	12	642	3720	2	684	2	5	1	3	12	635	3090	2	2824
2	2	1	4	13	675	4400	2	2249	2	5	1	4	13	713	4791	2	1791
2	2	1	5	14	624	3629	2	628	2	5	1	5	14	675	4082	2	2592
2	2	1	6	15	596	2812	2	611	2	5	1	6	15	623	2920	2	1637
2	2	1	7	16	590	2540	2	706	2	5	1	7	16	657	4366	2	2578
2	2	1	8	17	590	2631	2	993	2	5	1	8	17	708	4281	2	1748
2	2	1	9	18	610	2903	2	524	2	5	1	9	18	676	3969	2	1613
1	3	1	1	1	598	3204	1	1568	1	6	1	1	1	594	2948	1	1187
1	3	1	2	2	539	2013	1	412	1	6	1	2	2	582	3034	1	1186
1	3	1	3	3	597	2863	1	685	1	6	1	3	3	676	4338	1	1063
1	3	1	4	4	458	1333	1	296	1	6	1	4	4	694	4564	1	1752
1	3	1	5	5	521	1900	1	744	1	6	1	5	5	661	4366	1	1048
1	3	1	6	6	605	3130	1	957	1	6	1	6	6	548	2552	1	1298
1	3	1	7	7	508	1678	1	275	1	6	1	7	7	591	3119	1	1513
1	3	1	8	8	532	1996	1	1103	1	6	1	8	8	678	4763	1	2165
1	3	1	9	9	635	1905	1	782	1	6	1	9	9	610	3629	1	3627
2	3	1	1	10	601	3062	2	656	2	6	1	1	10	646	4026	2	1435
2	3	1	2	11	579	2523	2	749	2	6	1	2	11	697	4451	2	1714
2	3	1	3	12	542	1900	2	318	2	6	1	3	12	647	4196	2	1090
2	3	1	4	13	628	2863	2	1684	2	6	1	4	13	546	3827	2	3317
2	3	1	5	14	674	2325	2	1340	2	6	1	5	14	638	3686	2	1822
2	3	1	6	15	591	2404	2	621	2	6	1	6	15	628	3402	2	1910
2	3	1	7	16	612	2994	2	1175	2	6	1	7	16	604	2863	2	1369
2	3	1	8	17	580	2586	2	650	2	6	1	8	17	663	4309	2	4052
2	3	1	9	18	577	2540	2	549	2	6	1	9	18	658	3515	2	1948

APPENDIX TABLE 4D. Maturity indices ($\overline{MI}_w$) and gonad weights (g.) for male coho caught by seine gear in Juan de Fuca Strait, and gillnet gear in the Fraser River, 1965.

Date		Male $\bar{X}$	Male SD	Male N	Female $\bar{X}$	Female SD	Female N
				SEINE			
August 2, 3	MI_w	20.8	11.7	55	24.6	11.8	37
	Gonad wt.	52.4	35.6		86.2	56.9	
9		30.5	11.9	61	28.2	15.6	39
		86.0	43.9		83.7	51.6	
16		31.0	12.8	54	32.2	12.8	39
		86.8	44.7		110.4	59.6	
25		38.1	13.1	50	41.9	18.1	42
		124.7	60.1		142.7	73.6	
31		39.9	14.0	53	56.9	25.2	43
		127.8	75.3		230.1	133.2	
September 7		44.4	12.8	48	56.4	16.9	52
		186.0	67.6		254.2	137.9	
13		50.0	11.8	36	72.9	20.3	43
		199.4	88.2		273.6	173.1	
20		43.4	13.9	47	61.8	23.1	52
		209.4	75.5		325.6	176.2	
27		48.2	6.2	17	81.6	20.7	30
		246.2	74.9		429.0	145.6	
				GILLNET			
October 15-17		63.3	12.1	8	111.8	27.9	12
		291.1	60.7		457.8	99.6	
26		66.0	6.1	5	107.2	34.8	5
		271.5	84.3		565.4	271.1	
November 14, 16					132.6	23.8	7
					643.7	226.7	

APPENDIX TABLE 5D. Organisms found in stomachs of troll seine caught coho salmon and total season percentage occurrence, 1965.

Organism	Overall percentage occurrence Seine (N=818)	Troll (N=357)
FISH		
1. Pacific herring	9.2[+]	8.7
Clupea pallasii	(15.8)[*]	(10.1)
2. Sand lance	8.8	19.3
Ammodytes hexapterus	(15.2)	(22.4)
3. Smelt, Eulachon	0.5	1.4
Thaleichthys pacificus	(0.9)	(1.6)
Surf smelt		
Hypomesus pretiosus		
4. Sablefish	0.6	-
Anoplopoma fimbria	(1.0)	
5. Rockfish	1.0	9.0
Sebastodes spp.	(1.7)	(10.4)
6. Pacific cod	0.2	-
Gadus macrocephalus	(0.4)	-
7. Salmon	0.1	-
Oncorhynchus	(0.2)	
8. Larval fish	1.6	2.2
(probably herring and sand lance)	(2.8)	(2.5)
9. Unidentified	0.2	0.3
	(0.3)	(0.4)
INVERTEBRATES		
1. Euphausiids	33.1	61.6
Euphausia pacifica	(57.2)	(71.4)
Thyanoessa spinifera		
2. Decapod stages	8.1	35.6
3. Other crustaceans	8.3	16.8
(mostly Amphipods)	(14.3)	(19.5)
MISCELLANEOUS	1.2	1.2
(squid, gastropod shells, wood, algae, feathers, insects)	(2.1)	(1.4)
Per cent feeding	57.9	86.3

[+] Per cent of total sample.

[*] Per cent of feeding coho.

APPENDIX TABLE 6D. Mean weight (kg.), euphausiid counts and euphausiid "feeding index" for seine (SN) and troll (TR) samples taken on ANCOVA dates, 1965.

	SN		TR		Euphausiid Feeding Index**		Index Difference
Date	$\overline{X}_W$ +	Count*	Count	$\overline{X}_W$	SN	TR	SN-TR
Aug. 2, 3	2.97	6.7	1.0	3.01	2.26	0.33	1.93
9	3.08	6.4	4.9	3.15	2.08	1.56	0.52
16	3.15	6.2	11.4	2.40	1.97	4.75	-2.78
25	3.17	7.2	39.8	3.87	2.27	10.28	-8.01
Sept. 7	4.63	4.9	41.9	3.64	1.06	11.51	-10.45
13	4.67	12.9	51.3	3.76	2.64	13.64	-11.00

\+ Mean weight, source data in Appendix Table 3D, week codes 1 to 6.

* Mean number euphausiids per coho.

** Count/$\overline{X}_W$.