NOAA Technical Memorandum NMFS-AFSC-18

Adult Sockeye and Pink Salmon Tagging Experiments for Separating Stocks in Northern British Columbia and Southern Southeast Alaska, 1982-1985

bY
Jerome Pella', Margaret Hoffman', Stephen Hoffman:
Michele Masuda', Sam Nelson', and Larry Talley'

'Auke Bay Laboratory
Alaska Fisheries Science Center
11305 Glacier Highway
Juneau AK 99801-8626

'Alaska Department of Fish and Game
Region 1
P.O. Box 240020
Douglas AK 99824-0020

U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary
National Oceanic and Atmospheric Administration
Diana Josephson, Acting Administrator

August 1993

This document is available to the public through:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

ABSTRACT

Adult sockeye (Oncorhynchus nerka) and pink (0. *gorbuscha)* salmon were-captured, tagged, and released in coastal fisheries of southern Southeast Alaska and northern British Columbia between 1982 and 1985. Sockeye salmon were tagged in 1982 and 1983; pink salmon were tagged in 1982, 1984, and 1985. The tagging experiments were part of a cooperative effort by the United States and Canada to assess contributions of stocks of each country to fisheries of the region and to learn about the coastal migrations of these salmon.

Catches and escapements in Alaska and Canada were sampled for the purpose of estimating numbers of tagged fish that either were caught among or escaped to contributing stocks. Estimated numbers of tagged fish in catches and escapements were used to assess stock composition of catches of the fisheries during the tagging years.

Most sockeye salmon in Alaskan fisheries were of Canadian origin, and only a small percentage of the catch in Canada was of Alaskan origin. Alaskan sockeye salmon were relatively more numerous in 1982 than in 1983, compared to Canadian stocks of those years. Sockeye salmon from the Canadian Nass and Skeena Rivers constituted major portions of catches of most fisheries. In 1983, southward-migrating stocks, probably mainly from Canada's Fraser River, occurred in outer coastal fisheries of Alaska and Canada, and in Canadian fisheries at the southern end of the study area..

Most pink salmon in nearly all Alaskan fisheries throughout the season were of Alaskan origin. Only in two of nine Alaskan fishing areas examined did the percentage from Alaskan stocks drop below 75% at times. Percentage of Alaskan pink salmon in Canadian fisheries was also substantial but more variable among areas and years of tagging than in Alaska. In Canada, percentage of Alaskan pink salmon was generally greatest in areas adjoining Alaska.

The interpretation of the experiments for assessing stock composition in fisheries was fraught with difficulties. Among the shortcomings were large potential errors in estimates of numbers of tagged fish escaping to the spawning grounds. How-'ever, numerical studies showed that stock-composition estimates for sockeye or pink salmon would generally not be misleading because of such errors. Lack of information on stock origin of tagged fish caught in intervening fisheries and the apparent incomplete accounting for tagged fish in sampled catches and escapements were further deficiencies whose potential effects on stock-composition estimates were not examined.

CONTENTS

LIST OF TABLES vii

LIST OF FIGURES. xiii

INTRODUCTION 1

METHODS 3

ASSUMPTIONS, DATA ANALYSIS, AND LIMITATIONS 9
Assumptions 9
Data Analysis 9

SOCKEYE SALMON TAGGING EXPERIMENTS OF 1982 AND 1983 . . 17
Primary Tagging in the Fisheries 17
Fishery Recoveries. 17
Terminal Recoveries . . 17
Stock-Composition Estimates. 22
Discussion 23
Sensitivity Analysis 24

PINK SALMON TAGGING EXPERIMENTS OF 1982, 1984, AND 1985 . 29
Primary Tagging in the Fisheries 29
Fishery Recoveries 29
Terminal Recoveries 29
Stock-Composition Estimates 31
Discussion 32
Sensitivity Analysis 33

DISCUSSION AND SUMMARY 35
Primary Tagging 35
Fishery Recoveries 35
Terminal Recoveries 36
Sockeye salmon 36
Pink salmon. 39
Stock-Composition Estimation Method 40
Stock-Composition Estimates 41
Sockeye salmon 41
Sensitivity analysis 42
Pink salmon 42
Sensitivity analysis 43
Caveats and Qualifications 44

ACKNOWLEDGMENTS. 47

CITATIONS 49

TABLES 51

F I G U R E S 105

GLOSSARY 133

LIST OF TABLES

Table 1. --Delineation of general areas of release in Southeast Alaska in terms of the Alaska Department of Fish and Game statistical system 53
Table 2. --Delineation of general areas of release in British Columbia in terms of the Canada Department of Fisheries and Oceans statistical system. 54
Table 3. --Delineation of areas of release in Canada's Dixon Entrance in terms of Canada Department of Fisheries and Oceans statistical system by year: 1984 and 1985 54
Table 4. --Number of tagged sockeye salmon released in southern Southeast Alaska and northern British Columbia, 1982 and 1983. 55
Table 5. --Estimates of total numbers of tagged sockeye salmon caught in Alaskan and Canadian fisheries by general area and period of release, 1982. 56
Table 6. --Estimates of total numbers* of tagged sockeye salmon caught in Alaskan and Canadian fisheries by general area and period of release, 1983. 57
Table 7. --Southeast Alaskan sockeye salmon escapement and weir counts by fishing district, 1982 and 1983. 58
Table 8. --Numbers of sockeye salmon released in secondary tagging on the Skeena, Nass, and Stikine Rivers (adjusted for straying), numbers recovered at weirs or during foot-surveys of spawning grounds (Nass and Skeena Rivers) or in the commercial river fishery (Stikine River), and the recovery rate of tagged fish in each river, 1982 and 1983 (Source: Gazey et al. 1983; English et al. 1984). 59
Table 9. --Estimates of total numbers of tagged sockeye salmon escaping to Alaskan and Canadian spawning areas by period and general area of release, 1982. 60
Table 10. --Estimates of total numbers of tagged sockeye salmon escaping to Alaskan and Canadian spawning areas by period and general area of release, 1983. 61
Table 11. --Numbers of tagged sockeye salmon released, combined numbers estimated as

caught or escaping, percentage of total estimated recoveries from catch and escapement, and recovery rate of tagged releases estimated as occurring in catch or escapement, by release fishery and year. 62

Table 12. --1982 stock-composition estimates (%) of sockeye salmon by area and period of release, totals for Alaska and Canada (%), and estimated numbers of tagged fish in Alaskan and Canadian escapements Best estimates of escapements were used, and recovery rate of primary-tagged entrants to major rivers in Canada was assumed to equal that of secondary-tagged fish. 63

Table 13. --1983 stock-composition estimates (%) of sockeye salmon by area and period of release, totals for Alaska and Canada (%), and estimated numbers of tagged fish in Alaskan and Canadian escapements Best estimates of escapements were used, and recovery rate of primary-tagged entrants to major rivers in Canada was assumed equal to that of secondary-tagged fish. 65

Table 14. --Percentage of Alaskan-origin* sockeye salmon (bootstrap standard error in parentheses) by fishery and period of release, 1982. Dash means no estimate could be made. 67

Table 15. --Percentage of Alaskan-origin* sockeye salmon (bootstrap standard error in parentheses) by fishery and period of release, 1983. Dash means no estimate could be made. 68

Table 16. --Number of tags recovered in catches and escapements of sockeye salmon by area and period of release in 1982. 69

Table 17. --Number of tags recovered in catches and escapements of sockeye salmon by area and period of release in 1983. 70

Table 18. --Percentages of Alaskan-origin sockeye salmon by area and period of release for which 10 or more tags were recovered in catch and escapement sampling, 1982 and 1983. 71

Table 19.--Estimated season stock compositions based on catch-weighted averages" of half-month percentage of sockeye salmon

in northern boundary fisheries bound for the other country, -1982 and 1983. 72

Table 20. --Effects of different estimates of Alaskan escapements and Canadian secondary-tagging mortality on estimated season percentages of Canadian sockeye salmon in Alaskan fisheries, 1982 and 1983. 73

Table 21.--Effects of different estimates of Alaskan escapements and Canadian secondary-tagging mortality on estimated season percentages of Alaskan sockeye salmon in Canadian fisheries, 1982 and 1983. 74

Table 22. --Number of tagged pink salmon released in southern Southeast Alaska and northern British Columbia, 1982, 1984, and 1985. . . . 75

Table 23. --Estimates of total* tagged pink salmon caught in Alaskan and Canadian fisheries by general area and period of release in 1982. 76

Table 24. --Estimates of total[e] tagged pink salmon caught in Alaskan and Canadian fisheries by general area and period of release in 1984. 77

Table 25. --Estimates of total* tagged pink salmon caught in Alaskan and Canadian fisheries by general area and period of release in 1985. 78

Table 26. --Southeast Alaska pink salmon escapement estimates and numbers of carcasses examined for tags by ADF&G statistical areas, 1982, 1984, and 1985. 79

Table 27. --British Columbia pink salmon escapement estimates and numbers of carcasses examined for tags by fishing area, 1984 and 1985. 80

Table 28. --Numbers of pink salmon tagged in major Canadian rivers (adjusted for straying), numbers recovered in the rivers, and the recovery rate (%) by tagging year. 81

Table 29. --Estimates of total numbers of tagged pink salmon escaping to Alaskan and Canadian spawning systems by general area and period of release, 1982. 82

Table 30. --Estimates of total numbers of tagged pink salmon escaping to Alaskan and Canadian spawning systems by general. area and period of release, 1984. 83

Table 31.--Estimates of total numbers of tagged pink salmon escaping to Alaskan and Canadian spawning systems by general area and period of release, 1985. 84

Table 32.--Number of tagged pink salmon released, total number estimated as caught or escaping, percentage of estimated total recoveries from catch and escapement, and estimated recovery rate (2) in catch or escapement, by release fishery, 1982. 85

Table 33.--Number of tagged pink salmon released, total number estimated as caught or escaping, percentage of estimated total recoveries from catch and escapement, and estimated recovery rate (Z) in catch or escapement, by release fishery, 1984. 86

Table 34.--Number of tagged pink salmon released, total number estimated as caught or escaping, percentage of estimated total recoveries from catch and escapement, and estimated recovery rate (%) in catch or escapement, by release fishery, 1985. 87

Table 35.--1982 stock-composition estimates (%) of pink salmon by release area and period, totals for Alaska and Canada (%), and estimated numbers of tagged fish in Alaskan and Canadian escapements (%). Best estimates of escapements were used, and recovery rate of primary-tagged entrants in Canada was assumed equal to that of secondary-tagged fish. Dash indicates no recovery in escapement samples. 88

Table 36.--1984 stock-composition estimates (%) of pink salmon by release area and period, totals for Alaska and Canada (%), and estimated numbers of tagged fish in Alaskan and Canadian escapements (%). Best estimates of escapements were used, and recovery rates of primary-tagged entrants to the Skeena and Kwinamass Rivers were assumed equal to that of secondary-tagged fish. Dash indicates no recovery in escapement samples. 90

Table 37.--1985 stock-composition estimates (%) of pink salmon by release area and period, totals for Alaska and Canada (%), and

estimated numbers of tagged fish in Alaskan and Canadian escapements (%). Best estimates of escapements were used, and recovery rates of primary-tagged entrants to the Skeena and Kwinamass Rivers were assumed equal to that of secondary-tagged fish. 92

Table 38. --Estimated percentage of Alaskan-origin* pink salmon (bootstrap standard error in parentheses) by fishery and period of release, 1982. Dash indicates no estimate could be made. 94

Table 39. --Estimated percentage of Alaskan-origin' pink salmon (bootstrap standard error in parentheses) by fishery and period of release, 1984. Dash indicates no estimate could be made. 95

Table 40. --Estimated percentage of Alaskan-origin' pink salmon (bootstrap standard error in parentheses) by fishery and period of release, 1985. Dash indicates no estimate could be made. 96

Table 41. --Numbers of tags recovered in escapements and catches of pink salmon by area and period of release in 1982. 97

Table 42. --Numbers of tags recovered in escapements and catches of pink salmon by area and period of release in 1984. 98

Table 43. --Numbers of tags recovered in escapements and catches of pink salmon by area and period of release in 1985. 99

Table 44. --Estimated percentages of Alaskan-origin pink salmon by fishery and period of release for which 10 or more tags were recovered in catch and escapement sampling in 1982, 1984, and 1985. 100

Table 45.--Estimated season stock compositiEc$s based on catch-weighted averages of half-monthly percentages of pink salmon in northern boundary fisheries bound for the other country, 1982, 1984, and 1985. 101

Table 46.--Effects of different estimates of Alaskan and Canadian escapements[a] and Canadian secondary-tagging mortality on estimated percentages of Canadian pink salmon in Alaskan fisheries, 1982, 1984, and 1985. 102

Table 47.--Effects of different estimates of Alaskan and Canadian escapements' and Canadian secondary-tagging mortality on estimated percentages of Alaskan pink salmon in Canadian fisheries, 1982, 1984, and 1985. 103

LIST OF FIGURES

Figure 1.--International boundary area of southern Southeast Alaska and northern British Columbia, place names, and associated area codes to help identify where returning adult salmon were tagged, 1982-85. 107
Figure 2.--ADFtG Southeast Alaska statistical areas 101 and 102. 108
Figure 3.--ADFtG Southeast Alaska statistical areas 103 and 104. 109
Figure 4.--ADF&G Southeast Alaska statistical areas 105-108. 110
Figure 5.--British Columbia subareas l-10 through 1-18 of area 1 in Dixon Entrance, 1984. . . . 111
Figure 6.--British Columbia subareas l-l through l-5 (Langara Island) and 101-4 through 101-10 of area 1 in Dixon Entrance, 1985. 112
Figure 7.--British Columbia areas 3 through 5. 113
Figure 8.--1982 and 1983 stock-composition estimates (%) of sockeye salmon by area and period of release. Best estimates of escapements were used, and primary-tagged entrants in Canada were assumed to experience the same loss rates in rivers as secondary-tagged fish. Blanks indicate no recoveries were made; a bar indicates the stock-composition estimates are based on fewer than 10 tag recoveries from releases in this fishery and period. 114
Figure 9.--1982, 1984, and 1985 stock-composition estimates (%) of pink salmon by release area and period. Best estimates of escapements were used, and primary-tagged entrants to Canadian streams with secondary tagging were assumed to experience the same recovery rates as secondary-tagged fish. Blanks indicate no recoveries were made; a bar indicates stock-composition estimates are based on fewer than 10 tag recoveries from releases in this fishery and period. 120

INTRODUCTION

Joint U.S.-Canada salmon research in the international. boundary area off the coasts of southern Southeast Alaska and northern British Columbia has emphasized development and application of stock-separation techniques for resolving salmon-interception issues and improving management of Pacific salmon resources of the region. A major component of these studies was a sockeye (Oncorhynchus nerka) and pink (0. gorbuscha) salmon-tagging project, coupled with incidental tagging of chum salmon (0. keta), conducted from 1982 through 1985. Sockeye salmon were tagged in 1982 and 1983. Pink salmon were tagged in 1982, 1984, and 1985. Each year, tagging was conducted simultaneously in fisheries of southern Southeast Alaska and northern British Columbia by the Alaska Department of Fish and Game (ADF&G), contracted by the National Marine Fisheries Service, and by LGL Limited, Environmental Research Associates, Sidney, B.C., contracted by the Canada Department of Fisheries and Oceans. The immediate purpose of tagging was to provide estimates of stock composition in Alaskan and Canadian fisheries of the international boundary area, for assessing numbers of fish from each country intercepted in fisheries of the other nation. In addition, tagging provided information on the coastal migrations of salmon useful for managing fisheries of the region. This report describes each tagging experiment and the assessment of stock composition in the boundary fisheries. The Glossary at the end defines terms that may be unfamiliar.

METHODS

Purse-seine, gill-net, and troll vessels similar to those used in a commercial fishery in a given area were chartered to capture adult pink and sockeye salmon. The salmon were caught, tagged, and released throughout the season in locations within southern Southeast Alaska fisheries of Sumner Strait, Clarence Strait, Tree Point, Cordova Bay, Noyes Island, and Dall Island (Fig. 1). Similar fishing and tagging operations occurred within northern British Columbia fisheries of Dixon Entrance, Hecate Strait, and Portland Inlet. These operations in the coastal fisheries were termed *primary taggings* to distinguish them from subsequent *secondary taggings* conducted on fish which had escaped these fisheries. Methods for *secondary* taggings will be discussed later.

Petersen disk tags, used during the 1982 and 1983 field seasons, were replaced by spaghetti tags in 1984 and 1985 because fish with Petersen disk tags were probably more vulnerable to fishing gear, disk tags easily fouled in commercial nets, and ancillary studies indicated equal or higher recovery rates of spaghetti tags over disk tags (English et al. 1984). Greater numbers of tagged fish escaping the fisheries would result in better estimates of stock composition for the release fisheries. Both tag types were colored the highly-visible international orange, uniformly labeled with instructions for return, and numbered serially.

Tag-recovery efforts were directed toward both spawning grounds and commercial fisheries to determine numbers and places where tagged fish released from each fishery were caught or escaped to spawning grounds. Tags were recovered from commercial fisheries through wide-scale port-sampling programs in both Southeast Alaska and British Columbia. For each fishing area, information obtained included estimates of numbers of fish caught, numbers examined for tags, and tag identification numbers. Substantial proportions of catches of each fishery were examined for tags, and estimates of total number of tagged fish caught from any release in any fishery were obtained by simple" expansion of numbers of tags observed (to account for the unexamined catch).

As with the commercial catches, the number of tagged fish in the spawning escapements of either country could not be directly counted. Instead, these numbers were estimated for both sockeye and pink salmon by examination of portions of escapements for tagged fish and appropriate expansion of the numbers of tags recovered to account for the unexamined escapements. Procedures differed between countries and species. In all cases, recovery of tagged fish in escapements was accomplished at weirs across streams, from spawning-ground foot surveys, or from fisheries in terminal areas where stock origins were evident.

In Canada, both tagged sockeye and pink salmon were recovered at weirs. However, not all Canadian weirs were operated each year of the tagging experiments.

The largest populations of sockeye salmon in the boundary area occur in Canada in the drainages of Nass and Skeena Rivers. Weirs near Babine Lake (Skeena) and Meziadin Lake (Nass) allowed enumeration of major portions of escapements to these rivers and capture of tagged fish. To recover additional tagged sockeye salmon, Canada established weirs on the following less-important lake systems in northern British Columbia: Tahltan Lake (Stikine River drainage), Devon Lake, Bonilla Lake, and Eden Lake.

Canada could not examine escapements to many sockeye salmon grounds south of the boundary area that potentially contained tagged fish; outlet rivers from these grounds occur along the central and southern Canadian coasts and Vancouver Island coastline. Monitoring some catches from southern British Columbia, however, partially covered these stocks and recovered tagged fish which otherwise would have been missed.

A weir intended primarily to recover tagged pink salmon was placed on the Yakoun River of the Queen Charlotte Islands in northern British Columbia. Escapement sampling from weirs in Canada is described later under individual experiments.

Weirs were used in Southeast Alaska to recover tagged sockeye salmon, but none were built to recover pink salmon. When the tagging program was planned, sockeye salmon stocks of northern Southeast Alaska were not thought to contribute significantly to boundary-area fisheries. The Chilkat and Chilkoot Rivers are the major sockeye salmon systems of northern Southeast Alaska, and the ADF&G routinely operates weirs on both rivers to obtain management information. During the 1982 and 1983 tagging years, combined escapements to these two rivers equaled at least 50% of that estimated for all of southern Southeast Alaska, yet only a few tagged sockeye salmon from releases in the boundary-area fisheries were observed at these weirs and only one tag was recovered. Therefore, the initial supposition that the main Alaskan stocks involved in the boundary-area fisheries were from southern Southeast Alaska appears correct.

Southern Southeast Alaska has numerous sockeye salmon systems, though none with escapements of the magnitude of Canada's Nass or Skeena Rivers. Only part (roughly one-third to one-half) of the total escapement of sockeye salmon to southern Southeast Alaska could be examined for tags at weirs. The weirs were located mainly on lake systems that were large

---

'S. A. McPherson, fishery biologist, ADF&G, Region 1, P.O. Box 240020, Douglas, AK 99824-0020, pers. commun.

producers of sockeye salmon, including Hugh Smith Lake, McDonald Lake, Naha River, Kegan Lake, Karta Lake, Sarkar Lake, Hetta Lake, Klakas Lake, Klawock Lake, Salmon Bay Lake, Chuck Lake, and Tamgas Lake. As in Canada, not all weirs were operated in both years of sockeye salmon tagging. Details are in Pella et al. (1988) and are summarized later under individual experiments.

Spawning-ground foot surveys were also used to recover tagged salmon in both countries. During the pink salmon taggings, regular surveys were conducted on 316-388 streams in Alaska and 20-60 streams in British Columbia, depending on tagging year. Tagged sockeye salmon were also sought during foot surveys on 13-17 lake systems in Southeast Alaska and within the Skeena, Nass, and Fraser Rivers in British Columbia. Numbers of tagged fish recovered during foot surveys were expanded to account for numbers in the portions of escapements not examined.

Recovery of primary-tagged fish entering the Nass and Skeena Rivers was expected to be incomplete. Unmonitored subsistence fishing occurred within the rivers. Shedding of tags and mortality of tagged fish seemed likely because of the great distances (240 km on the Nass River and 480 km on the Skeena River) fish migrated to the weirs. Tagged fish on' spawning grounds within the river systems not covered by the weirs might be missed by foot survey crews or even migrate to unsurveyed spawning grounds.

Secondary, riverine tagging experiments (as opposed to primary-tagging in the coastal fisheries) on sockeye salmon were performed in the Nass and Skeena Rivers to develop expansions for recoveries at the weirs and from foot surveys to estimate total numbers of tagged entrants to the rivers. Proportions of primary-tagged entrants recovered in the rivers were estimated by the known proportions of secondary-tagged fish recovered at the weirs and from foot surveys. A basic assumption in this procedure was that the expected percentage of primary-tagged entrants recovered equaled that of the secondary-tagged fish. This assumption will be scrutinized and effects of alternative assumptions on analyses of the tagging experiments will be determined.

In Alaska, secondary taggings were also conducted on several sockeye salmon stocks in both 1982 and 1983 (Pella et al. 1988) to estimate total escapement to systems without weirs by expanding their estimated average escapement per system by the number of such systems. Such estimates of total escapement could then be used to expand tag recoveries at weirs for those missed in systems without weirs. The estimated average escapement per system was determined for a sample of systems without weirs from a combination of Petersen tagging experiments adjusted for mortality of tagged fish and foot-survey counts expanded to account for unobserved fish.

The estimate of total escapement of sockeye salmon to various ADF&G statistical areas of southern Southeast Alaska was the sum of the known escapements to systems with weirs and the estimated escapements to systems without weirs. Finally, numbers of tagged fish recovered at weirs were expanded to estimate total numbers of tagged fish for all systems of a statistical area. The expansion was based on the assumption that the expected recovery percentage of tagged fish from all escapements to the statistical area equaled the percentage of its total escapement covered by the weirs. Riverine tag loss in advance of the weirs was considered negligible because outlet streams were short; maximum distance to any weir was 1 km or less.

Secondary tagging of pink salmon was also conducted in a number of Alaskan streams in 1982, but the practice was abandoned when large numbers of tagged fish were observed to migrate from the intertidal tagging locations of target streams to other streams (Jones and Thomason 1983). Usefulness of secondary tagging of Alaskan pink salmon stocks was questionable in view of the observed migration patterns of these fish.

Secondary tagging of pink salmon was also conducted on a number of Canadian stocks subsequent to fish reaching their natal streams. These fish were tagged to estimate percentages of primary-tagged entrants to the streams that were unobserved for whatever reason (e.g., tag shedding, mortality, capture in unmonitored native food fisheries, or limited examination of spawning escapements), so that counts of primary-tagged fish could be expanded to estimate total numbers escaping to the spawning grounds. Canada studied major escapements of the Skeena, Kwinamass, Khutzeymateen, and Yakoun Rivers. In the Skeena and Yakoun Rivers, fish to be tagged were captured within the rivers. Tagging was conducted at the mouth of the Kwinamass and Khutzeymateen Rivers. Numbers of secondary-tagged pink salmon that strayed and which were either caught in fisheries or detected in other escapements were estimated, and corresponding numbers initially released were reduced by these estimates before the percentages recovered in the Canadian escapements were computed.

Finally, the ADF&G estimated pink salmon escapements to southern Southeast Alaska. Counts from repeated aerial surveys of escapements to most of the significant stocks in Southeast Alaska are obtained each year as part of the routine fisheries-management program. The maximum of such counts from a stream was expanded by a factor to estimate total escapement (Hoffman et al. 1984). Similarly, Canadian fishery

---

M. Seibel, Alaska Department of Fish and Game, Commissioner's Office, P.O. Box 25526, Juneau, AK 99802-5526, pers. commun.

officers on foot surveys counted pink salmon escapements in northern British Columbia. These counts were also adjusted to estimate total escapement'.

[3]K. English, LGL Limited, Environmental Research Associates, 9768 Second St., Sidney, B.C. V8L-4P8, Canada, pers. commun.

ASSUMPTIONS, DATA ANALYSIS, AND LIMITATIONS

Assumptions

Two assumptions are fundamental in the use of primary tagging to determine stock composition and numbers of salmon intercepted in fisheries of the boundary area. First, representative samples of stocks comprising the mixtures in fisheries must be tagged. In this study, the number of tagging vessels necessarily was small compared to those of the commercial fisheries because of costs of employing crews and vessels. Undoubtedly, coverage of fisheries in time and space was restricted, so stock composition of fish actually tagged probably deviated from that of the catch in the fisheries. However, limited coverage would not bias -estimated stock composition in fisheries in the sense that abundances of certain stocks would be consistently overestimated or underestimated during their time of passage through the fisheries.

Second, migratory behavior must not be severely affected by tagging. If migration routes or destinations were altered by tagging, results of the experiments could not be easily extrapolated to the salmon stocks of the region. Comparison of scale features of tagged and untagged fish in escapements of these studies showed no evidence of pronounced altering of destinations due to tagging (Oliver and Walls 1985). Migration may be delayed for a period of some days to several weeks after tagging,,judging from results of freshwater tagging of sockeye salmon (Greenough 1971). Bevan (1962) observed that movements of many of the sockeye salmon tagged in the coastal fishery of Kodiak Island were probably reduced for about 48 hours after tagging. If recovery of normal movement for most tagged fish occurs within a few days, the effect on stock-composition estimates would probably be unimportant. Our assumption is that choices of routes and destinations were unaffected by tagging.

Data Analysis

Primary tagging of returning adult salmon to determine stock composition in interceptive fisheries relied on 1) release of tagged fish in the fisheries of concern, and 2) enumeration of these fish, or estimation of their numbers, when their stock origins became evident. Relative numbers of tagged fish of a release belonging to each stock contributing to the interceptive fishery would then provide the estimates of stock composition in that fishery. However, although

---

[4]J. Eiler, Auke Bay Laboratory, National Marine Fisheries Service, NOAA, 11305 Glacier Hwy., Juneau, AK 99801-8626, pers. commun., September 1989.

recovery of tagged fish in escapements and some catches provided clear evidence of stock origins, substantial numbers were recovered in subsequent catches of other interceptive fisheries; hence, stock origins of these fish remained unknown. (Had the stock origins of the tagged fish been evident in the interceptive fisheries, stock composition in the release fishery would have simply and correctly been estimated by relative numbers from the contributing stocks occurring in combined catches and escapements.) Importantly, even though the stock origins were unknown, the recoveries could not be ignored.

Stock composition of the survivors of any group of tagged salmon released in a fishery was probably altered by intervening fisheries as the individuals migrated toward their various spawning streams. In particular, tagged fish of Canadian stocks released from an Alaskan fishery, such as Noyes Island, encountered intervening fisheries of both British Columbia and Alaska; however, Alaskan fish of the release mainly encountered Alaskan fisheries. On the other hand, tagged fish of Alaskan stocks released from a Canadian fishery, such as area 4 in Hecate Strait, encountered fisheries of both Canada and Alaska; however, Canadian fish of the release encountered mainly Canadian fisheries. The proportions caught of the various stocks comprising the initial release group would differ. As a result, the relative numbers in escapements to the stocks comprising the release group were not the same as they were at the time of release in the originalfishery. To correct stock composition based on only relative numbers in escapements, the number of tagged fish subsequently caught in intervening fisheries was allocated to stocks and combined with tagged fish in escapements.

The correction for tagged fish caught in intervening fisheries omits tags shed by fish during encounters with fishing gear. Petersen disk tags were probably more likely than spaghetti tags to be shed by entanglement in nets, and such shedding would also alter stock composition of surviving tagged fish as they migrated to their spawning grounds. Substantial percentages of tagged fish of each experiment were not accounted for by catches and escapements; presumably some of the missing tagged fish had shed their tags. Information for estimating numbers of tags shed during the experiments was not obtained.

The procedure by which recovered tags in catches were allocated to stocks was described by Gazey (1983). The proportion of recoveries from primary tagging in any fishing area destined for any stock (this is the estimate of that stock's unknown actual proportion in the release fishery) was computed as that stock's proportion of the total recoveries from the primary-tagged release group; these recoveries were either found in the escapement to that stock or allocated to that

stock from tags caught in intervening fisheries. Tags recovered in intervening fisheries were allocated to stocks by the estimates of stock proportions in each interceptive fishery where they were captured. Although the allocation of recovered tags in catches involved use of the estimates of stock proportions desired (and so appears circular), this allocation and calculation of stock composition for all fishing areas was done in a single mathematical operation next described.

The procedure by which tags caught in intervening fisheries were allocated and stock composition was computed can be illustrated by considering the general situation in which S stocks occur in mixtures in F fisheries. Tagged fish must be released in each fishery. Numbers of tagged fish from these releases subsequently caught in each intervening fishing area, and numbers returning to each spawning stock are presumed known. Let the following definitions apply:

E is the number of tagged fish released in fishing area *f* which escaped to stock s;

C is the number of tagged fish released in fishing area f that were subsequently caught in fishery *f′;*

T, is the total number of tagged fish released in fishing area f that were recovered; and

p_f, is the proportion of tagged fish in fishing area *f* that we're destined for stock s,

where s = 1,2,...,S; *f* = 1,2,...,F; and *f′* = 1,2 ....F.

Simple relationships among the catch and escapement recoveries were proposed (Gazey 1983) by which to allocate tags caught in intervening fisheries and compute the estimates of stock composition for each fishery:

$$
\begin{aligned}
E_{1,s} + \sum_{f=1}^{F} C_{1,f} \cdot p_{f,s} &= T_1 \cdot p_{1,s} \\
E_{2,s} + \sum_{f=1}^{F} C_{2,f} \cdot p_{f,s} &= T_2 \cdot p_{2,s} \\
&\vdots \\
E_{F,s} + \sum_{f=1}^{F} C_{F,f} \cdot p_{f,s} &= T_F \cdot p_{F,s} \,.
\end{aligned}
\qquad (1)
$$

Each equation in the set above refers to recoveries of tagged fish of a particular stock from one release area. Each equation can be restated in words as follows: the number of tagged fish recovered in the escapement to any stock s, plus the sum across fisheries of the caught tags multiplied by corresponding proportions from stock s, equals the total number of tagged fish recovered times the proportion destined for stock s. More simply yet, the numbers of tagged fish which escaped to stock s plus caught tagged fish allocated to stock s equals the total number of recovered tagged fish from the release area which were destined for stock s. Values of all variables are known except for the p-variables. However, the F p-variables occur linearly in the F equations, so their values can be easily determined from the other known values. The p-variables are the estimates of stock composition from tagging. Solving the system above for the p-variables provides the estimates of proportions of fish in each fishing area which came from stock s. Solving S such systems for their p-variables provides the complete set of stock-composition estimates for all S stocks in all *F* fisheries.

Although allocation of caught tags by the equation system appears reasonable on superficial examination, closer inspection reveals an aspect of dubious validity. Tagged fish subsequently caught in any intervening fishery are assigned by the procedure in the same proportions to the stocks regardless of where (i.e., which fishery) the fish originally were tagged. (Notice in the equation system above that the same *F* p-variables occur in each of the *F* equations.) However, fish tagged at Noyes Island and caught in Canada's area 3X, for example, could be destined for different stocks, or probably could occur in different proportions to the same stocks than those caught in the same area but originally released from Canada's area 4. However, tagged fish from the two areas are allocated in the same proportions.

Numerical simulation studies indicate that the procedure provides reasonably accurate estimates of stock composition if numbers tagged in fisheries were in proportion to abundance. However, estimates of stock composition became inaccurate when numbers tagged were not in proportion to abundance (Gazey et al. 1983). The tagging program was conducted with the intent to approximate such proportional tagging. Violations of proportional tagging presumably induced errors in the stock-composition estimates. We could not evaluate the magnitude of such errors because the potential degree of deviations from proportional tagging was unknown.

Significant numbers of tagged fish could not be accounted for by catches and escapement estimates. Soon after release, many may have died from the stress of tagging. The loss of tagged fish through such mortality was simply equivalent to

releasing fewer tagged fish in the fisheries if fish of the various stocks were equally susceptible to stress. Therefore, had actual numbers of tagged fish released been proportional to abundance, tagged survivors should also have been proportional to abundance, provided the percentage surviving the tagging was uniform among release fisheries. However, even given that tagging was proportional to abundance, numbers of survivors from tagging stress might not have been proportional to abundance if survival rate varied among release fisheries; later results show considerable apparent variation among release fisheries in percentage of tagged fish accounted for by catches and escapements.

In summary, essential data for calculation of stock composition in each interceptive fishery were the numbers of tagged fish released from each fishery which subsequently escaped to each contributing stock and corresponding numbers of tagged fish caught in each intervening interceptive fishery. This information was needed for all significant interceptive fisheries before stock composition could be calculated for any of them. Next described are details of the application of Equation (1) shared by all the tagging experiments.

Releases of tagged sockeye and pink salmon were stratified into half-month periods: 15-30 June, l-15 July, 16-31 July, and l-15 August. Some tagged fish used in the analyses were released before 15 June or after 15 August; these were included in the nearest period. Such stratification allows a straightforward comparison of stock composition among years. However, numbers of tagged fish recovered from releases of some fisheries and half-month periods were too small to reliably assess stock composition. Information concerning the number of recoveries and precision of stock-composition estimates for each fishery and time stratum is provided so that the reader will be warned of unreliable estimates.

Tagged fish were also stratified into areas of release. Areas of release correspond to the interceptive fisheries of concern; their definitions are provided in Tables 1, 2, 3 and Figs. 2-7. The area definitions are straightforward, but some explanation of the subdivisions of Canada's Dixon Entrance is provided.

During the course of the studies, Canada developed areal statistical systems for increasing resolution, primarily within the open water of Dixon Entrance. At the beginning of the studies in 1982, open water of Dixon Entrance was treated as a single statistical area; it was divided into nine areas in 1984 (Fig. 5), and redefined into seven areas in 1985 (Fig. 6). Areas with few tagged-fish releases were aggregated into' larger units (Table 3; Figs. 5, 6) with greater total numbers of releases.

Catches were stratified by weeks and fishing areas. The boundary fishing areas included ADF&G statistical areas 101 through 108 in Southeast Alaska and areas 1, 3X, 3Y, 3Z, 4, 5, and 6 in northern British Columbia. Within the British Columbia portion of the boundary area, area stratification was no finer, but in Alaska, fishing areas were further subdivided because of higher area resolution of the Alaskan statistical system.

Fishing areas outside this border region were generally monitored only incidentally to other management activities by agencies of either country. However, Canada began monitoring the Johnstone Strait fishery at Vancouver Island for tagged sockeye salmon in 1983 after tagged fish unexpectedly appeared in catches.

Numbers of fish examined for tags from catches were available by statistical week, gear, and fishing area, and also by ADF&G statistical subarea for Alaskan fisheries. The total numbers of tagged fish in Alaskan catches (by half-month period and area of release, and week and area of recovery) were estimated by expanding numbers of tagged fish recovered in the weekly catch samples to account for unexamined catches.

Statistical records from Canadian fisheries were less refined than those from Alaskan fisheries, and records were inadequate to determine with certainty the size of weekly catch from which samples were obtained (Gazey et al. 1983; English et al. 1984). However, the season catch by gear and fishing area was available. Therefore, the total numbers of tagged fish in Canadian catches (by half-month period and area of release, and week and area of recovery) were estimated by expanding numbers of tagged fish recovered in the weekly catch samples by each gear in the recovery area for an estimate of the part not examined. The estimate of the part of the weekly catches not examined was the season portion of the catch by the gear in the recovery area that was unexamined.

Total numbers of tagged fish that were part of the escapements to spawning stocks of either country (from releases of a half-month period and area) were estimated by expanding numbers of tagged fish recovered at weirs or during foot surveys on streams to account for portions of the escapements not examined for tags. Various methods were used to estimate the percentages of the escapements examined (or the complementary percentages unexamined) for tagged fish. We describe these methods under the individual experiments.

Estimates of stock composition in the fishing areas during a release period were computed from the basic equation system for tag recoveries (Equation 1). We substituted estimates for unknown quantities of the equations before solving for the stock proportions (p-variables). Estimated numbers of tagged fish from release areas, which were subsequently caught

in intervening fishing areas, were substituted for the corresponding unknown values in the equations. Similarly, estimated numbers of tagged fish which escaped to major individual stocks or regional groups of stocks were substituted for the corresponding unknown values in the equations. We then solved the equation system for the percentages from major individual stocks or regional groups of stocks in the fisheries; the solutions were our point estimates of stock composition in each fishery and period.

The bootstrap approach (Efron and Tibshirani 1986) was used to evaluate potential error in the point estimate of stock composition due to subsampling catches and escapements for tagged fish. This procedure consisted of drawing samples with replacement and equivalent size from actual samples. These bootstrap samples were used to estimate numbers of tagged fish in escapements and catches, just as the actual samples were used in computing the original point estimates. Bootstrap values for numbers in escapements and catches were substituted into Equation (1), which was solved for the stock percentages when possible.

Resampling of samples, estimation of numbers of tags in catches and escapements, and recomputation of stock percentages were repeated 100 times for each experiment. By this procedure, we determined empirically the variation in estimates of the stock percentages in the fisheries, which was induced by subsampling escapements and catches. We used the standard errors of the bootstrap estimates of stock percentages as a measure of their precision. A rule of thumb regarding the precision of a reported estimate of a stock percentage in a fishery is as follows: in 95 of 100 imagined repetitions of the samplings of catches and escapements for tags during the tagging experiments, the unknown actual stock percentage in the fishery would be within two standard errors of the reported estimate. Therefore, a small standard error for a reported stock percentage indicates the estimate was not subject to much variation due to subsampling catches and escapements. Contrariwise, if the standard error was large, then the reported estimate of the stock percentage may have been poorly determined because of subsampling errors.

In some cases, stock percentages could not be recomputed from the bootstrap samples because Equation (1) became singular. Equation (1) became singular if no recovery occurred in the bootstrap samples from releases in one or more fisheries. If such singular cases were rare among the 100 repetitions, they were simply omitted from our evaluations of precision; that is, the empirical distributions were based on corresponding reduced numbers of bootstrap estimates of stock percentages. When singular cases became frequent, the fisheries causing the singular problem were omitted from the evaluation. This practice led to mildly optimistic estimates

of precision by understating the variation in stock composition estimates induced by subsampling.

In addition to the bootstrap results regarding precision, observed numbers of tag recoveries in escapements and catches are reported; these recoveries are classified by half-month period and area of release. If tag recoveries were few, especially in escapements, the estimates of stock composition from that release were viewed skeptically. In a few cases, bootstrap evaluation of possible error in stock-composition estimates did not reflect the obvious uncertainty due to few recoveries; therefore, numbers of recoveries were considered when judging reliability of estimates.

Furthermore, the bootstrap evaluation of variation in stock-composition estimates due to subsampling catches and escapements did not include errors incurred from estimating escapements of salmon in spawning systems without weirs. Neither did the evaluation account for possible bias in estimates of tagged fish in escapements from possible differences between in-river recovery rates of primary- and secondary-tagged fish. To evaluate such errors and differences, estimation of stock composition was repeated for ranges of possible escapements and recovery rates. To compare these analyses, catch-weighted averages were computed of half-month estimates of Alaskan and Canadian percentages for a fishery using percentage of the season catch in each period as the weight for the corresponding half-month stock percentage. Such catch-weighted averages are inherently important because they represent the stock composition of the catch for the entire season in the fishery. If no reliable estimate of stock composition was available in a fishery during a half-month period, the unreliable estimate available was combined with a reliable estimate of an adjacent period, or the estimate from the adjacent period was simply substituted for the period that lacked an estimate altogether. Specifically, for a period with an unreliable stock-composition estimate, a weighted average of the estimate and the estimate from an adjacent period was computed; numbers of tagged fish recovered in the periods were used as the weights. Only if 75% or more. of the catch for the season in a fishery was covered by reasonably reliable estimates of stock composition was a catch-weighted average computed. The 75% criterion was chosen to limit the reported catch-weighted averages to those least distorted from the underlying season stock composition because of missing estimates of stock composition within the season.

SOCKEYE SALMON TAGGING EXPERIMENTS OF 1982 AND 1983

Primary Tagging in the Fisheries

A total of 40,455 sockeye salmon were tagged in 16 general areas during 1982 (Table 4). Numbers tagged varied substantially among areas; fewer than 100 fish were tagged in Cordova Bay and Dixon Entrance, but other areas had well over 1,000 tagged fish. In 1983, the tagging program was reduced (Table 4). Total number of tagged fish released during 1983 was 21,293--about one-half the number of the previous year. Tagged sockeye salmon were released in 13 areas--with more than 1,000 released in 8 of the areas.

Fishery Recoveries

Estimates of total numbers of primary-tagged fish subsequently caught in intervening fisheries in Alaska and Canada are provided by area and period of release for either year (Tables 5 and 6); these estimates were obtained by summing estimates over statistical areas in Alaska or Canada. The vast majority of tagged fish released in British Columbia waters and caught in intervening fisheries were recovered in Canadian fisheries. Canadian fisheries also recovered substantial portions of tagged fish caught from Alaskan releases. The broad implication of these recoveries is clear: given that significant fisheries and sockeye salmon catches occurred in both Alaska and Canada, most tagged sockeye salmon were migrating toward Canadian waters. However, catches of tagged fish alone are not sufficient to estimate stock composition in fisheries.' The number of tagged fish escaping to the spawning grounds in Alaska and Canada must also be considered.

Terminal Recoveries

Corresponding estimates of total numbers of tagged fish in escapements were obtained by expanding numbers of tagged fish recovered at weirs and from riverine fisheries to account for unexamined fish or incomplete recovery of tagged fish entering rivers with weirs. Expansions for Alaskan escapement were based on numbers of sockeye salmon examined for tags at weirs and on estimates of total numbers escaping to southern Southeast Alaska (Pella et al. 1988). These numbers (weir counts and estimates) are provided for Alaskan fishing districts (Table 7).

Weirs on the Skeena River system at Babine Lake and the Nass River system at Meziadin Lake were used to recover tagged fish in both years. The weirs accounted for most of the primary-tag recoveries in both the Skeena River (92% in 1982

and 94% in 1983) and Nass River (98% in 1982 and 99% in 1983). The weirs also accounted for most of the secondary-tag recoveries in the Skeena (96% in 1982 and 99% in 1983) and Nass Rivers (94% in 1982 and 99% in 1983). Foot surveys of spawning grounds in the two river systems accounted for the additional recoveries.

Based on the results of secondary tagging, many primary-tagged sockeye salmon entering the Skeena and Nass Rivers were not recovered at the weirs or by the spawning surveys. The estimated percentage of secondary-tagged sockeye salmon recovered ranged from only 17% to 61% (Table 8). Tagged fish may have died, shed their tags, been caught in unsampled native food fisheries, been undetected during foot surveys, or migrated to unsurveyed spawning grounds. Although some tagged fish avoided capture at the weirs, this was not an important cause for the shortfall in recoveries.

In 1983, Canada released secondary-tagged sockeye salmon at three locations along the Skeena River (English et al. 1984). Recovery rate at the Babine weir ranged from 22% for estuary releases, to 2% for a midway location, and 7% for the uppermost site about 140 km upriver. Corresponding recovery rates from these tagging locations when foot-survey recoveries were included with the weir recoveries were 25, 2, and 7%.

Secondary tagging within the Nass River in 1983 also resulted in only a combined 6% recovery rate for the Meziadin Lake weir and foot-survey recoveries. The recovery rate at the Meziadin Lake weir from releases in the nearby ocean fishery (area 32) was greater than that from releases within the Nass River. The outcome of secondary tagging in the Nass River was similar to that in the Skeena River; that is, recovery rate at the Babine Lake weir of tagged sockeye salmon released in the estuary of the Skeena River was also considerably greater than that of tagged fish released within the river.

Observed recovery rate during 1983 was inconsistent with the initial supposition that both primary- and secondary-tagged fish would be recovered at similar rates. Clearly, recovery rates of primary-tagged fish entering the Skeena and Nass Rivers are not well known.

We adopted interim estimates of recovery rates proposed by LGL Limited analysts (Gazey et al. 1983; English et al. 1984) (Table 8) for our initial analyses. In 1983, the observed recovery rate for salmon tagged in the estuary of the Skeena River was 25%, which was slightly higher than the 1982 recovery rate based on in-river tagging (17%). The recovery rate for the Nass River in 1983 (61%) was simply the midpoint of a range of possible values considered extreme by LGL Limited analysts, which was higher than the 1982 rate (43%) based on in-river tagging.

Numbers of primary-tagged salmon recovered at the weirs and during foot surveys of- spawning grounds in the Skeena and Nass Rivers were expanded to estimate initial numbers entering the rivers; the expansions were based on recovery rates of secondary-tagged sockeye salmon (Table 8). This procedure for estimating numbers of primary-tagged entrants follows closely that used earlier by LGL Limited analysts (Gazey et al. 1983; English et al. 1984).

In addition to examining major escapements of the Skeena and Nass River systems, Canada extended their coverage in 1983 to include the Stikine River, Johnstone Strait, and several smaller sockeye salmon systems. A secondary-tagging program was conducted by Canada on the Stikine River in 1983 to estimate the number of primary-tagged fish returning to this system; the Canadian commercial fishery in the Stikine River was the recovery mechanism for tagged fish, analogous to the weirs on the Skeena and Nass Rivers. In 1983, a total of 862 sockeye salmon were tagged in the river below the U.S.-Canadian border on the U.S. side, and 187 (22%) of these tagged fish were recovered in the fishery. Numbers of primary-tagged fish in the catches were expanded correspondingly to estimate total numbers in the river.

Johnstone Strait represented a fishery located between Vancouver Island and the British Columbia mainland rather than a spawning ground. Unexpectedly, this Canadian fishery, far south of the boundary area, caught primary-tagged sockeye salmon released in 1983 (English et al. 1984). Evidence of their origin was limited, but the Fraser River--a major sockeye salmon system which enters the Pacific Ocean south of the fishery--was the logical primary source. Four 1983 tags occurred within the escapement to the Pitt River, which enters the Fraser River about 48 km above its mouth. Eleven live, tagged sockeye salmon were observed during index counting of escapement at the Hell's Gate fishway 200 km above the mouth of the Fraser River by Pacific Salmon Commission personnel, but subsequent foot surveys of the Fraser River system above Hell's Gate produced[5] only a single tag--from the stream bottom of the Seymour River. A single tag, volunteered from the sport fishery of Lake Washington, showed sockeye salmon from Washington State were also probably at Johnstone Strait; however, the Washington State contribution was probably small. Estimated total return of sockeye salmon to the Fraser River was more than lo-fold that of sockeye salmon from Washington State in 1983.

---

[5]Dr. James Woodey, Chief Biologist, Fishery Management, Pacific Salmon Commission, No. 600, 1155 Robson St., Vancouver, B.C. V6E-lB9, Canada, pers. commun., 28 October 1991.

Although the Johnstone Strait fishery was not sampled by personnel of the tagging program until 20 August, fishermen volunteered recoveries as early as 12 July. After 20 August, volunteer recoveries from fishermen comprised about 42% of the tagged fish in catches (as estimated from program sampling). Recoveries volunteered by fishermen before program sampling were assumed to equal 42% of the primary-tagged fish of these catches. Therefore, the analysis included the entire return through Johnstone Strait of the presumed Fraser River-origin tagged sockeye salmon.

Weirs were installed on Devon, Bonilla, and Eden Lakes--coastal systems supporting minor (compared to the Skeena, Nass, and Stikine Rivers) Canadian sockeye salmon populations. Losses of tags in the short rivers leading to these lakes were assumed negligible, so numbers of tags recovered at these weirs were treated as the total escapement of tagged fish.

Estimates of total numbers of tagged fish escaping to spawning areas in Alaska and Canada are provided by period and general area of release for each year (Tables 9 and 10). During both years, the vast majority of sockeye salmon tagged throughout the season in Canadian fisheries escaped to Canadian river systems. Also, more tagged sockeye salmon released during the season from several Alaskan fishing areas (e.g., Noyes Island, Dall Island, and Tree Point) escaped to Canadian than to Alaskan spawning areas; but the disparity in recovery rates was not as great as for spawning-area recoveries of releases from Canadian fishing areas. Furthermore, at times more tags from releases of some Alaskan fisheries were recovered in Alaskan escapements than in Canadian escapements (e.g., Lower Clarence Strait and Revillagigedo Channel in the first period of 1982, Middle and Upper Clarence Straits and Revillagigedo Channel in the second period of 1982, Upper Clarence Strait throughout 1983, and Sumner Strait from the second period of 1983 onward).

Numbers of tagged sockeye salmon released at most locations in either year exceeded the combined estimates of recoveries in catches and escapements to Alaska and Canada, often by wide margins (Table 11). The overall recovery rate of total releases from Alaska or Canada accounted for by estimates of tagged fish in catches and escapements was consistent with findings of secondary tagging in saltwater estuaries in Alaska. Ancillary experiments during secondary-tagging studies in Alaska included release of tagged sockeye salmon captured purse seining by hand adjacent to the mouths of several outlet streams with weirs to count them (Pella et al. 1988). Counts at the nearby weirs and recoveries from all weirs, foot surveys, and commercial and subsistence fisheries of Southeast Alaska could not account for roughly 40% of these secondary-tagged fish. Tagged fish may have shed their tags or died from the effects of tagging (Pella et al. 1988). However,

shedding of a substantial percentage of tags was improbable because the fish had less than 1 km to migrate to the weir on the way to their spawning grounds. More likely, tagged fish died from tagging stress, either directly or indirectly due to their increased vulnerability to predation.

Similarly, primary-tagged sockeye salmon released in Alaska and Canada, which were not accounted for in catch or escapement, may have died from tagging stress or predation, shed their tags, been caught in native food fisheries, or migrated from the region to unmonitored spawning grounds. Such overall loss of tags from Alaskan tag releases was 50% in 1982 and 39% in 1983 (loss = 100% minus recovery rate from last pair of columns of Table 11). Corresponding estimates of overall loss for Canadian releases in those years were 13% and 43%. Only the loss from Canadian releases of 1982 (13%) was inconsistent with a conjecture, based on the experience of secondary tagging in Alaska, that around 40% of primary-tagged fish may have died from tagging stress. However, recovery rate varied substantially among release locations, and was far greater than 60% (conjectured survival rate from tagging stress) for many locations in either year.

Estimated percentage of tagged fish in catches and escapements from two Canadian release locations (areas 3Y and 4) was l0l-105% in 1982. Generally, recovery rates in catches or escapements from Canadian release locations during 1982 were high compared to Alaskan releases of both years, or Canadian releases of 1983. Recovery rates among Alaskan locations in either year were comparatively high for Lower Clarence Strait, Revillagigedo Channel, and Tree Point.

Possibly the apparently high recovery rates of fish tagged in Canadian release locations and nearby Alaskan locations in Lower Clarence Strait, Revillagigedo Channel, and Tree Point were caused partly by overestimates of tagged fish in Canadian escapements to the Nass and Skeena Rivers--the destinations of most fish released from these tagging locations. Estimated numbers of primary-tagged fish in escapements to the Nass and Skeena River systems depended inversely on estimates of recovery rates of these fish after they entered the rivers. If the recovery rate of primary-tagged entrants was underestimated, primary-tagged fish escaping to these systems was overestimated. If this were the case, then estimated numbers of primary-tagged fish accounted for by catches and escapements (Table 11) could exceed 100%. As mentioned earlier, interim estimates of recovery rates of primary-tagged entrants to these rivers proposed by LGL Limited analysts (Gazey et al. 1983; English et al. 1984) were used (notwithstanding our questions of their accuracy) to compute estimates of numbers of primary-tagged fish in Canadian escapements. The discussion below (see Sensitivity Analysis,

p. 24) explains why recovery rates of primary-tagged entrants to the Canadian systems may have been underestimated.

Furthermore, numbers of tag recoveries in some Canadian catches possibly were over- or underestimated because proportions of the catches sampled in the various Canadian fisheries varied during the season. Such variation could not be accounted for when actual recoveries were expanded to estimate total recoveries. (For Canadian fishing areas, the weekly proportions of catches examined for tags were not available, so the proportions sampled for the entire season were used to expand actual tag recoveries to total tag recoveries.) The expansions were applied to tagged fish recovered in Canadian catches from both Canadian and Alaskan release locations, possibly accounting for the high recovery rate from releases of some Alaskan locations.

The observed variation among release locations in percentage of tags accounted for by catches and escapements is not satisfactorily explained by uniform mortality rates from tagging stress, overestimation of tagged fish in Canadian escapements, or errors in estimates of tagged fish caught in Canadian fisheries. Most fish released at Noyes Island, Dall Island, and Langara Island were destined for the Skeena and Nass Rivers and many were caught in Canadian fisheries, yet recovery rates from these locations remained comparatively low both years. Recovery rates also remained comparatively low for other release locations--such as Sumner Strait, Upper Clarence Strait, Middle Clarence Strait, and Union Bay--less dominated by Nass and Skeena River stocks. Whatever causes may underlie the variation in recovery rate among the release locations, the apparent effect varied among locations and between years of tagging.

Stock-Composition Estimates

Estimates of total recoveries in catches and escapements by location and period of release were used to compute stock composition in fisheries (Tables 12, 13) by the algorithm described earlier. Skeena and Nass River stocks were abundant throughout much of the region during the entire season; Nass River stocks returned earlier than Skeena River stocks (Fig. 8). Southern stocks passing through Johnstone Strait in 1983 were in the boundary area mainly from mid-July to the end of tagging (Fig. 8). Along the outer-coast fisheries, abundance of the southern stocks peaked during August, constituting an estimated 58% and 30% of sockeye salmon at Langara Island and Noyes Island, respectively. The main Alaskan stocks in the fishing areas originated in ADF&G statistical areas 101 and 102.

Generally, greater changes occurred in stock composition estimates from Alaskan releases than Canadian releases after tags recovered in intervening fisheries were allocated to stocks (Tables 12, 13); that is, percentages of Alaskan or Canadian fish in combined escapements (last pair of columns) from Alaskan releases often changed substantially (next to last pair of columns) after caught tagged fish were allocated. As expected, estimates in the percentages of tagged Canadian sockeye salmon in Alaskan fisheries increased substantially after the allocation of caught tags because tagged fish released in Alaskan fisheries and destined for Canadian spawning grounds were exploited in intervening Alaskan and intense Canadian fisheries, but releases destined for Alaskan systems were exploited mainly in Alaskan fisheries.

Alaskan and Canadian percentages of Alaskan-origin sockeye salmon in the fisheries were summarized using Alaskan percentages; corresponding Canadian percentages can be obtained by subtraction from 100% (Tables 14, 15). Variation of stock-composition estimates due to subsampling catches and escapements, but not including variation from escapement estimates, was evaluated by the bootstrap approach (Tables 14, 15). Standard errors of most estimates of stock percentages appeared reasonably small (<55%), but several were greater. Because credibility of estimates of stock percentages depends partly on numbers of tagged fish recovered in escapements or catches, these were also summarized (Tables 16, 17). As expected, estimates of stock percentages were quite unreliable (as indicated by bootstrap standard errors) when total tags recovered in catches and escapements was small.

Estimates of stock proportions for both years are summarized by omitting release time and area strata for which fewer than 10 total tag recoveries were obtained in sampling catches and escapements (Table 18); hence, the remaining estimates generally had reasonably low standard errors based on bootstrap results.

Discussion

Two generalities concerning Alaskan and Canadian percentages in the fisheries were evident by inspection of the results of our analysis (Table 18). First, the percentage of Alaskan-origin sockeye salmon in Alaskan fisheries is greater than in Canadian fisheries; hence, the percentage of Canadian fish in Canadian fisheries is greater than in Alaskan fisheries. Second, the percentage of Canadian sockeye salmon in Alaskan fisheries tends to be much greater than the percentage of Alaskan sockeye salmon in Canadian fisheries.

Catch-weighted averages, of half-month stock-composition estimates for each fishery provided estimates of season stock

composition (Table 19). Most sockeye salmon in Alaskan catches were of Canadian origin (except in Sumner Strait), whereas only a small percentage of Canadian catches were of Alaskan origin. Contribution rates from Alaskan stocks to Canadian fisheries were greater in 1982 than in 1983, and contribution rates of Canadian stocks to Alaskan fisheries were greater in 1983 than in 1982 for two of the three fisheries where comparison was possible.

Sensitivity Analysis

Outcomes of the analyses should be considered with circumspection. Stock-composition estimates depended heavily on estimates of tagged fish escaping to either country. Estimates of tagged fish escaping to Alaska depended directly on the estimate of total Alaskan escapement. Specifically, an estimate of larger escapement to Alaska would result in an estimate of more tagged fish escaping to Alaska; conversely, an estimate of smaller escapement to Alaska would result in an estimate of fewer tagged fish escaping to Alaska. The estimates of total escapements of sockeye salmon to southern Southeast Alaska for 1982 and 1983 were 354,000 (90% confidence interval 254,000-466,000) and 324,000 (90% confidence interval 216,000-458,000), respectively (Pella et al. 1988). Imprecise estimates of Alaskan escapements in 1982 and 1983 possibly caused large errors in estimates of escaping tagged fish.

Estimates of tagged fish escaping to Canadian spawning grounds depended inversely on estimates of recovery rates of terminal entrants to the Nass, Skeena, and Stikine Rivers. Such estimates were the percentages of secondary-tagged sockeye salmon recovered at weirs and spawning grounds of the Nass and Skeena River systems or in the commercial fishery of the Stikine River. Estimates of lower recovery rates in the Canadian systems would result in estimates of more primary-tagged fish escaping to Canada. Conversely, estimates of higher recovery rates in Canadian systems would result in estimates of fewer primary-tagged fish escaping to Canada.

Estimates of recovery rates of primary-tagged sockeye salmon entering Canadian rivers (Table 8) were too low if recovery rates of secondary-tagged sockeye salmon were less than those of the primary-tagged sockeye salmon. The recovery rate of secondary-tagged fish could have been substantially less than of primary-tagged terminal entrants to the rivers if fish died from tagging stress (similar in magnitude to that inferred from estuarine secondary-tagging studies in Alaska) within a few days after tagging. That is, primary-tagged entrants had already survived tagging stress during the time of ocean migration to the river entrance, but the secondary-tagged fish could have experienced losses due to it, reducing

the percentage of secondary-tagged sockeye salmon recovered at weirs and spawning grounds.

In 1982, secondary taggings conducted within the Nass and Skeena Rivers were used to estimate the recovery rate of primary-tagged sockeye salmon (Table 8). However, the estimates of recovery rate of primary-tagged sockeye salmon in the rivers during 1983 were based on either recovery rate of estuary releases on the Skeena River or fishery releases from area 32 near the Nass River entrance. Evidence presented earlier from secondary tagging of sockeye salmon in estuaries in Alaska indicated that possibly 40% of estuary-tagged fish died of tagging stress. Similarly, sockeye salmon released in ocean fishing areas may also suffer substantial mortality, for recoveries in catches and escapements constitute but a portion of total Alaskan or Canadian primary-tagged releases (Table 11). Yet recovery rates at-the weirs of the Skeena River estuary and area 32 releases during 1983 were larger than from secondary taggings within the rivers themselves.

Further evidence for substantial mortality -from tagging stress of returning adult sockeye salmon released in coastal fishing areas comes from a 1949 tagging experiment at Kodiak Island (Bevan 1962). Sockeye salmon were tagged from trap catches, a seemingly less stressful mode of capture than the purse seine, gill-net, and troll gear used in the present studies. Fishermen reported only 32% of the tagged fish, even though the tagging program emphasized recovery of tags from the fishery. Bevan (1962) must have considered recovery of tags from the fishery to be nearly complete because his model of the results does not include the possibility of unreported tag recoveries. Another 25% of the releases were observed passing the Karluk weir, the stock considered to be the major contributor to the fishery from which the tagged fish were released. Escapements of other stocks may have accounted for another 1% if tags recovered in foot surveys of these escapements constituted the same percentage of their total tagged fish as did the tags recovered in foot surveys of the Karluk River. If these catch and escapement recoveries are expanded for the estimated 11% shedding loss provided by Bevan (1962), the total tagged fish accounted for by catches, escapements, and shedding equals only 66% of the releases. In other words, 34% were missing.

Bevan (1962) modeled these losses as a continuous process during the return through the fishery rather than as an abrupt mortality shortly after tagging. However, his view was based on the outcome of an experiment which would not have detected a large initial mortality from stress if it were not increased by additional handling of fish being tagged. In addition to mortality from tagging stress, the Kodiak experiment also demonstrated that the behavior of tagged fish is initially

affected; recovery rates in the fishery were depressed for two days after tagged groups were released.

In summary regarding the recovery rates of primary-tagged sockeye salmon entrants to the Nass and Skeena Rivers, we judged that values obtained from secondary-tagging experiments upstream within the rivers were questionable because of the contradictory outcomes of 1983. In view of the probable mortality of some of these fish from tagging stress shortly after release, we also questioned whether values obtained from estuarine or nearby fisheries provided valid estimates of such recovery rates.

The uncertainty in actual recovery rates of primary-tagged sockeye salmon in the major rivers of Canada demands further analysis. To evaluate the effects of potential errors in estimates of tagged fish escaping to Canadian or Alaskan spawning grounds on the outcomes of' the analyses, the analyses were repeated using several combinations of estimates of Alaskan escapements and recovery rates in the Skeena, Nass, and Stikine River systems. Three estimates of Alaskan escapements were used: the point estimate and the lower and upper bounds of the 90% confidence interval of each year (Table 7). Two estimates of recovery rates of primary-tagged fish in the Canadian rivers were used, equivalent to 0% and 40% mortality of secondary-tagged fish. A 40% tagging mortality reduced estimates of numbers of terminal entrants to the Nass, Skeena, and Stikine River systems to 60% of the values computed using 0% mortality.

Evaluations of the effects of errors in estimates of tagged fish escaping to Alaska and Canada on stock-composition estimates were computed for five combinations of estimates of Alaskan escapement and Canadian secondary-tagging mortality (Tables 20, 21). Almost certainly, the extremes of possible errors were included.

As expected, estimates of larger Alaskan escapement reduced estimates of percentages of Canadian-origin sockeye salmon in the fisheries, and a 40% secondary-tagging mortality further reduced the percentages (Tables 20, 21). On the other hand, estimates of smaller Alaskan escapement increased estimates of percentages of Canadian-origin sockeye salmon in the fisheries, and a 0% Canadian tagging mortality further increased percentages. Estimates of season stock composition in the fisheries changed most between the combination of the upper 90% bound on Alaskan escapement and 40% Canadian secondary-tagging mortality and the combination of the lower 90% bound on Alaskan escapement and 0% Canadian secondary-tagging mortality (compare lines 3 and 4 of Tables 20 and 21).

Regardless of the combination of Alaskan escapement and Canadian secondary-tagging mortality, the 1982-season stock composition in Alaskan fisheries changed by 15 percentage

points or less, depending on the fishery; for 1983, the changes were 8 percentage points or less at Noyes Island, Dall Island, Lower Clarence Strait, and Tree Point (Table 20). Greatest changes (percentage points are indicated in parentheses below) occurred when contributions of Alaskan and Canadian stocks were nearly equal, such as Upper Clarence Strait (10) and Revillagigedo Channel (15) during 1982, or Upper Clarence Strait (19) and Sumner Strait (25) during 1983. Corresponding changes in Canadian fisheries were at most 6 percentage points in both 1982 and 1983 (Table 21).

Concern that errors in estimating tagged fish escaping to spawning systems of Alaska or Canada could seriously distort estimates of stock composition and interceptions was largely allayed for all Canadian fishing areas and the important Alaskan fishing areas at Noyes Island, Dall Island, and Tree Point. However, the effect on stock-composition estimates of such extreme errors in estimating numbers of tags escaping to spawning areas of either country was greater for some remaining Alaskan fishing areas. Nonetheless, most sockeye salmon in Alaskan fisheries were estimated to originate from Canadian stocks, regardless of the extremes of errors examined.

The ranges of reported estimates of season stock composition (Tables 20, 21) understate the uncertainty in actual season stock composition. Point estimates summarized possible effects of errors in estimated numbers of tagged fish escaping to Canada and Alaska. However, uncertainty in actual stock composition included variation due to subsampling catches and escapements; such variation was generally not large (e.g., see standard errors of season stock-composition estimates in Table 19), and would be superimposed on the reported point estimates (Tables 20, 21). Finally, the uncertainty in actual season stock composition due to the tagged fish unaccounted for by catches and escapements remains unmeasured.

PINK SALMON TAGGING EXPERIMENT OF 1982, 1984, AND 1985

Primary Tagging in the Fisheries

Large numbers of pink salmon were tagged in the boundary waters of the United States and Canada during 1982, 1984, and 1985 (Table 22). In 1982, more than 151,000 pink salmon were tagged in 9 Alaskan and 7 Canadian fishing areas. Even-year stocks were tagged again in 1984, but only slightly more than 82,000 fish were tagged in 5 Alaskan and 6 Canadian fishing areas. Odd-year stocks were first tagged in 1985; more than 125,000 fish were tagged in 10 Alaskan and 8 Canadian fishing areas.

Fishery Recoveries

Numbers of primary-tagged pink salmon subsequently recovered in intervening fisheries from each general area and period of release were expanded to account for the unexamined portion of catches to estimate total recoveries. Estimates of total tagged pink salmon caught in Alaska and Canada were obtained by summing estimates of total tag recoveries over fisheries within each country (Tables 23, 24, 25).

Generally, Alaskan catches of pink salmon tagged in Alaskan waters (other than at Tree Point) greatly exceeded Canadian catches. On the other hand, relative numbers of Canadian releases caught in Alaska and Canada depended more on the year, time, and place of release.

Terminal Recoveries

Estimates of tagged pink salmon in escapements from each general release area and period were computed from tagged fish recovered at weirs (in a few Canadian rivers) or from the numbers of tagged carcasses observed during foot surveys of streams (in both Alaska and Canada). Actual tag recoveries were expanded to account for unexamined fish or tagged fish which entered the rivers but did not arrive at the Canadian weirs.

Total tagged fish escaping to Alaskan systems were estimated from numbers of pink salmon carcasses counted and examined for tags during stream surveys, numbers of tags recovered from the carcasses, and estimates of total escapements to southern Southeast Alaska. In 1982, a total of 569 foot surveys were made on 375 Alaskan streams. In 1984 the total was 475 surveys on 316 streams, and in 1985 the total was 588 surveys on 388 streams. Survey counts of carcasses and estimated escapements were classified by ADF&G statistical areas for each tagging year (Table 26). Observed numbers of

carcasses with tags were divided by the proportions of total escapements examined during the surveys to estimate tagged fish in the escapements. Proportions of escapements examined were computed from the cumulative counts of carcasses examined and corresponding escapements in groups of ADF&G statistical areas listed (Table 26).

Expansions to estimate numbers of tagged pink salmon returning to British Columbia spawning systems depended on the system and were based on either 1) numbers of carcasses examined for tags combined with escapement estimates, as was done for Alaska, or 2) results of secondary-tagging experiments. Escapement estimates were based on counts made from foot surveys, which were expanded to account for escapement not seen. Numbers of carcasses examined for tags and escapement estimates were classified by tagging year and fishing area (Table 27). No escapement estimates were available for 1982 when only stocks of the Skeena, Kwinamass, and Khutzeymateen Rivers (where secondary-tagging studies were conducted) were included in the analysis.

Secondary tagging of pink salmon was conducted on the Skeena and Kwinamass Rivers during each tagging year, but only during 1982 on the Khutzeymateen River. The percentage of secondary-tag releases in these rivers subsequently recovered at weirs or during surveys was generally low and no more than 14%. The recovery rate varied among years by slightly more than twofold for the Skeena and Kwinamass Rivers (Table 28). Such variation could occur as amount-or effectiveness of recovery effort changed; for example, effectiveness of recovery effort could vary with water levels of the rivers. Recovery rate in the Kwinamass River was consistently greater than in the Skeena River. Differences among rivers in recovery rate was expected because the portions of escapements accessible to survey probably differed.

Recovery rate of secondary-tagged fish was assumed to equal the rate of primary-tagged fish in the rivers. Before computing their recovery rate, numbers of secondary-tagged fish released were reduced by numbers estimated to have strayed. The number of primary-tagged fish 'observed in these rivers was expanded to account for those unobserved by dividing by the recovery rate of secondary-tagged fish.

Estimates of total tagged fish escaping to Alaskan and Canadian spawning streams were summarized for each tagging year by area and period of release (Tables 29, 30, 31). These estimates were obtained by summing estimated tagged fish in the various escapements of Alaska or Canada. Generally, numbers of primary-tagged pink salmon escaping to Alaskan spawning streams from nearly all Alaskan release areas throughout the season were vastly greater than numbers escaping to Canada. Relative numbers of Canadian releases escaping to Alaska and Canada were more dependent on time and place of

release than were Alaskan releases. For the first two release periods, the combined number of Canadian releases escaping to Alaska roughly equaled or exceeded the number escaping to Canada; however, in the last two periods, Canadian releases escaping to Canada greatly exceeded those to Alaska. Clearly, fish from Alaskan stocks predominated in most Alaskan fisheries throughout the season and were more abundant in Canadian fisheries earlier than later in the season.

Estimates of total number of recoveries of tagged pink salmon in catches and escapements were plausible (Tables 32, 33, 34) in the sense that the numbers released at any location in any tagging year exceeded the numbers estimated in catches and escapements. Overall percentages of Alaskan or Canadian releases subsequently observed in catches and escapements were similar each year. However, in 1982, estimated overall recovery rate was 39%; this value is considerably lower than that of 1984 (52%) or 1985 (59%).

The type of tags used may have affected the recovery rate of tagged salmon in catches and escapements. Petersen disk tags were used in 1982, but spaghetti tags were used in 1984 and 1985. Possibly more pink salmon died from the use of Petersen tags. Substantial percentages (,61%, 48%, and 41% in 1982, 1984, and 1985, respectively) of primary-tagged pink salmon were not accounted for in either catches or escapements. Presumably the tagged pink salmon died from tagging stress or predation, shed their tags, or migrated to areas not completely covered by tag-recovery sampling.

Stock-Composition Estimates

Estimates of tagged pink salmon in catches and escapements were used to estimate stock composition in fisheries by the algorithm described earlier. Estimates of percentages contributed by regional stock groups were summarized by release year, area, and time of season (Tables 35, 36, 37; Fig. 9). Generally, fish from Alaskan stocks were abundant throughout the season over much of the boundary area in all years. The more significant contributors were Alaskan stocks of ADF&G statistical area 101, especially early in the season. Stocks from ADF&G statistical areas 102, 103, and 104 appeared in substantial numbers during the latter half of the season, especially in Alaskan fisheries (excluding Tree Point), and in Canadian fisheries of area 1. Canadian area 3 and Skeena River stocks were significant contributors to Canadian fishing areas and, at times, to Tree Point, Revillagigedo Channel, Noyes Island, and Dall Island. Pink salmon from stocks south of the Skeena River (Canadian areas 5 through 14) were detected in 1984 and 1985. In 1984, tag recoveries in catches and escapements occurred as far south as Canada area 6. In 1985, escapement recoveries were made farther south in central

British Columbia, and catch recoveries were made even farther south in Johnstone Strait and the western coast of Vancouver Island. Increase in geographic range of recoveries from 1982 to the later years coincided with increased coverage of escapements by the sampling program (recall that in 1982, coverage of Canadian escapements was limited to the Skeena, Khutzeymateen, and Kwinamass Rivers).

Percentages of Alaskan pink salmon in fisheries were summarized (Tables 38, 39, 40). Precision of stock-composition estimates, excluding variation from escapement estimates, was evaluated using the bootstrap technique. Standard errors of most stock-composition estimates appeared reasonably small (15%), but some were subject to large variation from subsampling catches and escapements for tags. Numbers of tagged fish recovered in catches and escapements affect the accuracy of stock-composition estimates, and therefore were summarized (Tables 41, 42, 43). As expected, stock-composition estimates were quite unreliable (as indicated by bootstrap methods) when total tags recovered in catches and escapements was small. Therefore, we summarized what we considered the reasonably reliable estimates of stock composition for the 3 years of tagging by omitting time and area strata for which fewer than 10 total tags were recovered in sampling catches and escapements (Table 44).

Discussion

Several generalities on stock distribution of pink salmon were evident from the estimated percentages of Alaskan-origin pink salmon in international boundary fisheries (Table 44). First, the percentage of pink salmon of Alaskan origin caught in Alaskan fisheries generally remained, high (>75%) throughout the season in all tagging years. The main exceptions were at Tree Point and Revillagigedo Channel, where the percentage from Alaska was sometimes lower. Second, percentage of Alaskan-origin pink salmon in Canadian fisheries varied more among areas and years of tagging than in Alaska. The percentage of Alaskan-origin pink salmon was generally greatest in Canadian areas adjacent to Alaska (Dixon Entrance, Langara Island, and areas 3X, 3Y, and 3Z). Finally, the percentage of Alaskan pink salmon in Canadian fishing areas in 1984 and 1985 was generally highest early in the season and declined later. In 1982, the percentage of Alaskan pink salmon in the Canadian fishing areas was also high early in the season, generally declined through the third release period, and then recovered in the last release period.

Catch-weighted averages of stock-composition estimates were computed across release periods to approximate season stock composition of the interceptive fisheries (Table 45). Resulting averages were reasonably precise because imprecise

estimates of stock composition usually corresponded to release periods with small catches. The percentage of season catches in Alaska from Canadian stocks was low (<12%) in all years and fisheries except Tree Point. On the other hand, the percentage of season catches in Canadian areas consisting of Alaskan-origin stocks was variable among areas and years, and ranged to near 50% and higher for areas adjacent to Alaska, including Dixon Entrance and area 3.

Sensitivity Analysis

All stock-composition estimates should be treated with circumspection because their values were determined mostly from estimated numbers of tagged fish escaping to either Alaskan or Canadian spawning systems. Estimates of tagged fish in escapements depended, in turn, on estimates of escapements; the accuracy of escapement estimates to each country was unknown. However, included with the best estimates of escapements provided by analysts of LGL Limited and ADF&G were lower and upper bounds within which the true escapements probably occurred (Tables 26 and 27). We considered the estimates of escapements as expert opinions, and the bounds were the only measures of their accuracy.

Canada utilized secondary tagging to estimate numbers of escaping primary-tagged pink salmon in several major river systems (Table 28). Recovery rate of secondary-tagged pink salmon was used to expand recoveries of primary-tagged fish to estimate numbers of primary-tagged entrants to the rivers. Similar to the sockeye salmon experiments, if secondary-tagged pink salmon suffered losses not experienced by primary-tagged fish after the latter entered the rivers, numbers of primary-tagged pink salmon entering these rivers would be overestimated. Such bias could affect stock-composition estimates, causing Canadian-origin pink salmon to be overestimated.

Results of behavioral experiments on pink salmon (Helle 1966) at Olsen Creek, Alaska,. were consistent with our postulated tagging mortality. On 10 dates between 29 July and 3 September 1961, Helle captured five maturing pink salmon of each sex in Olsen Creek within tidal influence of Olsen Bay. The fish were tagged with Petersen disk tags without the use of an anesthetic (anesthetic was not used for primary or secondary tagging during the present study) and released several miles away in seawater at Port Gravina, a major body of salt water which contains Olsen Bay. Also on each date, a control group of fish was captured, tagged, but released at the capture location rather than being moved. Olsen Creek was surveyed by foot daily for the tagged fish, and 12 nearby salmon streams within Port Gravina were surveyed by foot weekly. The totals of tagged fish which could be accounted for from the foot surveys were 54 and 58 of the 100 released

from the displaced and nondisplaced groups, respectively. In other words, 46% and 42% of the displaced and nondisplaced groups, respectively, were not found even though the likely places to which they might have strayed were monitored.

To evaluate effects of possible errors in estimates of escaping tagged fish, stock-contribution estimates were recomputed under several combinations of estimates of escapements and mortality of secondary-tagged pink salmon for the Skeena, Kwinamass, and Khutzeymateen Rivers. The three escapement estimates used for Alaska and Canada in each tagging year were the lower and upper bounds and the best point estimates (Tables 26, 27). Two choices of mortality rate of secondary-tagged fish in the Canadian rivers were 0% and 40%. Assuming a 40% mortality rate of secondary-tagged fish reduced estimates of tagged fish escaping to the Skeena, Kwinamass, and Khutzeymateen systems to 60% of the estimates computed assuming 0% mortality. Five combinations of estimates of Alaskan escapements and Canadian secondary-tagging mortality rates were examined for 1982. (Recall that Canadian escapements to systems other than those in the secondary-tagging program of 1982 were not available.) Four combinations of Alaskan and Canadian escapements and Canadian secondary-tagging mortality rates were examined for 1984 and 1985. Presumably, the extremes of possible errors in estimated tagged fish escaping to Alaska and Canada were included.

Regardless of the combination of estimates or tagging year, the season stock-composition estimates changed by only a few percentage points in Alaskan fisheries other than Tree Point and Revillagigedo Channel (Table 46). Some fisheries in Canada were affected more: changes in seasonal stock-composition estimates ranged up to 21 percentage points (Table 47). Concern that potential errors in escapement estimates or mortality rates of secondary-tagged fish could seriously mislead us was allayed for most fisheries.

The ranges of reported estimates of seasonal stock composition (Tables 46, 47) understate the uncertainty in actual season stock composition. Point estimates were used to summarize possible effects of errors in estimated tagged fish escaping to Canada and Alaska. However, uncertainty in actual stock composition also included variation due to subsampling catches and escapements; such variation was generally not large (e.g., see standard errors of season stock-composition estimates in Table 45), and would be superimposed on the reported point estimates (Tables 46, 47).

DISCUSSION AND SUMMARY

Major tagging experiments on adult sockeye and pink salmon were conducted in southern Southeast Alaska and northern British Columbia between 1982 and 1985. Sockeye salmon were tagged in coastal ocean fisheries during 1982 and 1983; pink salmon were tagged during 1982, 1984, and 1985. The immediate purpose of the experiments was to assess interceptions of fish originating in Canada or the United States by fishermen of the other nation. In addition, the studies provided information on timing and migration routes of major salmon stocks which could be used in management of the fisheries.

Primary Tagging

Returning adult salmon were captured and tagged in the international boundary-area fisheries of Southeast Alaska and northern British Columbia. Adults were primary tagged in Southeast Alaska fishing areas at Noyes Island, Dall Island, Cordova Bay, Sumner Strait, Clarence Strait, and Tree Point, as well as in northern British Columbia at Dixon Entrance and Hecate Strait, including near Langara Island, Dundas Island, Tracy Bay, Boston Rocks, Stephens Island, Porcher Island, Birnie Island, Maskelyne Island, Portland Inlet, and Canada areas 5 and 6. Total tagged sockeye salmon released from Alaskan fisheries were 9,050 and 9,156 in 1982 and 1983, respectively; corresponding numbers released from Canadian fisheries were 31,405 and 12,137. Totals of tagged pink salmon released from Alaskan fisheries were 83,487, 30,502, and 68,811 in 1982, 1984, and 1985, respectively; corresponding numbers released from Canadian fisheries were 67,854, 51,631, and 56,801.

Fishery Recoveries

Portions of catches in boundary-area fisheries were examined for tagged fish. Time and place of release were identified for tagged fish recovered during catch sampling. Total numbers of tagged fish occurring in catches of each fishery from half-month interval releases of each fishery were estimated by expanding numbers of tagged fish recovered in catch samples to account for tagged fish in portions of catches not examined for tags.

Terminal Recoveries

Portions of spawning escapements of both countries were also examined for tagged fish, and time and place of release were identified from recovered tags. Total numbers of tagged fish arriving at various streams or regional stream groupings from half-month interval releases of each fishery were estimated by expanding the numbers of tagged fish recovered in the samples to account for fish which were not examined for tags, died, or shed their tags. Several methods were used to expand recoveries from escapements.

Sockeye salmon

Based on early migration studies and general knowledge of sockeye salmon stocks of the region, the main Alaskan stocks contributing to boundary-area fisheries were presumed to originate from southern Southeast Alaska (ADF&G statistical areas 101 through 108). Weirs were built on some larger Alaskan lake systems for nearly complete counting of escapements and recovery of tagged fish. Additional tagged sockeye salmon in escapements to systems without weirs were estimated by two steps. First, fish escaping to systems without weirs were estimated from secondary Petersen tagging experiments adjusted for mortality of tagged fish and from foot-survey counts expanded for unseen fish. Second, the tagged fish among these escapements were estimated, assuming that escapements at weirs represented a random sample of tagged and untagged fish in escapements to all systems with or without weirs. The two-step process was applied to regional stock groups. Ranges of possible total escapements to Alaskan spawning grounds were broad because only a sample of 12 of the 48 known stocks in nonweired systems could be included in the first step in either year. Total escapement to southern Southeast Alaska in 1982 was estimated as 354,000 (90% confidence interval 254,000-477,000); in 1983 the estimate was 324,000 (90% confidence interval 216,000-458,000). Therefore, approximately 48% (90% confidence interval 36%-67%) and 39% (90% confidence interval 27%-58%) of the estimated total escapements of 1982 and 1983, respectively, were examined for tags at Alaskan weirs.

In Canada, the main stocks of sockeye salmon were considered in 1982 to be limited to the Nass and Skeena Rivers. Canada used weirs and foot surveys on the Nass and Skeena Rivers to recover tagged sockeye salmon. Meziadin Lake weir in-the Nass River system and the Babine Lake weir in the Skeena River system were believed to cover most sockeye salmon escapements to each system, although nonweired spawning tributaries existed in either system. In 1983, Canada extended sampling coverage of its escapements. A commercial Canadian

fishery on the Stikine River was used to recover tagged sockeye salmon. Canada also built weirs on several minor systems in the boundary area. In addition, in 1983, substantial numbers of southward-migrating tagged sockeye salmon were caught as far south as Johnstone Strait. Canada sampled catches in Johnstone Strait for tagged fish to estimate total tagged fish in catches. Most southward-migrating fish probably originated in the Fraser River, although other stocks occur as far south as the Columbia River. Escapement to the Fraser River equaled nearly 1 million fish and total return was estimated as slightly more than 5 million fish in 1983 (Pacific Salmon Commission 1988). The main sockeye populations from Washington State were from the Cedar River in the Lake Washington system and Lake Wenatchee on the Columbia River; their combined escapements in 1983 were over 300,000 fish, and their total returns were about 380,000 fish.

Estimation of tagged sockeye salmon entering the large Nass, Skeena, and Stikine River systems posed special difficulty because of incomplete recovery of tagged fish entering the rivers. Some tagged fish probably migrated to spawning grounds without weirs and were not seen during foot surveys; others may have shed their tags, been caught in unsampled native food fisheries on the rivers, or died from other causes. In the Stikine River, recoveries obtained from the Canadian commercial fishery obviously did not include all tagged entrants. Therefore, counts of tagged fish caught in the Stikine River fishery or recovered at weirs and during foot surveys of spawning grounds of the Nass and Skeena Rivers, represented only a portion of the initial entrants to each river. Canada attempted to estimate the total tagged entrants based on numbers of tagged fish recovered by estimating the percentage of entrants which were recovered. To estimate recovery rate, fish were captured, tagged, and released at the estuary or locations within the rivers throughout migration. The recovery rate of such secondary-tagged fish was used to estimate the recovery rate of the primary-tagged entrants to the rivers.

However, outcomes of secondary-tagging experiments on sockeye salmon in the Skeena and Nass Rivers in 1983 were inconsistent. Recovery rate of releases upriver was lower than releases in the estuary or nearby ocean fisheries. If fish tagged in the rivers were representative of ocean-tagged entrants, the recovery rate of upriver releases should have been no less than that of releases in estuaries or in nearby ocean fisheries.

---

[6]Kurt Fresh, Washington Department of Fisheries, 115 General Administration Building, Olympia, WA 98504, pers. commun.

LGL Limited analysts provided estimates of recovery rate of primary-tagged sockeye salmon entering the Nass and Skeena Rivers (Gazey et al. 1983; English et al. 1984). The recovery rate during 1982 was based on taggings upstream within each river. The recovery rate during 1983 for the Skeena River was based solely on estuary tagging because of the contradictory lower recovery rate of upriver tagging. The recovery rate used for the Nass River for 1983 was the midpoint of a postulated range of extreme values determined partially on the nearby ocean fishery tagging, and partially on a proposed maximum. The outcome of the taggings for the Skeena and Nass Rivers in 1983 discredited upstream tagging for estimating the recovery rate of primary-tagged entrants. The recovery rate based on estuary or ocean tagging near the river entrances appeared more plausible. However, estuary or ocean tagging also probably induced mortality of sockeye salmon such that their recovery rates were not representative of primary-tagged entrants.

Substantial percentages (roughly 40%) of secondary-tagged Alaskan sockeye salmon released in estuaries during 1982 and 1983 probably died from short-term tagging stress (Pella et al. 1988). Further, we estimated that 34% of returning adult sockeye salmon tagged and released in coastal fishing areas at Kodiak Island during 1949 (Bevan 1962) were not present in catches or escapements in which they should have occurred had they survived.

Finally, the outcome of the present tagging experiments confirmed a substantial loss of primary-tagged fish from the ocean releases. Cause of the losses was not determined, but presumably included mortality, tag shedding, and migration to unsampled fisheries and spawning escapements. Initially, estimates of recovery rate provided by LGL Limited analysts were used to compute primary-tagged fish in escapements to these rivers. Later, estimates of primary-tagged sockeye salmon in all escapements and catches were combined to estimate the total accounted for by the experiments. Only 50% and 61% of the tagged fish released from Alaskan fisheries subsequently occurred in catches and escapements in 1982 and 1983, respectively. Corresponding recovery rates for releases from Canadian fisheries were 87% and 57%. Viewed in the complementary sense, 50% and 39% of primary Alaskan releases were not found in escapements or catches of 1982 and 1983, respectively; 13% and 43% were corresponding values for Canadian releases. Recovery rates from releases in individual fisheries varied considerably among the fisheries in both years.

In summary, we judged that the recovery rates obtained from secondary-tagging experiments within the Nass and Skeena Rivers are questionable in view of the contradictory outcomes of 1983. We also questioned whether values obtained from tagging in the estuary or nearby fisheries provided valid

estimates of such recovery rates in view of the probable losses from these tagged releases before they entered the rivers. Therefore, although we initially used LGL Limited analysts' estimates of recovery rates within the rivers for our assessment; alternative values were tried to evaluate effects on estimates of stock composition in the fisheries.

Pink salmon

Both Canada and Alaska had many more pink than sockeye salmon stocks. Not only were the numbers of stocks greater, but the total number of pink salmon returning to the boundary area was manyfold that of sockeye salmon during the tagging years. Pink salmon catches in boundary-area fisheries were 13, 23, and 33 million fish in 1982, 1984, and 1985 compared to corresponding sockeye salmon catches of 3, 2, and 4 million fish.

The difficulty in determining numbers of primary-tagged pink salmon in escapements was vastly increased when compared to sockeye salmon. The use of weirs to cover significant portions of escapements to either country was impractical; pink salmon spawning streams are far more numerous than sockeye salmon spawning systems, and the large physical size of many streams with large numbers of fish limited use of weirs.

Similar to sockeye salmon, the only Alaskan pink salmon stocks contributing to boundary-area fisheries were presumed those of ADFCG statistical areas 101 through 108. Pink salmon in Alaskan escapements were estimated by the ADF&G biologists from counts made during regular aerial surveys of spawning streams. These estimates and bounds, which probably contained the actual values, were available for regions within Southeast Alaska. We evaluated neither the accuracy of these escapement estimates nor validity of the bounds but viewed both as expert opinions of the analysts.

Pink salmon tags in Alaska were recovered during surveys of spawning grounds. On the surveys, carcasses examined for tags were counted and any tags were recovered. Estimates of tagged pink salmon escaping to Alaskan spawning grounds from fishery releases tagged during half-month intervals were obtained by expanding numbers of tagged fish recovered in escapements to account for escaping pink salmon not examined during the surveys. These estimates of tagged fish in escapements were obtained for regions in Southeast Alaska.

Canadian pink salmon in boundary-area fisheries were initially thought to arise mainly from stocks of northern British Columbia, but southward-migrating odd-year stocks were detected beyond the geographical range of program sampling in the 1985 tagging experiment. Numbers of these southward-migrating

fish could not be determined and such stocks were omitted from our analysis.

Tagged pink salmon escaping to spawning grounds of northern and central British Columbia were estimated from 1) stream surveys and escapement estimates from foot-survey counts, following the procedure used for Alaska, or 2) secondary-tagging experiments in conjunction with recoveries from weirs or stream surveys. Secondary tagging of pink salmon was conducted on the Skeena and Kwinamass Rivers each tagging year but on the Khutzeymateen River only in 1982. Tagged fish recovered in Canadian escapements were identified to fishery and half-month period of release, as was done for Alaskan escapements. The number of primary-tagged fish recovered in any of these rivers was expanded to account for those unobserved.

The estimates of total tagged pink salmon in boundary-area catches and escapements from Alaskan releases were 42, 55, and 59% of the fish released in 1982, 1984, and 1985, respectively; corresponding values for Canadian releases were 34, 51, and 59%. As with sockeye salmon, substantial proportions of primary-tagged pink salmon were apparently missing. Possibly the number of recoveries in catches and especially escapements were underestimated but mortality from tagging stress, shedding of tags, and migration to unsampled fisheries and spawning grounds were probably largely responsible. Similar to sockeye salmon, mortality of secondary-tagged pink salmon may have been substantial. Results of a behavioral experiment on pink salmon (Helle 1966) at Olsen Creek, Alaska, were consistent with a possible mortality from tagging stress of 40% or‘ more.

Stock-Composition Estimation Method

After computing estimates of tagged sockeye and pink salmon in catches in various fisheries and escapements, we calculated estimates of the stock composition in the release fisheries. Ideally, estimation of stock composition from primary tagging in interceptive fisheries would be based directly on relative numbers of tagged fish from any release belonging to each contributing stock. Although the recovery of tagged fish in escapements and some catches provided clear evidence of origins, more tagged fish were caught in other interceptive fisheries when compared with terminal fisheries. Therefore, origins of most caught tagged fish were unknown. Nonetheless, recoveries of tagged fish of unknown origin in the catches could not be ignored because the stock composition of survivors to escapements was altered by intervening fisheries. To correct stock-composition estimates based on relative numbers in escapements, tagged fish caught in interceptive fisheries were allocated to stocks and combined with tagged

fish in escapements. Although fish which lost their tags should also have been included in the correction, no estimate of their numbers was available. Estimates of the percentages of fish from stocks or regional groups of stocks in an interceptive fishing area were then computed as the percentages of total recoveries from the releases in that area, either in the escapements or allocated from the catches to the stocks or stock groups. Releases were grouped by fishery and half-month period of the season, and corresponding estimates of stock composition were determined for these strata.

The procedure by which we allocated recovered tags of catches to stocks was described by Gazey (1983). Any allocation was arbitrary to some extent, in that no basis exists by which the destinations of releases from a particular fishery, subsequently caught in an interceptive fishery, can be inferred from the taggings. The method of Gazey (1983) infers the stock destinations of the mix of tags originating from all release areas subsequently caught in an intervening fishery from the presumed-available stock composition in the intervening fishery. However, the stock composition of the component groups of tagged fish, coming from different release sites to the intervening fishery, almost surely varies among the groups, yet the method allocates the tagged fish of these groups caught by the intervening fishery as if they were the same. Numerical simulation studies demonstrated that the adopted procedure provided accurate estimates of stock composition if numbers tagged in fisheries were proportional to abundance. The tagging program was conducted with the intention, at least, to approximate such proportional tagging. However, we could not determine the degree to which this condition was satisfied.

Stock-Composition Estimates

Sockeye salmon

Most sockeye salmon in Alaskan and Canadian catches originated in Canada. The percentage of Alaskan-origin sockeye salmon in Alaskan fisheries was greater than in Canadian fisheries; only a small percentage of the catch in Canada was of Alaskan origin. Alaskan sockeye salmon stocks were relatively more abundant in 1982 than in 1983, compared to Canadian stocks of those years.

As expected, the Canadian Nass and Skeena River sockeye salmon stocks were major contributors to most fisheries of the boundary area. Although both stocks were present throughout the fishing seasons, the bulk of Nass River stocks tended to return earlier than that of the Skeena River stocks. The main Alaskan stocks originated in Southeast Alaska (ADF&G statistical areas 101 and 102). Stikine River sockeye salmon stocks

were significant contributors at times during 1983 in several fisheries, including Sumner Strait and Tree Point in Alaska, and at Langara Island in Canada. Finally, southward-migrating stocks, presumably mainly from the Fraser River, were found in significant percentages at times in 1983. The southward-migrating stocks appeared most abundant in outer coastal fisheries at Noyes Island in Alaska and Langara Island in Canada, as well as in Canadian fisheries at the southern portion of the study area.

Sensitivity analysis.-To evaluate the effects of possible errors in estimates of escaping tagged fish, stock-composition estimates were recomputed for several combinations of estimates of Alaskan escapements and mortality rates of secondary-tagged fish of the Nass, Skeena, and Stikine rivers. The three estimates of Alaskan escapements were the point estimate, and lower and upper bounds of the 90% confidence interval. Two choices of mortality rate of secondary-tagged fish in the Canadian rivers were 0% and 40%. Assuming 40% mortality reduced estimates of ocean-tagged fish escaping to the Nass, Skeena, and Stikine rivers to 60% of the values using 0% mortality. Five combinations of estimates of Alaskan escapement and Canadian tagging mortality were examined. The extremes of possible errors in estimates of tagged fish escaping were presumably included in the values used.

Regardless of the combination of estimates used, subsequent stock-composition estimates of season catches in Canada changed by 6 percentage points or less. Changes in some Alaskan fisheries were greater, as much as 25 percentage points. However, in 2 of 4 Alaskan fisheries of 1982 and 4 of 6 of 1983, changes were no greater than 10 percentage points. Concern that errors in Alaskan escapement estimates or mortality of secondary-tagged fish severely affect stock composition estimates was largely allayed for all Canadian fishing areas, as well as the important Alaskan fishing areas at Noyes Island, Dall Island, Lower Clarence Strait, and Tree Point.

Pink salmon

The catch of Alaskan-origin pink salmon in Alaskan fisheries generally remained greater than 75% throughout the season in all years of tagging. Only at Tree Point and Revillagigedo Channel did the percentage drop lower. Furthermore, the percentage of Alaskan pink salmon in Canadian fisheries was more variable among areas and years of tagging than in Alaska; as expected, the percentage of Alaskan pink salmon was generally greatest in Canadian areas adjoining Alaska.

Finally, the percentage of Alaskan pink salmon in Canadian fishing areas in 1984 and 1985 was generally greatest early in the season but declined later. In 1982, the percentage of Alaskan pink salmon in the Canadian fishing areas also was high early and generally declined until it rebounded near the end of the season.

Pink salmon stocks from Alaska, ADF&G statistical area 101, were abundant throughout most of the boundary area, especially early in the season for all years. Stocks from ADF&G statistical areas 102 and 103 appeared later and primarily in Alaskan fisheries or in Canadian fisheries of Dixon Entrance. Canada area 3 stocks and Skeena River stocks were significantcontributors to Canadian fishing areas, as well as to Alaskan fishing areas bounding Dixon Entrance. Stocks south of the Skeena River were detected in 1984 and 1985. In 1984, no tags were recovered in catches or escapements south of Canada area 6. However, in 1985, tags were recovered in escapements as far south as central British Columbia and in catches around Vancouver Island. Increased geographical region of recovery of tagged fish may have resulted from increase in Canadian recovery efforts.

Sensitivity analysis.-To evaluate the effects of possible errors in estimates of escaping tagged fish, stock-composition estimates were recomputed for several combinations of estimates of escapements and mortality rates of secondary-tagged pink salmon of the Skeena, Khutzeymateen, and Kwinamass Rivers. The three estimates of escapements to Alaska and Canada were the upper and lower bounds and point estimates. Two choices of mortality rate of secondary-tagged fish in the Canadian rivers were 0% and 40%. Assuming 40% mortality of secondary-tagged fish reduced estimates of ocean-tagged fish escaping to the Skeena, Khutzeymateen, and Kwinamass Rivers to 60% of the values using 0% mortality. Five combinations of estimates of Alaskan escapements and Canadian secondary-tagging mortality rate were examined for 1982. (Canadian escapements to systems other than those in the secondary-tagging program were omitted for 1982.) Four combinations of Alaskan and Canadian escapement estimates and Canadian secondary-tagging mortality rate were examined for 1984 and 1985. The extremes of possible errors in estimates of tagged fish escaping were presumably included in the values used.

Regardless of the combination of estimates used, subsequent stock-composition estimates of season catches in Alaskan fisheries (other than Tree Point and Revillagigedo Channel) changed by only a few percentage points. In some Canadian fisheries, stock-composition estimates of season catches changed up to 21 percentage points. Concern that errors in escapement estimates or mortality of secondary-

tagged pink salmon severely affect subsequent stock-composition estimates was allayed for many fisheries.

Caveats and Qualifications

Information derived from the U.S.-Canada program of tagging adult salmon in fisheries for estimation of stock composition of catches was rife with difficulties. Stock origins of tagged fish released from interceptive fisheries could not be identified until they had migrated to terminal areas. Intervening fisheries caught many tagged fish before they could escape to terminal areas. Importantly, substantial numbers of tagged fish apparently died from tagging stress *or* shed their tags, and some may have migrated to unmonitored spawning grounds or been caught in unsampled fisheries. The numbers of tagged survivors released in a fishery, which escaped to the various terminal areas, were not representative of their original numbers at release. Correction of stock-composition estimates, based on relative numbers of tagged fish in escapements, for losses en route to the spawning grounds only accounted for tagged fish caught in intervening fisheries. Furthermore, this correction, which relied on the allocation of the tagged fish in catches to stocks of origin, was only expected to be successful if numbers of tagged fish released were in proportion to overall stock abundance in the fisheries. Tagging was directed to this goal, but degree of achievement was unknown. Therefore, in the tagging years, the stock-composition estimates presented must be considered susceptible to this source of bias. In years without tagging, estimation of stock composition in northern boundary-area fisheries presents even greater difficulty.

Stock composition in the northern boundary-area fisheries probably varies among years as magnitudes of stocks, ocean conditions, and the fisheries themselves change. Clearly, past or future stock contributions to northern boundary-area fisheries vary from their levels during the tagging studies as relative magnitudes of stocks change. As an example, the odd-year pink salmon stocks of the Skeena River appeared to have increased significantly in magnitude relative to Southeast Alaska stocks after the 1985 taggings.

Migration routes of stocks are probably affected by annual changes in oceanographic conditions of the region (Hamilton and Mysak 1986). Therefore, an El Nino event during 1982-83 (Wooster and Fluharty 1985) with associated warmer ocean temperatures along the western coast of Southeast Alaska and British Columbia in 1983, as compared to 1982, would have contributed to observed variations of stock composition of northern boundary-area fisheries during tagging years. El Nino events occur at irregular intervals roughly every 2-7 years, vary in strength, and presumably affect to varying

degrees the stock composition in northern boundary-area fisheries.

Finally, distribution of fishing effort and associated catch by time of season within fishing areas change because of decisions by fishermen and fishery managers.< Because salmon stocks have their own timings of passage through the fishing areas, the fishery changes could alter the stock composition of catches. Clearly, based on results of these experiments, assessing stock composition of catches in northern boundary-area fisheries in years without tagging will be subject to great uncertainty.

As a final caveat, we warn that the estimates of stock composition and interpretation of results are ours alone for use by the United States in negotiations with Canada regarding northern boundary-area fisheries; Canada has obtained similar analyses of the taggings from staff of LGL Limited. We used much of the methodology developed by LGL Limited in our analysis; generally, their estimates of stock composition in northern boundary-area fisheries from the taggings appear to agree reasonably well with our estimates when we assumed, as they did, that initial mortality of secondary-tagged fish from stress was negligible. Unique aspects of the analyses necessarily make identification of the source of any disagreements difficult. For example, partitioning of time of release differed (LGL Limited chose months and we chose half-month periods) because of individual judgments of best approach. In a few cases, area of release was partitioned differently by us because of interests within Alaska. Efforts are ongoing between Canada and the United States within the Pacific Salmon Commission to determine estimates of stock composition in northern boundary-area fisheries that are mutually agreeable to both countries.

ACKNOWLEDGMENTS

The scale of these tagging experiments required the cooperation of many fisheries management and research employees of Canada and the United States. We shall not attempt to identify the many individuals involved, but acknowledge those we knew were involved directly in the planning and direction of these studies.

The planning of these tagging experiments was begun by personnel of the Canada Department of Fisheries and Oceans and the Alaska Department of Fish and Game. Brian Riddell of the Pacific Biological Station at Nanaimo, B.C., and consultants of Environmental and Social Systems Analysts Ltd. of Vancouver, B.C., and LGL Limited of Sidney, B.C.,--including Karl English, Bill Gazey, and Mike Staley--developed and applied for Canada the basic estimation procedure we followed; they also recommended the numbers of tagged fish to be released in each experiment, based on simulation studies. Staff of LGL Limited also directed the tagging and recovery of both sockeye and pink salmon in Canada. Dave Cantillon, Gary Gunstrom, and Mel Seibel of the Alaska Department of Fish and Game initiated the planning of tagging and recovery in Alaska. Jack Bailey, Bill Heard, and Jack Helle of the National Marine Fisheries Service (NMFS) directed the planning and execution of the recovery effort for sockeye salmon in Alaska. Jim Olsen of the NMFS administered the program for the United States.

We received helpful reviews of an earlier version of the manuscript from Jim Blick and Mel Seibel (Alaska Department of Fish and Game), and Richard Carlson and Aven Andersen (NMFS).

CITATIONS

Bevan, D. E. 1962. Estimation by tagging of the size of migrating salmon populations in coastal waters. *In Koo,* T. S. Y. (editor), Studies of Alaska red salmon, p. 373-449. University of Washington Publications in Fisheries. New series, vol. 1. Univ. Washington Press, Seattle.

Efron, B., and R. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Stat. Sci. 1:54-77.

Efron, B., and R. Tibshirani. 1991. Statistical data analysis in the computer age. Science 253:390-395.

English, K. K., W. J. Gazey, and J. A. Taylor. 1984. Part C. The 1983 North Coast tagging study. *In* Gazey, W. J., and D. A. Birdsall (editors), Design and execution of a stock interception study. Draft of unpubl. rep. by LGL Limited and ESSA Environmental Social Systems Analysts Ltd., for Fisheries and Oceans Canada, 115 p. LGL Limited, No. 333, 2453 Beacon Ave., Sidney, B.C., Canada.

Gazey, W. J.. 1983. Part A. Theoretical development, design and data management. *In* Gazey, W. J., and D. A. Birdsall (editors), Design and execution of a stock interception study. Unpubl. rep. by LGL Limited and ESSA Environmental Social Systems Analysts Ltd., for Fisheries and Oceans Canada, 47 p. LGL Limited, No. 333, 2453 Beacon Ave., Sidney, B.C., Canada.

Gazey, W. J., J. Taylor, K. K. English,, T. Webb, and D. A. Birdsall. 1983. Part B. 1982 North Coast tagging study. *In* Gazey, W. J., and D. A. Birdsall (editors). Design and execution of a stock interception study. Unpubl. rep. by LGL Limited and ESSA Environmental Social Systems Analysts Ltd., for Fisheries and Oceans Canada, 107 p. LGL Limited, No. 333, 2453 Beacon Ave., Sidney, B.C., Canada.

Greenough, J. W. 1971. Estimation of sockeye, coho, and chinook salmon runs at Wood Canyon on the Copper River in 1966, 1967, and 1968, 109 p. Unpubl. rep., U.S. Dep. Interior, Fish and Wildlife Service, Anchorage, AK.

Hamilton, K., and L. A. Mysak. 1986. Possible effects of the Sitka eddy on sockeye *(Oncorhynchus nerka)* and pink salmon *(Oncorhynchus gorbuscha)* migration off Southeast Alaska. Can. J. Fish. Aquat. Sci. 43:498-504.

Helle, J. H. 1966. Behavior of displaced adult pink salmon. Trans. Am. Fish. Soc. 95:188-195.

Hoffman, S. H., L. Talley, and *M.* C. Seibel. 1984. U.S./ Canada cooperative pink and sockeye salmon tagging, interception rates, migration patterns, run timing, and stock intermingling in southern Southeast Alaska and northern British Columbia, 1982. Technical Data Report no. 110, 188 p. Available from Alaska Department of Fish and Game, P.O. Box 3-2000, Juneau, AK.

Jones, J. D., and G. Thomason. 1983. Southern Southeast Alaska pink salmon secondary tagging and escapement enumeration studies, 1982, 13 p. *In* Final Report. 1982 salmon research conducted in Southeast Alaska by the Alaska Department of Fish and Game in conjunction with joint U.S.-Canada interception investigations. Alaska Dep. Fish and Game, Div. Commercial Fisheries, Juneau, AK.

Oliver, G. T., and S. L. Walls. 1985. Estimated contribution from Alaska and Canada stocks to the catches of sockeye salmon in southern Southeast Alaska, 1984, based on the analysis of scale patterns, 46 p. *In* Alaska Department of Fish and Game. Final Rep. 1984 salmon research conducted in Southeast Alaska by the Alaska Department of Fish and Game in conjunction with the National Marine Fisheries Service's Auke Bay Laboratory for joint U.S.-Canada interception studies, Contract no. WASC-84-00179, June 1985.

Pacific Salmon Commission. 1988. Report of the Fraser River Panel to the Pacific Salmon Commission on the 1987 Fraser River sockeye and pink salmon fishing season, 48 p.

Pella, J. J., J. C. Olsen, J. H. Helle, J. H. Eiler, J. A. Orsi, and D. G. Mortensen. 1988. Sockeye salmon *(Oncorhynchus nerka)* escapements to southern Southeast Alaska in 1982 and 1983, 33 p. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-150.

Wooster, W. S., and D. L. Fluharty (editors). 1985. El Nino north. Nino effects in the eastern subarctic Pacific Ocean, 312 p. Washington Sea Grant Program. University of Washington, Seattle.

TABLES

Table 1. --Delineation of general areas of release in Southeast Alaska in terms of the Alaska Department of Fish and Game statistical system.'

Release area	Areas and subareas
Noyes Island	10430, 10435, 10440
Dall Island	10410, 10420
Cordova Bay	10311, 10325, 10328, 10330, 10340
Lower Clarence Strait	10125, 10129, 10210, 10220, 10240, 10250
Middle Clarence Strait	10270, 10280
Union Bay	10710
Upper Clarence Strait	10610, 10620, 10630
Sumner Strait	10641
Revillagigedo Channel	10123, 10130, 10141, 10153
Tree Point	10111

*The first three digits represent an ADF&G statistical area, and the last two digits represent a statistical subarea.

Table 2.--Delineation of general areas of release in British Columbia in terms of the Canada Department of Fisheries and Oceans statistical system.

Release area	Areas and subareas
Langara Island	l-l through l-5
3x	3.1
3Y	3.2 through 3.6
3Z	3.7 through 3.12
4	4.1 through 4.11
5	5.1 through 5.20
6	6.5 through 6.10

Table 3.--Delineation of areas of release in Canada's Dixon Entrance in terms of Canada Department of Fisheries and Oceans statistical system by year: 1984 and 1985.

	Areas and subareas	
Release area	1984	1985
Northwest	l-10	101-4
Northeast	l-11,1-12	101-8
South	l-16,1-17,1-18	101-7
Other	l-13,1-14 l-15	l0l-5,101-6, l0l-9,101-10

Table 4.--Number of tagged sockeye salmon released in southern Southeast Alaska and northern British Columbia, 1982 and 1983.

Release location	1982	1983
Alaska		
Noyes Island	2,813	3,047
Dall Island	1,442	1,039
Cordova Bay	29	0
Lower Clarence Strait	373	473
Middle Clarence Strait	386	0
Union Bay	114	0
Upper Clarence Strait	2,196	1,716
Sumner Strait	0	1,998
Revillagigedo Channel	617	134
Tree Point	1,080	749
Alaska total	9,050	9,156
Canada		
Langara Island	7,909	4,314
Dixon Entrance	47	0
3x	10,090	2,958
3Y	5,920	1,308
3Z	1,348	2,493
4	5,637	758
5	490	306
Canada total	31,405	12,137
Totals	40,455	21,293

Table 5.--Estimates of total numbers' of tagged sockeye salmon caught in Alaskan and Canadian fisheries by general area and period of release, 1982.

Release location	Release period: 15-30 Jun Alaska	15-30 Jun Canada	1-15 Jul Alaska	1-15 Jul Canada	16-31 Jul Alaska	16-31 Jul Canada	1-15 Aug Alaska	1-15 Aug Canada
Alaska								
Noyes Island	150	177	86	166	43	151	52	15
Dall Island	55	122	0	6	0	0	0	9
Cordova Bay	0	0	0	0	0	0	0	0
Lower Clarence Strait	16	17	10	31	0	0	10	4
Middle Clarence Strait	0	0	86	5	0	3	2	2
Union Bay	0	0	0	0	0	12	0	0
Upper Clarence Strait	0	0	124	71	99	299	35	37
Revillagigedo Channel	13	89	8	10	36	69	8	0
Tree Point	40	127	11	152	11	167	13	13
Alaska total	274	532	325	441	189	701	120	80
Canada								
Langara Island	234	1,395	139	670	5	428	0	0
Dixon Entrance	0	0	3	27	0	10	0	0
3x	256	441	233	1,807	32	2,629	8	77
3Y	55	3,155	84	533	10	338	0	18
3Z	10	494	6	74	0	91	0	0
4	16	135	33	493	66	1,797	0	56
5	0	0	0	0	0	27	0	45
Canada total	571	5,620	498	3,604	113	5,320	8	196
Totals	845	6,152	823	4,045	302	6,021	128	276

*Numbers of actual tag recoveries expanded for subsampling of catches.

Table 6.--Estimates of total numbers* of tagged sockeye salmon caught in Alaskan and Canadian fisheries by general area and period of release, 1983.

Release location	Release period: 15-30 Jun Alaska	15-30 Jun Canada	1-15 Jul Alaska	1-15 Jul Canada	16-31 Jul Alaska	16-31 Jul Canada	1-15 Aug Alaska	1-15 Aug Canada
Alaska								
Noyes Island	47	2	91	147	375	142	71	74
Dal1 Island	29	23	7	5	70	106	22	94
Lower Clarence Strait	0	0	0	0	1	130	32	115
Upper Clarence Strait	27	0	39	117	87	72	42	1
Sumner Strait	121	12	122	33	26	35	91	13
Revillagigedo Channel	0	1	21	10	0	11	0	0
Tree Point	15	0	50	67	32	184	14	115
Alaska total	239	38	330	379	605	680	272	412
Canada								
Langara Island	91	20	13	252	14	84	0	29
3x	15	21	15	374	0	123	0	232
3Y	15	10	14	60	5	49	7	309
3Z	19	8	0	67	24	739	7	296
4	0	1	0	112	5	19	0	10
5	0	0	0	11	0	0	0	0
Canada total	140	60	42	876	48	1,014	14	876
Totals	379	98	372	1,255	653	1,694	286	1,288

*Numbers of actual tag recoveries expanded for subsampling of catches.

Table 7. --Southeast Alaskan sockeye salmon escapement and weir counts by fishing district, 1982 and 1983.

Fishing district	Weir counts 1982	Weir counts 1983	Escapement estimates' 11,000s of fish) 1982 Low	1982 Best	1982 High	1983 Low	1983 Best	1983 High
101	75,570	72,616	76	106	143	72	108	153
102	55,966	31,283	58	81	109	43	64	90
103	22,213	8,327	48	66	89	33	50	71
104-108	16,042	14,023	72	101	136	68	102	144
Totals	169,791	126,249	254	354	477	216	324	458

*Estimates of total escapement and its lower (Low) and upper (High) 90% confidence bounds are provided by Pella et al. (1988); corresponding values for fishing districts were obtained from unreported numerical results of Pella et al. (1988) by summing weir counts and estimates over systems within districts.

Table 8.--Numbers of sockeye salmon released in secondary tagging on the Skeena, Nass, and Stikine Rivers (adjusted for straying), numbers recovered at weirs or during foot-surveys of spawning grounds (Nass and Skeena Rivers) or in the commercial river fishery (Stikine River), and the recovery rate of tagged fish in each river, 1982 and 1983 (Source: Gazey et al. 1983; English et al. 1984).

	1982			1983'		
River system	Number tagged	Number recovered	Recovery rate (%)	Number tagged	Number recovered	Recovery rate (%)
Skeena	3,325	559	17	1,698	420	25
Nass	3,049	1,305	43	150	92	61
Stikine	0			862	187	22

*In 1983, results of tagging in the Skeena River estuary (area 4.12) were used for the Skeena River. Also in 1983, the value for number tagged on the Nass River was concocted by LGL Limited analysts to provide the reported value of recovery rate based on actual number recovered. The reported value of recovery rate for the Nass River was the midpoint between extremes determined by portion recovered from primary tagging in area 32 and other unspecified information (English et al. 1984).

Table 9.--Estimates of total numbers of tagged sockeye salmon escaping to Alaskan and Canadian spawning areas by period and general area of release, 1982.

Release location	Release period							
	15-30 June		1-15 July		16-31 July		1-15 August	
	Alaska	Canada	Alaska	Canada	Alaska	Canada	Alaska	Canada
Alaska								
Noyes Island	80	303	14	20	0	170	0	12
Dall Island	49	60	5	0	0	0	0	53
Cordova Bay	0	0	0	0	0	0	0	0
Lower Clarence Strait	46	14	17	23	0	0	3	0
Middle Clarence Strait	0	0	58	0	4	12	2	0
Union Bay	0	0	1	0	10	18	1	0
Upper Clarence Strait	0	0	88	2	46	133	23	98
Revillagigedo Channel	43	33	35	7	20	58	1	5
Tree Point	8	19	14	85	35	83	8	12
Alaska total	226	429	232	137	115	474	38	180
Canada								
Langara Island	102	1,251	18	209	5	229	0	0
Dixon Entrance	0	0	6	2	0	0	0	0
3x	68	379	58	770	11	2,192	0	454
3Y	7	1,057	14	657	3	199	6	83
3Z	1	44	0	95	4	122	0	0
4	12	1,405	0	299	22	1,037	0	305
5	0	0	0	0	0	6	0	311
Canada total	190	4,136	96	2,032	45	3,785	6	1,153
Totals	416	4,565	328	2,169	160	4,259	44	1,333

Table 10.--Estimates of total numbers of tagged sockeye salmon escaping to Alaskan and Canadian spawning areas by period and general area of release, 1983.

Release location	Release period: 15-30 June Alaska	15-30 June Canada	1-15 July Alaska	1-15 July Canada	16-31 July Alaska	16-31 July Canada	1-15 August Alaska	1-15 August Canada
Alaska								
Noyes Island	14	73	53	138	18	436	8	117
Dall Island	9	148	4	6	7	154	0	27
Lower Clarence Strait	0	0	0	0	6	105	3	16
Upper Clarence Strait	41	3	167	33	84	23	15	8
Sumner Strait	102	131	120	53	99	49	64	4
Revillagigedo Channel	1	12	18	21	0	11	0	0
Tree Point	6	28	16	52	26	66	0	31
Alaska total	173	395	378	303	240	844	90	203
Canada								
Langara Island	9	73	7	113	1	176	0	38
3x	4	385	2	394	0	375	1	146
3Y	5	269	7	220	0	53	0	110
3Z	1	408	4	287	0	537	0	66
4	0	10	0	34	0	57	0	0
5	0	7	0	5	0	0	0	0
Canada total	19	1,152	20	1,053	0	1,198	1	360
Totals	192	1,547	398	1,356	241	2,042	91	563

Table 11.--Numbers of tagged sockeye salmon released, combined numbers estimated as caught or escaping, percentage of total estimated recoveries from catch and escapement, and recovery rate of tagged releases estimated as occurring in catch or escapement, by release fishery and year.

Release fishery*	Number released		Total recoveries		Percentage of recoveries: Catch		Percentage of recoveries: Escapement		Recovery rate (%)	
	1982	1983	1982	1983	1982	1983	1982	1983	1982	1983
Alaska										
Noyes	2,813	3,047	1,439	1,806	58	53	42	47	51	59
Dall	1,442	1,039	359	71l	53	50	47	50	25	68
Cordova	29	0	0	0	0	0	0	0		
Lclar	373	473	191	432	46	68	54	32	51	91
Mclar	386	0	174	0	56	0	44	0	45	
Union	114	0	42	0	29	0	71	0	37	
Uclar	2,196	1,716	1,055	759	63	51	37	49	48	44
Sumner	0	1,998	0	1,075	0	42	0	58		54
Revla	617	134	435	106	54	41	46	59	71	79
Tree	1,080	749	798	702	67	68	33	32	74	94
Alaska tot.	9,050	9,156	4,493	5,591	59	53	41	47	50	61
Canada										
L=%	7,909	4,314	4,685	920	61	55	39	45	59	21
Dixon	47	0	48	0	83	0	17	0		·
3x	10,090	2,958	9,415	2,087	58	37	42	63	93	71
3Y	5,920	1,308	6,219	1,133	67	41	33	59	105	87
3Z	1,348	2,493	941	2,463	72	47	28	53	70	99
4	5,637	758	5,676	248	46	59	54	41	101	33
5	490	306	389	23	19	48	81	52	79	8
Can. tot.	31,405	12,137	27,373	6,874	58	45	42	55	87	57
Totals	40,455	21,293	31,866	12,465	58	48	42	52	79	59

*Noyes = Noyes Island; Dall = Dall Island; Cordova = Cordova Bay; Lclar = Lower Clarence Strait; Mclar = Middle Clarence Strait; Union = Union Bay; Uclar = Upper Clarence Strait; Sumner = Sumner Strait; Revla = Revillagigedo Channel; Tree = Tree Point; Lang - Langara Island; and Dixon - Dixon Entrance.

Table 12.--1982 stock-composition estimates (%) of sockeye salmon by area and period of release, totals for Alaska and Canada (%), and estimated numbers of tagged fish in 'Alaskan and Canadian escapements (%). Best estimates of escapements were used, and recovery rate of primary-tagged entrants to major rivers in Canada was assumed to equal that of secondary-tagged fish.

Release area[a]	Alaska stocks				Canada stocks		Total		Esc.	
	101	102	103	other	Nass	Skeena	AX	Can.	AK	Can.
Release period 1: June										
Alaska										
Noyes	7	4	3	1	37	48	15	85	21	79
Dall	15	3	5	1	34	44	23	78	45	55
Lclar	27	24	3	0	33	12	55	45	77	23
Revla	28	0	0	0	62	10	28	72	57	43
Tree	9	0	0	0	75	15	10	90	31	69
Canada										
Lang	5	1	0	0	27	67	7	93	8	92
3x	9	0	0	0	60	30	10	90	15	85
3Y	4	1	0	0	86	10	4	96	1	99
3Z	5	1	0	0	85	9	6	94	3	97
4	0	0	0	0	3	97	0	100	0	100
Release period 2: early to mid-July										
Alaska										
Nowey	10	7	3	2	21	57	22	78	41	59
Dall	14	34	0	0	31	20	48	52	100	0
Uclar	14	26	0	5	18	38	44	56	97	3
Union[b]	0	100	0	0	0	0	100	0	100	0
Mclar	27	27	0	16	16	14	70	30	100	0
Lclar	21	6	0	1	16	56	28	72	43	57
Revla	52	2	0	10	24	12	64	36	83	17
Tree	8	0	0	0	35	56	9	91	14	86
Canada										
Dixon	17	0	0	0	46	36	18	82	71	29
Lang	8	1	1	1	18	71	10	90	8	92
3x	5	0	0	0	22	72	5	95	7	93
3Y	4	0	0	1	58	37	5	95	2	98
3Z	1	0	0	0	79	20	1	99	0	100
4	3	0	0	1	8	88	4	96	0	100

Table 12. --Continued.

Release area[a]	Alaska stocks 101	102	103	other	Canada stocks Nass	Skeena	Total AK	Can.	Esc. AK	Can.
Release period 3: mid- to end July										
Alaska										
Noyes	1	0	1	0	7	90	3	97	0	100
Uclar	3	3	1	5	8	80	12	88	26	74
Union[b]	4	8	0	14	3	72	26	74	36	64
Mclar[b]	0	0	0	22	1	77	22	78	26	74
Revla	14	0	1	0	22	64	15	85	25	75
Tree	12	0	1	1	20	66	14	86	30	70
Canada										
Dixon[b]	1	0	1	0	4	93	3	97	0	100
Lang	1	0	1	0	8	89	3	97	2	98
3X	1	0	1	0	7	91	2	98	1	99
3Y	1	0	1	0	15	83	2	98	1	99
3Z	2	0	0	0	35	62	3	97	3	97
4	1	0	1	0	4	93	3	97	2	98
5[b]	1	0	1	0	5	93	2	98	0	100
Release period 4: August										
Alaska										
Noyes	4	0		0	16	79	4	96	0	100
Dall	0	0		0	8	92	0	100	0	100
Uclar	3	17		6	9	65	26	74	19	81
Union[b]	0	100		0	0	0	100	0	100	0
Mclar[b]	2	47		0	5	46	49	51	100	0
Lclar[b]	11	25		9	35	20	44	56	100	0
Revla[b]	23	0		0	77	0	23	77	23	77
Tree	18	28		0	25	29	46	54	42	58
Canada										
3X	0	0		0	1	98	0	100	0	100
3Y	5	0		0	4	90	5	95	6	94
4	0	0		0	0	100	0	100	0	100
5	0	0		0	0	100	0	100	0	100

[a]Noyes = Noyes Island; Dall = Dall Island; Union = Union Bay; Lclar = Lower Clarence Strait; Mclar = Middle Clarence Strait; Uclar = Upper Clarence Strait; Revla = Revillagigedo Channel; Tree = Tree Point; Lang = Langara Island; and Dixon = Dixon Entrance.

[b]Fewer than 10 tagged fish were recovered in catches and escapements from these releases of tagged fish, and the estimates of stock composition should be considered in light of this limited basis.

Table 13.--1983 stock-composition estimates (%) of sockeye salmon by area and period of release, totals for Alaska and Canada (%), and estimated numbers of tagged fish in Alaskan and Canadian escapements

Best estimates of escapements were used, and recovery rate of primary-tagged entrants to major rivers in Canada was assumed equal to that of secondary-tagged fish.

Release area[b]	Alaska stocks				Canada stocks				Total		Esc.	
	101	102	103	oth.	Nass	Skn.	oth.	Stik.	AK	Can.	AK	Can.
Release period 1: June												
Alaska												
Noyes	5	7	5	0	59	19	1	4	17	83	16	84
Dall	3	4	0	0	73	16	0	4	7	93	6	94
Sumnr	8	30	0	4	22	0	1	34	43	57	44	56
Uclar	3	64	0	0	30	0	0	2	68	32	93	7
Revla[c]	11	0	0	0	89	1	0	0	11	89	11	89
Tree	18	0	0	0	69	0	0	14	18	82	18	82
Canada												
Lang	12	3	0	0	69	6	1	9	15	85	12	88
3X	1	1	0	0	27	70	1	1	2	98	1	99
3Y	2	1	0	0	91	3	1	2	3	97	2	98
3Z	1	0	0	0	90	8	0	0	1	99	0	100
4[c]	0	0	0	0	50	0	50	0	0	100	0	100
5[c]	0	0	0	0	25	60	15	0	0	100	0	100
Release period 2: early to mid-July												
Alaska												
Noyes	6	4	5	4	38	39	4	0	18	82	28	72
Dall[c]	8	20	0	0	38	31	2	1	27	73	42	58
Sumnr	18	8	0	24	23	14	2	10	51	49	69	31
Uclar	43	9	0	0	27	14	3	4	51	49	84	16
Revla	30	0	0	0	45	22	2	1	30	70	46	54
Tree	15	1	0	0	56	22	3	3	15	85	24	76
Canada												
Lang	4	0	0	0	42	43	11	0	4	96	6	94
3X	1	0	0	0	26	64	9	0	1	99	1	99
3Y	3	0	0	0	84	10	3	0	3	97	3	97
3Z	1	0	0	0	81	14	3	0	1	99	2	98
4	1	0	0	0	38	36	25	0	1	99	0	100
5	0	0	0	0	35	0	65	0	0	100	0	100

Table 13.--Continued.

Release area[b]	Alaska stocks 101	102	103	oth.	Canada stocks[a] Nass	Skn.	oth.	Stik.	Total AK	Can.	Esc. AK	Can.
Release period 3: mid- to end July												
Alaska												
Noyes	3	1	0	0	6	89	1	0	4	96	4	96
Dall	1	0	2	0	6	90	1	0	4	96	5	95
Sumnr	19	0	0	33	4	28	0	16	52	48	67	33
Uclar	29	3	0	3	4	59	0	2	35	65	79	21
Lclar	3	0	0	0	7	90	0	0	3	97	5	95
Revla[c]	0	0	0	0	33	67	0	0	0	100	0	100
Tree	8	1	0	0	13	77	0	0	10	90	29	71
Canada												
Lang	1	0	0	0	1	91	7	0	1	99	1	99
3X	0	0	0	0	1	97	2	0	0	100	0	100
3Y	1	0	0	0	7	92	0	0	1	99	0	100
3Z	1	0	0	0	4	95	0	0	1	99	0	100
4	1	0	0	0	2	97	0	0	1	99	0	100
Release period 4: August												
Alaska												
Noyes	3	1	0	0	6	60	30	0	4	96	6	94
Dall	0	0	0	0	17	76	6	0	0	100	0	100
Sumnr	18	0	0	21	5	54	1	0	40	60	94	6
Uclar	23	3	0	0	8	65	0	0	27	73	66	34
Lclar	2	0	0	0	8	90	1	0	2	98	16	84
Tree	0	0	0	0	16	84	1	0	0	100	0	100
Canada												
Lang	0	0	0	0	2	39	58	0	0	100	0	100
3X	0	0	0	0	4	95	0	0	0	100	1	99
3Y	0	0	0	0	6	92	2	0	0	100	0	100
3Z	0	0	0	0	7	92	1	0	0	100	0	100

'Nass - Nass River; Skn. = Skeena River; oth. - other; and Stik. - Stikine River.

[b]Noyes - Noyes Island; Dall = Dall Island; Sumnr = Sumner Strait; Lclar = lower Clarence Strait; Uclar = Upper Clarence Strait; Revla - Revillagigedo Channel; Tree - Tree Point; and Lang - Langara Island.

'Fewer than 10 tagged fish were recovered in catches and escapements from these releases of tagged fish, and the estimates of stock composition should be considered in light of this limited basis.

Table 14.--Percentage of Alaskan-origin* sockeye salmon (bootstrap standard error in parentheses) by fishery and period of release, 1982. Dash means no estimate could be made.

Release fishery	June	Early to mid-July	Mid- to end July	August
Alaska				
Noyes Island	15 (1.8)	22 (2.2)	3 (0.4)	5 (7.0)
Dall Island	23 (2.9)	48 (10.5)	-	0 (0.0)
Lower Clarence Strait	55 (5.6)	28 (5.3)	-	51 (17.1)
Middle Clarence Strait	-	70 (4.0)	22 (16.9)	77 (19.0)
Union Bay		100 (0.0)	26 (11.0)	100 (0.0)
Upper Clarence Strait	-	44 (2.9)	12 (1.3)	27 (5.8)
Revillagigedo Channel	28 (3.2)	64 (6.1)	15 (3.3)	23 (28.9)
Tree Point	10 (3.1)	9 (1.8)	14 (2.4)	58 (8.5)
Canada				
Dixon Entrance		18 (5.8)	3 (0.7)	-
langara Island	7 (0.7)	10 (1.1)	3 (0.8)	
3x	10 (1.6)	5 (0.7)	2 (0.4)	0 (0.5)
3Y	4 (1.9)	5 (0.7)	2 (0.6)	6 (3.3)
3Z	6 (2.6)	1 (0.2)	3 (1.2)	
4	0 (0.1)	4 (0.7)	3 (0-7).	0 (0.0)
5	-		2 (0.6)	0 (0.0)

*Standard errors account for chance variation of recoveries from subsampling catches and escapements, but not for errors in escapement estimates for either Alaska or Canada.

Table 15.--Percentage of Alaskan-origin* sockeye salmon (bootstrap standard error in parentheses) by fishery and period of release, 1983. Dash means no estimate could be made.

Release fishery	June	Early to mid-July	Mid- to end July	August
Alaska				
Noyes Island	17 (5.4)	18 (3.9)	4 (0.8)	4 (1.3)
Dal1 Island	7 (2.5)	27 (11.3)	4 (2.3)	0 (0.0)
Lower Clarence Strait	-		3 (1.3)	2 (1.3)
Upper Clarence Strait	68 (6.6)	51 (3.0)	35 (3.4)	27 (6.9)
Sumner Strait	43 (4.8)	51 (5.1)	52 (7.1)	40 (6.4)
Revillagigedo Channel	11 (11.2)	30 (6.3)	0 (0.1)	.
Tree Point	18 (10.0)	15 (3.3)	10 (2.0)	0 (0.1)
Canada				
Langara Island	15 (5.1)	4 (0.9)	1 (0.6)	0 (0.0)
3x	2 (0.8)	1 (0.3)	0 (0.1)	0 (0.5)
3Y	3 (1.1)	3 (1.2)	1 (0.2)	0 (0.1)
3Z	1 (0.5)	1 (0.8)	1 (0.2)	0 (0.0)
4	0 (0.0)	1 (0.3)	1 (0.2)	
5	0 (0.0)	0 (0.0)		.

'Standard errors account for chance variation of recoveries from subsampling catches and escapements, but not for errors in escapement estimates for either Alaska or Canada.

Table 16.--Number of tags recovered in catches and escapements of sockeye salmon by area and period of release in 1982.

	June		Early to mid-July		Mid- to end July		August	
Release area	Esc.	Catch	Esc.	Catch	Esc.	Catch	Esc.	Catch
Alaska								
Noyes Island	130	62	11	46	30	45	2	9
Dall Island	51	43	5	2	0	0	10	4
Lower Clarence Strait	44	7	18	10	0	0	3	2
Middle Clarence Strait	0	0	45	6	5	1	2	2
Upper Clarence Strait	0	0	83	30	62	89	33	14
Cordova Bay	0	0	0	0	0	0	0	0
Tree Point	14	30	34	37	51	42	11	6
Revillagigedo Channel	45	19	28	5	31	20	3	1
Union Bay	0	0	1	0	11	4	1	0
Canada								
Dixon Entrance	0	0	5	7	0	2	0	0
Langara Island	331	401	54	182	48	107	0	0
3X	166	130	199	488	427	641	76	30
3Y	445	586	255	143	51	84	19	4
3Z	20	90	39	18	41	20	0	0
4	238	49	50	121	191	433	51	15
5	0	0	0	0	1	6	52	23

Table 17.--Number of tags recovered in catches and escapements of sockeye salmon by area and period of release in 1983.

	June		Early to mid-July		Mid- to end July		August	
Release area	Esc.	Catch	Esc.	Catch	Esc.	Catch	Esc.	Catch
Alaska								
Noyes Island	41	8	65	36	128	78	31	25
Dall Island	83	7	4	3	44	28	12	17
Lower Clarence Strait	0	0	0	0	34	23	6	25
Upper Clarence Strait	22	4	117	30	58	22	12	10
Tree Point	19	2	36	19	44	38	13	21
Revillagigedo Channel	8	1	22	5	5	3	0	0
Sumner Strait	86	28	55	41	45	18	25	12
Canada								
Langara Island	45	19	40	60	47	20	9	8
3X	133	17	101	65	96	19	37	37
3Y	162	6	136	14	15	9	28	50
3Z	236	10	167	12	144	119	18	45
4	8	1	10	18	14	4	0	2
5	3	0	4	7	0	0	0	0

Table 18.--Percentages of Alaskan-origin sockeye salmon by area and period of release for which 10 or more tags were recovered in catch and escapement sampling, 1982 and 1983.

Release area	June		Early to mid-July		Mid- to end July		August	
	1982	1983	1982	1983	1982	1983	1982	1983
Alaska								
Noyes Island	15	17	22	18	3	4	5	4
Dall Island	23	7	-	-	-	4	0	0
Sumner Strait		43	-	51	-	52	-	40
Upper Clarence Strait	-	68	44	51	12	35	27	27
Union Bay		-	-	-	26	-	-	-
Middle Clarence Strait	-	-	70	-	-	-	-	-
Lower Clarence Strait	55	-	28	-	-	3	-	2
Revillagigedo Channel	28	-	64	30	15	-	-	-
Tree Point	10	18	9	15	14	10	58	0
Canada								
Dixon Entrance	-	-	18	-	-	-	-	-
Langara Island	7	15	10	4	3	1	-	0
3x	10	2	5	1	2	0	0	0
3Y	4	3	5	3	2	1	6	0
3Z	6	1	1	1	3	1	-	0
4	0	-	4	1	3	1	0	-
5	-	-	-	0	-	-	0	-

Table 19.--Estimated season stock compositions based on catch-weighted averages" of half-month percentage of sockeye salmon in northern boundary fisheries bound for the other country, 1982 and 1983.

Fishery	Percentage from other country	
	1982	1983
Alaska		
Noyes Island	86.1 (2.4)	93.7 (1.0)
Dall Island	ne[c]	97.0 (1.1)
Lower Clarence Strait	ne	97.3 (0.9)
Middle Clarence Strait	nc[d]	nt
Upper Clarence Strait	63.9 (2.2)	62.0 (2.4)
Sumner Strait	nt[e]	51.1 (3.3)
Union Bay	ne	nt
Revillagigedo Channel	67.2 (3.1)	ne
Tree Point	84.1 (1.6)	91.7 (1.5)
Canada		
Langara Island	5.2 (0.6)	1.8 (0.5)
3X	3.0 (0.3)	0.3 (0.1)
3Y	3.9 (0.5)	0.7 (0.1)
3Z	3.3 (1.0)	0.5 (0.1)
4	2.7 (0.5)	ne
5	ne	ne

*Catch-weighted averages were computed for a fishing area provided that the reasonably reliable half-month estimates of stock composition (those of release periods for which at least 10 tagged fish were recovered) covered at least 75% of the season catch in the area.

[b]Standard errors in parentheses account for chance variation of recoveries from subsampling catches and escapements but not for errors in escapement estimates of either Alaska or Canada.

[c]ne - Less than 75% of the season catch occurred during the periods for which stock-composition estimates were reasonably reliable.

[d]nc = No catches were made in this area.

[e]nt - No tagging occurred this year in this area.

Table 20.--Effects of different estimates of Alaskan escapements and Canadian secondary-tagging mortality on estimated season percentages of Canadian sockeye salmon in Alaskan fisheries, 1982 and 1983.

1982

Alaskan escapement (1,000s)	Canadian tagging mortality	Canadian percentage in fishery			
		Noyes Island	Upper Clarence Strait	Revilla-gigedo Channel	Tree Point
354	0%	86	64	67	84
477	0%	84	61	62	81
477	40%	80	57	57	76
254	0%	88	67	72	87
254	40%	84	64	68	83
Range		8	10	15	11

1983

Alaskan escapement (1,000s)	Canadian tagging mortality	Canadian percentage in fishery					
		Noyes Island	Dall Island	Clarence Strait Lower	Clarence Strait Upper	Sumner Strait	Tree Point
324	0%	94	97	97	62	51	92
458	0%	92	92	96	54	42	89
458	40%	90	90	95	52	36	86
216	0%	96	98	98	71	61	94
216	40%	94	95	98	69	55	92
Range		6	8	3	19	25	8

Table 21. --Effects of different estimates of Alaskan escapements and Canadian secondary-tagging mortality on estimated season percentages of Alaskan sockeye salmon in Canadian fisheries, 1982 and 1983. Dash means no estimate could be made.

Alaskan escapement (1,000s)	Canadian tagging mortality	Alaskan percentage in fishery				
		Langara Island	3X	3Y	3Z	4
		1982				
354	0%	5	3	4	3	3
477	0%	6	4	5	4	3
477	40%	10	7	8	7	7
254	0%	4	2	3	3	2
254	40%	7	4	6	5	4
Range		6	5	5	4	5
		1983				
324	0%	2	0	1	1	-
458	0%	2	0	1	1	
458	40%	4	1	2	1	
216	0%	1	0	0	0	-
216	40%	2	0	1	1	-
Range		3	1	2	1	-

Table 22. --Number of tagged pink salmon released in southern Southeast Alaska and northern. British Columbia, 1982, 1984, and 1985.

Release Location	1982	1984	1985
Alaska			
Noyes Island	17,200	5,464	17,968
Dal1 Island	5,795	9,652	10,298
Cordova Bay	5,606	0	4,012
Lower Clarence Strait	12,713	6,375	7,573
Middle Clarence Strait	15,499	0	5,970
Union Bay	1,310	0	3,349
Upper Clarence Strait	6,960	0	7,152*
Revillagigedo Channel	11,321	2,937	7,458
Tree Point	7,083	6,074	5,031
Alaska total	83,487	30,502	68,811
Canada			
Langara Island	3,465	0	5,603
Dixon Entrance	12,487	17,293	9,250
Dundas Island (area 3X)	12,749	12,195	8,439
Tracy/Boston (area 3Y)	17,624	6,490	7,241
Portland Inlet (area 3Z)	4,924	6,003	7,481
Stephens/Percher (area 4)	7,132	4,534	5,680
Area 5	9,473	5,116	7,005
Area 6	0	0	6,102
Canada total	67,854	51,631	56,801
Totals	151,341	82,133	125,612

*Composed of 6,108 releases from Upper Clarence Strait and 1,044 from Sumner Strait.

Table 23.--Estimates of total* tagged pink salmon caught in Alaskan and Canadian fisheries by general area and period of release in 1982.

Release location	Release period: 1 June-15 July		16-31 July		1-15 August		16 Aug-1 Sept	
	Alaska	Canada	Alaska	Canada	Alaska	Canada	Alaska	Canada
Alaska								
Noyes Island	37	40	299	45	1,238	51	1,706	191
Dall Island	56	4	0	0	740	87	509	7
Cordova Bay	0	0	0	0	884	2	737	18
Lower Clarence Strait	333	24	0	0	1,263	36	694	6
Middle Clarence Strait	256	6	392	27	3,017	17	395	5
Union Bay	0	0	65	2	15	2	0	0
Upper Clarence Strait	25	2	229	8	268	185	5	2
Revillagigedo Channel	1,312	110	782	99	103	51	633	31
Tree Point	552	12	166	181	216	325	309	109
Alaska total	2,571	198	1,933	362	7,744	756	4,988	369
Canada								
Langara Island	579	220	136	106	158	3	0	0
Dixon Entrance	300	17	1,706	59	1,388	209	398	18
3x	262	167	216	648	439	816	113	559
3Y	49	123	112	232	256	577	620	1,465
3Z	15	44	10	337	14	11	31	0
4	44	10	235	849	25	797	0	0
5	0	0	0	22	171	654	0	73
Canada total	1,249	581	2,415	2,253	2,451	3,067	1,162	2,115
Totals	3,820	779	4,348	2,615	10,195	3,823	6,150	2,484

*Numbers of actual tag recoveries expanded for subsampling of catches.

Table 24.--Estimates of total tagged pink salmon caught in Alaskan and Canadian fisheries by general area and period of release in 1984.

Release location	Release period: 1 June-15 July		16-31 July		1-15 August		16 Aug- Sept	
	Alaska	Canada	Alaska	Canada	Alaska	Canada	Alaska	Canada
Alaska								
Noyes Island	171	77	262	124	217	5	679	0
Dal1 Island	350	91	274	155	1,437	198	735	10
Lower Clarence Strait	4	0	187	27	1,148	28	103	0
Revillagigedo Channel	98	44	90	12	151	3	356	3
Tree Point	82	141	320	541	505	710	46	38
Alaska total	705	353	1,133	859	3,458	944	1,919	51
Canada								
Dixon Entrance[b]								
l-10	0	0	350	209	260	80	0	0
l-11,-12	262	92	390	148	1,265	44	318	10
l-13,-14,-15	0	0	53	18	75	22	0	0
l-16,-17,-18	5	24	27	57	186	240	38	30
3x	34	212	179	761	514	1,609	97	846
3Y	4	320	37	543	80	631	35	207
3Z	7	1 6 5	13	591	66	710	26	252
4	13	48	67	485	159	504	0	46
5	35	141	29	450	8	570	17	184
Canada total	360	1,002	1,145	3,262	2,613	4,410	531	1,575
Totals	1,065	1,355	2,278	4,121	6,071	5,354	2,450	1,626

'Numbers of actual tag recoveries expanded for subsampling of catches.

[b]See Figure 5 for reference.

Table 25.--Estimates of total* tagged pink salmon caught in Alaskan and Canadian fisheries by general area and period of release in 1985.

Release location	Release period: 1 June-15 July		16-31 July		1-15 August		16 Aug-1 Sept	
	Alaska	Canada	Alaska	Canada	Alaska	Canada	Alaska	Canada
Alaska								
Noyes Island	434	47	1,312	144	2,426	39	298	0
Dall Island	245	56	663	165	1,196	74	744	5
Cordova Bay	0	0	0	0	896	5	34	0
Lower Clarence Strait	50	4	211	4	989	54	129	0
Middle Clarence Strait	31	0	42	1	342	0	654	0
Union Bay	16	0	55	0	388	2	3	0
Upper Clarence Strait	0	0	54	0	241	0	198	0
Revillagigedo Channel	265	5	354	81	310	82	1,202	0
Tree Point	9	34	169	528	55	602	34	17
Alaska total	1,050	146	2,860	923	6,843	858	3,296	22
Canada								
Langara Island	125	191	89	289	132	259	0	0
Dixon Entrance	81	66	386	338	253	433	53	15
3x	0	4	3	392	130	898	153	39
3Y	9	66	9	49	68	653	28	57
3Z	6	25	7	346	22	663	6	27
4	3	5	0	422	16	594	0	2
5	0	16	31	726	16	575	4	0
6	6	38	0	236	0	571	0	148
Canada total	230	411	525	2,798	637	4,646	244	288
Totals	1,280	557	3,385	3,721	7,480	5,504	3,540	310

*Numbers of actual tag recoveries expanded for subsampling of catches.

Table 26.--Southeast Alaska pink salmon escapement estimates and numbers of carcasses examined for tags by ADF&G statistical areas, 1982, 1984, and 1985.

Statistical areas	Escapement[b] (1.000s) Low	Best	High	Number examined
		1982		
101	2,851	3,634	5,050	256,386[a]
102	925	1,198	1,700	138,418[a]
103	2,795	3,584	5,018	95,331
104-108	1,607	2,057	13,117	89,877
Totals	8,178	10,473	24,885	580,012
		1984		
101	3,568	5,352	6,422	323,044
102	892	1,338	1,606	73,884
103-104	3,270	4,905	5,886	53,341
105-108	1,220	1,830	2,196	76,668
Totals	8,950	13,425	16,110	526,937
		1985		
101	3,692	5,538	5,833	285,570
102	1,118	1,677	1,766	40,109
103-104	4,559	6,839	7,203	319,834
105-108	2,815	4,224	4,448	332,357
Totals	12,184	18,278	19,250	977,870

[a]Sample sizes were obtained from Gazey et al. (1983).

[b]Escapement estimates were obtained from Appendix 13 of Hoffman et al. (1984) and M. Seibel, National Marine Fisheries Service, Alaska, (at ADF&G), P.O. Box 25526, Juneau, AK 99802-5526.

Table 27.--British Columbia pink salmon escapement estimates and numbers of carcasses examined for tags by fishing area, 1984 and 1985.

Fishing area	Escapement (1,000s) Low[B]	Best	High	Number examined
		1984		
1[b]	896	1,086	1,277	724,000
2	192	250	300	56,267
3[c]	256	330	450	32,528
5	160	200	300	5,050
Totals	1,504	1,886	2,327	817,845
		1985		
3[c]	150	225	270	17,754
5	175	263	315	24,749
6	1,062	1,593	1,912	106,578
7	329	494	592	39,464
8	2,300	2,500	2,700	284,405
Totals	4,016	5,075	5,789	472,950

*Low estimates were unexpanded foot-survey counts.

[b]The Yakoun River was the stock examined for tags; a weir missed an unknown portion of total escapement to the river during flooding.

[c]Kwinamass River was omitted from escapement estimates because estimates of primary-tag recoveries were obtained by secondary tagging.

Source: K. English and J. Taylor, LGL Limited, Environmental Research Associates, 9768 Second St., Sidney, B.C., VBL-4P8, Canada, pers. commun.

Table 28. --Numbers of pink salmon tagged in major Canadian rivers (adjusted for straying), numbers recovered in the rivers, and the recovery rate (%) by tagging year.

River system	Number tagged	Number recovered	Recovery rate (%)
		1982	
Skeena	2,262	119	5.3
Kwinamass	1,345	83	6.2
Khutzeymateen	131	5	3.8
		1984	
Skeena	2,815	69	2.5
Kwinamass	1,477	196	13.3
		1985	
Skeena	4,842	127	2.6
Kwinamass	3,288	453	13.8

Table 29.--Estimates of total numbers of tagged pink salmon escaping to Alaskan and Canadian spawning systems by general area and period of release, 1982.

Release location	Release period: 1 June-15 July		16-31 July		1-15 August		16 Aug-1 Sept	
	Alaska	Canada	Alaska	Canada	Alaska	Canada	Alaska	Canada
Alaska								
Noyes Island	0	0	114	0	223	16	1,739	130
Dall Island	23	0	0	0	446	57	357	0
Cordova Bay	0	0	0	0	234	19	553	0
Lower Clarence Strait	321	0	0	0	1,893	38	2,246	0
Middle Clarence Strait	512	0	770	19	1,872	0	1,986	0
Union Bay	24	0	62	0	276	0	0	0
Upper Clarence Strait	143	0	395	19	1,347	23	95	0
Revillagigedo Channel	747	19	650	17	14	17	264	0
Tree Point	23	0	236	67	57	68	193	35
Alaska total	1,793	19	2,227	122	6,362	238	7,433	165
Canada								
Langara Island	111	35	32	16	0	0	0	0
Dixon Entrance	234	0	594	54	398	147	195	19
3x	183	19	207	398	83	466	74	38
3Y	37	33	99	375	179	342	499	785
3Z	0	38	354	703	14	49	32	0
4	23	0	273	145	71	1,616	0	0
5	0	0	14	0	51	588	0	247
Canada total	588	125	1,573	1,691	796	3,208	800	1,089
Totals -	2,381	144	3,800	1,813	7,158	3,446	8,233	1,254

Table 30. --Estimates of total numbers of tagged pink salmon escaping to Alaskan and Canadian spawning systems by general area and period of release, 1984.

Release location	Release period: 1 June-15 July		16-31 July		1-15 August		16 Aug-1 Sept	
	Alaska	Canada	Alaska	Canada	Alaska	Canada	Alaska	Canada
Alaska								
Noyes Island	139	0	398	41	415	0	211	0
Dal1 Island	343	0	377	78	1,381	140	509	91
Lower Clarence Strait	24	0	106	10	1,081	18	120	0
Revillagigedo Channel	412	0	198	0	115	0	82	0
Tree Point	132	0	362	8	199	353	0	61
Alaska total	1,050	0	1,441	137	3,191	511	922	152
Canada								
Dixon Entrance*								
l-10	0	0	186	23	109	92	0	0
l-ll,-12	154	41	341	103	355	44	24	41
l-13,-14,-15	0	0	33	0	0	85	0	0
l-16,-17,-18	16	0	33	0	49	277	0	43
3x	115	41	249	159	115	1,594	0	2,003
3Y	165	23	165	127	395	227	16	401
3Z	82	8	296	195	216	563	16	173
4	0	41	16	214	33	779	0	10
5	33	10	33	334	0	326	0	0
Canada total	565	164	1,352	1,155	1,272	3,987	56	2,671
Totals	1,615	164	2,793	1,292	4,463	4,498	978	2,823

*See Figure 5 for reference.

Table 31.--Estimates of total numbers of tagged pink salmon escaping to Alaskan and Canadian spawning systems by general area and period of release, 1985.

Release location	Release period							
	1 June-15 July		16-31 July		1-15 August		16 Aug-1 Sept	
	Alaska	Canada	Alaska	Canada	Alaska	Canada	Alaska	Canada
Alaska								
Noyes Island	679	39	3,116	46	1,365	116	320	39
Dall Island	735	13	1,480	15	1,250	0	172	92
Cordova Bay	0	0	0	0	1,570	0	41	0
Lower Clarence Strait	361	0	1,099	0	1,830	92	189	0
Middle Clarence Strait	500	0	422	0	660	0	371	7
Union Bay	398	0	415	0	750	0	0	0
Upper Clarence Strait	0	0	1,350	0	1,026	0	254	0
Revillagigedo Channel	362	0	1,149	7	310	0	233	77
Tree Point	310	7	698	44	407	120	110	104
Alaska total	3,345	59	9,729	112	9,168	328	1,690	319
Canada								
Langara Island	245	150	19	262	181	272	0	0
Dixon Entrance	103	15	974	78	161	551	0	30
3x	19	0	175	218	187	1,524	58	1,774
3Y	116	15	78	7	1,920	649	175	663
32	78	0	756	143	1,454	1,250	116	563
4	19	0	0	349	52	1,748	0	1,088
5	19	0	97	1,033	39	1,176	0	1,075
6	0	75	0	389	19	533	0	833
Canada total	599	255	2,099	2,479	4,013	7,703	349	6,026
Totals	3,944	314	11,828	2,591	13,181	8,031	2,039	6,345

Table 32.--Number of tagged pink salmon released, total number estimated as caught or escaping, percentage of estimated total recoveries from catch and escapement, and estimated recovery rate (%) in catch or escapement, by release fishery, 1982.

Release fishery	Number released	Total recoveries	Percentage of recoveries Catch	Percentage of recoveries Escapement	Estimated recovery rate (%)
Alaska					
Noyes Island	17,200	5,683	63	37	33
Dall Island	5,795	2,229	63	37	38
Cordova Bay	5,606	2,428	68	32	43
Lower Clarence Strait	12,713	6,882	35	65	54
Middle Clarence Strait	15,499	9,255	44	56	60
Union Bay	1,310	446	19	81	34
Upper Clarence Strait	6,960	2,704	27	73	39
Revillagigedo Channel	11,321	4,796	65	35	42
Tree Point	7,083	2,379	79	21	34
Alaska total	83,487	35,117	49	51	42
Canada					
Langara Island	3,465	1,396	86	14	40
Dixon Entrance	12,487	5,736	71	29	46
3x	12,749	2,827	48	52	22
3Y	17,624	5,783	59	41	33
3Z	4,924	1,652	28	72	34
4	7,132	4,088	48	52	57
5	9,473	1,820	51	49	19
Canada total	67,854	23,302	58	42	34
Totals	151,341	58,419	53	47	39

Table 33.--Number of tagged pink salmon released, total number estimated as caught or escaping, percentage of estimated total recoveries from catch and escapement, and estimated recovery rate (%) in catch or escapement, by release fishery, 1984.

Release fishery	Number released	Total recoveries	Percentage of recoveries		Estimated recovery rate (%)
			Catch	Escapement	
Alaska					
Noyes Island	5,464	2,739	56	44	50
Dal1 Island	9,652	6,169	53	47	64
Lower Clarence Strait	6,375	2,856	52	48	45
Revillagigedo Channel	2,937	1,564	48	52	53
Tree Point	6,074	3,498	68	32	58
Alaska total	30,502	16,826	56	44	55
Canada					
Dixon Entrance	17,293	6,252	67	33	36
3x	12,195	8,528	50	50	70
3Y	6,490	3,376	55	45	52
3Z	6,003	3,379	54	46	56
4	4,534	2,415	55	45	53
5	5,116	2,170	66	34	42
Canada total	51,631	26,120	57	43	51
Totals	82,133	42,946	57	43	52

Table 34.--Number of tagged pink salmon released, total number estimated as caught or escaping, percentage of estimated total recoveries from catch and escapement, and estimated recovery rate (%) in catch or escapement, by release fishery, 1985.

Release fishery	Number released	Total recoveries	Percentage of recoveries Catch	Escapement	Estimated recovery rate (%)
Alaska					
Noyes Island	17,968	10,420	45	55	58
Dal1 Island	10,298	6,905	46	54	67
Cordova Bay	4,012	2,546	37	63	63
Lower Clarence Strait	7,573	5,012	29	71	66
Middle Clarence Strait	5,970	3,030	35	65	51
Union Bay	3,349	2,027	23	77	61
Upper Clarence Strait	7,152	3,123	16	84	44
Revillagigedo Channel	7,458	4,437	52	48	60
Tree Point	5,031	3,248	45	55	65
Alaska total	68,811	40,748	39	61	59
Canada					
Langara Island	5,603	2,214	49	51	40
Dixon Entrance	9,250	3,537	46	54	38
3x	8,439	5,574	29	71	66
3Y	7,241	4,562	21	79	63
3Z	7,481	5,462	20	80	73
4	5,680	4,298	24	76	76
5	7,005	4,807	28	72	69
6	6,102	2,848	35	65	47
Canada total	56,801	33,302	29	71	59
Totals	125,612	74,050	35	65	59

Table 35.--1982 stock-composition estimates (%) of pink salmon by release area and period, totals for Alaska and Canada (%), and estimated numbers of tagged fish in Alaskan and Canadian escapements (%). Best estimates of escapements were used, and recovery rate of primary-tagged entrants in Canada was assumed equal to that of secondary-tagged fish. Dash indicates no recovery in escapement samples.

Release area[a]	Alaska stocks 101	102	103	other	Canada stocks 3	Skeena	Total AK	Can.	Escapement recoveries AK	Can.
				Release period 1: 1 June-15 July						
Noyee[b]	4	0	0	77	19	0	81	19		
Dal1	96	0	0	0	4	0	96	4	100	0
Lclar	91	0	0	6	3	0	97	3	100	0
Mclar	73	0	0	26	1	0	99	1	100	0
Uclar	50	0	0	49	1	0	99	1	100	0
Tree	92	0	0	0	7	0	93	7	100	0
Revla	90	0	0	3	7	0	93	7	94	6
Union[b]	50	0	0	50	0	0	100	0	100	0
Dixon	97	0	0	0	3	0	97	3	100	0
Lang	86	0	0	0	14	0	85	15	76	24
3x	86	1	0	0	13	0	87	13	91	9
	48	0	0	0	52	0	48	52	30	70
	4	0	0	41	56	0	44	56	0	100
4	5	0	0	88	7	0	93	7	100	0
				Release period 2: 16-31 July						
Noyes	81	3	0	0	14	2	84	16	100	0
Mclar	72	1	0	21	3	3	94	6	98	2
Uclar	55	6	0	30	6	4	91	9	95	5
Tree	64	2	0	0	30	3	66	34	72	28
Revla	82	0	0	0	16	1	83	17	90	10
Union[b]	56	1	0	28	13	1	85	15	100	0
Dixon	64	5	2	14	12	3	84	16	92	8
Lang	65	4	0	0	26	5	69	31	66	34
3x	49	1	0	0	34	16	49	51	33	67
3Y	22	1	0	10	57	10	33	67	19	81
3Z	28	0	0	4	66	2	33	67	29	71
4	53	3	0	8	21	14	64	36	65	35
5[b]	55	0	0	6	32	6	62	38	100	0

Table 35. --Continued.

Release area'	Alaska stocks 101	102	103	other	Canada stocks 3	Skeena	Total AK	Can.	Escapement recoveries AK	Can.
Release period 3: 1-15 August										
Noyes	24	13	18	21	17	6	77	23	93	7
Dal1	33	12	15	14	18	9	73	27	89	11
Lclar	40	29	9	14	5	3	91	9	98	2
Mclar	50	23	5	17	3	2	94	6	100	0
Uclar	60	14	1	20	3	2	95	5	99	1
Cordv	6	23	28	35	4	4	91	9	92	8
Tree	30	2	1	4	52	12	36	64	46	54
Revla	29	4	1	8	51	7	42	58	45	55
Union	91	0	0	8	0	0	100	0	100	0
Dixon	41	15	5	7	17	15	67	33	73	27
Lang	12	18	21	28	16	6	78	22	-	
3x	24	3	0	0	38	36	26	74	15	85
3Y	29	1	0	0	54	15	30	70	30	70
32	24	1	0	2	71	3	27	73	23	77
4	7	0	0	1	11	80	8	92	4	96
5	12	2	1	4	25	56	19	81	8	92
Release period 4: 16 August-l September										
Noyes	33	21	36	4	1	5	94	6	93	7
Dal1	59	11	29	0	1	2	98	2	100	0
Lclar	32	60	1	8	0	0	99	1	100	0
Mclar	59	23	0	18	0	0	100	0	100	0
Uclar	30	45	0	24	0	0	100	0	100	0
Cordv	30	36	28	5	0	1	98	2	100	0
Tree	83	5	0	0	5	7	87	13	84	16
Revla	90	5	0	1	1	2	96	4	100	0
Dixon	61	29	4	0	1	5	94	6	91	9
3x	61	11	0	2	7	19	74	26	66	34
3Y	51	11	1	0	18	19	63	37	38	62
3Z[b]	28	56	0	15	0	0	100	0	100	0
5	6	2	0	1	1	90	9	91	0	100

'Noyes - Noyes Island; Dal1 = Dal1 Island; Lclar - Lower Clarence Strait; Mclar = Middle Clarence Strait; Uclar - Upper Clarence Strait; Cordv - Cordova Bay; Tree = Tree Point; Revla - Revillagigedo Channel; Union - Union Bay; Dixon = Dixon Entrance; and Lang - Langara Island.

[b]Fewer than 10 tagged fish were recovered in catches and escapements from releases of tagged fish, and the estimates of stock composition should be considered in light of this limited basis.

Table 36.--1984 stock-composition estimates (%) of pink salmon by release area and period, totals for Alaska and Canada (%), and estimated numbers of tagged fish in Alaskan and Canadian escapements (%). Best estimates of escapements were used, and recovery rates of-primary-tagged entrants to the Skeena and Kwinamass Rivers were assumed equal to that of secondary-tagged fish. Dash indicates no recovery in escapement samples.

Release area[a]	Alaska stocks 101	102	103&4	other	Canada stocks 1	3	Skeena	5-6	Total AK	Total Can.	Esc. recov. AK	Esc. recov. Can.
Release period 1: 1 June-15 July												
Noyes	78	0	0	19	0	2	1	0	97	3	100	0
Dal1	66	0	0	32	0	1	1	0	98	2	100	0
Tree	92	0	0	3	0	3	2	0	95	5	100	0
Revla	98	0	0	1	0	1	0	0	99	1	100	0
Lclar[b]	14	0	0	85	0	0	0	0	100	0	100	0
1B	53	0	0	36	0	1	10	0	88	12	79	21
1D	80	0	0	5	0	4	11	0	86	14	100	0
3X	83	0	0	0	0	4	12	0	84	16	74	26
3Y	89	0	0	0	0	9	1	0	89	11	88	12
3Z	90	0	0	0	0	8	2	0	91	10	92	8
4	54	0	0	0	0	4	42	0	54	46	0	100
5	84	0	0	2	0	9	4	0	86	14	76	24
Release period 2: 16-31 July												
Noyes	51	3	25	7	0	4	9	0	86	14	91	9
Dall	47	7	23	4	0	9	9	0	82	18	83	17
Tree	80	0	0	0	0	11	9	0	80	20	98	2
Revla	95	0	0	1	0	2	2	0	97	3	100	0
Lclar	78	0	1	10	0	7	3	0	89	11	91	9
1A	70	8	1	2	0	10	9	0	81	19	89	11
1B	58	15	0	7	0	7	9	4	80	20	77	23
1C	88	0	0	2	0	5	5	0	90	10	100	0
1D	74	0	0	0	0	8	17	0	74	26	100	0
3x	60	2	0	0	0	14	20	3	62	38	61	39
3Y	60	0	0	0	0	24	16	0	60	40	57	43
3Z	60	0	0	0	0	22	17	0	60	40	60	40
4	42	0	0	0	0	12	45	0	42	58	7	93
5	29	0	0	0	0	8	63	0	29	71	9	91

Table 36. --Continued.

Release area[a]	Alaska stocks 101	102	103&4	other	Canada stocks 1	3	Skeena	5-6	Total AK	Can.	Esc. recov. AK	Can.
Release period 3: 1-15 August												
Noyes	5	12	22	60	0	1	1	0	99	1	100	0
Dall	23	20	41	6	0	3	7	0	89	11	91	9
Tree	45	5	1	0	0	21	28	0	51	49	36	64
Revla	89	8	1	0	0	1	1	0	98	2	100	0
Lclar	30	58	8	1	0	2	1	0	97	3	98	2
1A	35	26	4	6	0	8	20	0	71	29	54	46
1B	40	37	12	3	0	2	5	0	92	8	89	11
1C	24	14	3	1	2	3	53	0	42	58	0	100
1D	23	11	2	1	7	9	47	0	36	64	15	85
3X	26	2	0	0	0	16	52	3	28	72	7	93
3Y	51	2	0	0	0	35	12	0	53	47	64	36
3Z	30	3	0	0	0	43	24	0	33	67	28	72
4	18	2	0	0	0	6	73	0	20	80	4	96
5	10	1	0	0	0	6	82	0	11	89	0	100
Release period 4: 16 August-1 September												
Noyes	1	5	43	49	0	0	1	1	98	2	100	0
Dall	6	18	47	19	0	2	5	4	90	10	85	15
Tree	6	15	1	10	0	28	40	0	32	68	0	100
Revla	62	8	0	6	0	10	14	0	76	24	100	0
Lclar	0	57	3	40	0	0	0	0	100	0	100	0
1B	3	38	3	36	0	2	17	0	81	19	37	63
1D	7	15	3	12	2	9	52	0	37	63	0	100
3X	3	1	0	1	0	53	41	0	5	95	0	100
3Y	7	2	0	1	0	59	31	0	10	90	4	96
3Z	10	2	0	2	0	49	38	0	14	86	9	91
4	12	6	1	5	0	52	25	0	23	77	0	100
5	31	5	0	4	0	37	22	0	40	60	-	-

[a]Noyes = Noyes Island; Dall = Dall Island; Tree = Tree Point; Revla = Revillagigedo Channel; Lclar = Lower Clarence Strait; 1A = 1-10; 1B = 1-11, 1-12; 1C = 1-13, 1-14, 1-15; 1D = 1-16, 1-17, 1-18.

[b]Fewer than 10 tagged fish were recovered in catches and escapements from releases of tagged fish, and the estimates of stock composition should be considered in light of this limited basis.

Table 37.--1985 stock-composition estimates (%) of pink salmon by release area and period, totals for Alaska and Canada (%), and estimated numbers of tagged fish in Alaskan and Canadian escapements (%). Best estimates of escapements were used, and recovery rates of primary-tagged entrants to the Skeena and Kwinamass Rivers were assumed equal to that of secondary-tagged fish.

Release area[a]	Alaska stocks 101	102	103&4	other	Canada stocks 3	Skeena	5-14	Total AK	Can.	Esc. recov. AK	Can.
Release period 1: 1 June-15 July											
Noyes	62	1	5	27	0	5	0	95	5	95	5
Dal1	85	1	0	12	0	0	2	98	2	98	2
Tree	98	0	0	0	2	0	0	98	2	98	2
Revla	95	0	0	4	0	0	0	100	0	100	0
Lclar	72	21	0	7	0	0	0	100	0	100	0
Mclar	48	0	0	52	0	0	0	100	0	100	0
Union	60	0	0	40	0	0	0	100	0	100	0
101-4	59	4	0	18	0	0	18	81	19	46	54
101-7	91	2	0	1	0	0	5	95	5	100	0
Lang	62	1	0	9	0	12	16	72	28	62	38
3X	100	0	0	0	0	0	0	100	0	100	0
	91	0	0	0	8	0	0	92	8	89	11
	99	0	0	0	1	0	0	99	1	100	0
4	100	0	0	0	0	0	0	100	0	100	0
5[b]	99	0	0	0	1	0	0	99	1	100	0
6	33	0	0	0	0	0	67	33	67	0	100
Release period 2: 16-31 July											
Noyes	42	1	21	33	1	2	0	97	3	99	1
Dal1	65	8	12	11	1	1	1	96	4	99	1
Tree	89	0	0	0	9	1	0	90	11	94	6
Revla	93	3	2	0	2	0	0	98	2	99	1
Lclar	60	22	9	9	0	0	0	100	0	100	0
Mclar	38	0	0	62	0	0	0	100	0	100	0
Uclar	15	0	0	85	0	0	0	100	0	100	0
Union	25	0	0	74	0	0	0	100	0	100	0
101-4	74	9	7	6	1	1	1	97	3	100	0
101-7	43	0	1	9	7	26	14	54	46	46	54
Lang	20	1	1	1	2	15	60	23	77	7	93
3x	54	0	0	0	14	31	1	54	46	44	56
3Y	88	0	0	0	11	1	0	89	11	91	9
3Z	83	0	0	0	16	1	0	84	16	84	16
4	13	0	0	0	2	84	1	13	87	0	100
5	17	0	0	0	3	74	6	17	83	9	91
6	8	0	0	0	1	6	85	8	92	0	100

Table 37. --Continued.

Release area[a]	Alaska stocks 101	102	103&4	other	Canada stocks 3	Skeena	5-14	Total AK	Can.	Esc. recov. AK	Can.
Release period 3: 1-15 August											
Noyes	11	10	57	13	0	8	0	92	8	92	8
Dall	22	20	49	6	1	2	1	96	4	100	0
Cordv	4	11	81	2	0	1	0	98	2	100	0
Tree	66	1	0	0	21	11	1	67	33	77	23
Revla	86	4	0	0	6	3	0	90	10	100	0
Lclar	17	69	4	4	2	5	0	94	6	95	5
Mclar	12	28	5	54	0	0	0	99	1	100	0
Uclar	0	25	1	74	0	0	0	100	0	100	0
Union	40	13	1	45	0	0	0	100	0	100	0
101-4[b]	61	31	2	2	2	3	0	95	5	100	0
101-7	22	3	3	3	4	44	22	30	70	20	80
Lang	30	3	9	1	4	29	24	43	57	40	60
3X	18	1	0	1	5	62	14	19	81	11	89
3Y	70	0	0	0	20	9	1	71	29	75	25
3Z	53	0	0	0	34	11	1	54	46	54	46
4	6	0	0	1	2	88	3	7	93	3	97
5	6	0	0	0	1	84	8	7	93	3	97
6	5	0	0	0	1	3	91	5	95	4	96
Release period 4: 16 August-1 September											
Noyes	5	10	61	15	0	8	0	92	8	89	11
Dall	11	30	37	9	0	12	2	87	13	65	35
Cordv[b]	29	34	37	0	0	0	0	100	0	100	0
Tree	44	2	0	5	24	18	5	52	48	51	49
Revla	51	25	5	1	1	16	0	83	17	75	25
Lclar	0	89	11	0	0	0	0	100	0	100	0
Mclar	7	52	3	36	1	0	0	99	1	98	2
Uclar	1	16	1	81	0	0	0	100	0	100	0
101-7	12	30	4	0	0	16	38	46	54	0	100
3X	6	2	0	0	7	73	11	9	91	3	97
3Y	21	0	0	0	49	24	6	22	78	21	79
3Z	17	0	0	0	42	34	6	18	82	17	83
4	0	0	0	0	0	96	4	0	100	0	100
5	0	0	0	0	0	79	21	0	100	0	100
6	0	0	0	0	0	9	91	0	100	0	100

[a]Noyes = Noyes Island; Dall = Dall Island; Tree = Tree Point; Revla = Revillagigedo Channel; Lclar = Lower Clarence Strait; Mclar = Middle Clarence Strait; Uclar = Upper Clarence Strait; Union = Union Bay; Cordv = Cordova Bay; and Lang = Langara Island.

[b]Fewer than 10 tagged fish were recovered in catches and escapements from releases of tagged fish, and the estimates of stock composition should be considered in light of this limited basis.

Table 38.--Estimated percentage of Alaskan-origin* pink salmon (bootstrap standard error in parentheses) by fishery and period of release, 1982. Dash indicates no estimate could be made.

Release fishery	Late June to mid-July	Mid- to late July	Early to mid-August	Mid-Aug to early Sep
Alaska				
Noyes Island	81 (4.5)	84 (4.2)	77 (2.8)	94 (1.5)
Dall Island	96 (1.5)		73 (4.7)	98 (0.5)
Cordova Bay			91 (2.3)	98 (0.3)
Lower Clarence Strait	97 (1.3)		91 (1.7)	99 (0.1)
Middle Clarence Strait	99 (0.3)	94 (1.9)	94 (1.1)	100 (0.0)
Union Bay	100 (0.0)	85 (6.2)	100 (0.1)	·
Upper Clarence Strait	99 (0.6)	91 (4.2)	95 (1.3)	100 (0.3)
Revillagigedo Channel	93 (3.9)	83 (6.7)	42 (12.8)	96 (1.0)
Tree Point	93 (0.3)	66 (8.0)	36 (8.6)	87 (3.7)
Canada				
Dixon Entrance				
Overall	97 (1.3)	84 (3.6)	67 (3.4)	94 (3.0)
Langara Island	85 (2.6)	69 (6.2)	78 (3.9)	
3x	87 (3.8)	49 (4.9)	26 (6.4)	74 (6.7)
3Y	48 (13.9)	33 (6.0)	30 (7.3)	63 (4.0)
3Z	44 (16.1)	33 (6.1)	27 (19.1)	100 (0.0)
4	93 (3.8)	64 (6.6)	8 (2.3)	·
5		62 (19.0)	19 (4.4)	9 (3.1)

*Standard errors account for chance variation in numbers of recoveries from subsampling catches and escapements but not for errors in escapement estimates of Alaska or Canada.

Table 39.--Estimated percentage of Alaskan-origin' pink salmon (bootstrap standard error in parentheses) by fishery and period of release, 1984. Dash indicates no estimate could be made.

Release fishery	Late June to mid-July	Mid- to late July	Early to mid-August	Mid-Aug to early Sep
Alaska				
Noyes Island	97 (1.8)	86 (5.4)	99 (0.5)	98 (1.5)
Dal1 Island	98 (1.0)	82 (5.7)	89 (2.6)	90 (4.7)
Lower Clarence Strait	100 (0.6)	89 (4.0)	97 (1.0)	100 (0.2)
Revillagigedo Channel	99 (0.9)	97 (1.2)	98 (0.8)	76 (8.3)
Tree Point	95 (3.2)	80 (3.2)	51 (4.0)	32 (10.8)
Canada				
Dixon Entrance[b]				
l-10		81 (3.0)	71 (7.7)	
l-11,-12	88 (7.5)	80 (5.2)	92 (2.4)	81 (8.6)
l-16,-17,-18	86 (8.5)	74 (6.7)	36 (5.4)	37 (18.2)
3x	84 (8.5)	62 (5.3)	28 (3.1)	5 (1.0)
3Y	89 (5.6)	60 (7.4)	53 (4.4)	10 (3.4)
3Z	91 (8.3)	60 (7.7)	33 (5.2)	14 (6.0)
4	54 (23.0)	42 (9.0)	20 (3.4)	23 (5.6)
5	86 (6.3)	29 (7.4)	11 (3.5)	40 (4.6)

'Standard errors account for chance variation in numbers.of recoveries from subsampling catches and escapements but not for errors in escapement estimates of Alaska or Canada.

[b]See Figure 5 for reference.

Table 40. --Estimated percentage of Alaskan-origin' pink salmon (bootstrap standard error in parentheses) by fishery and period of release, 1985. Dash indicates no estimate could be made.

Release fishery	Late June to mid-July	Mid- to late July	Early to mid-August	Mid-Aug to early Sep
Alaska				
Noyes Island	95 (4.0)	97 (1.0)	92 (3.4)	92 (7.4)
Dal1 Island	98 (1.3)	96 (0.8)	96 (0.6)	87 (5.9)
Cordova Bay			98 (0.4)	100 (0.0)
Lower Clarence Strait	100 (0.0)	100 (0.0)	94 (2.0)	100 (0.0)
Middle Clarence Strait	100 (0.0)	100 (0.0)	99 (0.2)	99 (1.2)
Union Bay	100 (0.0)	100 (0.0)	100 (0.1)	·
Upper Clarence Strait	·	100 (0.0)	100 (0.0)	100 (0.2)
Revillagigedo Channel	100 (0.1)	98 (0.7)	90 (1.6)	83 (9.1)
Tree Point	98 (2.0)	90 (1.6)	67 (4.0)	52 (12.5)
Canada				
Dixon Entrance[b]				
101-4	81 (12.3)	97 (0.5)	95 (2.1)	·
101-7	95 (1.9)	54 (12.6)	30 (4.3)	46 (11.6)
Langara Island	72 (7.4)	23 (3.4)	43 (5.6)	·
3x	100 (0.3)	54 (6.8)	19 (2.5)	9 (2.2)
3Y	92 (6.3)	89 (6.9)	71 (3.0)	22 (6.2)
32	99 (5.9)	84 (4.0)	54 (3.6)	18 (6.1)
4	100 (0.3)	13 (4.5)	7 (1.6)	0 (0.0)
5	99 (1.4)	17 (3.3)	7 (1.8)	0 (0.1)
6	33 (14.6)	8 (1.2)	5 (3.4)	0 (0.0)

"Standard errors account for chance variation in numbers of recoveries from subsampling catches and escapements but not for errors in escapement estimates of Alaska or Canada.

[b]See Figure 6 for reference.

Table 41.--Numbers of tags recovered in escapements and catches of pink salmon by area and period of release in 1982.

Release area	Late June to mid-July		Mid- to late July		Early to mid-August		Mid-Aug to early Sept	
	Esc.	Catch	Esc.	Catch	Esc.	Catch	Esc.	Catch
Alaska								
Noyes Island	0	9	6	28	14	78	84	297
Dall Island	1	6	0	0	27	109	17	26
Cordova Bay	0	0	0	0	8	6	32	68
Upper Clarence Strait	12	3	29	10	86	68	8	3
Union Bay	2	0	5	4	13	9	0	0
Middle Clarence Strait	30	11	42	27	119	140	128	77
Lower Clarence Strait	15	18	0	0	135	126	204	97
Revillagigedo Channel	42	83	40	73	3	37	19	55
Tree Point	1	9	21	84	8	194	15	72
Canada								
Dixon Entrance	11	28	40	92	35	156	12	61
Langara Island	11	67	3	40	0	8	0	0
3x	13	58	41	186	33	449	8	271
3Y	7	26	41	81	39	261	81	540
3Z	8	10	95	95	4	7	4	5
4	1	7	26	171	94	235	0	0
5	0	0	1	6	43	225	13	25

Table 42. --Numbers of tags recovered in escapements and catches of pink salmon by area and period of release in 1984.

Release area	Late June to mid-July		Mid- to late July		Early to mid-August		Mid-Aug to early Sept	
	Esc.	Catch	Esc.	Catch	Esc.	Catch	Esc.	Catch
Alaska								
Noyes Island	8	71	15	130	15	77	6	118
Dall Island	19	118	19	142	40	494	11	173
Tree Point	8	68	23	286	31	400	3	20
Revillagigedo Channel	25	38	12	33	7	43	5	84
Lower Clarence Strait	1	1	7	66	59	365	6	28
Canada								
Dixon Entrance*								
l-10	0	0	14	185	9	115	0	0
l-11,-12	9	96	24	181	20	395	2	85
l-13,-14,-15	0	0	2	20	5	33	0	0
l-16,.-17,-18	1	10	2	27	37	158	3	16
3x	8	78	23	318	71	729	131	298
3Y	13	105	21	194	52	232	33	75
3Z	6	55	34	203	68	255	13	90
4	1	20	7	183	22	227	1	15
5	3	55	11	166	8	207	0	73

*See Figure 5 for reference.

Table 43.--Numbers of tags recovered in escapements and catches of pink salmon by area and period of release in 1985.

Release area	Late June to mid-July		Mid- to late July		Early to mid-August		Mid-Aug to early Sept	
	Esc.	Catch	Esc.	Catch	Esc.	Catch	Esc.	Catch
Alaska								
Noyes Island	42	106	190	355	72	459	18	51
Dall Island	42	96	78	241	59	286	11	141
Cordova Bay	0	0	0	0	72	156	2	7
Tree Point	17	21	42	339	31	327	14	19
Revillagigedo Channel	19	88	59	158	16	141	14	374
Lower Clarence Strait	17	17	52	63	58	268	5	30
Middle Clarence Strait	33	8	29	13	40	83	20	134
Upper Clarence Strait	0	0	101	15	67	56	20	44
Union Bay	25	5	30	17	46	100	0	1
Canada								
Dixon Entrance*								
101-4	2	20	40	98	1	7	0	0
101-7	1	13	6	31	31	244	2	22
101-N	0	0	2	19	0	0	0	0
101-5	0	0	0	5	0	0	0	0
101-6	4	11	2	17	0	7	0	0
101-8	0	0	2	7	0	0	0	0
101-g	0	5	2	77	0	0	0	0
101-10	0	0	0	0	0	0	0	1
Langara Island	21	114	20	142	22	163	0	0
3x	1	2	21	192	62	433	68	65
3Y	8	36	5	30	158	369	62	37
3Z	4	15	58	195	206	357	52	15
4	1	3	9	145	51	221	31	2
5	1	6	38	276	37	203	43	1
6	5	17	26	105	37	266	53	70

*See Figure 6 for reference.

Table 44. --Estimated percentages of Alaskan-origin pink salmon by fishery and period of release for which 10 or more tags were recovered in catch and escapement sampling in 1982, 1984, and 1985.

Release Area*	Late June to mid-July			Mid- to late July			Early to mid-August			Mid-Aug to early Sept		
	1982	1984	1985	1982	1984	1985	1982	1984	1985	1982	1984	1985
Alaska												
Noyes Island	-	97	95	84	86	97	77	99	92	94	98	92
Dall Island	-	98	98	-	82	96	73	89	96	98	90	87
Cordova Bay	-	-	-	-	-	-	91	-	98	98	-	-
Lclar	97	-	100	-	89	100	91	97	94	100	100	100
Mclar	99	-	100	94	-	100	94	-	99	100	-	99
Union Bay	-	-	100	-	-	100	100	-	100	-	-	-
Uclar	99	-	-	91	-	100	95	-	100	100	-	100
Revla	93	99	100	83	97	98	42	98	90	96	76	83
Tree	93	95	98	66	80	90	36	51	67	87	32	52
Canada												
Dixon Entrance												
Northwest	-	-	81	-	81	97	-	71	-	-	-	-
Northeast	-	88	-	-	80	-	-	92	-	-	81	-
South	-	86	95	-	74	54	-	36	30	-	37	46
Overall	97	-	-	84	-	-	67	-	-	94	-	-
Langara Is.	85	-	72	69	-	23	-	-	43	-	-	-
3X	87	84	-	49	62	54	26	28	19	74	5	9
3Y	48	89	92	33	60	89	30	53	71	63	10	22
3Z	44	91	99	33	60	84	27	33	54	-	14	18
4	-	54	-	64	42	13	8	20	7	-	23	0
5	-	86	-	-	29	17	19	11	7	9	40	0
6	-	-	33	-	-	8	-	-	5	-	-	0

*Lclar = Lower Clarence Strait; Mclar = Middle Clarence Strait; Uclar = Upper Clarence Strait; Revla = Revillagigedo Channel; and Tree = Tree Point.

Table 45.--Estimated season stock compositions based on catch-weighted averages of half-monthly percentages of pink salmon in northern boundary fisheries bound for the other country, 1982, 1984, and 1985.

Fishery	Percentage from other country 1982	1984	1985
Alaska			
Noyes Island	7.2 (1.4)	2.0 (1.0)	8.2 (4.0)
Dall Island	5.9 (0.7)	10.8 (2.6)	8.1 (2.5)
Cordova Bay	1.6 (0.3)	nt[c]	
Lower Clarence Strait	2.0 (0.3)	2.1 (0.5)	1.4 (0.4)
Middle Clarence Strait	nc[e]	nt	1.5 (1.2)
Union Bay		nt	
Upper Clarence Strait	3.9 (1.3)	nt	0.2 (0.1)
Revillagigedo Channel	8.3 (1.3)	6.2 (1.6)	12.1 (4.0)
Tree Point	22.2 (3.1)	42.5 (3.6)	33.4 (4.7)
Canada			
Dixon Entrance			
North[f]	ni[g]	ni	88.2 (6.8)
South[f]		ni	55.5 (4.2)
Langara Island	75.0 (3.2)	nt	36.8 (3.2)
3x	56.5 (4.0)	35.9 (2.6)	26.6 (2.3)
3Y	55.1 (3.3)	49.5 (4.1)	59.6 (2.6)
3Z		45.1 (4.4)	45.9 (2.9)
4	37.5 (3.2)	30.7 (4.4)	6.5 (1.1)
5	ne	28.8 (3.1)	6.4 (1.0)
6	nt	nt	2.3 (1.1)

'Catch-weighted averages were computed for a fishing area provided reasonably reliable half-month estimates of stock composition (those of release periods for which at least 10 tagged fish were recovered) covered at least 75% of the season catch in the area.

[b]Standard errors in parentheses account for chance variation in numbers of recoveries from subsampling catches and escapements but not for errors in escapement estimates of Alaskan or Canadian stocks.

[c]nt - No tagging occurred in this year and area.

[d]ne - Less than 75% of the season catch occurred during the periods for which stock-composition estimates were reasonably reliable.

[e]nc - No catch was made in this area.

[f]North includes 101-3, 101-4, 101-5, 101-8, and 101-9; South includes 101-6, 101-7, and 101-10. Proportions from tagging in 101-4 were used to represent North catches, and those from tagging in 101-7 were used for South catches.

[g]ni - Insufficient information on catches by time and area are currently available to compute an annual value.

Table 46.--Effects of different estimates of Alaskan and Canadian escapements" and Canadian secondary-tagging mortality on estimated percentages of Canadian pink salmon in Alaskan fisheries, 1982, 1984, and 1985.

Escapement (millions) AK	Escapement (millions) Can.	Canadian tagging mortality	Canadian percentage in fishery						
			1982						
			Noyes Island	Dall Island	Cordova Bay	Clarence Strait Low	Clarence Strait up	Revilla-gigedo Channel	Tree Point
10.5	na[b]	0%	7	6	2	2	4	8	22
24.9	na	0%	5	3	1	1	1	7	19
24.9	na	40%	3	2	1	1	1	5	13
8.2	na	0%	7	5	2	2	5	9	22
8.2	na	40%	5	4	1	2	3	7	16
Range			4	4	1	1	4	4	9

			1984				
			Noyes Island	Dal1 Island	Lower Clarence Strait	Revilla-gigedo Channel	Tree Point
13.4	1.9	0%	2	11	2	6	43
16.1	1.5	0%	2	9	2	6	40
9.0	2.3	0%	4	14	3	10	47
16.1	1.5	40%	1	7	1	5	34
Range			3	7	2	5	13

			1985						
			Noyes Island	Dal1 Island	Clarence Strait Low	Clarence Strait Mid	Clarence Strait Up	Revilla-gigedo Channel	Tree Point
18.3	5.1	0%	8	8	12		0	12	33
19.3	4.0	0%	8	7	1	1	0	11	31
12.2	5.8	0%	11	9	2	2	0	16	43
19.3	4.0	40%	5	5	1	1	1	8	24
Range			6	4	1	1	1	8	9

'Point estimates and bounds for total escapements appear in this table, but corresponding values for regional stock groups (Tables 26, 27) were used in the computations.

[b]na - data not available.

Table 47.--Effects of different estimates of Alaskan and Canadian escapements' and Canadian secondary-tagging mortality on estimated percentages of Alaskan pink salmon in Canadian fisheries, 1982, 1984, and 1985.

Escapement (millions) AK	Escapement (millions) Can.	Canadian tagging mortality	Alaskan percentage in fishery								
			1982								
			Langara Island	3X	3Y	4					
10.5	na[b]	0%	75	57	55	38					
24.9	na	0%	79	61	59	44					
24.9	na	40%	86	71	71	53					
8.2	na	0%	73	56	55	37					
8.2	na	40%	81	67	68	46					
Range			13	15	16	16					
			1984								
			3X	3Y	3Z	4	5				
13.4	1.9	0%	36	50	45	31	29				
16.1	1.5	0%	39	54	49	33	31				
9.0	2.3	0%	31	40	37	26	26				
16.1	1.5	40%	45	61	58	42	36				
Range			14	21	21	16	10				
			1985								
			Dixon Entrance North	Dixon Entrance South	Langara Island	3X	3Y	3Z	4	5	6
18.3	5.1	0%	88	56	37	27	60	46	7	6	2
19.3	4.0	0%	91	58	41	28	62	48	7	7	4
12.2	5.8	0%	85	51	30	22	51	37	6	5	2
19.3	4.0	40%	92	64	46	37	68	57	11	11	4
Range			7	13	16	15	17	20	5	6	2

'Point estimates and bounds for total escapements appear in this table, but corresponding values for regional stock groups (Tables 26, 27) were used in the computations.

[b]na - data not available.

FIGURES

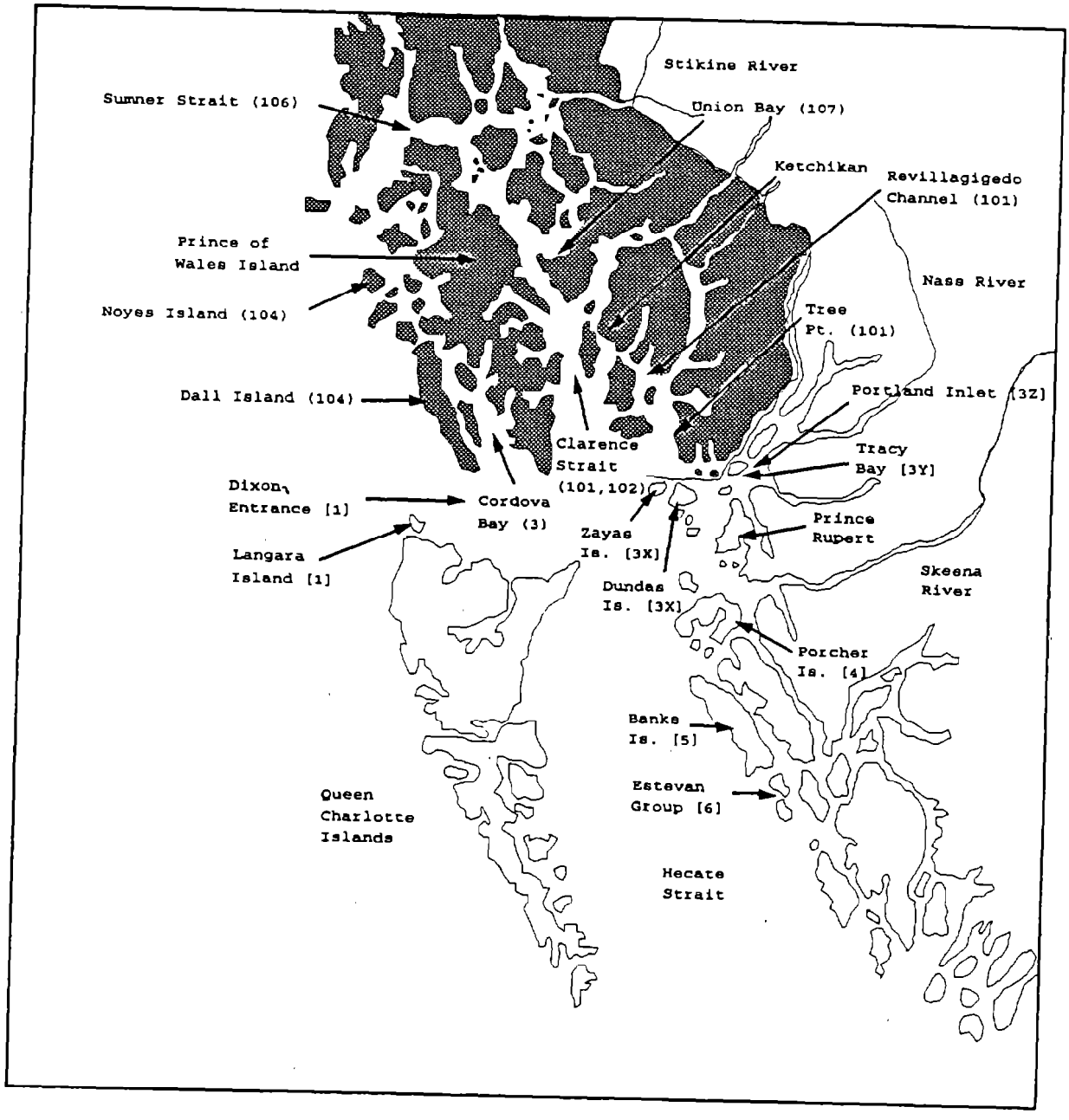

Figure l.--International boundary area of southern Southeast Alaska and northern British Columbia, place names and associated area codes to help identify where returning adult salmon were tagged, 1982-85.

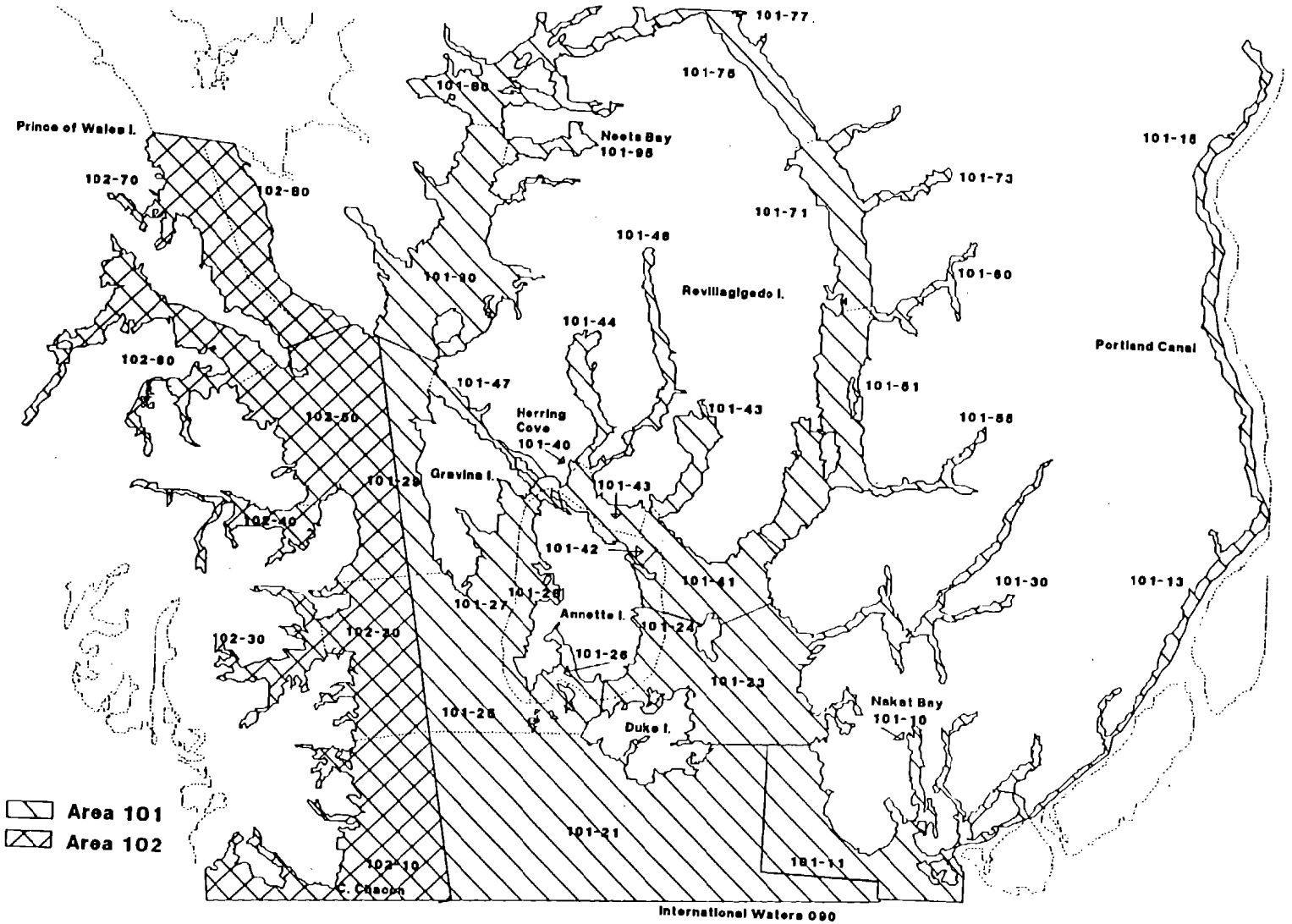

Figure 2.--ADF&G Southeast Alaska statistical areas 101 and 102.

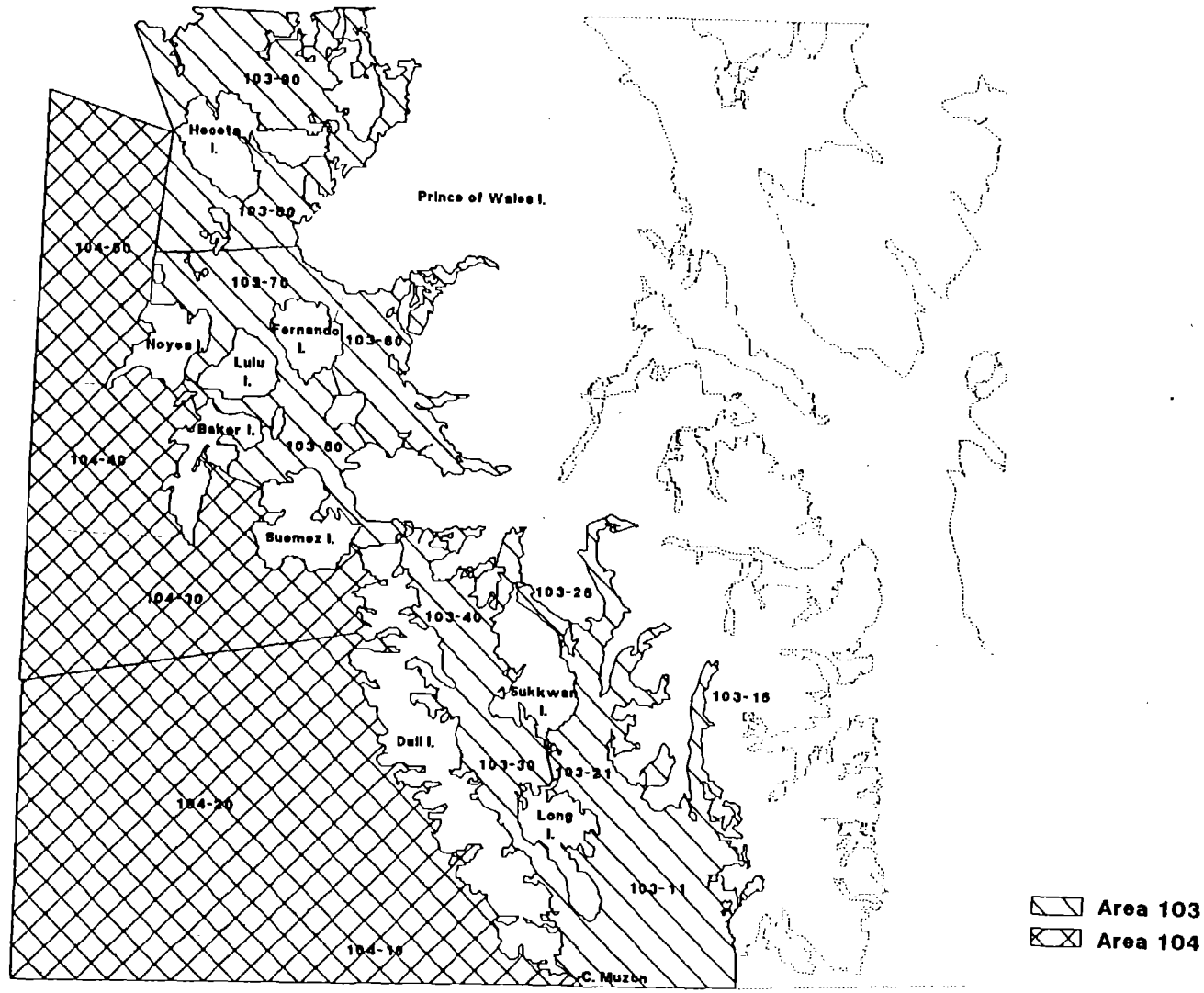

Figure 3.--ADF&G Southeast Alaska statistical areas 103 and 104.

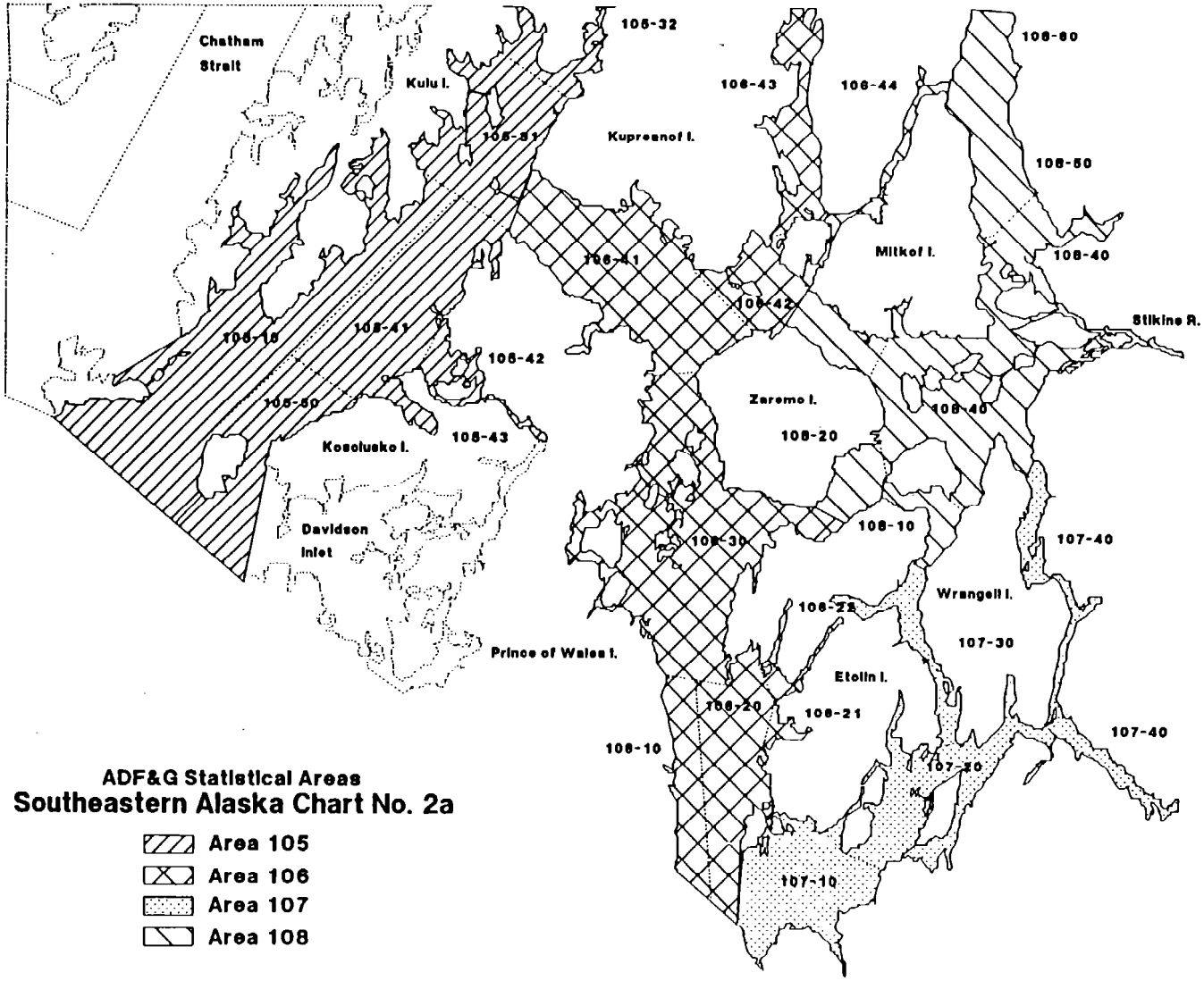

Figure 4. --ADF&G Southeast Alaska statistical areas 105-108.

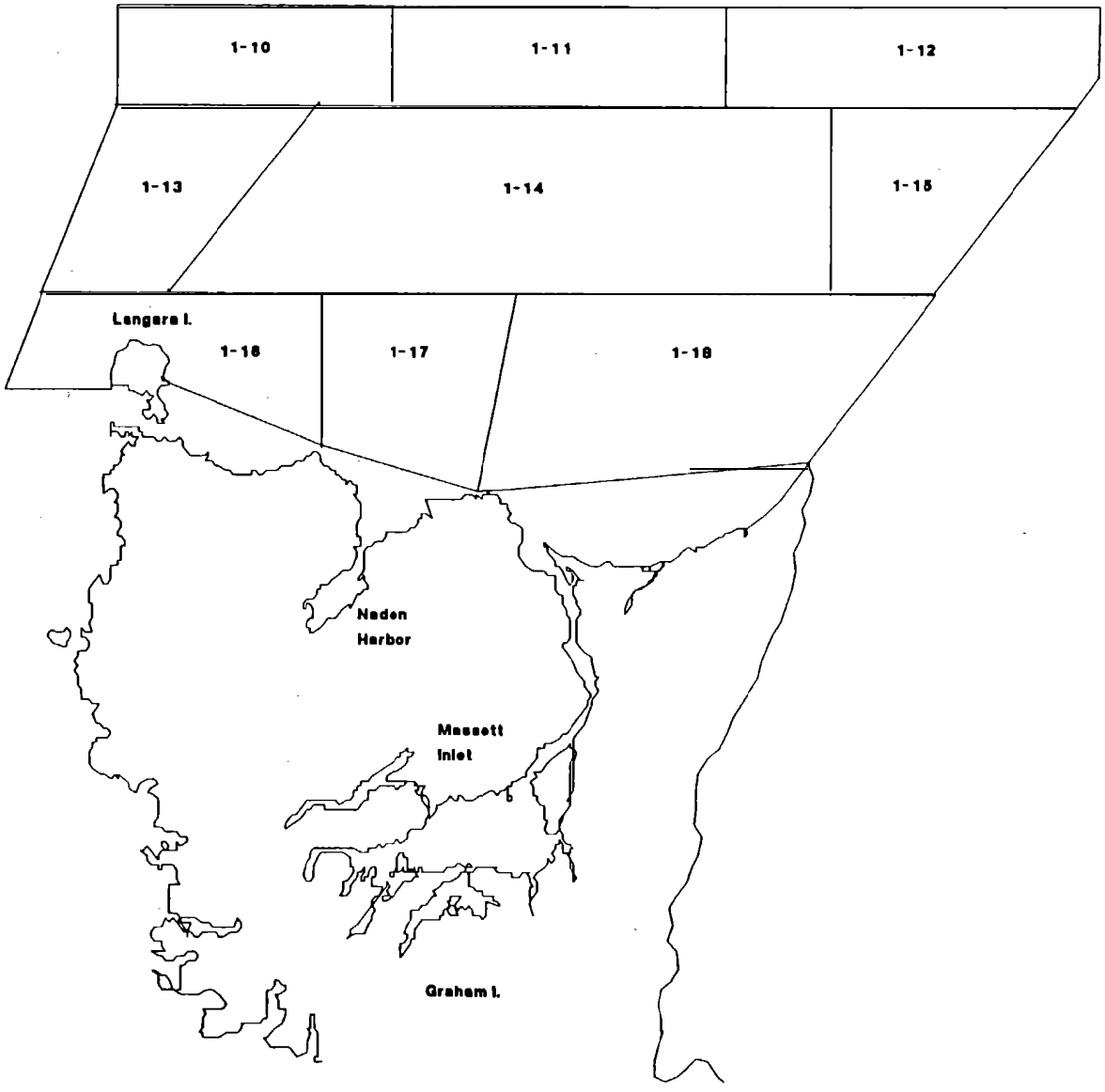

Figure 5.--British Columbia subareas 1-10 through 1-18 of area 1 in Dixon Entrance, 1984.

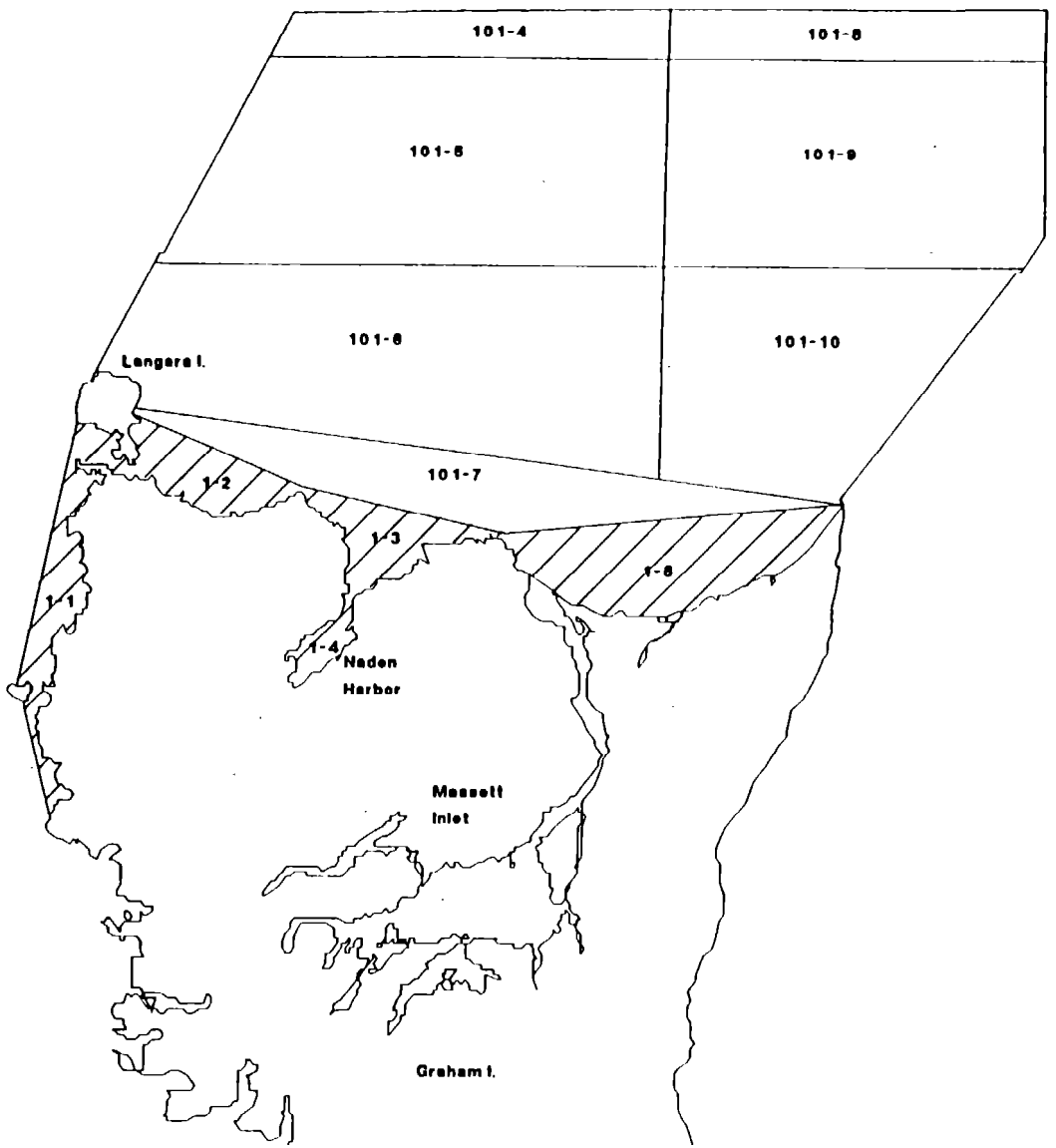

Figure 6.--British Columbia subareas l-l through l-5 (Langara Island) and 101-4 through 101-10 of area 1 in Dixon Entrance, 1985.

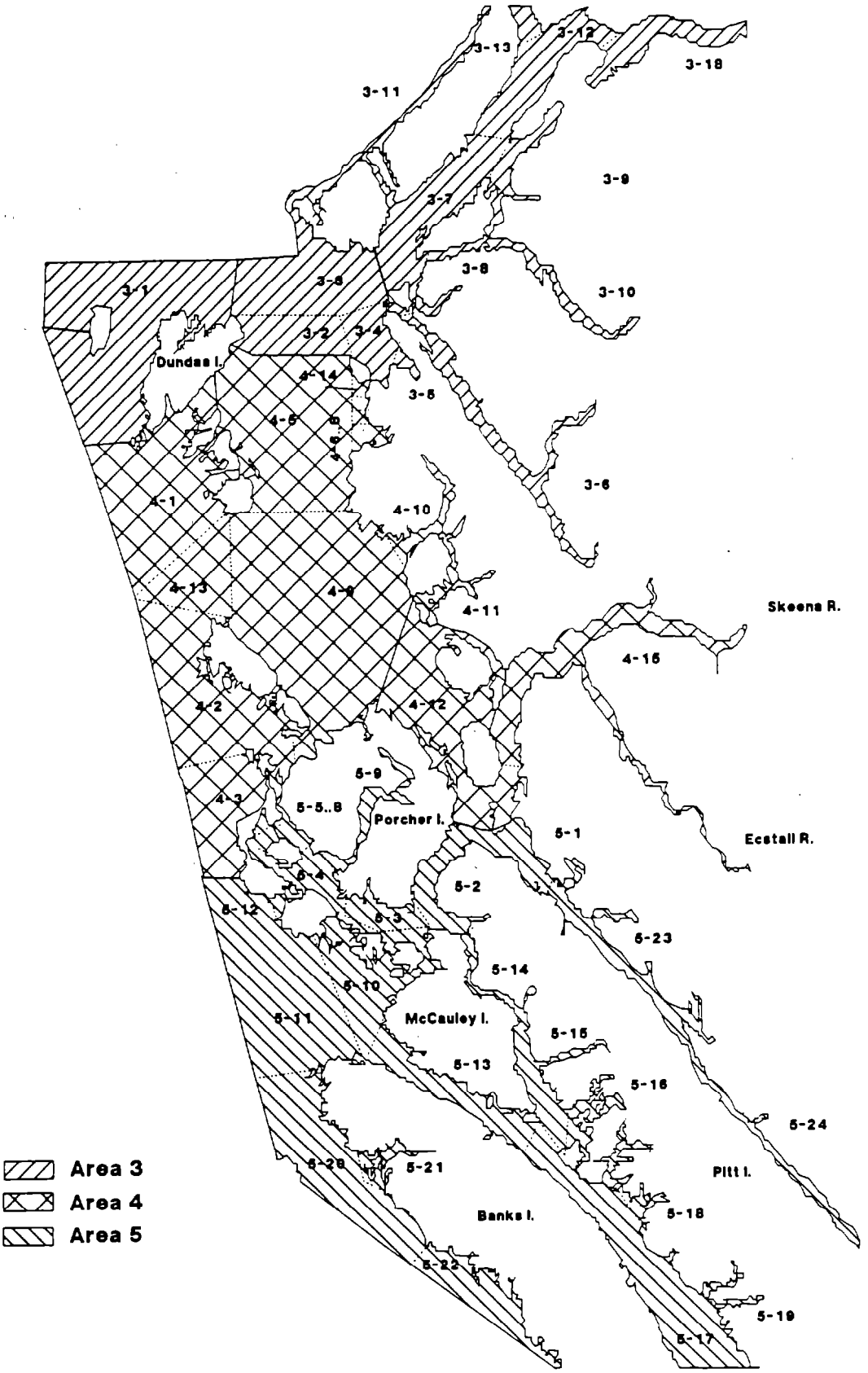

Figure 7. --British Columbia areas 3 through 5.

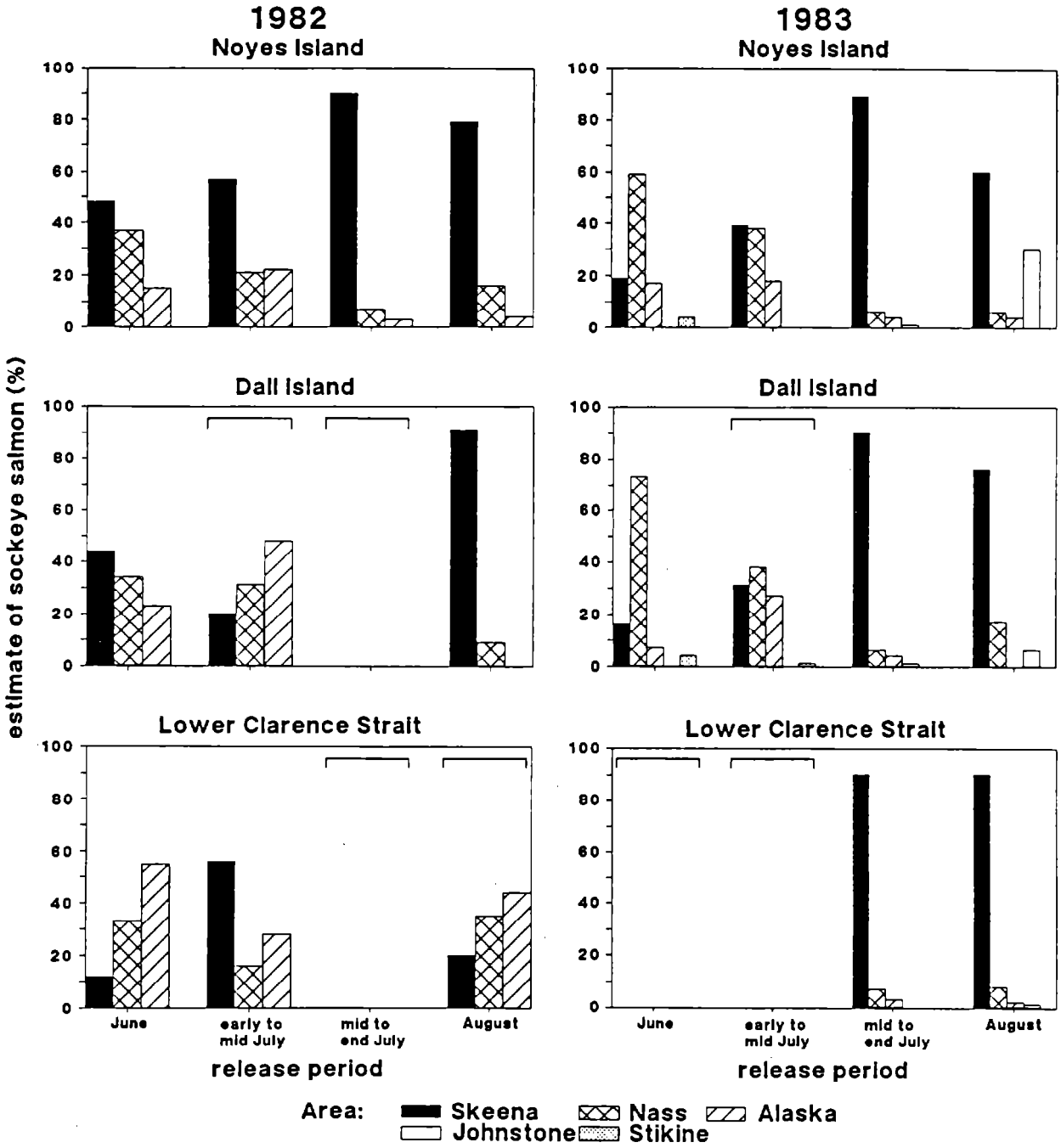

Figure 8.--1982 and 1983 stock-composition estimates (%) of sockeye salmon by area and period of release. Best estimates of escapements were used; and primary-tagged entrants in Canada were assumed to experience the same loss rates in rivers as secondary-tagged fish. Blanks indicate no recoveries were made; a bar indicates the stock-composition estimates are based on fewer than 10 tag recoveries from releases in this fishery and period.

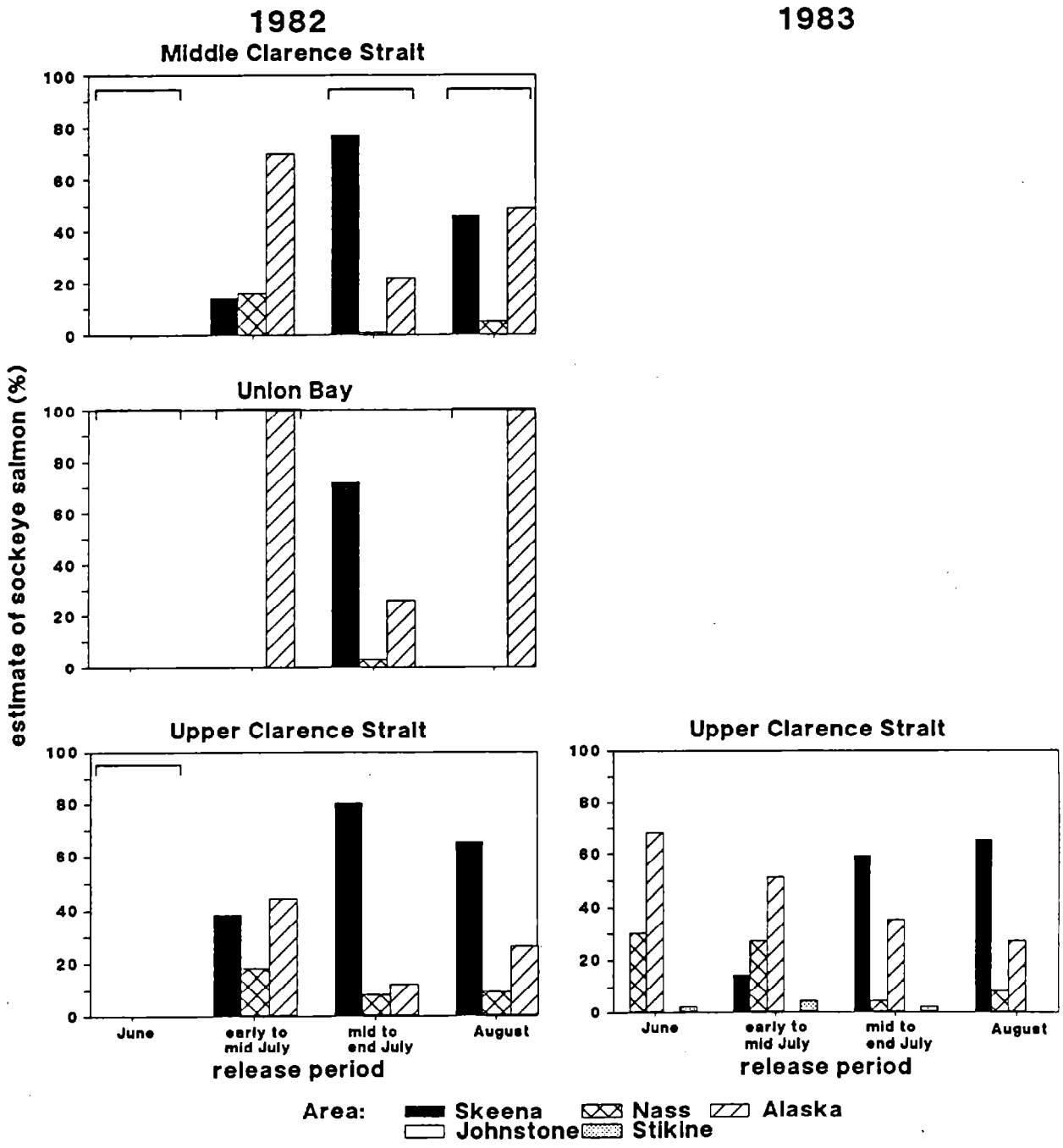

Figure 8. --Continued.

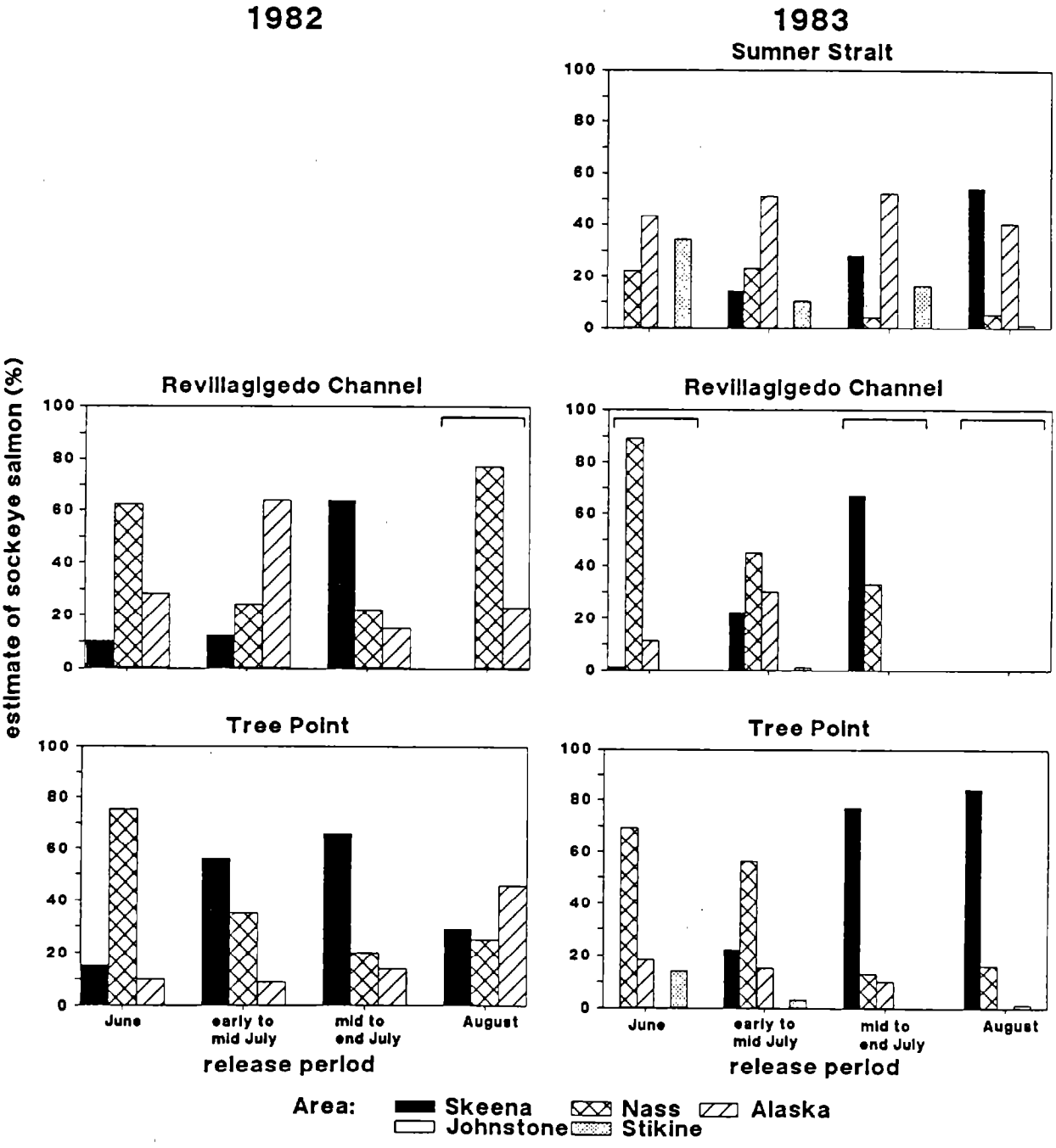

Figure 8. --Continued.

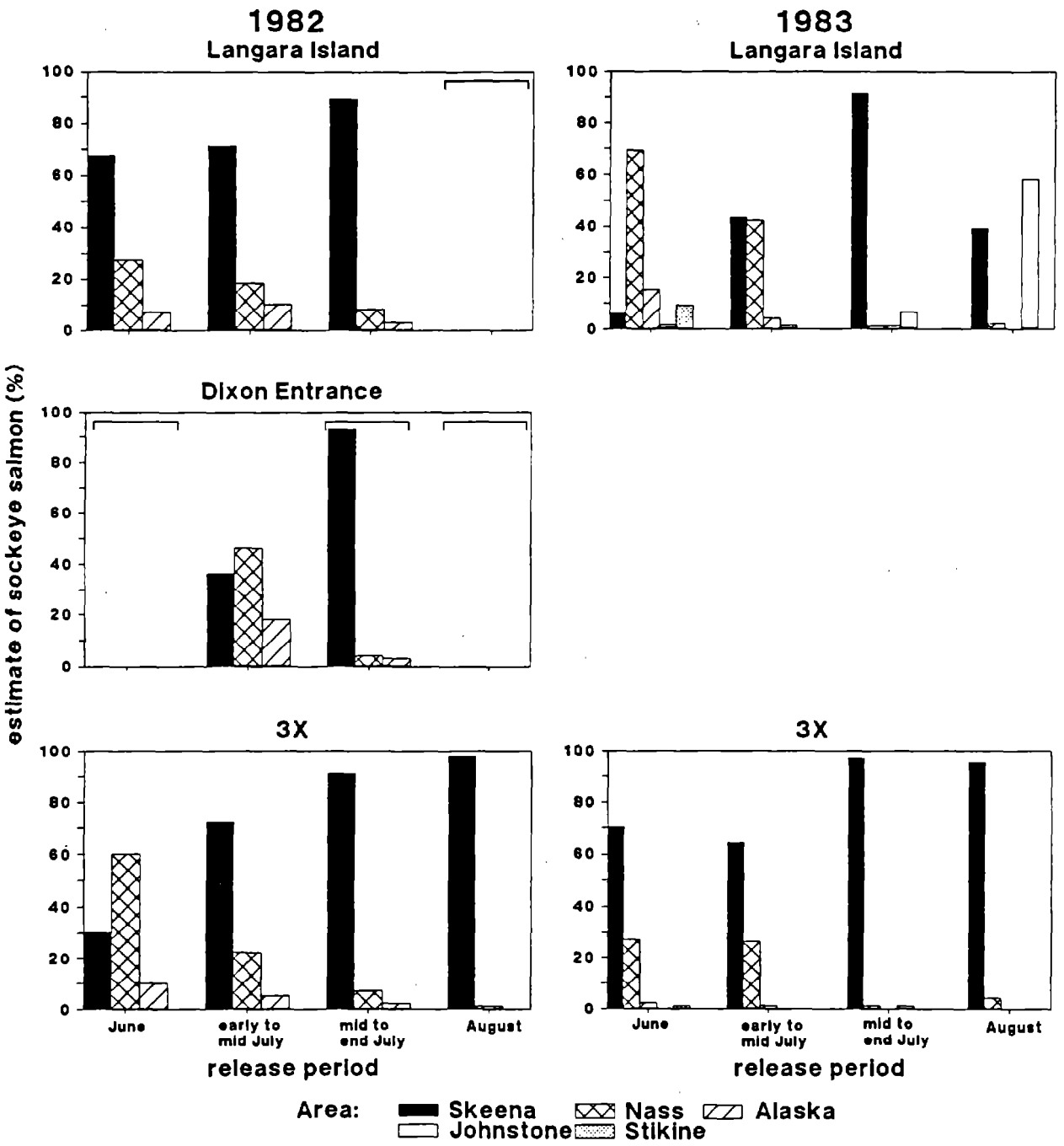

Figure 8. --Continued.

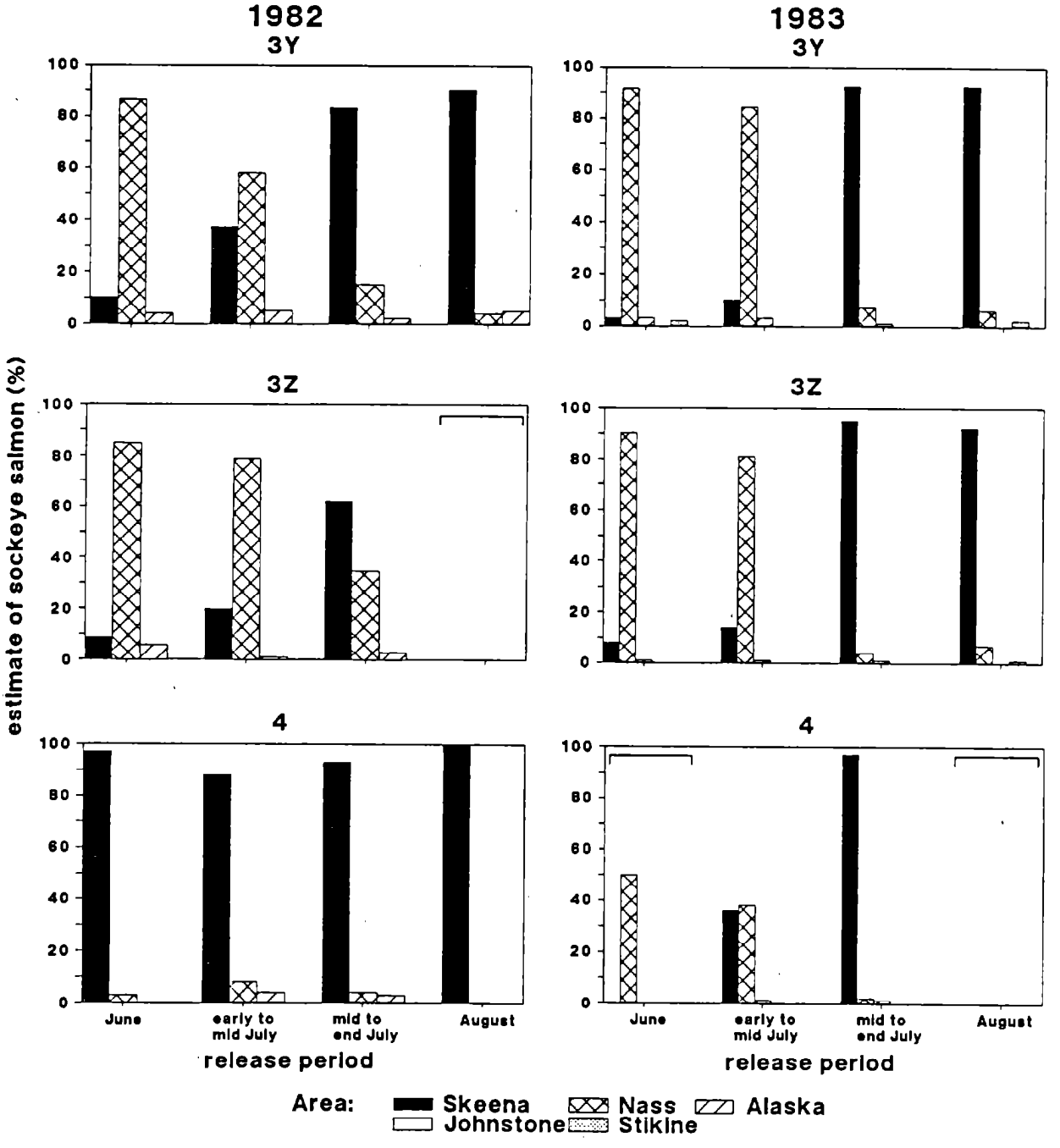

Figure 8. --Continued.

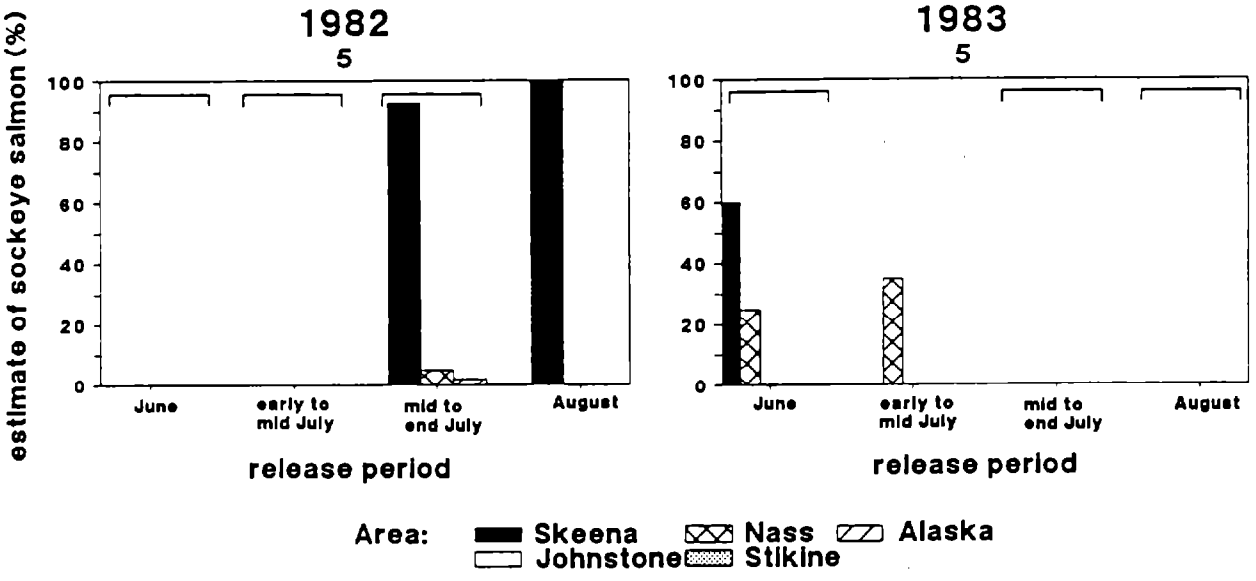

Figure 8. --Continued.

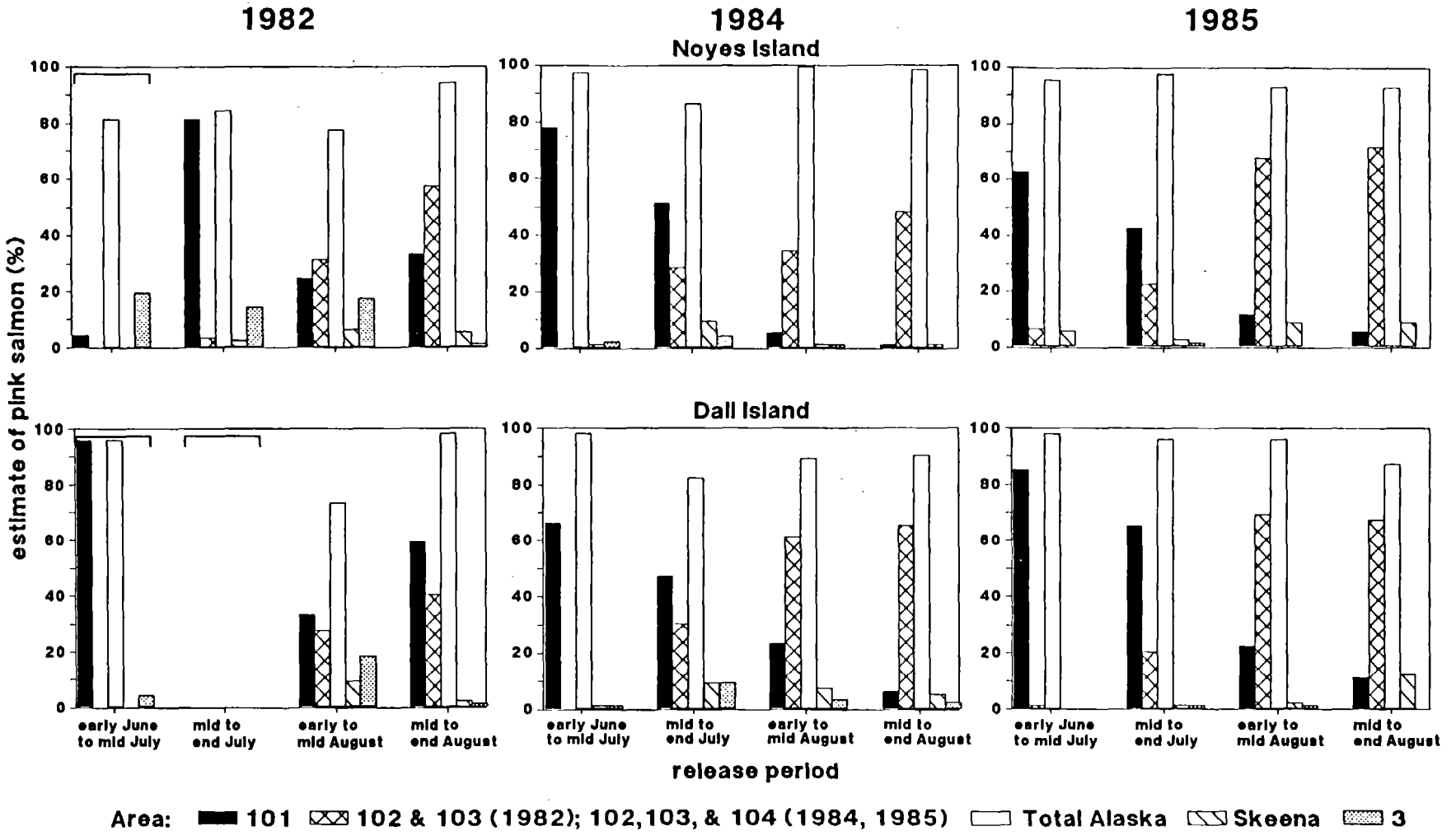

Figure 9.--1982, 1984, and 1985 stock-composition estimates (%) of pink salmon by release area and period. Best estimates of escapements were used, and primary-tagged entrants to Canadian streams with secondary tagging were assumed to experience the same recovery rates as secondary-tagged fish. Blanks indicate no recoveries were made; a bar indicates stock-composition estimates are based on fewer than 10 tag recoveries from releases in this fishery and period.

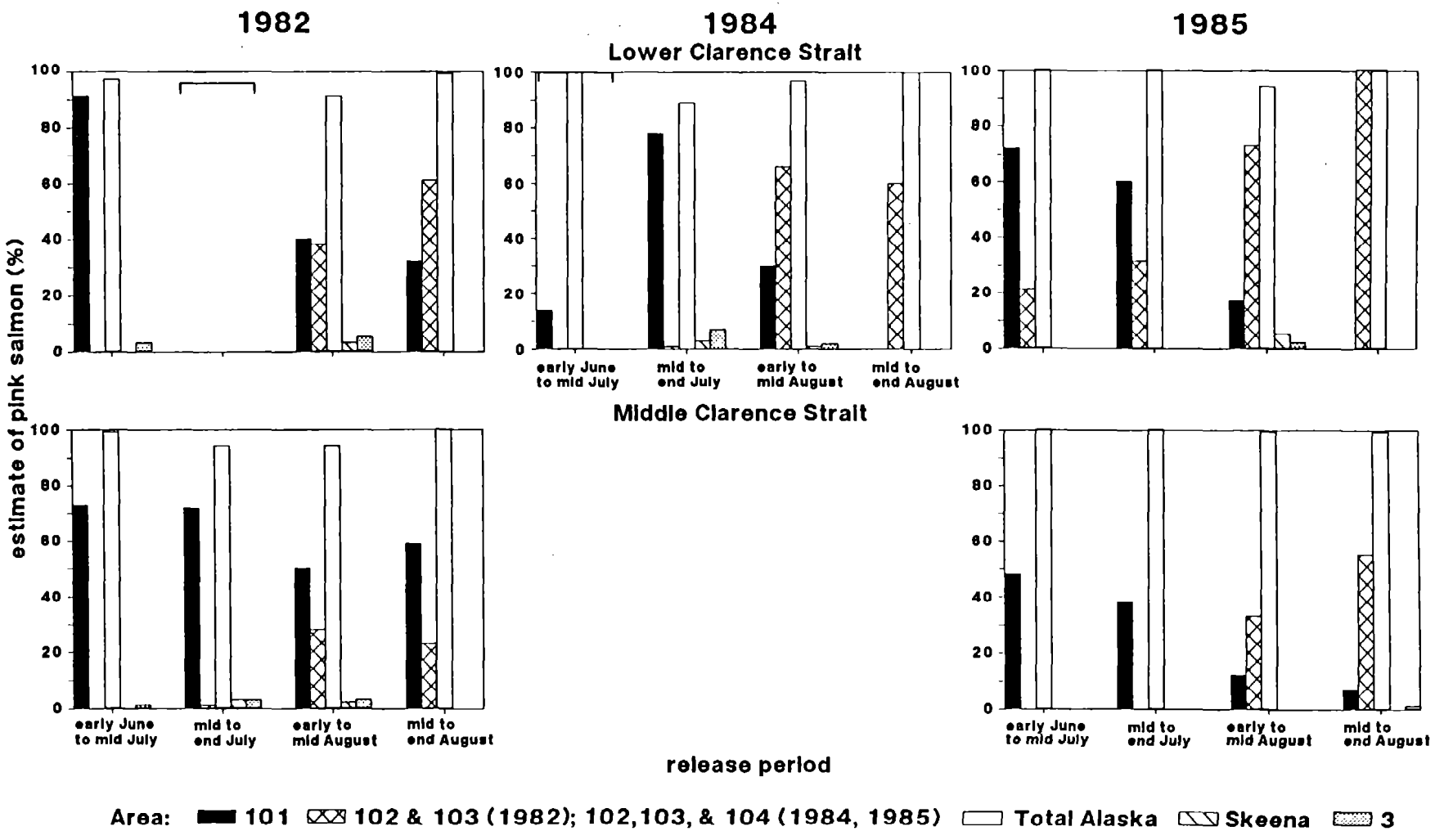

Figure 9. --Continued.

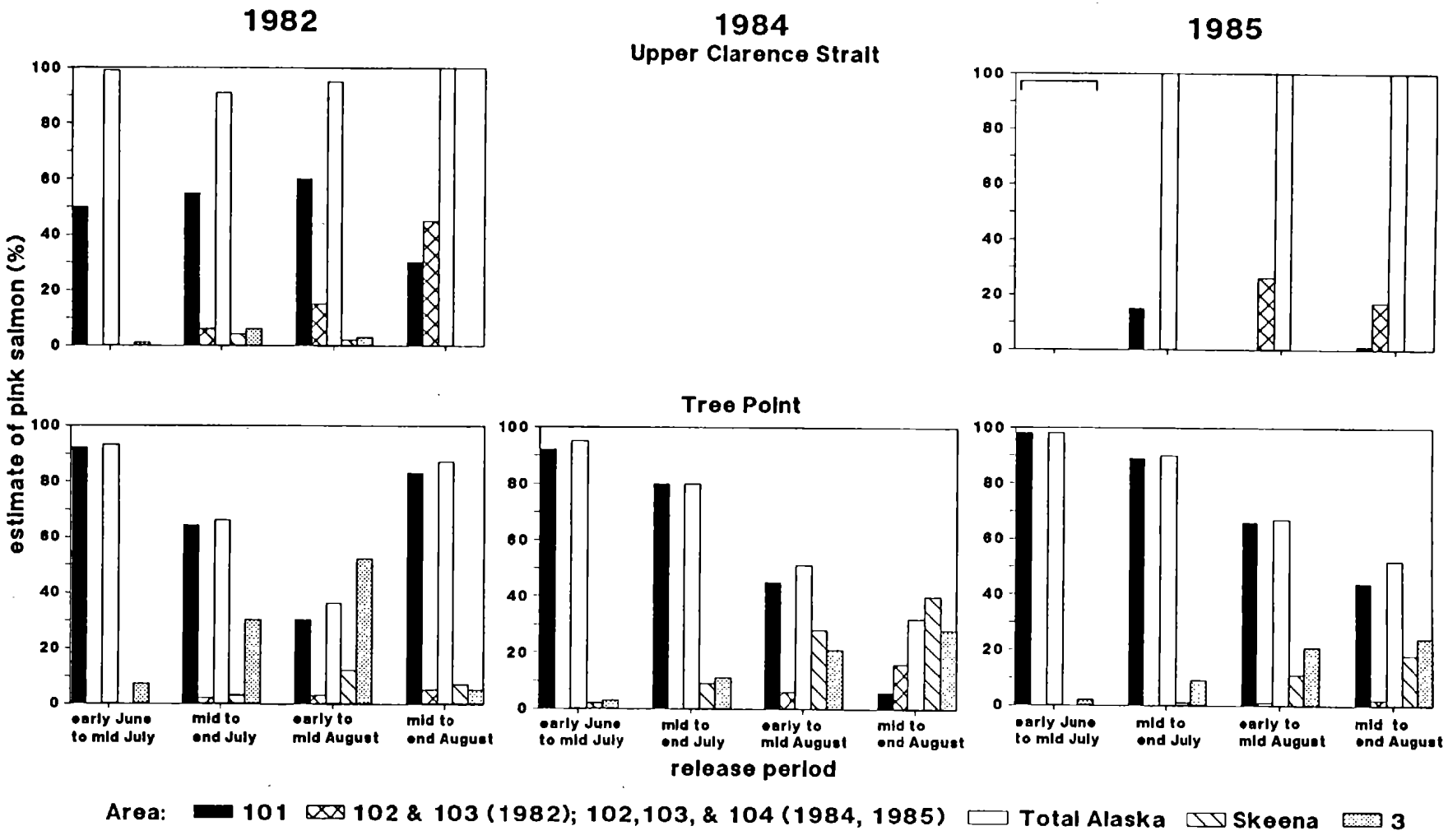

Figure 9.--Continued.

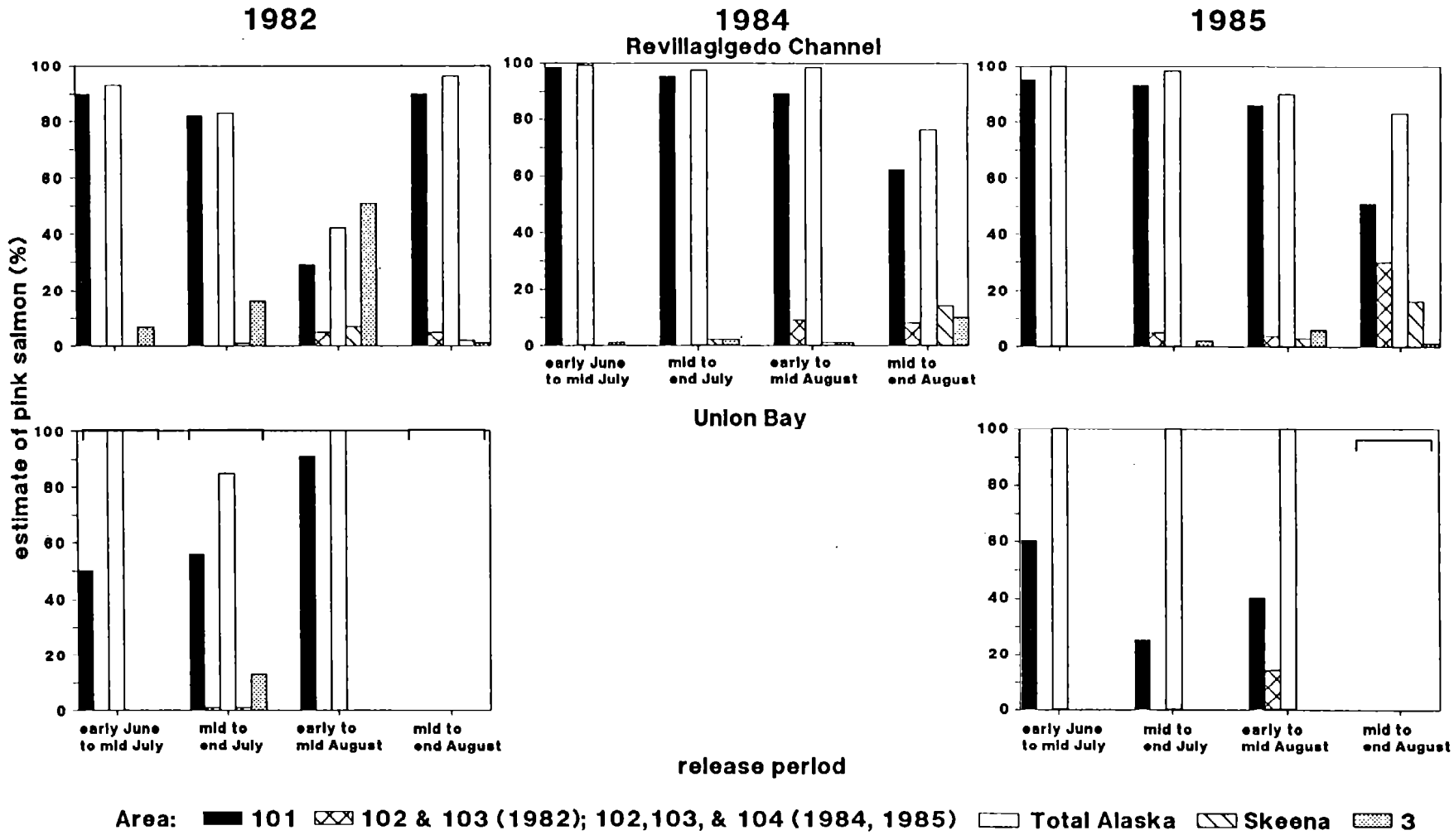

Figure 9. --Continued.

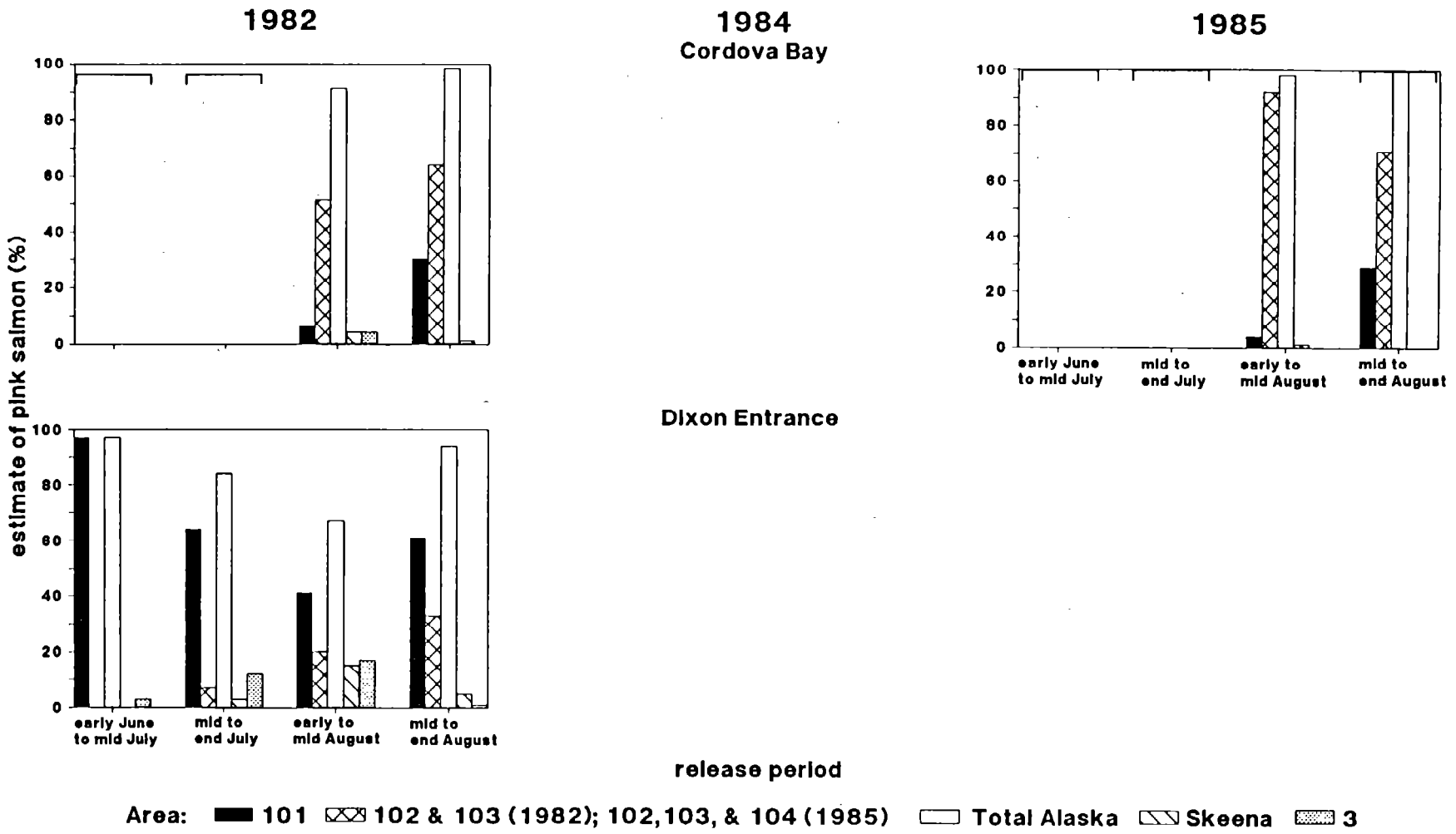

Figure 9. --Continued.

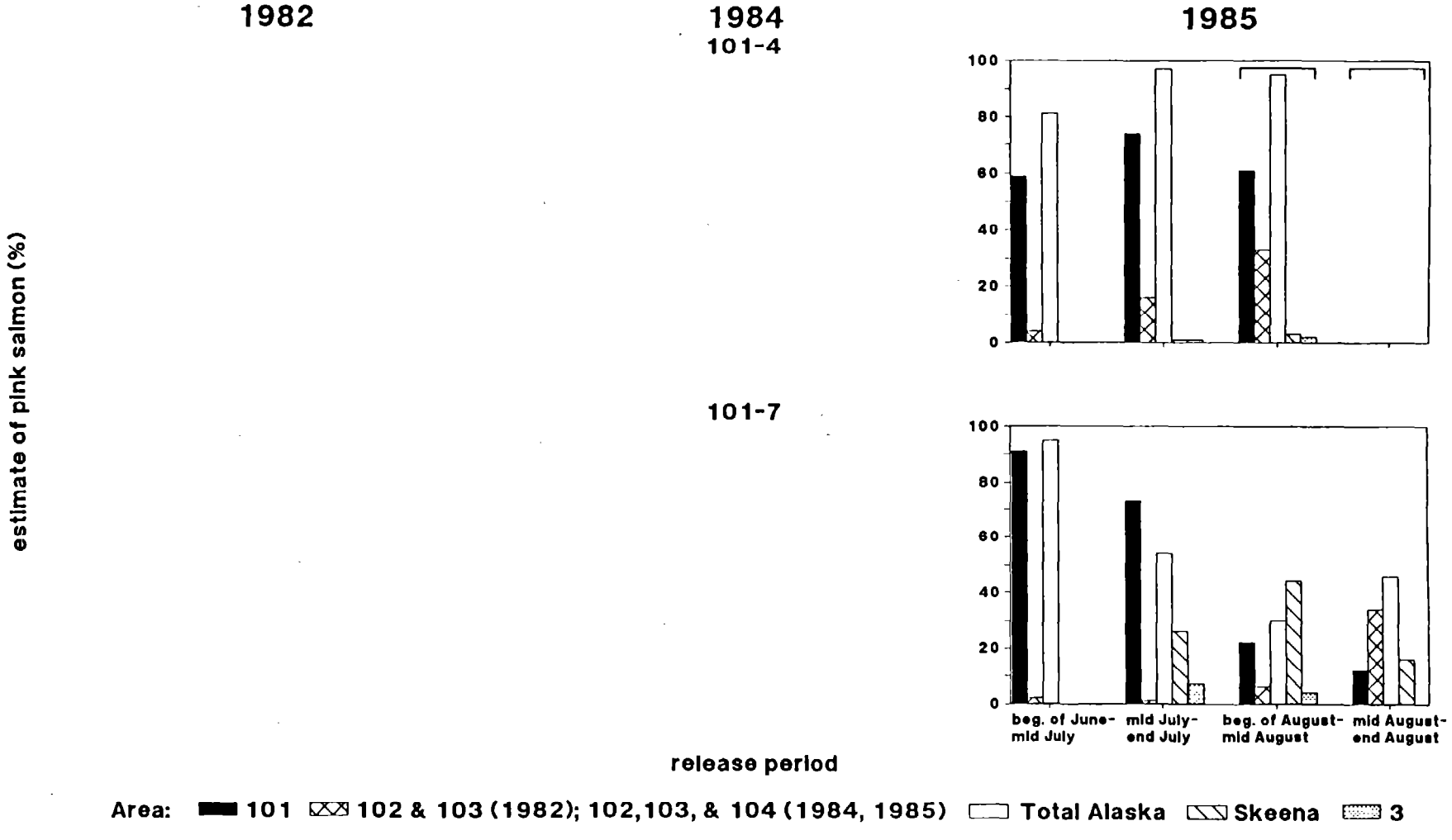

Figure 9. --Continued.

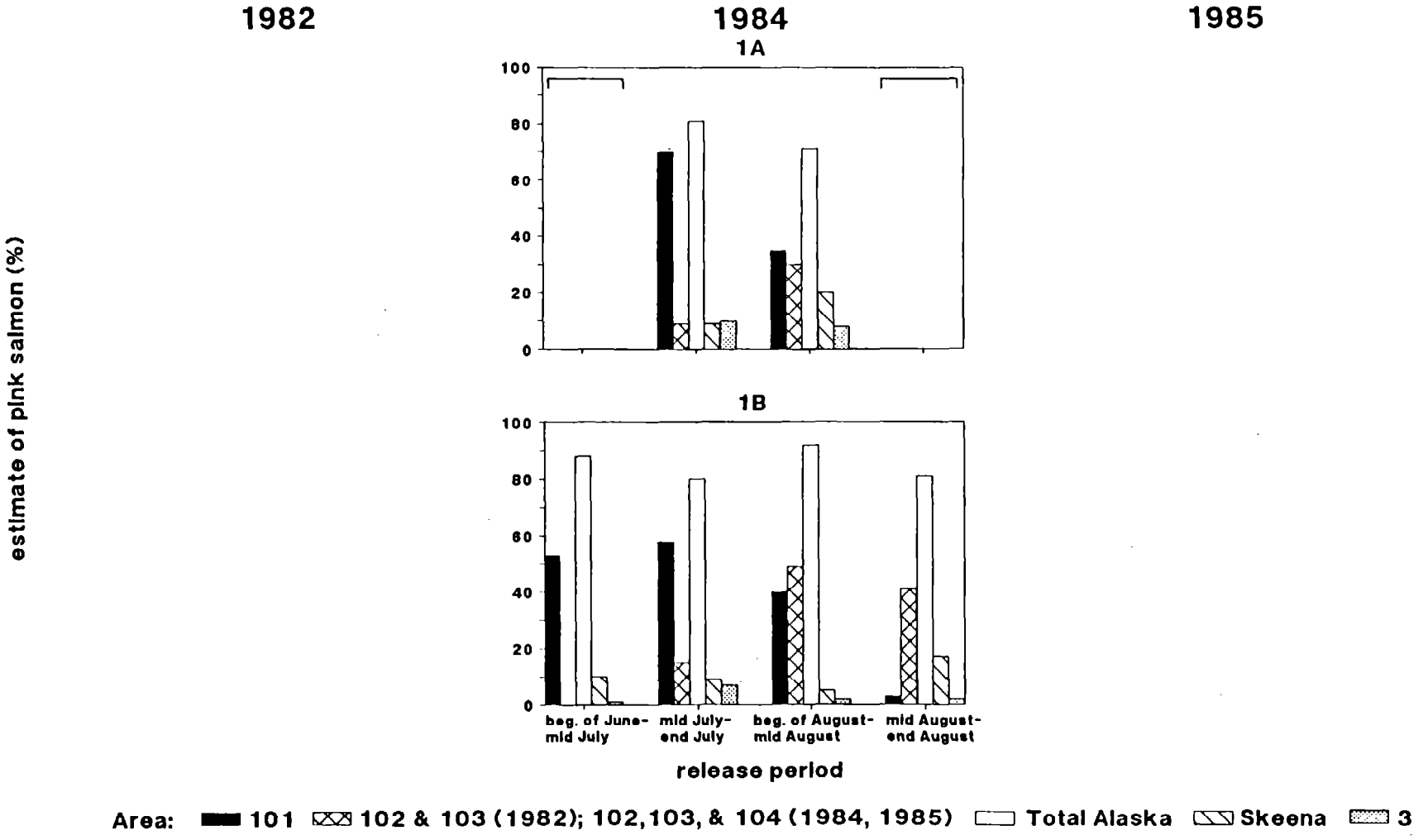

Figure 9. --Continued.

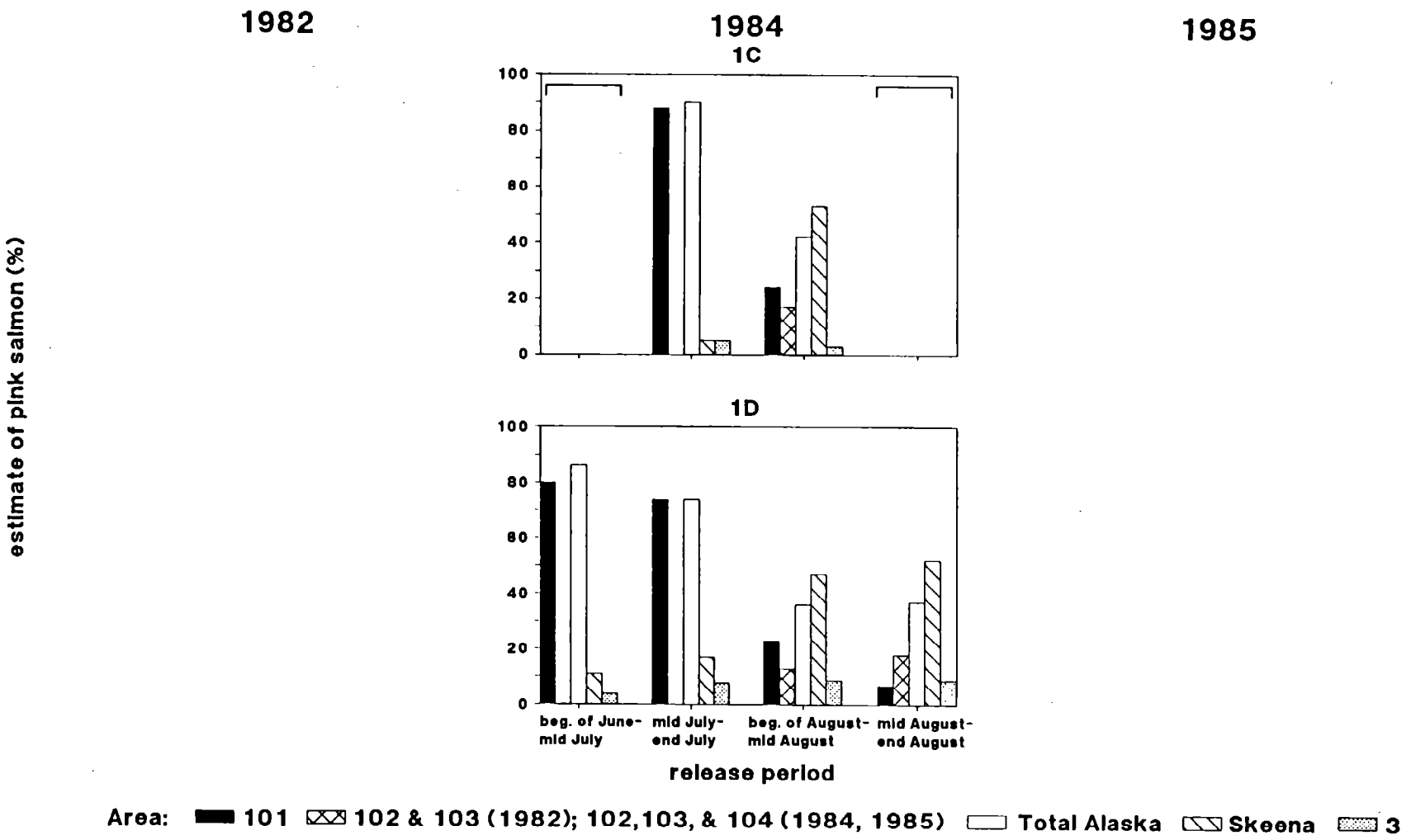

Figure 9. --Continued.

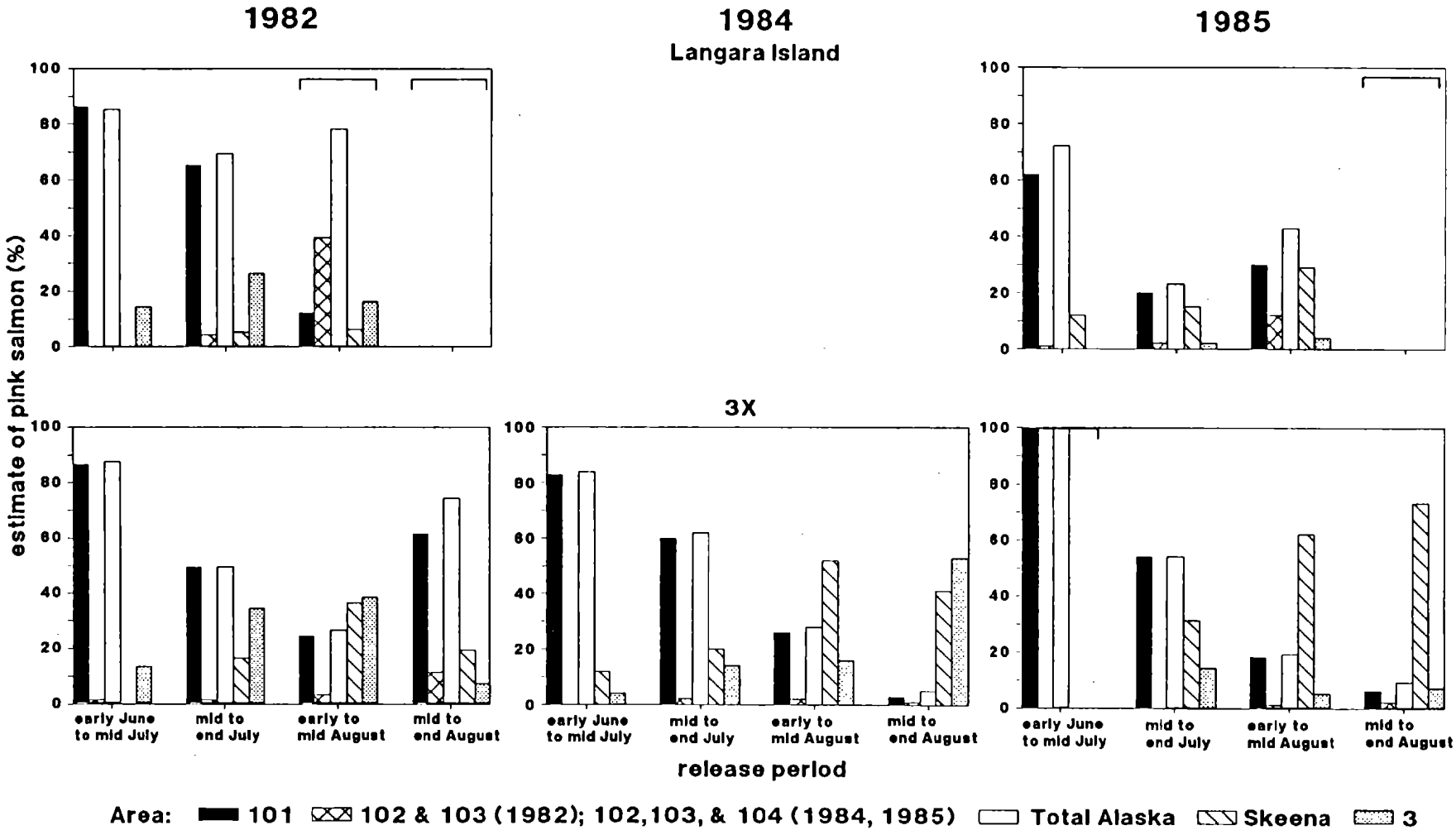

Figure 9.--Continued.

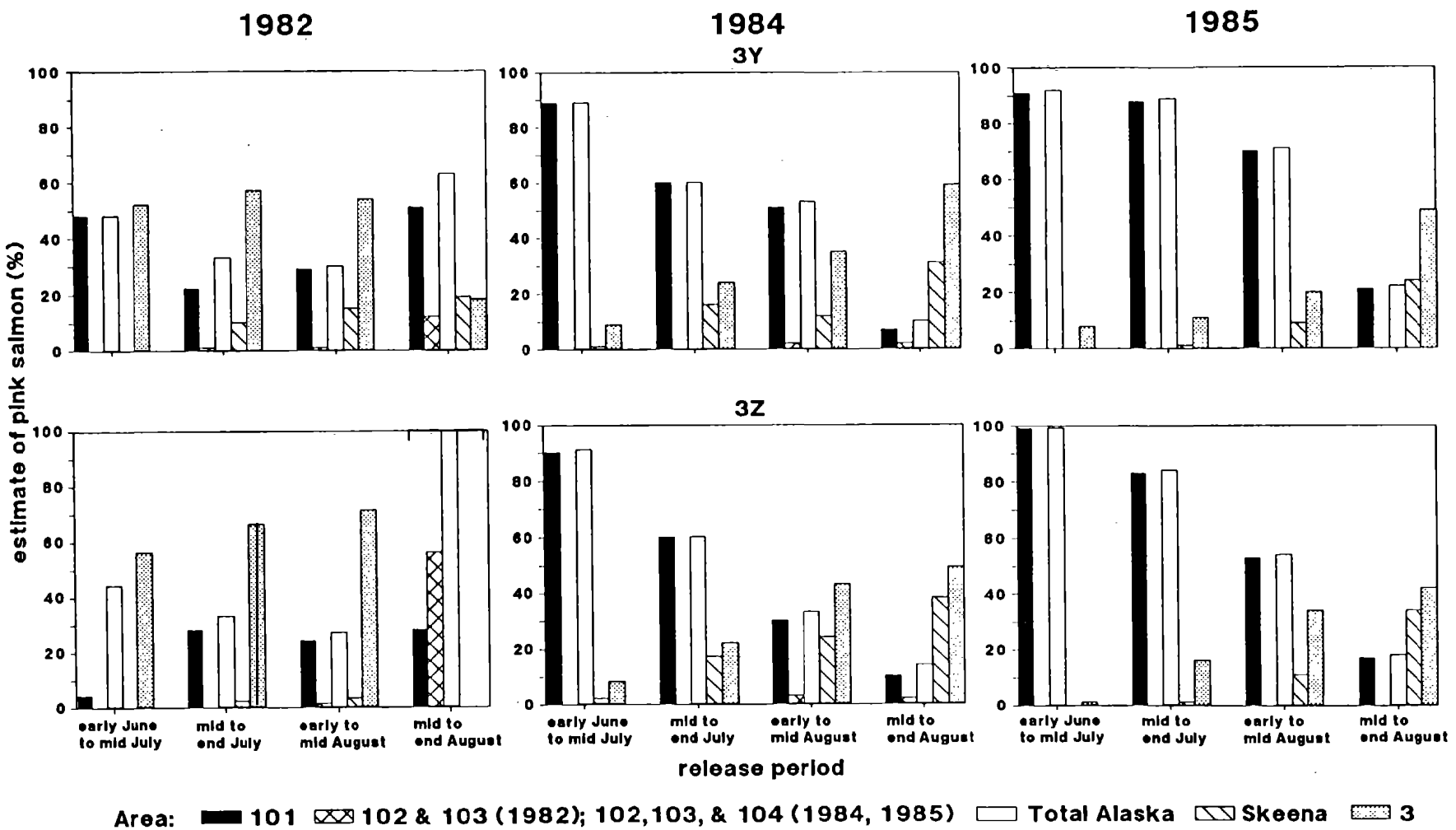

Figure 9.--Continued.

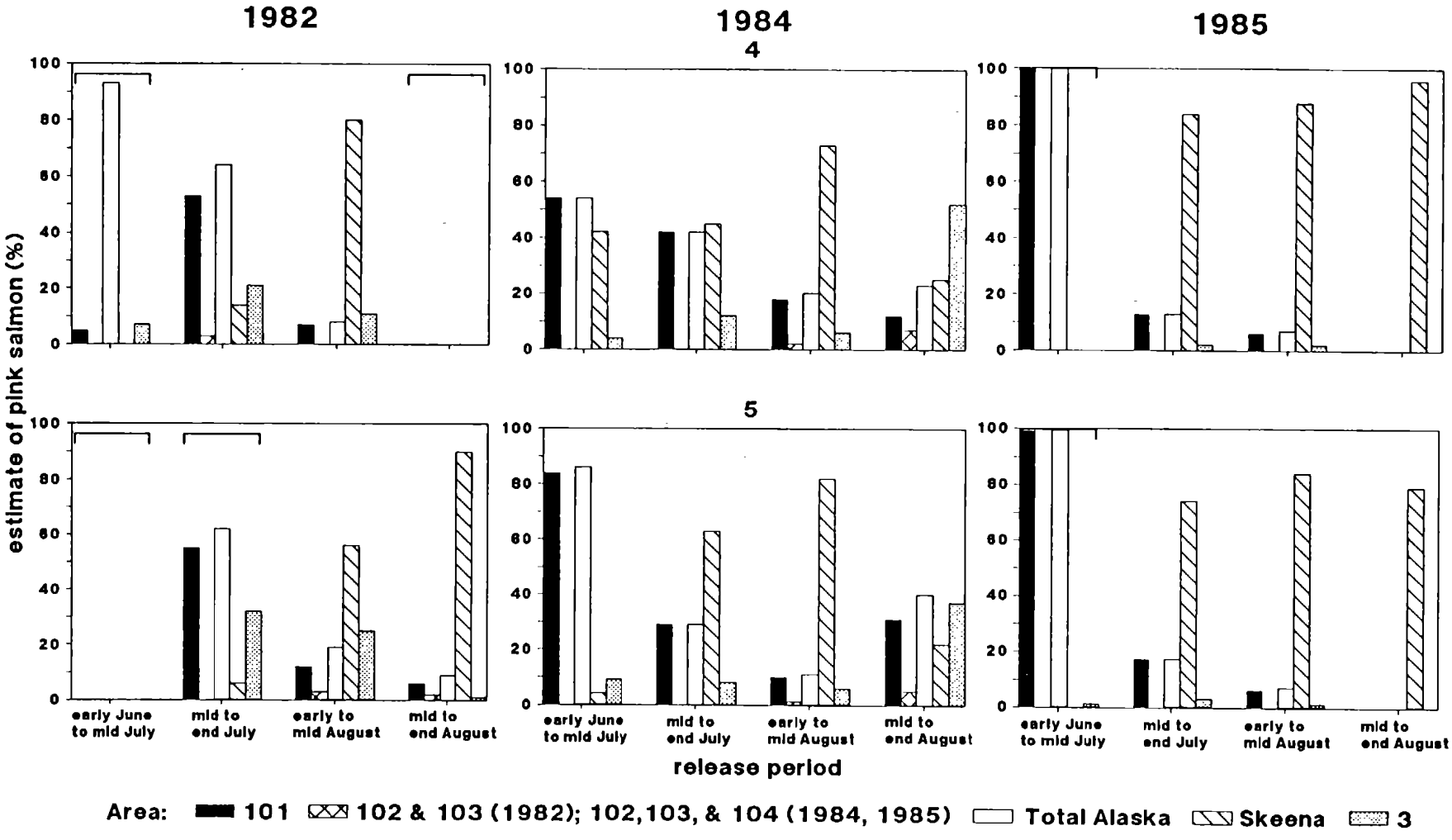

Figure 9.--Continued.

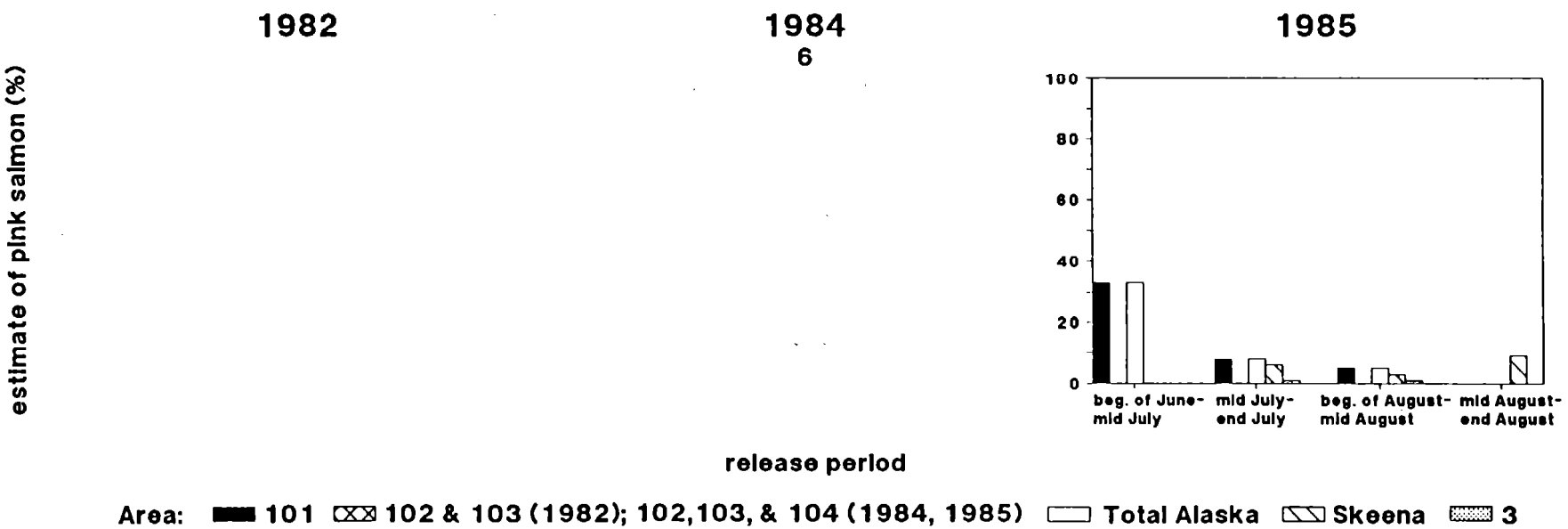

Figure 9.--Continued.

GLOSSARY

[***Italicized*** words in a definition are also defined in this glossary.]

Bootstrap--A computer-intensive method used to evaluate the variation in stock-composition estimates caused by subsampling catches and escapements for tag recovery. The measure of variation used in the present study was the *standard error of the* estimates. Good descriptions of this general statistical method can be found in Efron and Tibshirani (1986, 1991).

Catch or fishery recoveries--Primary- and secondary-tagged salmon recovered during *tagging-program sampling* of catches of *intervening fisheries.*

Confidence interval--A numerical statement consisting of a lower and upper bound for describing the precision with which an unknown quantity (such as *escapement* or the proportion of a catch comprising fish from a particular stock) has been determined. Were it possible to repeatedly replace and draw anew the randomly sampled observations used to compute the *point estimate* of the unknown quantity, a 90% confidence interval would include the unknown quantity in 90% of the drawings.

Escapement--The maturing adult salmon which survive to return to spawning systems.

Escapement recoveries--Tagged salmon recovered at weirs, in riverine fisheries, or during spawning-ground surveys as part of the *tagging-program sampling.*

Expand--The total number of tagged fish (T) among a group of N tagged and untagged fish can be estimated by counting the number of tagged fish recovered *(r)* in a random subsample of size n. The proportion of fish in the subsample which are tagged, *p,* equals *r/n,* and this proportion estimates the unknown proportion of tagged fish among the N fish, *P,* equal to *T/N.* The estimate of *T* is obtained as T = *Np* = *(N/n).r;* that is, the number of tagged fish recovered in the subsample is multiplied by a number greater than one W/n), or expanded to account for the unexamined fish.

Intervening fishery--A fishery along the migration route of *primary-tagged* salmon as they proceed toward the spawning grounds of their river of origin. The fishery from which the tagged fish were released was considered one of the *intervening fisheries.*

Petersen tagging experiments--The number of fish (N) in a lake or on a spawning ground can be estimated by tagging a known number of fish (M) which then mix with the untagged members of the population. Subsequently, a sample of C

fish is obtained from the mixture and the number with tags (R) is determined. If the tagged and untagged fish are thoroughly mixed at the time the sample is obtained, the expected proportion of tagged fish in the sample *(R/C)* will equal the proportion in the lake (M/N). An estimate of the number of fish in the lake is obtained by equating the two proportions and solving for the unknown number in the lake. The estimate is *N=MC/R.*

Point estimate--The particular estimate of an unknown quantity obtained from observed information, in contradistinction to an interval estimate *(e.g., 90% confidence interval)* for the same unknown quantity.

Primary tagging--Salmon were caught and tagged in the coastal ocean fishing areas of southern Southeast Alaska and northern British Columbia.

Secondary tagging--Salmon were caught and tagged in *terminal areas* in salt water near the outlet streams or rivers to their spawning grounds, or were caught and tagged within the rivers themselves.

Standard error of an estimate--The average of squared deviations of the estimate of an unknown quantity about its average value from repeated samplings. The standard error of an estimate usually must itself be estimated. An approximate *95% confidence interval* for the unknown quantity is provided by the estimate of the quantity plus or minus 2 times the estimate of standard error of the estimate. The *bootstrap* was used in the present report to estimate the' standard error of the estimate.

Tagging-program sampling--Known or estimated portions of commercial catches of salmon and escapements to *terminal areas* were subsampled for tag recovery in order to estimate total numbers of tagged fish present. Such sampling was conducted by government agencies or their contracted representatives.

Terminal area--The ocean area and adjacent fresh waters (outlet stream or river and spawning grounds) within which the origin of the salmon is presumed known.

Terminal-area entrants--Salmon which have passed through the commercial fisheries and enter the *terminal areas* leading to their spawning ground.

Volunteer tag recovery--Any tag recovered by sampling other than the *tagging-program sampling.* Number of fish examined for tags (among which the tag was found) was not available. For example, fishermen recovered tags from fish in their catches but numbers of fish examined were unreported.