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FISHERIES RESEARCH INSTITUTE
School of Fisheries
University of Washington
Seattle, Washington 98195

CHIGNIK SOCKEYE STUDIES

Annual Report - Anadromous Fish Project

by

Steven S. Parker

and

Donald E. Rogers

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Approved R. C. Fran.
Director

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ABSTRACT

The migratory behavior of salmon must be accommodated in the regulation of a terminal fishery if the population is to be properly divided into catch and escapement. Ideally, the escapement is taken from each time segment of the migration to include components from each substock, but this practice places the fishery manager in the position of discovering the size and timing of the migration as it develops. The fishery manager must have prior knowledge of both the expected harvestable surplus of salmon and the expected distribution of surplus over time segments of the salmon run. Conventional harvest control methods are not suitable to the unique harvest control environment in the Chignik, Alaska sockeye salmon fishery.

The present study examines two solutions to the Chignik fishery manager's dilemma. In the first of these, an intraseason forecast model allocates total abundance from a pre-season forecast to time periods of the migration according to the proportions specified by an average performance curve (APC) to produce forecasts of cumulative abundance by time interval. This APC method is contrasted with an intraseason period forecast (IPF) which predicts cumulative abundance in time interval t+1 based on observed cumulative abundance in interval t and the historical significance of cumulative abundance on the (t+1)th time interval to that on the (t)th interval. It is hypothesized that the IPF model is more flexible to interannual variability in the perceived migratory behavior of Chignik sockeye.

The hypothesis is tested by direct comparisons of forecasting performance in reconstructions of Chignik sockeye salmon migrations in 1978-1983, inclusive. Results show that the APC model performs poorly in years when either the pre-season forecast or observed migration timing departs from expectation. The IPF method shows better performance in years of unusual timing or behavior of the sockeye migration, but suffers in years when abundance is very much different than the historical average for each time interval.

ACKNOWLEDGMENTS

Chignik Sockeye Studies has been funded for many years by federal and private sponsors. I wish to acknowledge the efforts of Ron Berg, our federal aid coordinator in the National Marine Fisheries Service, in securing funds through the Anadromous Fish Act (Public Law 89-304). Members of the Chignik salmon fishing industry, particularly Columbia-Wards Fisheries and many individual fishermen, also have consistently provided financial support.

Catch and escapement data were kindly supplied by Larry Nicholson and Peter Probasco, both with the Alaska Department of Fish and Game, Kodiak. Their cooperation during field operations was greatly appreciated. Robert Conrad, also with ADF&G, has been a valuable "sounding board" for the ideas presented here. Ward Johnson, Peter Cummings, and Jeff Fisher assisted in the field.

PREFACE

This report presents analysis conducted during FY1984 and is published as a Master of Science thesis by Steven S. Parker. Reporting has been delayed by a lengthy review process not uncommon to thesis publication. The report is submitted for the contract period 1 July 1983 to 30 June 1984, since the bulk of data collection and analysis was supported by Contract No. NA-83ABD-UWBC, Project No. AFC65-3.

INTRODUCTION

Management of a salmon fishery is a delicate exercise in balancing social and political demands on the resource against the biological constraints of resource conservation. The conflict is perhaps nowhere in salmon management so pointed as in the debate over regulation of the commercial harvest, wherein the short-term economic health of a regional salmon industry may depend on management decisions which have long term criteria. However, the regulatory process is not only the interface between commercial exploitation and biological conservation of the resource; it is also the pivot point of success or failure in delivering the objectives of a salmon management plan. The precision with which the commercial harvest is controlled determines how closely designated conservation goals are met.

Knowledge of the homing behavior of salmon is an integral part of the regulatory process for, unlike most marine fisheries which operate on closed, non-migratory populations, the conduct of the salmon fishery is constrained by the migration phenomenon to relatively narrow boundaries in time and space. Errors in decision-making cannot be recalled, for salmon escaping the fishing grounds are never harvested, and those harvested will never contribute progeny to the next generation. Furthermore, the decisions of a single season impact the biological production from preceding and following seasons. As the migratory behavior of salmon is a conservative and predictable phenomenon within stocks (Mundy 1979), approximate calendar dates have become historically associated with critical points, such as peak days, in the abundance of many salmon migrations (e.g., Royce 1965). Annual variability in the abundance and timing of returns may preclude effective control of the harvest at this level of precision.

The essence of a harvest control system is the predictability of salmon abundance on the terminal fishing grounds. Decisions to open or close fishing periods depend on assessments of the total size of the salmon population so that the fraction available for harvest can be determined. Although pre-season forecasts of abundance may provide the fishery manager with a degree of foresight, there are certain to be deviations from pre-season estimates of abundance because important predictor variables have not been accurately measured. It is therefore essential that the management agency be capable of making adjustments in fishing pressure during the fishing season to fully harvest the surplus from stock returns that exceed escapement needs or to protect those that do not.

In addition to simply ensuring that a designated escapement goal is met, harvest control should be implemented to ensure that the escapement is distributed over all time segments of the migration in recognition of the possibilty for differential timing (Thompson 1951) and productivity (Ricker 1958) of substocks within the composite stock migration. However, the practice of allocating escapements from each time period places the fishery manager in the uncomfortable position of discovering the size and timing of the migration as it develops. Use of the fishery as an indicator of abundance is risky because any given magnitude of catch has relevance to the understanding of total abundance only in so far as the timing of the migration is understood. For example, a small, early migration could be devastated by fishery regulations intended for a predicted large migration of average timing. To properly allocate total abundance in each time interval between catch and escapement, the fishery manager must anticipate not only the harvestable surplus of salmon, but also the distribution of surplus over time.

This problem has been addressed in recent years by a number of investigators (Walters and Buckingham 1975; Mobrand 1977; Mundy 1979; Hornberger and Mathisen 1980; Brannian 1982; Clark 1983; Schnute and Sibert 1983; Barth 1984). A harvest control system which is currently undergoing widespread scrutiny is that articulated by Mundy (1979) for application to the Bristol Bay sockeye salmon fishery. Historical patterns of catch and effort were statistically interpreted in terms of the dates by which specified proportions of total catch were taken within individual years. The time series of catch proportions was assumed to accurately reflect the time series of sockeye abundance at a fixed geographic reference point and was termed the "time density distribution" of the sockeye migration. The time density was presented as an empirical probability density function of the random variable, time, wherein the proportion of catch occuring in a time interval defined the probability of occurence of the time interval. Statistical analyses of means and variances for the annual time density distributions showed that a quantitative model of the migratory behavior of Bristol Bay sockeye could be used to objectively describe future migrations.

The harvest control system proposed by Mundy (1979) is based on the concept that empirical patterns in the time series of cumulative proportions of total catch, CPUE, or abundance are stable and predictable for many salmon migrations. Harvest effort in the commercial fishery is regulated in this system according to the cumulative proportion of the total allowable catch taken by the fleet in successive time periods. Intraseason predictions of total catch are calculated at each time interval by dividing the cumulative catch in the current year by the corresponding expected proportion of total catch specified by a cumulative time density function averaged from the historical record. The regulatory agency monitoring the progression of cumulative catch toward the catch quota imposes harvest control measures at appropriate times to ensure the progression remains "on track." Later termed the "performance curve" (Mundy et al. 1985), the cumulative time density model has found application in salmon fisheries from Puget Sound to Kotzebue (Mundy et al. 1985; see Mundy 1984 for review), as well as in such diverse fisheries as brown shrimp (Babcock and Mundy 1985; Matylewich and Mundy 1985) and blue crabs (Hester 1983) in Chesapeake Bay.

Unfortunately, migratory time density models may not meet the requirements of every harvest control situation. Because the migratory behavior of salmon is an environmentally mediated phenomenon (Mundy 1982), the time density of a single year may be of limited use for describing migratory timing for purposes of fisheries regulation (Rugolo

1984). The best image of migratory behavior generally is taken to be the average of several years' data, but the mean is not necessarily a good description of the migration in any given year. Walters and Buckingham (1975) concluded that their method was no more reliable than the judgement of an experienced fishery manager. Mundy (1979) found that predictions of total abundance based on an average performance curve did not reach acceptable levels of reliability in some cases until roughly 60% of the migration had passed. Barth (1984) examined several types of intraseason forecast systems and confirmed that average timing models showed poor performance early in the migration, but most improved considerably after the mean date of migration.

The harvest control environment at Chignik includes some aspects that inhibit the use of conventional migratory time density models. The Chignik sockeye salmon fishery currently is regulated on the basis of escapements enumerated at a weir on the Chignik River. Commercial harvests are permitted so long as cumulative daily escapements exceed cumulative daily escapement goals. It is well known locally that escapement counts may not accurately represent the true abundance of sockeye in the terminal fishing area because sockeye entering Chignik Lagoon tend to mill about for up to several days before moving upriver to be counted. The fact of milling in the lagoon violates the assumption of constant, unidirectional movement of the migration, stipulated by Mundy (1979) as the optimal condition for applying migratory time density theory.

A second, more pressing, concern to the Chignik fishery manager is the need for reliable information early in the migration. The critical period for harvest control occurs during the first days, when total abundance and timing must be evaluated from an incomplete image presented by cumulative escapement counts. Since harvest control decisions are dependent on daily reports of catch and escapement, the regulatory system responds to estimates of the abundance of fish already accounted for, rather than to the more relevant estimate of the abundance of those yet to be counted. Accordingly, the fishery manager is squarely in the position of discovering the size and timing of the migration as it develops, and a system of intraseason forecasting that cannot provide acceptable accuracy during this period is of little value.

This study explores two possible solutions to the Chignik fishery manager's dilemma. It is postulated that an intraseason abundance estimator of the type described by Walters and Buckingham (1975), Mundy (1979), Hornberger and Mathisen (1980) and Brannian (1982) is sabotaged at the outset by the migratory behavior of Chignik sockeye and by the requirement for accurate information early in the migrations. Therefore, the first proposed solution examines the feasibility of reversing the intraseason forecasting problem such that predictions of total abundance made from observations taken early in the migration, which typically show errors in the range of 50-200% prior to the mean date of migration (Barth 1984), are replaced by a single pre-season forecast of abundance which is allocated over time periods of the migration according to the proportions specified by an average performance curve. This model, termed the APC method, depends on the assumptions that pre-season forecasts are sufficiently accurate, and migratory timing parameters are sufficiently robust to violations of time density theory, that resulting projections of cumulative abundance by time interval adequately model observed data.

An alternative model is proposed in case both of the above assumptions are not generally met. A stochastic time series model (Thomas and Fiering 1962) is adapted to the problem at hand by assuming the error term to be a standard normal random deviate. The model is similar to a Markov chain in which the predicted state of the variate (cumulative abundance) at time t+1 is linearly related to the state of the variate at time t. The recursive form of the model provides a feedback mechanism whereby the sign, and magnitude, of prediction error in the current time interval influence the prediction for the next interval. It is proposed that this intraseason period forecast (IPF) model has the capacity to detect migrations that are extraordinary in terms of the distribution of abundance over time.

This report begins with a description of the study area and a brief review of previous research in the Chignik watershed. Details of pre-season forecast models prepared for each nursery lake stock are provided together with an accounting of their performance in hindcasting annual stock abundances. As the migratory behavior of adult sockeye remains the foundation of both intraseason forecast models, detailed descriptions of stock migrations are included. Final sections describe the APC and IPF models, and then compare the performance of each in reconstructing the migration patterns of Chignik sockeye in recent years.

Study Area

The Chignik watershed lies in a region of active volcanism at the westerly inflection of the Alaska Peninsula (Fig. 1). The two lakes and associated tributaries in the system together drain approximately 1,540 km^2 of tundra, marsh, and grassland on the west and glacially-sculpted mountains of the Aleutian Range on the east. Descriptions of the geology, flora, and fauna of the region given in Knappen (1929) largely apply today.

The nursery lake system arises in the many spring-fed streams of the Alec River drainage which, together with snowmelt and rainfall, supplies Black Lake. Black River connects Black Lake with Chignik Lake and collects additional input from Chiaktuak, West Fork, and Bearskin creeks. Clark River and several smaller streams also provide limited inputs of water to Chignik Lake. Chignik River drains the watershed into Chignik Lagoon, a shallow, nearly-enclosed coastal lagoon.

Pertinent physical measurements of the system are summarized in Table 1. The two lakes are physically dissimilar. The high surface

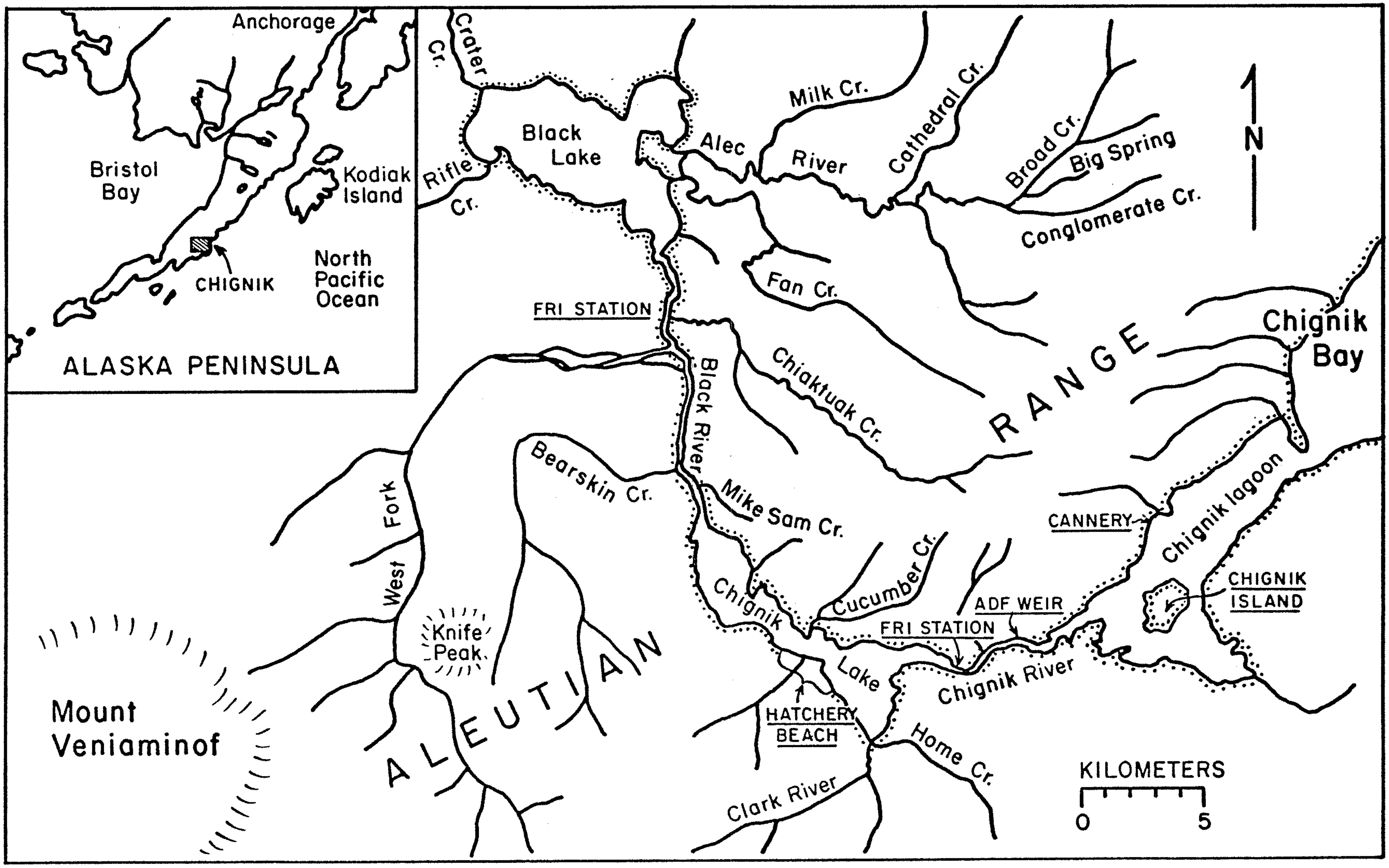

Fig. 1. Map of the Chignik watershed with inset of western Alaska.

Table 1. Morphometric measurements of Chignik and Black Lakes and Chignik Lagoon (modified from Narver, 1966; in Dahlberg, 1968).

Source	Altitude (m)	Depth (m)		Water[1] area (km^2)	Volume (km^3)	Shoreline[1]		Flow at outlet	
		Mean	Maximum			Length (km)	Development	(m^3/sec)	Date
Black Lake	15	3	6	41.1	0.10	27.0	1.19	17.0	6/25/63
Chignik Lake	5	29	64	22.7	0.64	27.7	1.64	79.5	6/23/63
								35.8	8/13/63
Total	-	-	-	63.8	0.74				
Chignik Lagoon[2]	-	3	15	41.8	0.13	46.7	2.04	-	

[1] Source: U.S.G.S. Topographic Maps, Chignik, Alaska (A2, A3, A4, B2, B3, B4), 1:63,360. 1963.

[2] Source: D. E. Phinney (personal communication). Area, depths, and volume calculated at mean high tide (7.9 ft).

area to volume ratio of Black Lake promotes rapid adiabatic heating, whereas the comparatively low ratio for Chignik Lake delays warming. The "growing season" is thought to commence in early April in Black Lake and mid-June in Chignik Lake (Narver 1966), although these approximate dates probably have changed in the past 10 years with the observed trend toward milder winter climate (Rogers 1980). Black Lake may lose up to one third of its total volume in dry summers and is subject to major changes in basin morphology due to siltation. Chignik Lake is considerably more stable in these characteristics.

The Chignik lakes were shown to be among the most productive of Alaska's sockeye nursery lakes by Burgner, et al. (1969). They reported that the system ranked first among 24 other nursery lakes in western Alaska in measurements of productivity and standing crop of phytoplankton (by area and volume), second in total dissolved solids, and second in the number of spawners per unit of lake surface area. Spawner densities since have increased by about 50% in both lakes.

Chignik Lagoon is an important secondary rearing area for post-smolt sockeye (Phinney 1968) and is the focus of commercial fishing activity during the adult return. A description of the lagoon is useful here because its physical properties strongly influence the operation of the fishery. The lagoon is 11.6 km long, about 2.5-3.5 km wide and has a surface area of 41.4 km^2 at high tide (Fig. 2). It is mostly very shallow and about half of its surface area is exposed at low tide. Dense Zostera beds provide excellent cover for the resident fauna (Narver and Dahlberg 1965), but restrict boat travel to a few channels. The dominance of tidal activity in the lagoon is revealed by the large tidal prism to river flow ratio (289), the high tidal exchange ratio (.57, indicating that over 50% of the volume of the lagoon is removed on the ebb tide), and the nearly complete mixing of salt water and freshwater (Phinney 1968). Tidal currents restrict times and locations at which fishing may be successfully conducted.

The physical confines of the lagoon limits the spatial distribution of migrating adults. Fish may congregate for up to several days in the relatively protected waters of the lagoon prior to moving upstream, a behavior commonly observed in the spawning migration of salmon. Its effect at Chignik can be spectacular, as the lagoon may become literally alive with several days' accumulation of adult sockeye before the first commercial harvest is announced. The "fish in a barrel" situation is conducive to intensive exploitation of the migration by most of the purse seine fleet. Up to 85% of the total harvest of sockeye salmon in the Chignik District normally is taken inside the lagoon or in adjacent waters outside the spit at the entrance.

Sockeye approaching the Chignik District are intercepted at Cape Igvak on the northeast boundary and at Stepovak Bay on the southwest boundary. Extremely limited data from tagging in the early 1960's indicated that about 80% of sockeye tagged at Cape Igvak and Stepovak Bay were recovered in the Chignik system. Fisheries at these locations are now regulated to a quota proportional to the Chignik sockeye catch.

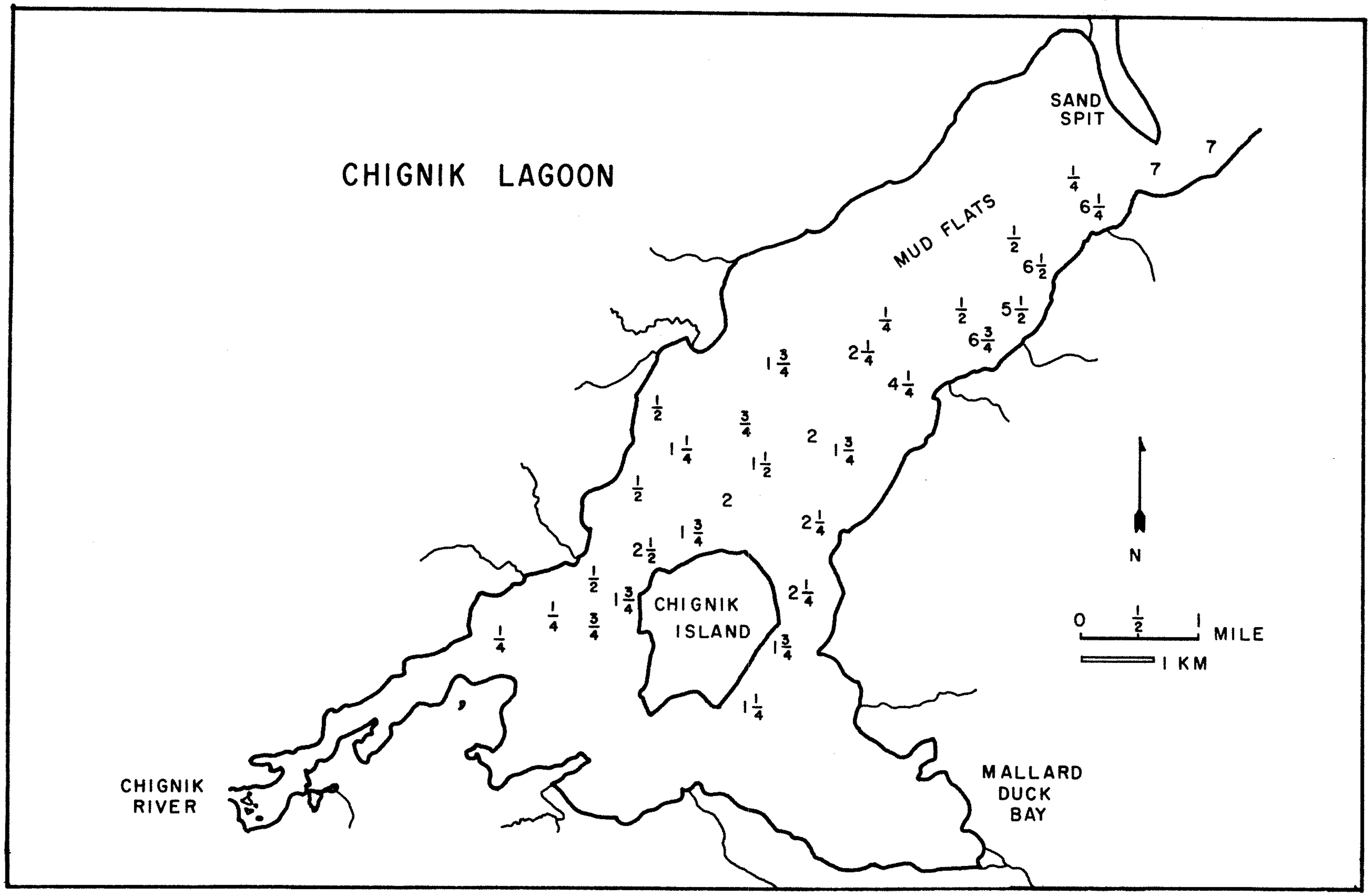

Fig. 2. Chignik Lagoon, Alaska. Depths in fathoms at mean lower low water (from Phinney, 1968).

Statistics in this report for the Chignik stocks include 80% of Cape Igvak catches, but do not include Stepovak Bay catches because they were extremely small during the period of this study and their reliability is difficult to assess.

REVIEW OF PREVIOUS RESEARCH

Commercial fishing began at Chignik in 1888 when a prospecting crew from the Fishermen's Packing Company returned to Astoria with tales of great abundance, and thousands of barrels of salted salmon to back them up. By 1897 the traps, seines, and gillnets employed in the fishery routinely captured over 1 million sockeye anually. Regulation of the harvest was virtually nonexistent until 1922, when a weir was constructed on the Chignik River to monitor escapements into the nursery lakes. The weir has been erected in all years since, except when budget restrictions or world war curtailed operations.

Early fisheries research consisted of routine scale sampling from the commercial catch of sockeye. Results of these initial studies are perhaps best summarized by the following passage:[1]

> "The problems relating to the red salmon of this river are proving to be of unusual complexity. The scales present irregularities that can not be interpreted with certainty until a detailed study has been made of the growth of the fingerlings and the development of their scales. The task of determining the number of fish of each age in the spawning migration is complicated by pronounced and irregular fluctuations in the age composition of the run at different times of the season. The study is further complicated by fluctuations in the time at which the bulk of the run is passing the commercial fishery. The run is in progress for approximately 20 weeks, but half or more of the fish may pass during a period of two weeks. This peak in the run may come as early as June or as late as August. The run is not always concentrated into a pronounced peak; in some cases it has remained quite constant for a period of 10 or more weeks."

The tone of this description is as valid today as it was in 1928. Much of the subsequent research in the system has attempted to resolve the "complexity" referred to above.

Investigations under the direction of Dr. C. H. Gilbert were expanded in 1928 to include studies of the freshwater life history of sockeye. It soon became apparent to the field project leader, Harlan B. Holmes, that more than a single "race" of sockeye returned to the Chignik system. Further research began to reveal differences in migratory timing, location of spawning grounds, length of freshwater residence by juveniles, and age at maturity (Higgins 1934). Unfortunately, budget restrictions were a fact of life then, as now, and detailed studies were curtailed after 1933. It would be 18 years before a sustained research project was resurrected at Chignik.

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[1] Higgins, E. 1930. Progress in biological inquiries, 1928. Page 645 in Report of the Commissioner of Fisheries to the Secretary of Commerce for the fiscal year ended June 30, 1929. U.S. Bureau of Fisheries.

Recent Research

Directed studies on the biology of sockeye salmon in the Chignik system were resumed by Fisheries Research Institute (FRI) at the request of the salmon canning industry, which had become alarmed at the declining trend in salmon production throughout Alaska in the early 1950's. Total returns of sockeye salmon to Chignik had by this time declined from an average of 2.8 million during the period 1922-1939 to an average of only 1.5 million between 1940 and 1955 (Dahlberg 1968). Initial studies were limited to the collection of routine fishery statistics and limited tagging experiments (Thorsteinson 1956). The project was expanded after 1955 to investigate the freshwater biology of sockeye. These studies attempted to relate the magnitude of smolt outmigrations to returns of adults (Roos 1958), and to identify major sources of mortality on the juveniles during lacustrine residence (Roos 1959, 1960a, 1960b). Cooperative studies with the Alaska Department of Fish and Game (ADF&G) were instituted in 1961 when ADF&G assumed management control of the Chignik fishery.

Major advancements in management of the sockeye resource resulted from comprehensive studies in the 1960's by Narver (1963,1966) and Dahlberg (1968). Narver (1963) confirmed the suggestion made some 30 years earlier by Holmes (1934) that the Chignik sockeye salmon migration is composed of two main segments which typically exhibit separate peaks of abundance in mid-June and mid-July. He found that "early run" fish are bound primarily for the Alec River/Black Lake nursery complex high in the watershed while "late run" fish are destined largely for the Black River/Chignik Lake complex (Figs. 3 and 4). During much of the season the two stocks mix in the fishery in varying relative proportions as the predominance of Black Lake-bound fish in the catch and escapement gradually shifts to a predominance of Chignik Lake-bound fish. However, he showed that these principal stocks actually are composites of four major and three minor substocks identified on the basis of time and location of spawning and lacustrine scale patterns (Table 2).

Two studies by Narver (1966) and Dahlberg (1968) were pivotal in the rehabilitation of Chignik sockeye stocks and remain the basis of the present management system. The objective of their research was to recommend escapement goals for each stock by 1) estimating the carrying capacity of each nursery lake for sockeye fry and calculating escapements needed to optimize fry densities; and 2) analyzing conventional spawner-recruit relationships from past years to recommend optimum escapements for each stock. The agreement in their recommendations is remarkable given the difference in methods used.

Narver's (1966) exhaustive study of the nursery lake ecosystem suggests that many aspects of the population dynamics of the stocks can be explained in terms of the effect of the physical environment on the freshwater ecology of juveniles. A pronounced stock-specific freshwater age composition probably results from the different conditions for growth of juveniles in the two lakes. Black Lake is extremely

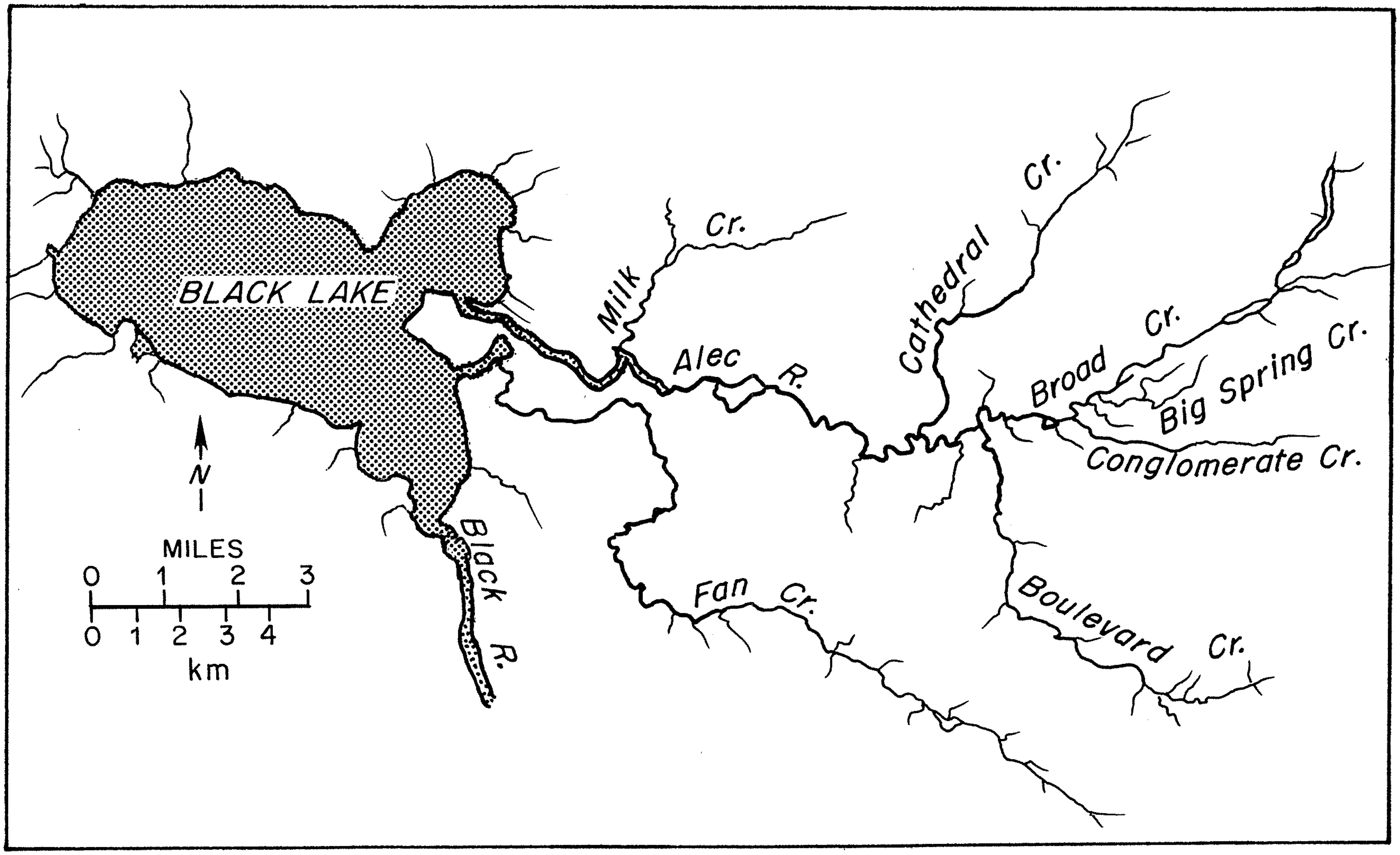

Fig. 3. Map of principal spawning tributaries and nursery areas utilized by the Black Lake stock.

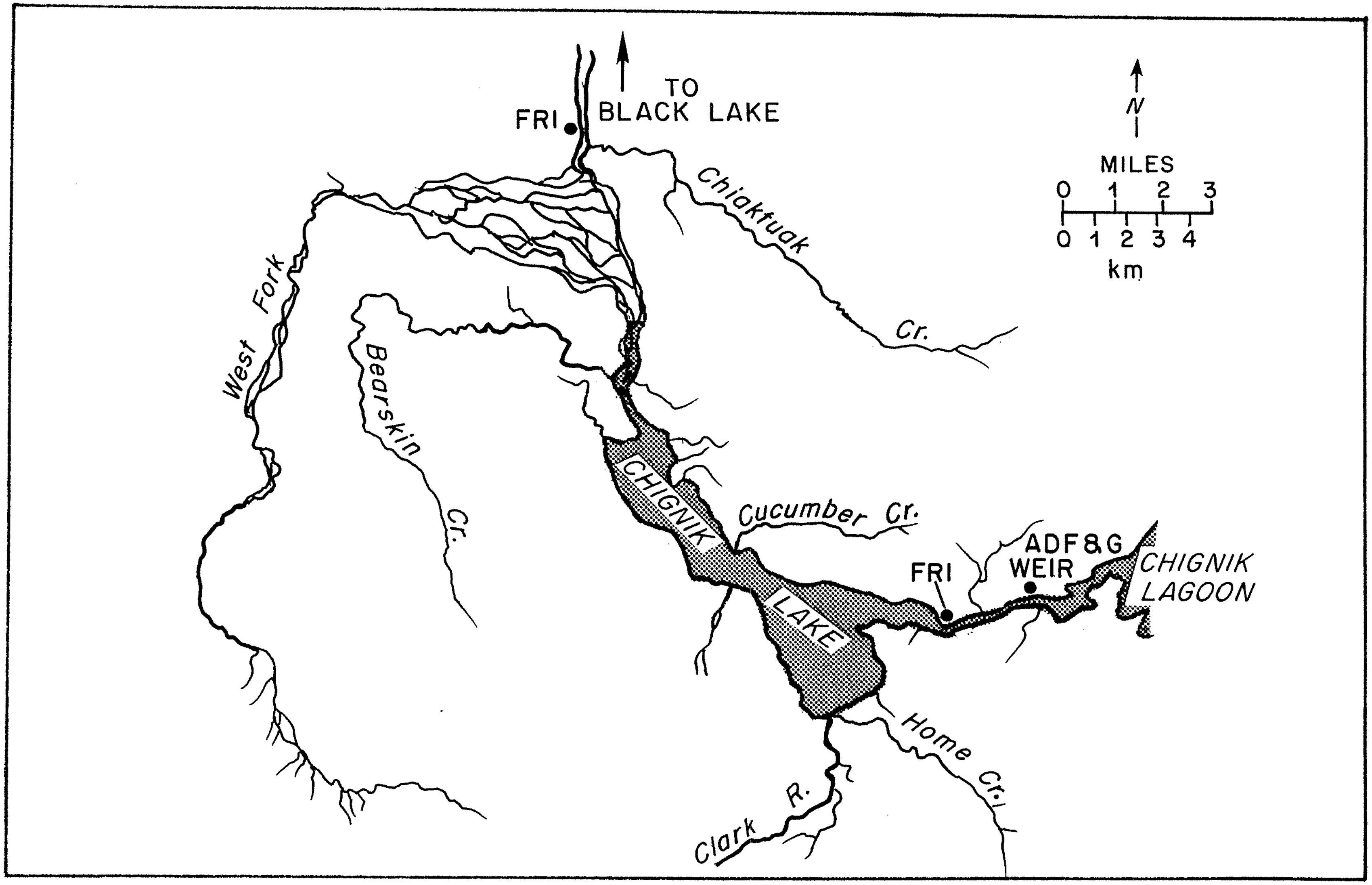

Fig. 4. Map of principal spawning tributaries and nursery areas utilized by the Chignik Lake stock.

Table 2. Characteristics of the spawning groups of Chignik sockeye salmon (adapted from Narver, 1963a).

Group	Lacustrine age	Time of entry	Spawning characteristics		Rearing area	Lacustrine scale	Importance
			Time	Location			
Black Lake (early)	I	6/10-7/6	7/25-8/20	Alec River system, Fan Creek	Black Lake	F_1 radius large	Major
Black River (early)	I	6/10-7/6	7/25-8/20	Upstream areas of West Fork, Chiaktuak, Bearskin Creek	Chignik Lake	F_1 radius small	Major
Black River (late)	I	6/20-8/10	8/20-9/20	Lower areas of Chiaktuak, Bearskin Creek	Chignik Lake	F_1 radius small	Minor
Black Lake (early)	II	6/10-7/6	7/25-8/20	Alec River system, Fan Creek	Black Lake and Chignik Lake	$F_1 + F_2$ count large	Major
Black River (early)	II	6/10-7/6	7/25-8/20	Upstream areas of West Fork, Chiaktuak, Bearskin Creek	Chignik Lake	$F_1 + F_2$ count small	Minor
Black River (late)	II	6/20-8/10	8/20-9/20	Lower areas of Chiaktuak and Bearskin Creek	Chignik Lake	$F_1 + F_2$ count small	Minor
Chignik Lake	I	6/20-9/20	8/20-11/15	Cucumber, Home, Clark Hatchery Beach	Chignik Lake	F_1 radius small	Major
Chignik Lake	II	6/20-9/20	8/20-11/15	Cucumber, Home, Clark Hatchery Beach	Chignik Lake	$F_1 + F_2$ count small	Major

turbid and relatively warm throughout the summer. The low volume and high turbidity likely restrict the production and consumption of zooplankton, thus forcing sockeye foraging toward consumption of high-quality prey such as emergent larval and winged adult insects (Narver 1966; Parr 1972). Chignik Lake is much less turbid, warms more slowly, and is relatively cooler throughout summer. Juvenile sockeye disperse to the limnetic area of Chignik Lake at about 30 mm length and thereafter feed primarily on zooplankton (Parr 1972). Studies on fish growth and age structure in the juvenile populations confirm that fry growth is accelerated in Black Lake and that holdover age I fingerlings are virtually absent, whereas growth is reduced in Chignik Lake and ages I and II fingerlings are common (Narver 1966; Marshall 1977). The differences in lacustrine growth and residence time are reflected in adult returns that may show characteristic fluctuations in freshwater age composition coinciding with the passage of each stock through the fishery. The Black Lake stock migration is composed primarily of age group 1.3[2], with ages 2.3, 1.2, and 2.2 less abundant. Chignik Lake stock are mainly 2.3 and 2.2 at return. Ages 1.3 and 1.2 rarely contribute more than 25% to Chignik Lake stock abundance (Conrad 1983). While quantitative data on age composition in the smolt migration are lacking, the freshwater age composition of returning adults normally shows that most survivors of the Black Lake stock migrated to sea as age I smolts and those from Chignik Lake were predominantly age II at seaward migration. This generalization is complicated by midsummer emigrations of age 0 fry from Black Lake into Chignik Lake (Roos 1958; Narver 1963). Presumably a fraction of Black Lake emigrants migrate from Chignik Lake as age I smolts and the rest migrate at age II. In some years, particularly those in which Black Lake stock abundance is weak, the percentage of 2.3's in the migration may exceed that of 1.3's.

As part of his work, Dahlberg (1968) devised a method for dividing historical abundance statistics into Black Lake and Chignik Lake stock components based on differences in their average migration timing. The transition from Black Lake to Chignik Lake stock in the fishery has been modelled since 1964 by a logistic time of entry (TOE) curve fit to data from tagging studies begun in 1962 (Fig. 5). Some features of the transition are consistent from year to year while others, such as the timing and rate at which the transition occurs, may show significant annual variation (Conrad 1983).

Researchers in subsequent years have become aware of the limitations of Dahlberg's method. Pedersen and Petersen (1971) pointed out that use of the curve is strictly appropriate only when the stocks are of approximately equal magnitudes. Parr and Pedersen (1969), Burgner and Marshall (1974), and Marshall and Burgner (1977) noted that age

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[2] European system of age designation: number of winters in freshwater, decimal point, number of winters at sea. Total age is the sum of years spent in freshwater and salt water, plus 1 year for that spent incubating in spawning grounds.

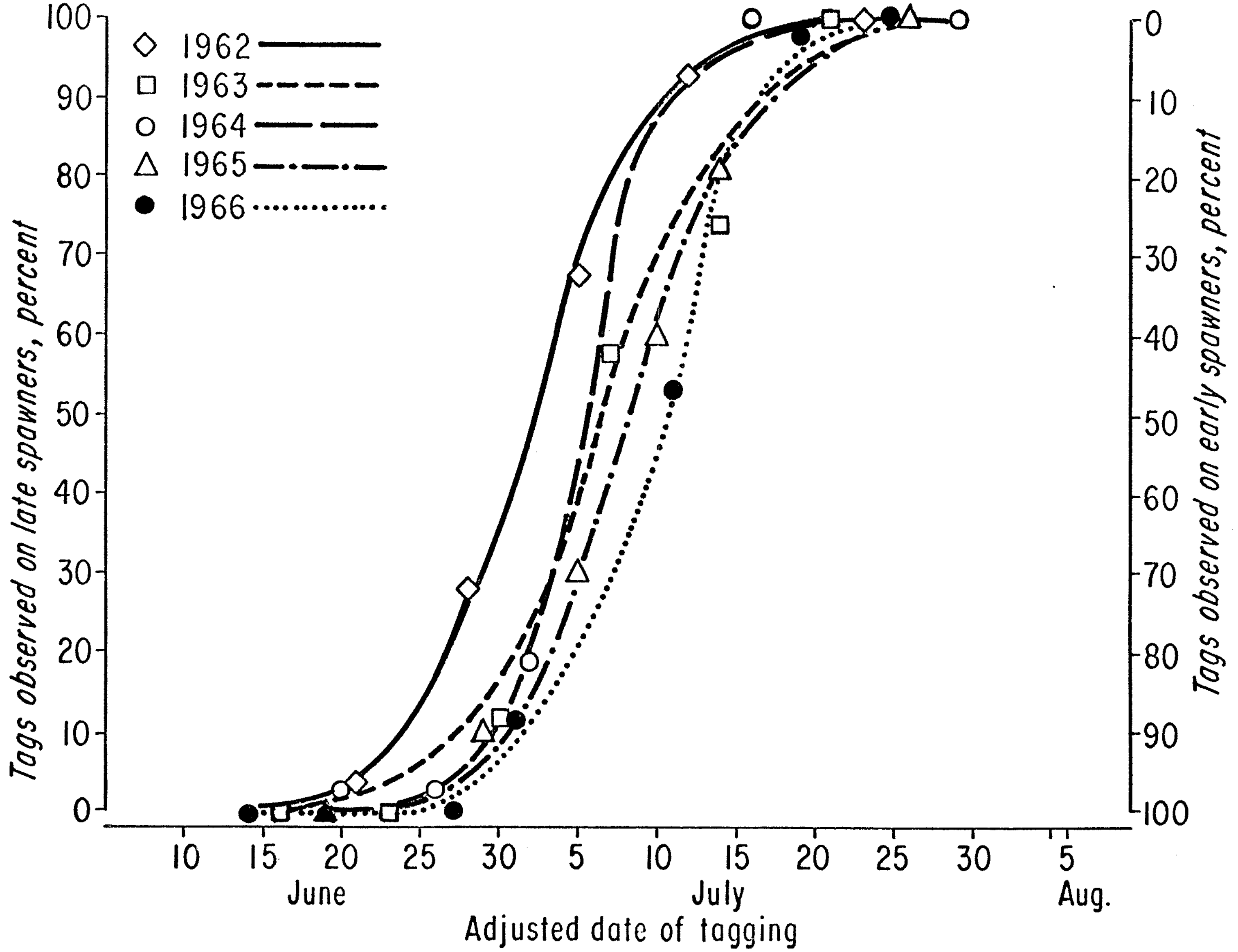

Fig. 5. Pattern of time of entry for Black Lake and Chignik Lake stocks, 1962-1966 (from Dahlberg, 1968)

composition statistics calculated for each stock from scale samples taken when the stocks mixed in the commercial fishery seldom resembled those calculated from samples taken on the spawning grounds. Additional errors in allocation to each stock were suspected to occur when the actual migration timing of the stocks varied from that predicted by the average time of entry curve.

Despite attempts to develop an alternative method for separating the stocks in the migration (Marshall and Burgner 1977), no satisfactory substitute was found until Marshall et al. (1980) reported the results of a stock separation experiment using scale growth patterns and discriminant function analysis. Their favorable results stimulated further research on the application of scale pattern analysis as a management tool to be used in-season for determining the relative proportions of each stock present in the catch and escapement on a daily basis. The results of this major study (Conrad 1982, 1983) clearly established the superiority of the method for providing reliable stock composition statistics for the Chignik sockeye catch and escapement. Catch, escapement, and age composition by stock have been recalculated for adult returns since 1977, and intraseason stock separation programs based on scale pattern analysis have provided real-time stock composition data since 1981 to aid in management decision-making.

The common objective of the studies outlined above has been to optimize the distribution of spawners among the spawning grounds of the two nursery lakes in the system. However, the intent to optimize implies the ability to control the process whereby optimization occurs. Effective control of a dynamic process, such as the spawning migration of salmon, requires the ability to both determine the status of the process, and predict its course. The body of research reviewed above relates almost exclusively to evaluating the status of the fishery on a daily basis. There exists no management tool whereby the fishery manager may anticipate stock abundance and timing, especially since early escapement counts may not accurately reflect the arrival and pooling of fish in Chignik Lagoon. Since up to 50% of the desired number of Black Lake spawners may surge past the weir in a period of 48 hrs, the fishery manager easily may "fall behind" with respect to controlling the distribution of escapements from all time segments. Misjudgement of abundance has resulted in large surplus escapements that represent not only lost revenue to the fishing industry, but also possibly severe burdens on the nursery lake forage base. The objective of this study is to provide the Chignik fishery manager with methods to anticipate the availability of harvestable salmon during the season so that the probability of occurence of such events is minimized.

METHODS AND MATERIALS

Pre-season Forecast Models

The abundance of returning adult salmon in year i is the product of potential brood strength times the fraction of the brood maturing in year i summed across all broods contributing to the stock migration in year i. The brood maturity schedule, which relates the mean number of age j-1 fish that return in year i-1 to the mean number in the brood that return at age j in year i, is widely used for predicting the abundance of salmon and steelhead one year in advance. Previous forecast models for Chignik sockeye salmon employed linear regression analysis to quantify the relationship between returns of sibling 2-ocean and 3-ocean age fish. However, this simple bivariate explanation for the observed variability in abundance of 3-ocean age fish proved to be inadequate in many years. A multivariate analysis was planned to consider a set of variables that are likely to be covariates of the potential strength and maturity rate of broods contributing to total abundance in a given year. Multiple regression analysis was the logical tool for investigating the relationships among these variables.

Since attempts to forecast abundance of a composite Chignik stock have met with little success, stock-specific data sets were compiled from fishery statistics published in ADF&G Area Management Reports for the years prior to 1978 and from Conrad (1983, 1984) for the years 1978-1983, from Fisheries Research Institute sampling records, and from NOAA air and water temperature data recorded at Woman's Bay, Kodiak Island. The dependent variable in each case was total abundance of 3-ocean age adults in year i, and the set of independent variables included:

1. Escapement in year i-5 (ESCP5).
2. Escapement in year i-6 (ESCP6).
3. Number of 1.2 jacks returning in year i-1 (AGE12).
4. Number of 2.2 jacks returning in year i-1 (AGE22).
5. Number of 2-ocean fish returning in year i-1 (AGEX2).
6. Mean length of 1.2 males in year i-1 (ML12M).
7. Mean length of 2.2 males in year i-1 (ML22M).

The potential impact of environmental variability on brood production (e.g., egg-to-fry survival) and maturity schedule (cf. Rogers 1980) was represented by five climatic variables:

8. Mean air temperature at Kodiak in the winter (Nov-Mar) prior to emergence (MAIRT).

9. Mean winter (Nov-Mar) sea surface temperature at Women 's Bay in years i, i-1, i-2, i-3 ($SSTEM_i$).

Data sets dating to 1964 were submitted to a stepwise multiple regression computer program in Minitab[3] which fit the data to the generalized model:

$$\hat{Y} = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_i x_i + e$$

where

$\hat{Y}$ = predicted value of the dependent variable
α = intercept of the regression
$\beta_1, \beta_2, \beta_i$ = regression coefficients
x_1, x_2, x_i = independent (predictor) variables
e = random error

Variables entered the model sequentially until a user-defined minimum significance level prevented further inclusion. I arbitrarily limited inclusion of variables to those that explained ≥ 5% of the variance in the model.

Variances on predictions of 3-ocean returns were computed by the matrix inversion technique in Draper and Smith (1966, p.121) for multiple linear regression models:

let M1 = the inverse of the transpose of the correlation matrix, $(X'X)^{-1}$
M2 = the vector of predictor values
M2'= the transpose of M2.

The variance of the predicted Y is approximated as:

$$\mathrm{Var}(\hat{Y}) = \mathrm{MSE}(M3 \times M2')$$

where M3 = (M2 X M1) and MSE is the mean square error of the regression model.

The forecast of total returns of the major ages in year i was obtained by adding the predictions for 3-ocean and 2-ocean returns. Returns of 2-ocean age fish in year i cannot be predicted accurately, so the expected return of this age class was simply the mean return for all years in the data set. A prediction interval on the total return was constructed by pooling variances for the estimates of 3-ocean and 2-ocean returns and multiplying the pooled standard deviation by the appropriate "t" value for 80% confidence.

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[3] Minitab Project, Statistics Department, 215 Pond Laboratory, The Pennsylvania State University, University Park, Pa. 16802.

Description of Migratory Timing

The examination of migratory timing for purposes of intraseason forecasting is essentially an examination of interannual variability in migration patterns. The degree of variability in timing and rate of arrival obviously limits the accuracy of a forecast system which incorporates these characteristics to predict the distribution of abundance over time. Since a fishery is a human activity (Royce 1983), it is well to note that the expression of migratory behavior is likely to be moderated by exogenous factors such as the time distribution of fishing effort (Leggett 1977) or climatic factors (Mundy 1982; Clark 1983). Therefore, much of the following analysis is intended to describe both the degree of variability in annual migration patterns and its effect on intraseason forecasting.

Migratory timing characteristics of the Chignik sockeye migration were described using techniques suggested by Mundy (1979; 1984). In following discussions, migratory timing refers to the abundance of fish as a function of time measured at a fixed geographic location. The migratory time density is defined as the probability distribution of abundance as a function of time, also at a fixed geographic reference point. The migratory time density function specifies the expected proportion of the total migration arriving in a fixed time interval. When each observation is the sum of expected proportions for the current and all preceding time intervals, the time series is termed the cumulative time density distribution.

Total abundance in Chignik Lagoon by julian day of the migration was calculated as the catch on day t plus the escapement on day t+1. Although Dahlberg (1968) reported a skewed distribution of travel times for fish tagged in the lagoon and used a modal value of 2 d for his time of entry studies, Conrad (1983) noted a stronger correlation between lagoon catch and escapement on the following day than for lagoon catch and escapement 2 d later. Parker and Rogers (1984) also assumed a 1-d migration delay, but they suggested that violations of this assumption were at least partly responsible for occasional bizarre estimates of daily catch rate calculated for the commercial harvest of sockeye in Chignik Lagoon. Complex models of migration delay (Schnute and Sibert 1983; Brannian 1982) were judged to be of little value because many of the assumptions required in these models cannot be justified in the present case.

Mundy (1979) defined migration timing as a conservative behavioral phenomenon specific to Mendelian populations and suggested that annual variability in the timing of some migrations may reflect variability in the relative timing and abundance of individual populations present in the composite stock. Given the potential for errors in stock allocation described previously for the average TOE curve, it was decided that a potential source of variabilty in migration timing could be reduced by using only stock abundance estimates derived from scale pattern analysis. The data set for this analysis consequently was limited to the years 1978-83, inclusive, because the Black Lake and

Chignik Lake stocks were separated in these years by scale pattern analysis (Conrad 1983,1984).

Estimates of total daily abundance were reduced to major stock using stock composition information supplied by scale pattern analysis. The midpoint in the transition from the Black Lake stock to the Chignik Lake stock was identified from stock composition data in Conrad (1983, 1984). The corresponding date was fixed as the inflection point of a logistic curve modeling the transition:

$$P_t = 1/[1 + e^{-(a+bt)}]$$

where P_t = proportion of Chignik Lake stock on julian day t. Estimates of relative mixing proportions of each stock were applied to estimates of total daily abundance to provide estimates of stock abundance by day. Note that estimates of stock abundance calculated in this manner do not coincide exactly with those in Conrad (1983, 1984).

Estimates of Chignik Lake stock abundance were increased to account for incomplete weir counts of the late season sockeye escapement. Chignik weir typically is dismantled early in August when daily escapements fall below 1,000 for several days (Pedersen, pers. comm.). Subsequent daily escapements are assumed to add 50,000 to cumulative escapements over the remainder of the migration. However, Parker and Rogers (1984) argued that large fluctuations in catch of sockeye in Chignik Lagoon during August and early September probably reflect similar fluctuations in the uncounted escapement. Their analysis, based on a relationship between CPUE and total abundance, showed that estimates of escapements to the Chignik Lake stock routinely exceed twice the presumed 50,000 figure and occasionally exceed three times that number. Estimates of late season sockeye escapements given in Parker and Rogers (1984) therefore were added to the Chignik Lake stock abundance estimates calculated above.

The migratory timing of each stock was quantified by the method of moments as described in Mundy (1984). The first moment is the mean, or central date of the migration, and it is estimated by $\bar{t}$:

$$\bar{t} = \sum_{t=1}^{m} tf_t$$

where $f_t = n_t/N$, n_t is abundance on time interval t (defined for this case as 1 day), and N is total abundance. The second moment about the mean, the variance, measures the dispersion of the migration about its central date. The variance is estimated as:

$$S^2 = \sum_{t=1}^{M} (t-\bar{t})^2 f_t$$

Large values of S^2 indicate a prolonged migration and small values indicate a highly concentrated migration.

Interannual variabilty in migration timing was assessed by comparing means of annual time density distributions against the grand mean of a years-pooled average. The grand mean for all years is given by:

$$\bar{\bar{t}} = \sum_{i=1}^{k} \bar{t}_i/k$$

where $\bar{t}_i$ is the mean date of migration in year i of k many years.

Annual mean dates of migration were characterized against the grand mean and its confidence interval:

$$\bar{\bar{t}} \pm b_{\alpha,k-1}(s^2\bar{\bar{t}}/k)^{\frac{1}{2}}$$

where b denotes values of Student's "t" distribution with α, k-1 degrees of freedom and $s^2\bar{\bar{t}}$ is the variance of the grand mean.

Interannual variability in the shape of empirical time density distributions was examined by comparisons of annual time densities against a years-pooled average. Comparisons were facilitated by use of the coefficient of variation (CV) because it is independent of the units of observations, i.e. the standard deviation is expressed as a fraction of the mean for both numerical and proportional data.

A last comparison was designed to reveal the nature of distortions in the migratory time density which, in many salmon migrations, approximates a normal distribution (Mundy 1979). Exogenous factors, such as the time distributions of fishing effort or climatic effects, can modify the perceived shape of the migratory time density distribution. Effects of these unmeasured factors were examined by comparing empirical time density distributions against normal probability density distributions having identical parameter values. The proportions of a normal probability distribution having parameters t and s^2 were obtained from the equation for a normal curve:

$$N(\bar{t},s^2;t) = 1/s\sqrt{2}\pi \,[\exp^{-[.5[(t-\bar{t})^2/s^2]]}]$$

where N represents the normal curve and $\bar{t}$, s^2 are the mean and variance.

Discrepancies between observed and theoretical distributions were described quantitatively by the likelihood function

$$L_i = \sum_{t=1}^{m} f_t \log[f_t/F_t]$$

where f_t is an observed value and F_t is expected. The function, L_i, is an information function associated with frequency data (Rao 1973; Zar 1974) which takes the value of 0 only when observed counts f_t agree exactly with expected counts F_t for each interval t. Larger values of L_i indicate greater departure from the hypothesis that counts f_t and F_t come from the same distribution of counts in the time domain. However, Rugolo (1984) pointed out that goodness-of-fit tests of the two distributions are not meaningful because the large sample sizes for these comparisons, wherein n = total abundance, produce overly-sensitive test statistics which invariably are rejected. The relative magnitudes of the L_i between years nonetheless are useful comparative statistics for observing the degree of distortion in theoretical time density distributions.

Intraseason Forecasting

Two systems of intraseason forecasting based on the migratory behavior of Chignik sockeye were evaluated in reconstructions of the sockeye migrations during 1978-83, inclusive. The logic of the APC model is expressed in the statement, "If the pre-season forecast for year i is correct and migration timing is average, then the cumulative total by day t should be $n_{t,i}$." The mathematical expression of the model is:

$$\hat{n}_{t,i} = \hat{N}_i \bar{p}_t$$

where

$\hat{n}_{t,i}$ = predicted cumulative abundance on day t in year i.

$\hat{N}_i$ = pre-season forecast of total abundance for year i.

$\bar{p}_t$ = mean cumulative proportion of the abundance on day t for all years; $\bar{p}_t = \sum_{i=1}^{k} p_{t,i}/k$.

The following recursive equation represents the IPF model:

$$\hat{N}_{t+1,i} = \bar{N}_{t+1} + b_{t+1}[N_{t,i} - \bar{N}_t]$$

in which

$\hat{N}_{t+1,i}$ = predicted cumulative abundance for interval t+1 in year i.

$\bar{N}_{t+1}$ = average observed cumulative abundance on interval t+1.

b_{t+1} = regression coefficient for relating cumulative abundance at interval t+1 to that at interval t;

$N_{t,i}$ = observed cumulative abundance at interval t in year i.

$\bar{N}_t$ = average observed cumulative abundance at interval t.

The method uses either numerical or proportional data, but use of proportional data in real time requires that day 0 of the migration be identified in terms of an arbitrary proportion, say 5% of total, which cannot be known with certainty until after the migration is completed. Since most fishery managers operate with numerical rather than proportional data, the model is demonstrated using estimates of fish abundance to facilitate interpretation.

Parameter values of the IPF model were taken from the results of the preceding section on migratory timing. The relationship between cumulative abundance on time period t and that on time period t+1 in all years was quantified by linear regression to provide estimates of b_{t+1} for the model. Time periods were 5-day intervals, judged to be adequate lead time for harvest control decisions while being short enough to closely monitor the development of incoming migrations.

Performance Evaluation

Performance of the forecasting methods was assessed by comparing the magnitude of residuals generated in the forecasting process. A jacknife validation procedure was used to determine the reliability of the pre-season forecast models in hindcasting stock abundances for years in the data sets. The jacknife procedure sequentially omitted a year of data, recalculated the model coefficients, then predicted abundance in the omitted year from the derived model. This approach simulates actual forecasting conditions, in which parameter values have not been biased by inclusion of the same data from which the forecast is made.

The accuracy of a forecasting system traditionally is expressed as the ratio of residuals to predicted values or, in other words, the proportion by which observation diverges from prediction. Barth (1984) suggests such a statistic for evaluating forecasting error because it allows precision bounds to be computed for predictions. However, this statistic, absolute percentage deviation (APD), may produce misleading results in comparisons of performance between different forecasting systems because a forecast model that produces high predictions, relative to observation, will have a lower APD than a model that produces low forecasts of the same observation even if the absolute error is identical for both. Residuals in predictions from the APC and IPF methods therefore were standardized against observation, and relative performance was judged by the absolute percentage error (APE) in paired comparisons. The APE is calculated simply as:

$$APE = 100\ |e_t|\ /N'_t$$

where

$e_t = \hat{N}_t - N'_t$.

$\hat{N}_t$ = predicted cumulative abundance on interval t.

N'_t = observed cumulative abundance on interval t.

Comparisons of overall performance between forecasting systems utilized the mean APE (MAPE), where

$$MAPE = [100/(k-1)] \sum_{i=1}^{k} e_{t,i}/N'_{t,i}$$

and k is the number of years in the record. As with interpretation of APE, small values of MAPE indicate better performance than do large values.

RESULTS

Pre-season Forecasts

Multiple linear regression analysis of Black Lake and Chignik Lake data sets indicated that returns of 3-ocean age sockeye (coded name AGEX3) are predictable from several parameters of brood production (Table 3). The Black Lake model provided a substantially better fit to observed data than did the Chignik Lake model. The models are considered separately below.

The first variable to enter the Black Lake model was the return of 1.2 age jacks in the previous year (AGE12). This relationship, termed the "jack ratio" rather than the "sibling ratio" used elsewhere, explained about 72% of the variability in abundance of 3-ocean (5- and 6-year-old) fish. A high coefficient of determination (r^2) despite a high degree of variability in AGE12 (CV = .8834) suggests a strongly linear relationship in the brood maturity schedule for this stock of fish.

The second variable to enter the regression model was escapement in year i-5 (ESCP5). Approximately 77% of the variabilty in returns of 3-ocean fish was explained by inclusion of both ESCP5 and AGE12. ESCP5 indexes the potential production of broods maturing primarily as 1.3 adults. The fact that variability in returns of all 3-ocean age fish is correlated with escapements for only the 1.3 component suggests that variability in stock abundance is determined largely by the production of 1.3's in Black Lake. Abundance of 1.3 adults ranged from about 99,000 in 1972 to about 1.6 million in 1982, whereas returns of 2.3 adults were relatively constant and ranged from about 64,000 in 1966 to unusually large returns of about 444,000 in 1977 and 587,000 in 1978.

Inclusion of mean length of 1.2 males (ML12M) completed model development and increased to roughly 83% the amount of variability in AGEX3 explained by the regression model. The negative sign of the regression coefficient supports the underlying hypothesis that larger body size of 2-ocean age fish in year i-1 indicates that a larger fraction of the brood matured as 2-ocean rather than as 3-ocean fish. The influence of ML12M in the model therefore is to adjust the jack ratio in the direction indicated by body size of jacks in the previous year.

Statistics for the distributions of variables in the model reveal no major departures from normality (Table 4). The distributions of AGE13 and AGE12 are marginally platykurtotic, indicating that the tails of these distributions are somewhat heavier than those of a normal distribution. Positive skew in the distributions suggests that the bulk of measurements are smaller than the mean value. However, the distribution of AGEX3 is neither strongly skewed nor kurtotic. Coefficients of variation show that more of the variability in AGEX3 is attributable to AGE13 than to AGE23.

Table 3. Summary of regression analysis of Black Lake and Chignik Lake stock data sets.

	Black Lake stock			Chignik Lake stock		
Step Number	Variable Entered	Coefficient	r^2	Variable Entered	Coefficient	r^2
0	Intercept	2369400		Intercept	338800	
1	AGE12	8.358	72.3	AGEX2	2.75	52.9
2	ESCP5	0.849	76.6			
3	ML12M	-4.74	83.2			

Table 4. Statistics of the distributions of variables in the Black Lake stock pre-season forecast model.

Variable	Mean	St. Dev.	CV	Skewness	Kurtosis
AGE13	544308	427261	0.785	1.026	0.241
AGE23	221641	124999	0.564	0.769	-0.5502
AGEX3	765949	432432	0.565	0.642	-0.556
AGE12	38607	34106	0.883	1.076	0.526
ESCP5	372882	157761	0.423	0.124	-1.031
ML12M	481.6	27.3	0.057	0.777	-0.869

Performance of the Black Lake model in hindcasting total returns in previous years is demonstrated in Figure 6. Prediction intervals ranged from 254,724 to 337,218. Absolute errors on jacknifed forecasts ranged from 1,666 to 894,363 and fell outside the prediction interval on 2 of 17 predictions. Absolute percent deviation was less than 40% in all but 4 cases and less than 20% in all but 5 cases. Mean absolute percent deviation for the 17 years examined was 24.6%.

Examination of residuals showed no evidence of bias in the regression model (Fig. 7). A runs test (Zar 1974) indicated that errors were distributed randomly with respect to sign. The absence of a trend in residuals implies that the assumption of linearity in parameters is valid for the model. An approximately normal distribution of standardized residuals (Durbin-Watson statistic = 1.62) suggests that errors are not serially correlated.

The Chignik Lake data set produced a less satisfactory forecast model. The jack ratio again proved to be the most significant predictor of 3-ocean returns, but no other relationship among the variables of Chignik Lake stock production attained the minimum significance level specified in the stepwise regression program. Approximately 53% of annual variability in returns of 3-ocean age sockeye was explained by variability in 2-ocean age jacks.

Performance of the Chignik Lake model in hindcasting total returns is shown in Figure 8. Prediction intervals ranged from 411,458 to 511,742. Forecast error ranged from 18,827 to 699,710 and fell outside prediction intervals on 4 of 20 predictions. Absolute percent deviation was less than 50% in 14 cases, less than 30% in 10 cases, and less than 20% in 7 of 20 cases. Mean absolute percentage deviation was 42.0%

A runs test of the apparent trend in sign of residuals over time (Fig. 9) failed to reject the hypothesis of random dispersion. Since the residuals plot (Fig. 10) suggested heteroscedasticity, independent variables were $\log_e$-transformed to normalize the variance of measurements and the analysis was repeated. Performance of the Chignik Lake model was not substantially improved by incorporating log-transformed data (Table 5).

Migratory Timing

Adult sockeye salmon were counted as early as May 21 to as late as September 30 during the years analyzed. Extremes in stock abundance during these years of about 1.5 million in 1980 to about 3.2 million in 1983 include all statistical sub-districts and estimated interception catches of Chignik-bound sockeye at Cape Igvak and Stepovak Bay. Stock sizes computed for this analysis (Table 6) do not include catches outside statistical sub-area 271-10, which includes Chignik Lagoon and adjacent waters, because catches in these outside fisheries may include sockeye bound for systems other than Chignik.

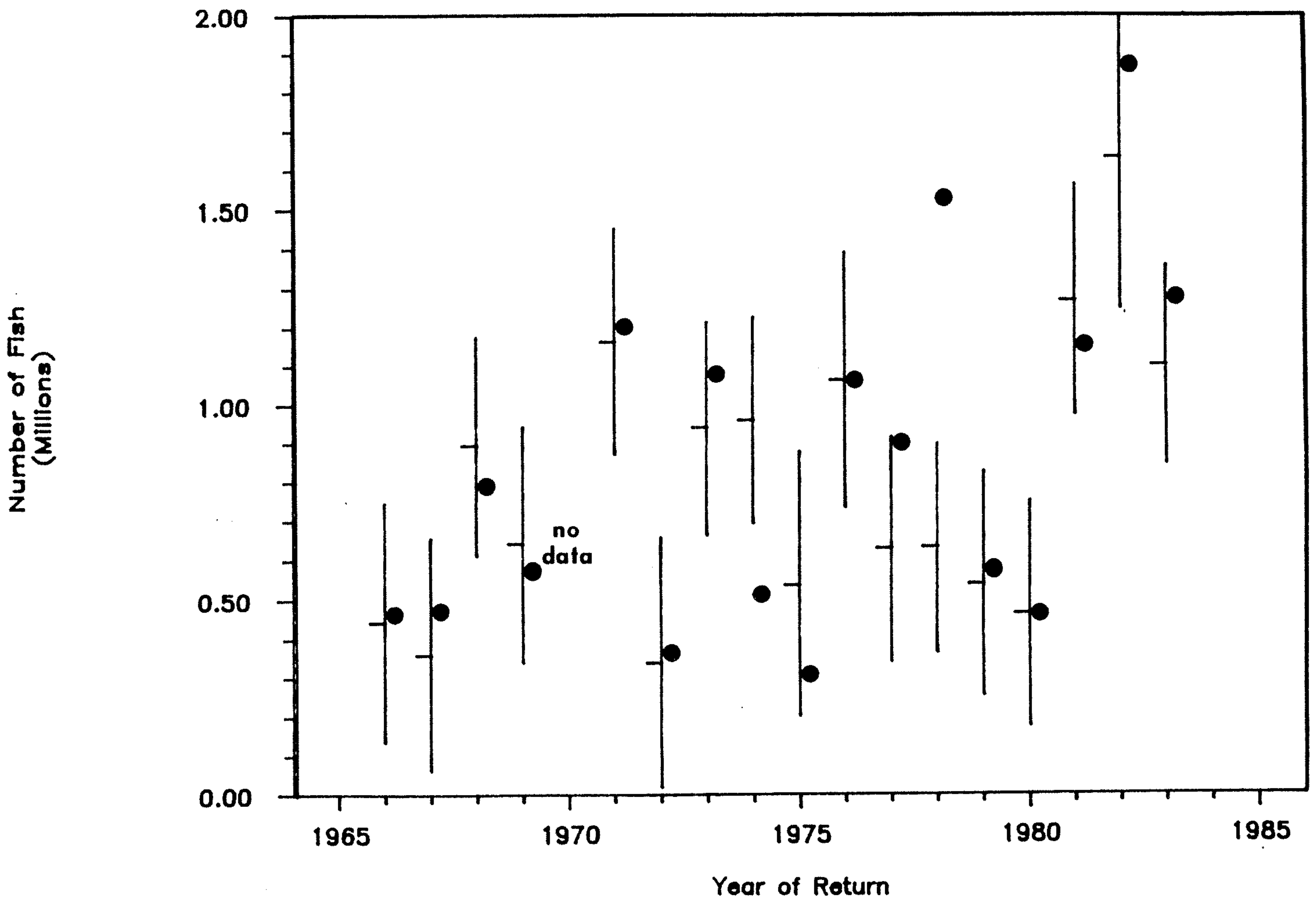


Fig. 6. Performance of the Black Lake stock forecast model in jacknifed hindcasts of stock abundance. Vertical bars represent 80% prediction intervals, circles indicate observed values.

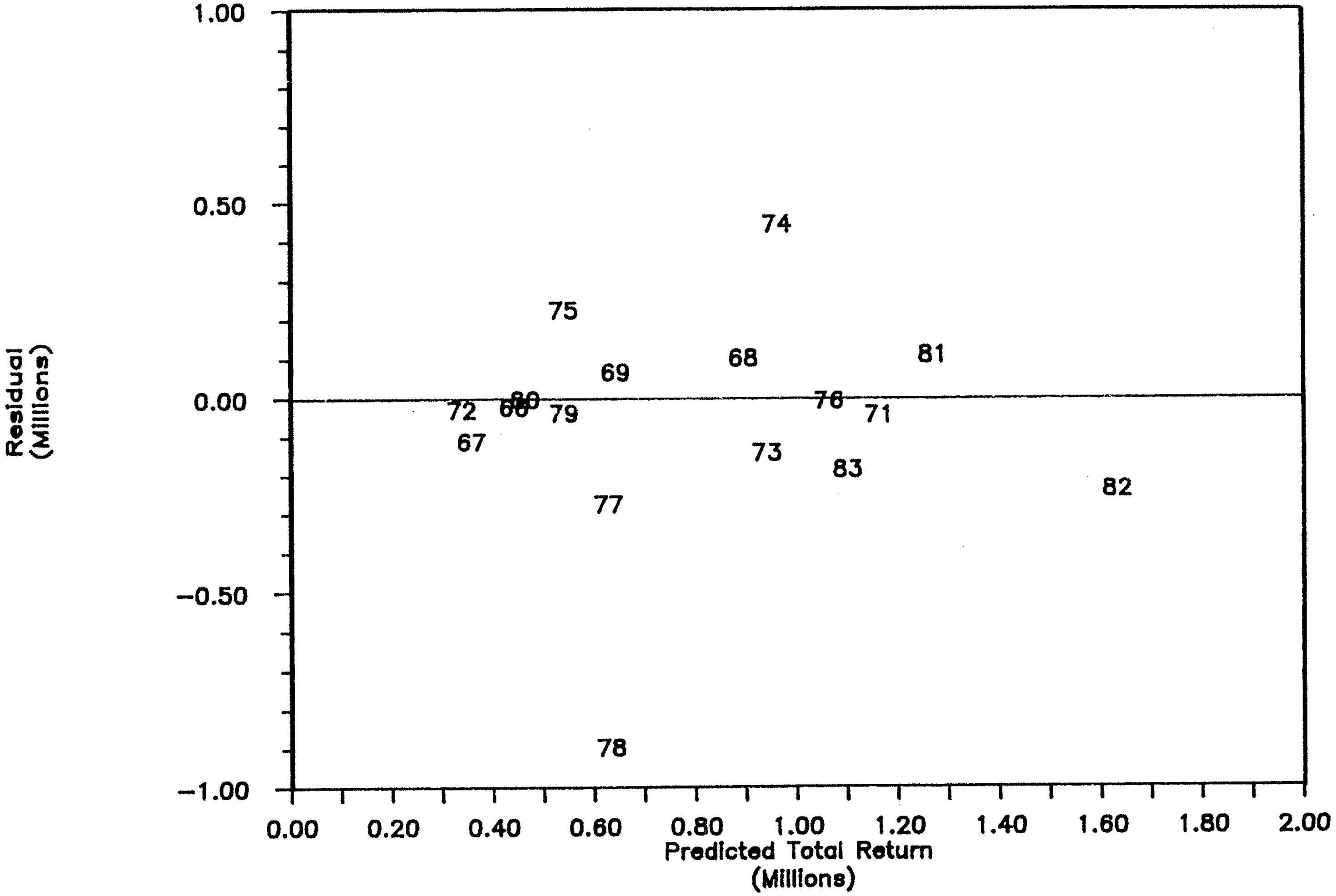


Fig. 7. Residuals plot for the Black Lake stock pre-season forecast model. Numbers indicate year of return.

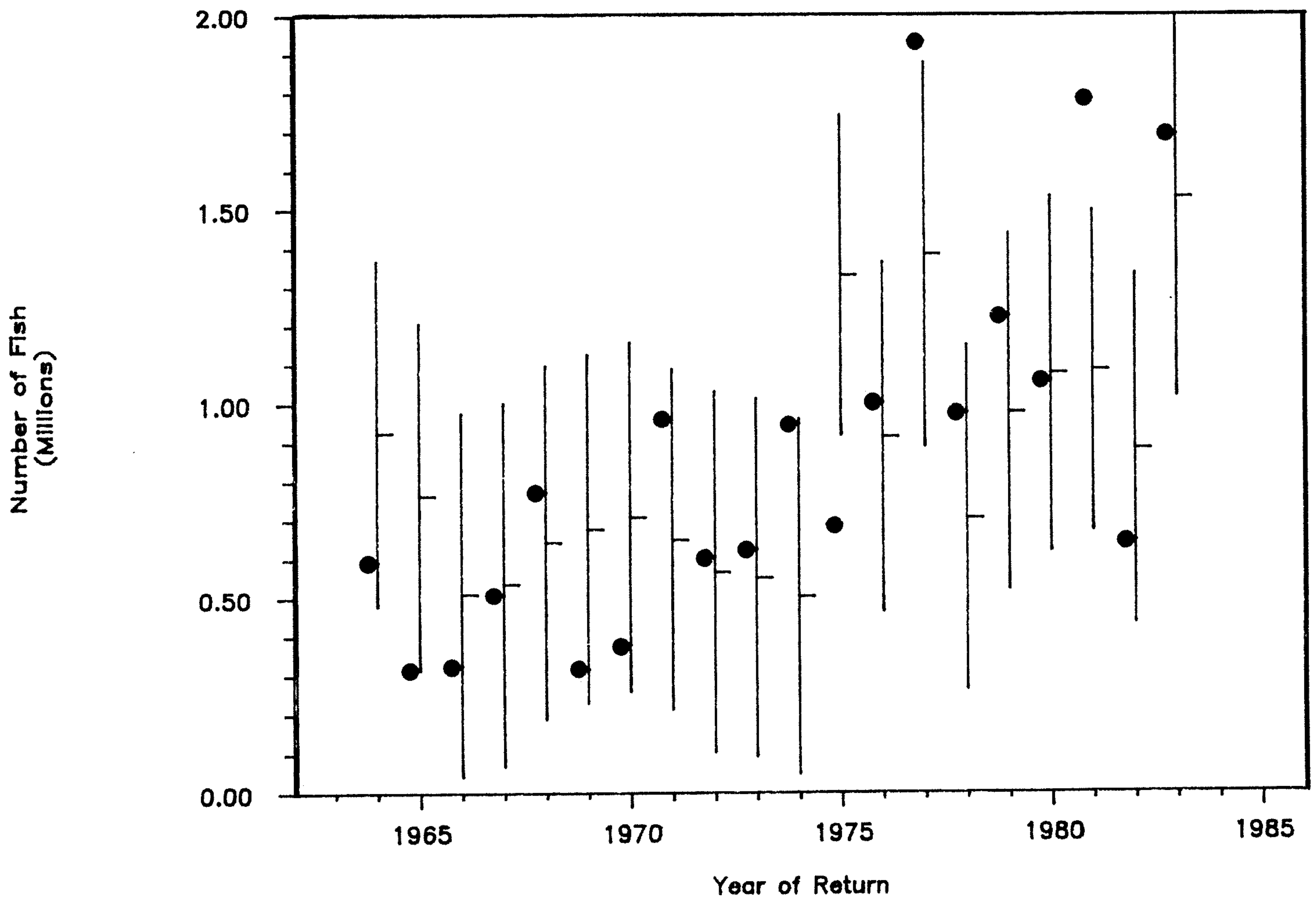


Fig. 8. Performance of the Chignik Lake stock forecast model in jacknifed hindcasts of stock abundance. Vertical bars represent 80% prediction intervals, circles indicate observed values.

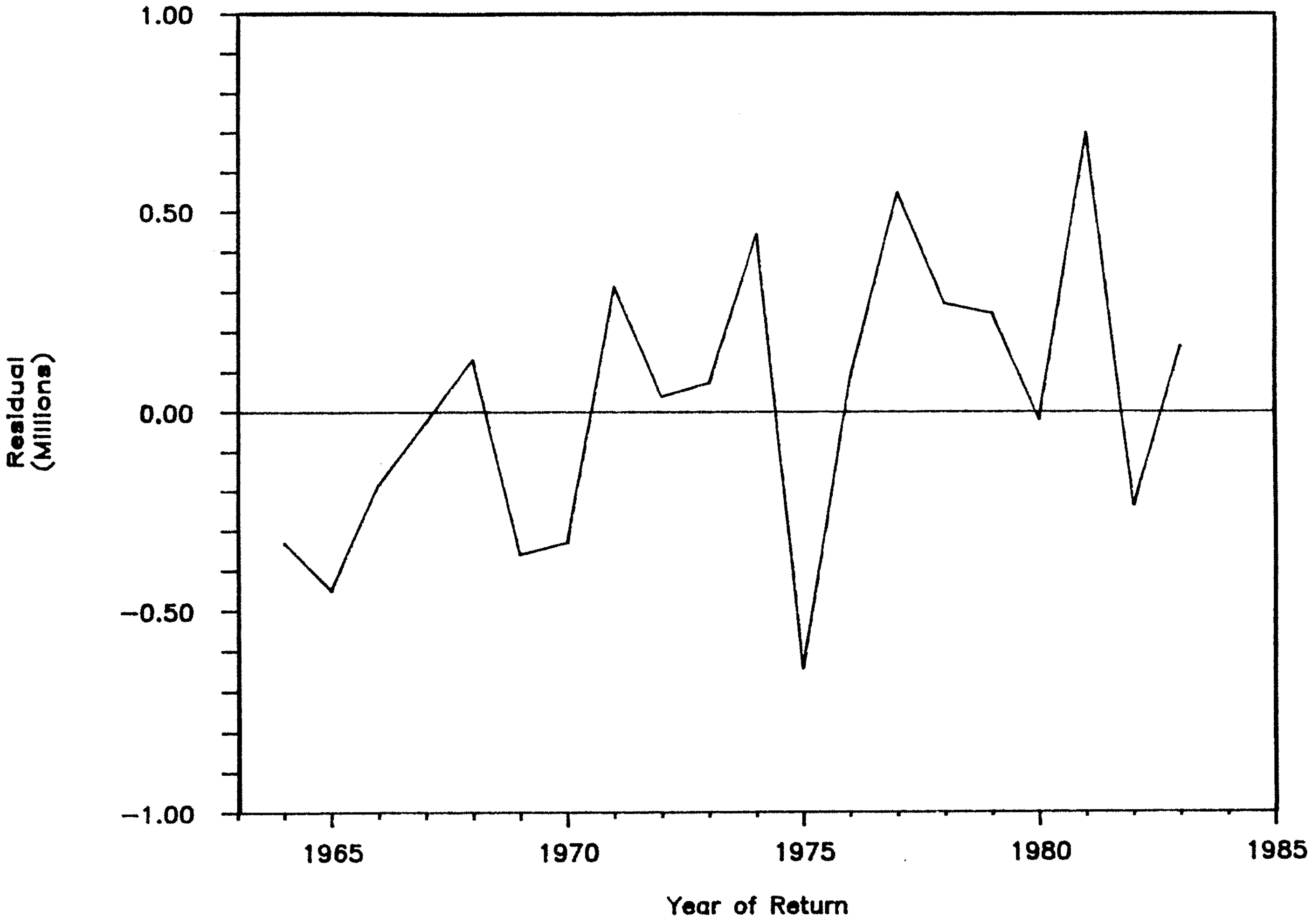


Fig. 9. Trend in residuals from the Chignik Lake stock forecast model over time.

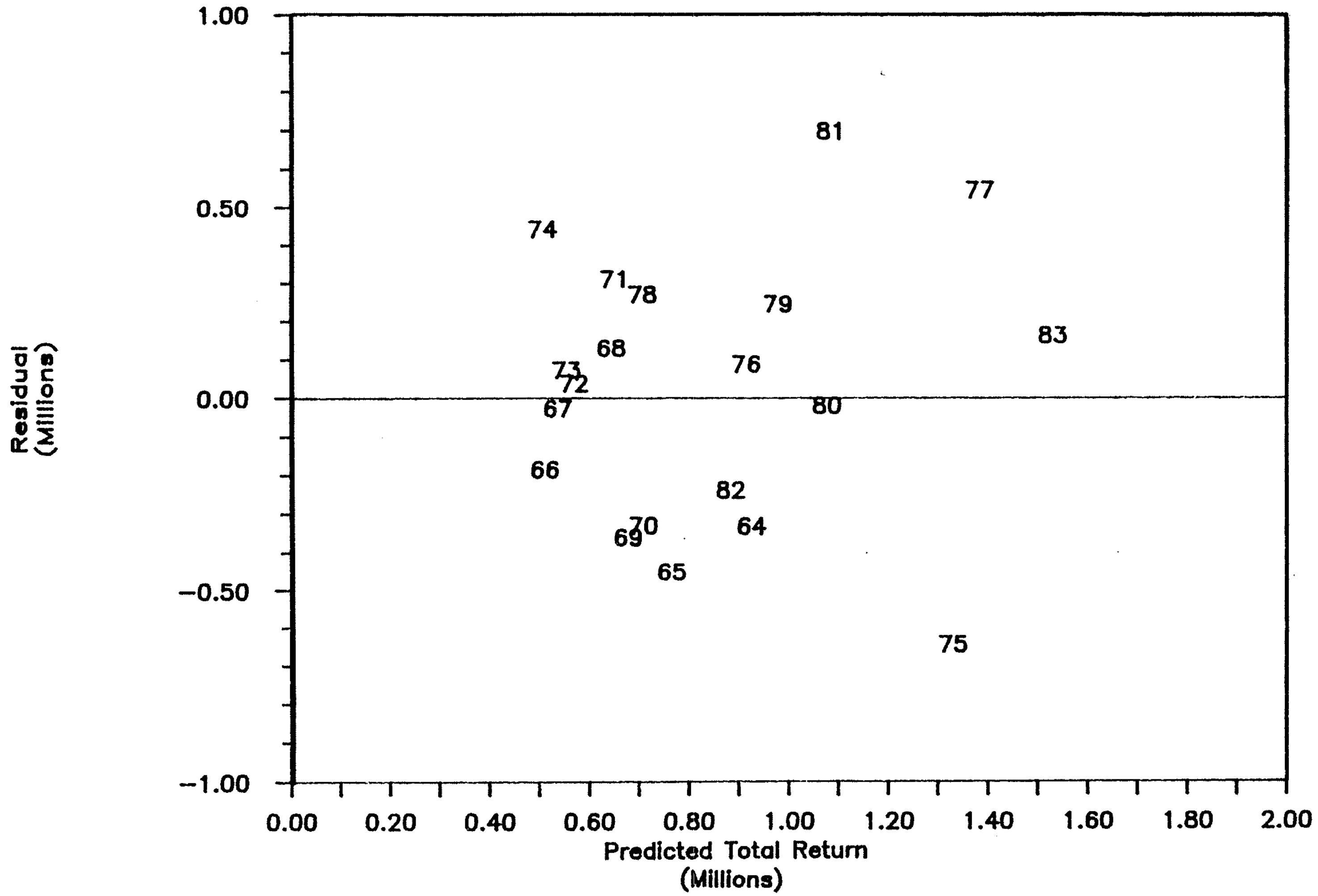


Fig. 10. Residuals plot for the Chignik Lake stock pre-season forecast model. Numbers indicate year of return.

Table 5. Absolute percentage error (APE) of predictions of 3-ocean age abundance in Chignik Lake stock migrations based on $\log_e$-transformed and on untransformed data.

Year	Transf. Predict.	Untransf. Predict.	Observed Return	APE Transf.	APE Untransf.
1963	702013	758142	355865	97.27	113.04
1964	699068	752134	491296	42.29	53.09
1965	606588	591498	303837	99.64	94.68
1966	300621	349914	302709	0.69	15.59
1967	384027	382647	389662	1.45	1.80
1968	536853	502421	694681	22.72	27.68
1969	536453	501981	232562	130.67	115.85
1970	566194	536858	301008	88.10	78.35
1971	554580	522719	918480	39.62	43.09
1972	444349	419250	476072	6.66	11.94
1973	438902	415418	583295	24.75	28.78
1974	380862	381054	641297	40.61	40.58
1975	828744	1076396	482541	71.75	123.07
1976	696400	746743	579589	20.15	28.84
1977	922017	1395256	1806658	48.97	22.77
1978	592371	571271	918117	35.48	37.78
1979	732826	824555	924171	20.70	10.78
1980	767226	906725	801731	4.30	13.10
1981	798036	987926	1612113	50.50	38.72
1982	681376	717266	560832	21.49	27.89
1983	907218	1339343	1302999	30.37	2.79
			MAPE is:	42.77	44.30

Table 6. Pre-season predictions and post-season estimates of stock abundance used in the analysis of intraseason forecasting methods.

		Stock Abundance		
Year		Black Lake	Chignik Lake	Total
1978	Pred.	632200	706500	1338700
	Obs.	1218303	928175	2146478
1979	Pred.	541200	978800	1520000
	Obs.	463027	1227423	1690450
1980	Pred.	464400	1077200	1541600
	Obs.	387860	1009978	1397838
1981	Pred.	1269800	1085100	2354900
	Obs.	1022750	1280693	2303443
1982	Pred.	1632900	884300	2517200
	Obs.	1492597	842341	2334938
1983	Pred.	1100900	1530400	2631300
	Obs.	967349	1493847	2461196

Plots of daily abundance for the individual years clearly illustrated the bimodality associated with passage of the principal stocks through the fishery (Fig. 11 a-f). Large fluctuations in the pattern of daily abundance result from catches of several days' accumulation of sockeye in Chignik Lagoon followed by days of no fishing. Note that peaks in abundance are variable in both scale and timing. To gain a preliminary insight into the migratory timing of the composite Chignik stock, it is convenient to describe the time series of abundance in terms of the dates when 5%, 50%, and 95% of the migration have arrived. Table 7 shows that the main body of annual migrations moved through the fishery in roughly 70 days, beginning about julian day 162 (± 2 wk), peaking around day 185 (± 3 wk), and ending about day 230 (± 4 wk; see Table 8 for conversion to calendar dates). Wide confidence intervals on these estimates illustrate the variability associated with migrations composed of more than one stock.

Much of the variability in timing of the Chignik migration can be explained by differences in the relative abundance of its major stock components. Recall that the mean date of migration is weighted by proportions of total abundance by day. The apparent lateness of the 1979 and 1980 migrations reflects the predominance of the Chignik Lake stock (73% of total abundance) in those years. The unusual lateness of the 95% day in 1982 relates to a strong late season showing of sockeye after day 215 (Parker and Rogers 1984).

Analysis of migration timing of the individual nursery lake stocks improved the precision of parameter estimates. The general results indicated remarkable stability in the central date of annual migrations but considerable variability in the time distribution of abundance about this date for both stocks. Means of Black Lake stock time density distributions ranged from day 162 (1981) to day 174 (1980) and the grand mean was calculated to fall within ± 10 d of day 169 (Table 9). Mean dates of Chignik Lake stock migrations spanned 9 d from day 192 (1981) to day 201 (1979, 1983) (Table 10). The average Chignik Lake stock migration peaked about 4 wk after the average Black Lake migration on day 198 (± 9 d). Annual means coincided with or closely followed corresponding medians (50% points) of the runs in all years except 1982, when the mean of the Chignik Lake migration preceded the median by 8 d. On average, 90% of the Black Lake migration moved through the fishery during the 26-d period from day 158 to day 184 and 90% of the Chignik Lake migration did so over the 55-d period from day 178 to day 233. However, variances on annual time density distributions of 27-75 d for the Black Lake stock and 151-384 d for the Chignik Lake stock signify that these averages are by no means representative of the migrations in individual years.

Plots of cumulative time density distributions display interannual variability in the migratory timing of the stocks. Migration timing has been initialized elsewhere as the date by which about 5% of total abundance is accounted for (Hornberger and Mathisen 1980; Brannian 1982). This date ranged from day 153 (1981) to day 163 (1982) for the Black Lake stock migration (Fig. 12) and day 168 (1981) to day 183

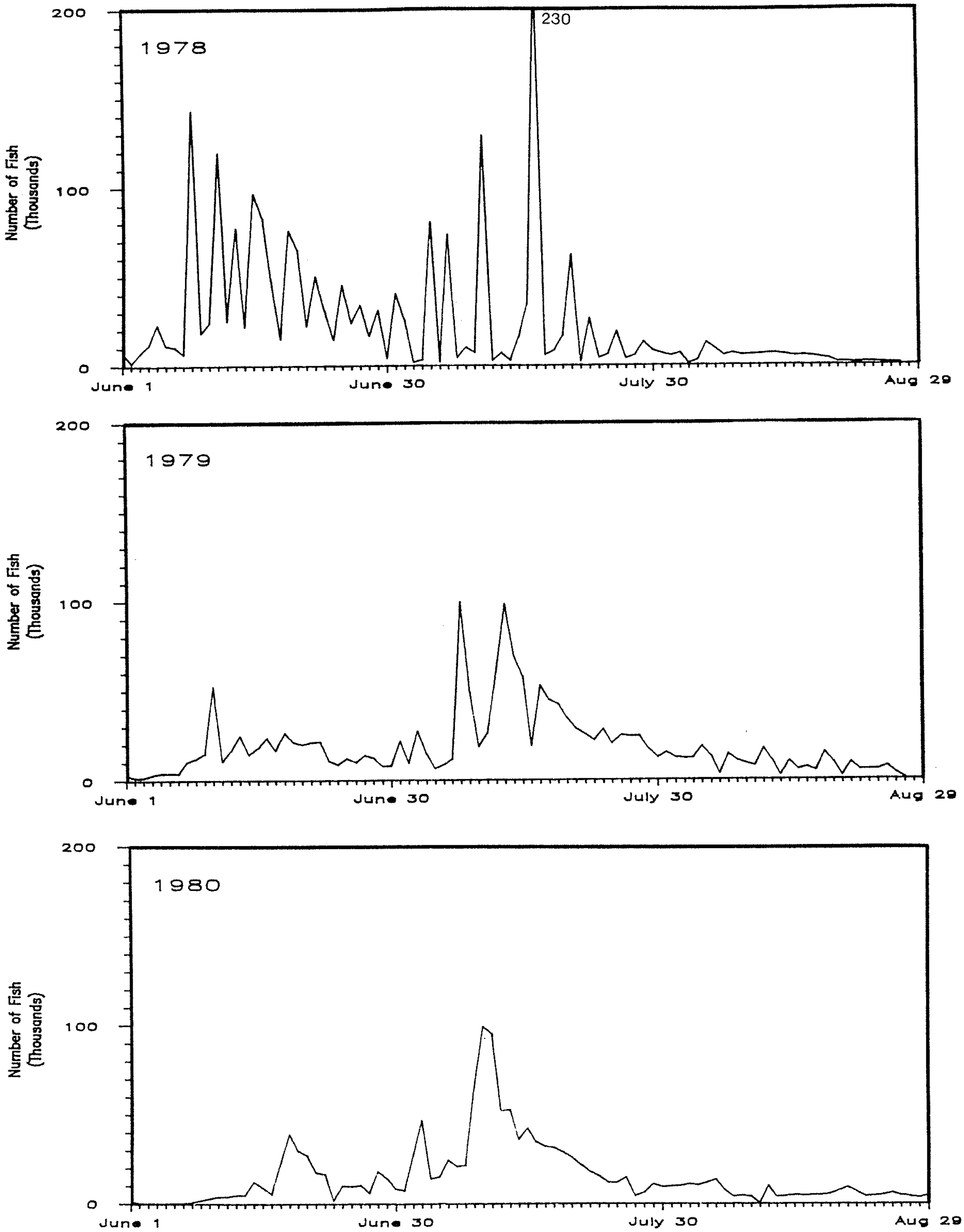


Fig. 11a-f. Daily abundance in sockeye salmon migrations to the Chignik watershed in 1978-1983.

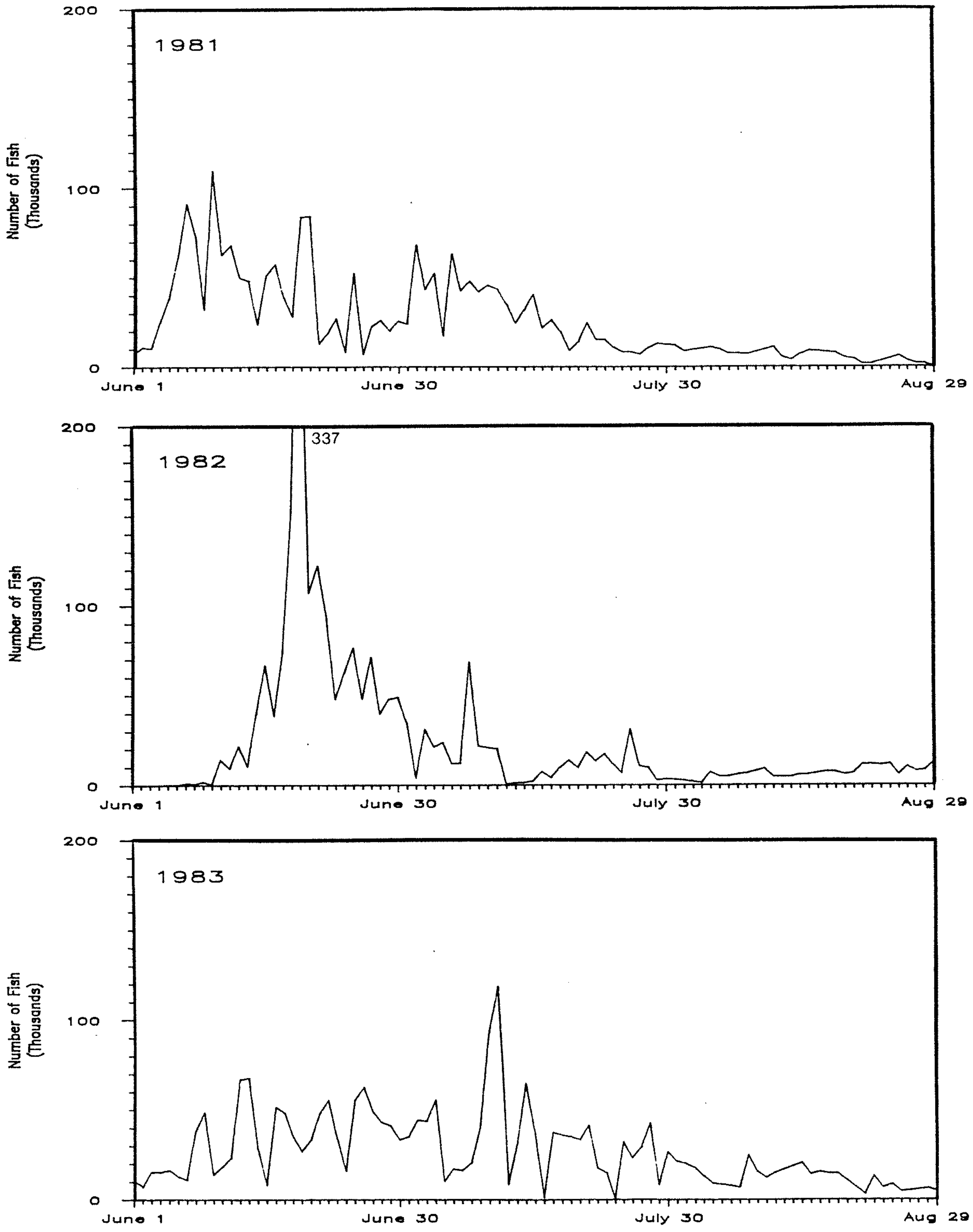


Fig. 11a-f. Continued.

Table 7. Timing of selected percentage points in annual migrations of the composite Chignik sockeye salmon stock.

Year	5% Day	50% Day	95% Day
1978	159	178	216
1979	162	195	227
1980	169	193	233
1981	156	177	221
1982	166	176	250
1983	159	188	231
Mean	162	185	230
95% C.I.	13	22	30

Table 8. Julian dates with corresponding calendar dates.

Julian Date	Calendar Date	Julian Date	Calendar Date	Julian Date	Calendar Date
150	5/30	185	7/4	220	8/8
151	5/31	186	7/5	221	8/9
152	6/1	187	7/6	222	8/10
153	6/2	188	7/7	223	8/11
154	6/3	189	7/8	224	8/12
155	6/4	190	7/9	225	8/13
156	6/5	191	7/10	226	8/14
157	6/6	192	7/11	227	8/15
158	6/7	193	7/12	228	8/16
159	6/8	194	7/13	229	8/17
160	6/9	195	7/14	230	8/18
161	6/10	196	7/15	231	8/19
162	6/11	197	7/16	232	8/20
163	6/12	198	7/17	233	8/21
164	6/13	199	7/18	234	8/22
165	6/14	200	7/19	235	8/23
166	6/15	201	7/20	236	8/24
167	6/16	202	7/21	237	8/25
168	6/17	203	7/22	238	8/26
169	6/18	204	7/23	239	8/27
170	6/19	205	7/24	240	8/28
171	6/20	206	7/25	241	8/29
172	6/21	207	7/26	242	8/30
173	6/22	208	7/27	243	8/31
174	6/23	209	7/28	244	9/1
175	6/24	210	7/29	245	9/2
176	6/25	211	7/30	246	9/3
177	6/26	212	7/31	247	9/4
178	6/27	213	8/1	248	9/5
179	6/28	214	8/2	249	9/6
180	6/29	215	8/3	250	9/7
181	6/30	216	8/4	251	9/8
182	7/1	217	8/5	252	9/9
183	7/2	218	8/6	253	9/10
184	7/3	219	8/7		

Table 9. Dates of selected features in migration patterns of the Black Lake stock.

Year	$\bar{t}$	S^2	5% Day	50% Day	95% Day
1978	169	67	157	167	186
1979	169	75	157	168	188
1980	174	75	162	172	191
1981	162	44	153	160	174
1982	171	27	163	169	180
1983	170	74	155	169	184
MEAN	169	60.3	158	168	184
95% C.I.	159-179		148-168	158-178	168-200

Table 10. Dates of selected features in migration patterns of the Chignik Lake stock.

Year	$\bar{t}$	S^2	5% Day	50% Day	95% Day
1978	199	151	181	198	225
1979	201	177	183	197	229
1980	198	177	183	195	235
1981	192	269	168	189	225
1982	195	384	174	203	250
1983	201	256	178	199	236
MEAN	198	235.7	178	197	233
95% C.I.	189-207		163-193	185-209	209-257

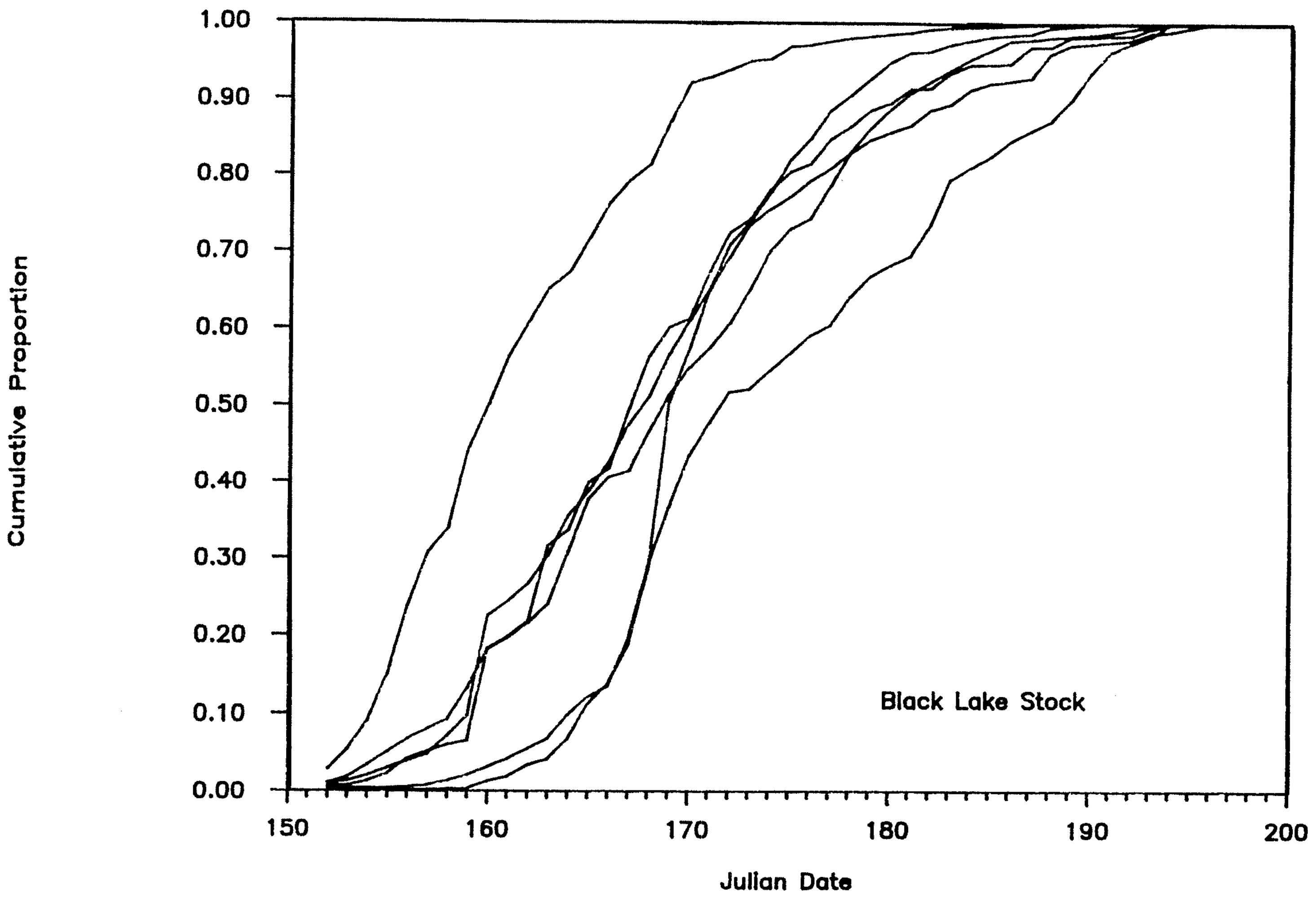


Fig. 12. Interannual variability in cumulative time densities for the Black Lake stock, 1978-1983.

(1982) for the Chignik Lake stock migration (Fig. 13). Inflection points (medians) in the curves ranged from day 160 (1981) to day 172 (1980) and from day 189 (1981) to day 203 (1982) for the respective migrations. On average, 10 days separated the 5% day from the 50% day of the Black Lake migration, but this time interval was as short as 6 d and as long as 14 d (Table 9). The Chignik Lake migration proceeded at a more leisurely pace, providing 14-29 d between the 5% and 50% points of the migration (Table 10).

The fishery manager's perception of migration timing is heavily influenced by the date of first appearance of significant numbers of fish. Note that the 5% day of the 1982 Black Lake stock migration was comparatively late even though the mean and median indicated approximately average timing. The 5% days in 1981 and 1983 were comparatively early, yet the mean and median for 1983 were of nearly average timing while those for 1981 remained early. Late 5% days in the 1979 and 1980 Chignik Lake migrations were followed by nearly average medians, although means were somewhat late in those years. The early 5% and 50% days in 1981 followed the earliness of the Black Lake migration in that year. It is evident that early indications can provide misleading information of migration timing in some years.

A summary of interannual variability in migratory timing is given by the behavior of coefficients of variation through time. The CV's reflect variation in the values of time density distributions on fixed dates, rather than variation in dates at fixed points of the time density distributions as in the results above. CV's for numerical and proportional migratory timing data for each stock (Appendix Tables 1-8) are summarized in Tables 11 and 12. The trend in CV's for daily numerical and proportional categories described an upward-opening parabola with minimum values in the vicinity of the mean date of migration. Variation in cumulative data categories also was high initially but decreased systematically over the time series for each stock migration. These patterns are consistent with those reported by Mundy (1982).

The degree of interannual variation in time density distributions and the rate at which it decreases over time are primary determinants of the accuracy delivered by a system of forecasting based on empirical models of migratory timing. The forecast system is of less value if acceptable accuracy cannot be obtained early in the migration. Tables 11 and 12 indicate that standard deviations in the least variable data category, cumulative proportion of abundance, were about 30% of the mean value by the central date of the Black Lake migration and about 23% by the central date of the Chignik Lake migration. Appropriate data from Appendix Tables 4 and 8, substituted into a variance estimation procedure of Walters and Buckingham (1975), indicates that confidence intervals for predictions of total abundance from average performance curves would be in the neighborhood of $\pm t_{\alpha,k-1}[55\% \; N_t]$ for the Black Lake stock and $\pm t_{\alpha,k-1}[47\% \; N_t]$ for the Chignik Lake stock by mean dates of the respective migrations.

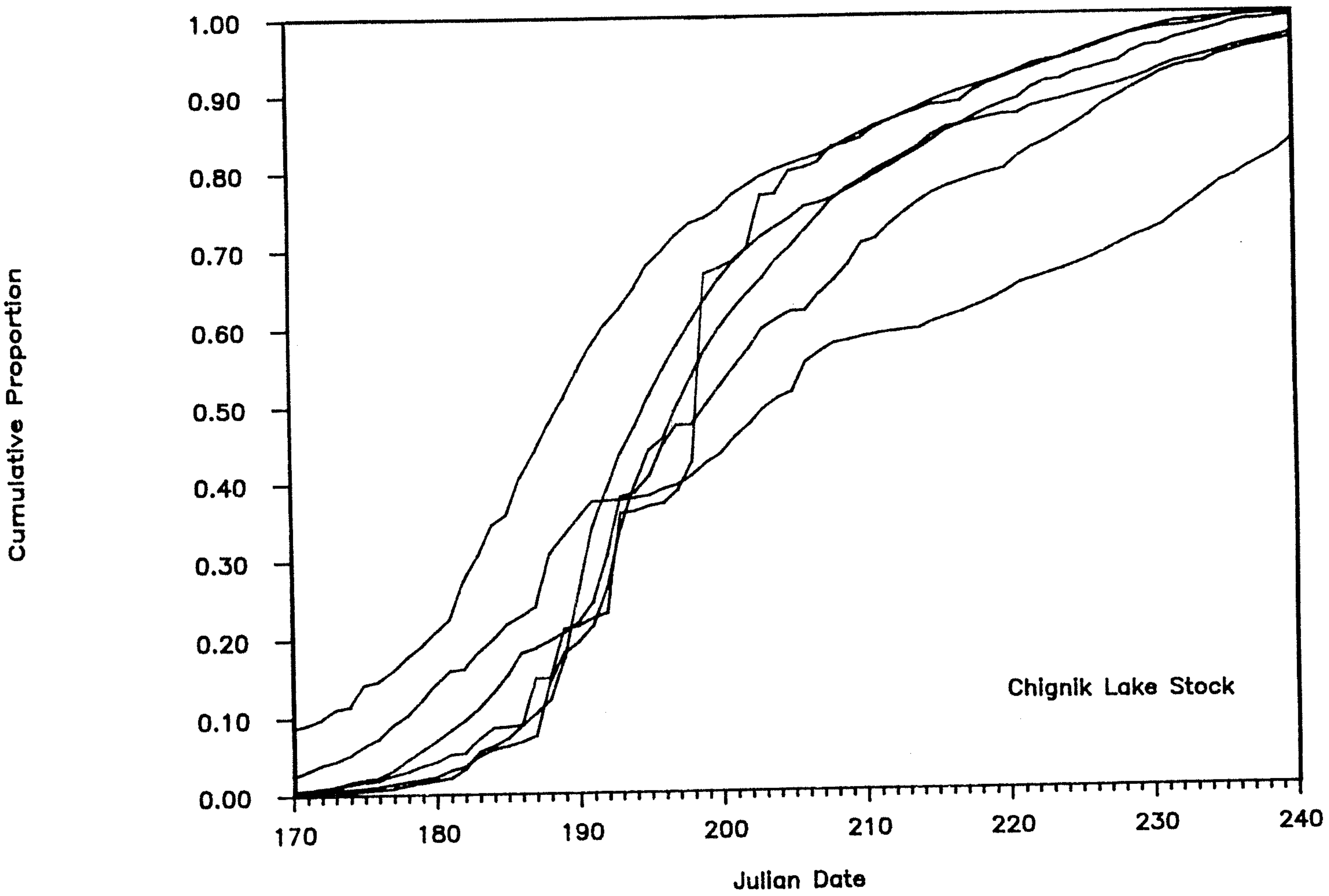


Fig. 13. Interannual variability in cumulative time densities for the Chignik Lake stock, 1978-1983.

Table 11. Coefficients of variation by day and by expected cumulative proportion of total for numerical and proportional data on timing of Black Lake stock migrations.

	Coefficients of variation				
Julian Date	Number	Cumulative Number	Pro-Portion	Cumulative Proportion	Expected Cumulative Proportion
152	1.2034	1.2034	0.6304	1.0178	0.0099
153	1.6132	1.3640	1.1324	1.1993	0.0161
154	1.3463	1.3547	1.0327	1.2194	0.0273
155	1.4834	1.4009	1.0745	1.2796	0.0432
156	1.5115	1.4347	1.0468	1.3338	0.0658
157	1.6072	1.4697	1.4365	1.3682	0.0832
158	0.9584	1.4038	1.6858	1.2770	0.0966
159	1.4595	1.4108	1.3235	1.2690	0.1272
160	0.8978	1.0597	1.1259	0.9265	0.1896
161	1.1291	1.0627	1.3575	0.9270	0.2108
162	0.6810	1.0198	1.1367	0.8877	0.2332
163	1.1749	0.9552	0.9911	0.8167	0.2700
164	0.6103	0.8458	0.7082	0.7107	0.3068
165	0.6242	0.7640	0.6573	0.6316	0.3523
166	0.5706	0.7374	0.4212	0.6097	0.3809
167	0.8108	0.6770	0.6305	0.5283	0.4264
168	0.8363	0.5873	0.4718	0.4014	0.4884
169	1.3226	0.5441	0.2196	0.2929	0.5704
170	0.7820	0.5353	0.7752	0.2641	0.6170

Table 11. Coefficients of variation by day and by expected cumulative proportion of total for numerical and proportional data on timing of Black Lake stock migrations (continued).

Julian Date	Coefficients of variation				Expected Cumulative Proportion
	Number	Cumulative Number	Pro- Portion	Cumulative Proportion	
171	0.9949	0.5337	0.8419	0.2281	0.6595
172	0.8235	0.5309	0.2694	0.2019	0.6984
173	0.7188	0.5249	0.6392	0.1933	0.7233
174	0.8292	0.5222	0.4224	0.1753	0.7520
175	0.8389	0.5268	0.5772	0.1682	0.7773
176	0.9210	0.5262	0.6614	0.1576	0.7935
177	0.8738	0.5291	0.4409	0.1515	0.8181
178	0.7062	0.5214	0.6236	0.1344	0.8418
179	0.6994	0.5188	0.5757	0.1239	0.8623
180	0.8640	0.5194	0.5830	0.1199	0.8763
181	0.7706	0.5191	0.4611	0.1170	0.8888
182	0.7238	0.5089	0.6777	0.1001	0.9027
183	0.6867	0.5011	0.4891	0.0770	0.9213
184	0.5323	0.4969	0.8982	0.0710	0.9325
185	0.8280	0.4942	1.4571	0.0659	0.9394
186	1.0011	0.4907	0.8264	0.0593	0.9461
187	1.5016	0.4896	0.9258	0.0545	0.9534
188	1.0434	0.4855	1.5216	0.0489	0.9624
189	0.9631	0.4810	1.0152	0.0380	0.9720
190	1.5315	0.4760	1.3009	0.0241	0.9790

Table 11. Coefficients of variation by day and by expected cumulative proportion of total for numerical and proportional data on timing of Black Lake stock migrations (continued).

Julian Date	Coefficients of variation Number	 Cumulative Number	 Pro-Portion	 Cumulative Proportion	Expected Cumulative Proportion
191	1.2347	0.4721	1.4028	0.0147	0.9849
192	1.1432	0.4697	1.8342	0.0110	0.9883
193	1.0964	0.4676	1.3717	0.0066	0.9936
Mean	0.9988	0.7485	0.8970	0.4596	
St. Dev.	0.3102	0.3512	0.4028	0.4685	
CV	0.3106	0.4692	0.4490	1.0194	

Table 12. Coefficients of variation by day and by expected cumulative proportion of total for numerical and proportional data on timing of Chignik Lake stock migrations.

	Coefficients of Variation				
Julian Date	Number	Cumulative Number	Pro-Portion	Cumulative Proportion	Expected Proportion
155	2.4495	2.4495	2.4495	2.4495	0.0000
156	2.4495	2.4495	2.4495	2.4495	0.0001
157	2.4495	2.4495	2.4495	2.4495	0.0001
158	2.4495	2.4495	2.4495	2.4495	0.0001
159	2.4495	2.4495	2.4495	2.4495	0.0002
160	2.4495	2.4495	2.4495	2.4495	0.0001
161	2.4495	2.4495	2.4495	2.4495	0.0004
162	2.2535	2.2790	2.3969	2.4042	0.0003
163	2.2650	2.2892	2.3619	2.3739	0.0005
164	1.9136	1.9543	2.2506	2.2719	0.0006
165	1.5430	1.4695	2.0777	2.0641	0.0008
166	1.4235	1.3170	1.9803	1.9466	0.0006
167	1.7679	1.6137	1.9255	1.8568	0.0012
168	1.6885	1.6285	1.8644	1.7983	0.0017
169	1.3718	1.2594	1.7577	1.6763	0.0018
170	1.1263	1.0537	1.6302	1.5277	0.0020
171	1.4337	1.3110	1.5427	1.4125	0.0062
172	1.6740	1.5417	1.5768	1.4449	0.0059
173	0.7444	0.8284	1.4468	1.3215	0.0030
174	0.6920	0.6754	1.3216	1.2033	0.0043

Table 12. Coefficients of variation by day and by expected cumulative proportion of total for numerical and proportional data on timing of Chignik Lake stock migrations (continued).

Julian Date	Coefficients of Variation Number	 Cumulative Number	 Pro-Portion	 Cumulative Proportion	Expected Proportion
176	0.7730	0.9384	1.2377	1.1275	0.0030
177	1.1148	1.0101	1.2075	1.1000	0.0097
178	1.0046	0.8175	1.0955	0.9980	0.0056
179	0.7171	0.7063	1.0182	0.9294	0.0092
180	0.7585	0.6442	0.9766	0.8880	0.0088
181	0.6333	0.5904	0.9170	0.8320	0.0102
182	0.8572	0.8794	0.9012	0.8245	0.0098
183	0.4888	0.4734	0.8358	0.7602	0.0133
184	1.0937	1.0071	0.8560	0.7570	0.0169
185	0.6235	0.5498	0.8050	0.7012	0.0188
186	0.9605	0.8384	0.8158	0.7066	0.0170
187	0.9940	1.1188	0.7318	0.6254	0.0183
188	1.1904	1.0929	0.7573	0.6457	0.0154
189	0.8026	0.9005	0.7112	0.6031	0.0231
190	0.8057	0.8274	0.6176	0.5235	0.0345
191	0.4942	0.4940	0.5568	0.4555	0.0297
192	0.8254	0.8024	0.5126	0.3977	0.0368
193	0.6626	0.7029	0.4333	0.3104	0.0604
194	0.9762	0.9984	0.4082	0.2821	0.0219
195	0.9960	0.9916	0.3753	0.2399	0.0290

Table 12. Coefficients of variation by day and by expected cumulative proportion of total for numerical and proportional data on timing of Chignik Lake stock migrations (continued).

Julian Date	Coefficients of Variation				Expected Proportion
	Number	Cumulative Number	Pro-Portion	Cumulative Proportion	
196	0.8424	0.7925	0.3766	0.2288	0.0267
197	0.6151	0.5920	0.3759	0.2286	0.0270
198	0.6827	0.7416	0.3596	0.2209	0.0186
199	1.2950	1.4714	0.3042	0.2126	0.0611
200	0.6205	0.5556	0.2997	0.2004	0.0207
201	0.6291	0.5469	0.2915	0.1859	0.0198
202	0.4734	0.3751	0.2879	0.1799	0.0193
203	0.4976	0.6019	0.2798	0.1818	0.0299
204	0.4949	0.4745	0.2760	0.1732	0.0135
205	0.2534	0.3827	0.2682	0.1695	0.0174
206	0.8400	0.7567	0.2633	0.1645	0.0104
207	0.7092	0.5099	0.2643	0.1588	0.0119
208	0.4023	0.5324	0.2513	0.1437	0.0191
209	0.8151	0.6688	0.2521	0.1357	0.0111
210	0.8686	0.6659	0.2563	0.1289	0.0135
211	0.4486	0.4502	0.2565	0.1321	0.0098
212	0.6427	0.4370	0.2600	0.1319	0.0100
213	0.5735	0.4072	0.2630	0.1322	0.0095
214	0.6147	0.4538	0.2654	0.1323	0.0082
215	0.5370	0.4196	0.2675	0.1334	0.0083

Table 12. Coefficients of variation by day and by expected cumulative proportion of total for numerical and proportional data on timing of Chignik Lake stock migrations (continued).

Julian Date	Coefficients of Variation Number	 Cumulative Number	 Pro-Portion	 Cumulative Proportion	Expected Proportion
216	0.6800	0.6366	0.2700	0.1342	0.0066
217	0.5150	0.4717	0.2694	0.1325	0.0089
218	0.3190	0.3762	0.2677	0.1336	0.0095
219	0.3233	0.3905	0.2661	0.1332	0.0062
220	0.4783	0.4096	0.2654	0.1320	0.0066
221	0.7348	0.5040	0.2670	0.1294	0.0085
222	0.4824	0.3339	0.2670	0.1265	0.0073
223	0.5520	0.5358	0.2664	0.1233	0.0066
224	0.4588	0.3277	0.2676	0.1235	0.0091
225	0.6162	0.4161	0.2688	0.1226	0.0068
226	0.8858	0.6570	0.2696	0.1211	0.0058
227	0.6521	0.4251	0.2711	0.1197	0.0077
228	0.5041	0.3104	0.2716	0.1182	0.0064
229	0.4911	0.3000	0.2720	0.1164	0.0070
230	0.5029	0.3632	0.2719	0.1140	0.0065
231	0.5182	0.3881	0.2723	0.1122	0.0078
232	0.3946	0.2918	0.2719	0.1106	0.0062
233	0.5772	0.6619	0.2701	0.1076	0.0048
234	0.7348	0.8688	0.2664	0.1024	0.0056
235	0.8131	0.8644	0.2649	0.0971	0.0056

Table 12. Coefficients of variation by day and by expected cumulative proportion of total for numerical and proportional data on timing of Chignik Lake stock migrations (continued).

Julian Date	Coefficients of Variation				Expected Proportion
	Number	Cumulative Number	Pro-Portion	Cumulative Proportion	
236	0.5963	0.7846	0.2624	0.0922	0.0052
237	0.5870	0.7574	0.2602	0.0871	0.0058
238	0.4259	0.4736	0.2592	0.0853	0.0047
239	0.6753	0.8938	0.2568	0.0807	0.0045
240	0.8520	1.0072	0.2552	0.0771	0.0033
241	0.8003	0.9703	0.2537	0.0732	0.0036
Mean	0.9540	0.9202	0.8160	0.7083	
St. Dev.	0.5962	0.6098	0.7518	0.7958	
CV	0.6249	0.6626	0.9213	1.1236	

The time distribution of fishing effort apparently affected the migratory time density distributions for both stocks. Distortion in time densities for the Black Lake stock were featured in comparisons with normal distributions having identical parameter values (Fig. 14a-f). Virtually every spike in the time series of daily proportion of abundance, particularly spikes occuring prior to the central date of migration, coincided with a commercial harvest of sockeye in Chignik Lagoon. The correlation was most striking in 1978, perhaps because commercial openings were separated by closed periods in which the lagoon refilled with arriving fish. Time densities for 1979 and 1980 migrations reflect the condition of little or no fishing pressure and more closely conform to a normal distribution. The pattern in 1983 illustrates the case of little or no migration delay in Chignik Lagoon. Reduced detection by the fleet lowered daily CPUE and distributed the catch more evenly over the migration period (Parker and Rogers 1984). Similar comparisons for Chignik Lake stock migrations show even stronger relationship between commercial harvests and abundance spikes (Figs. 15a-f).

Likelihood scores generally confirmed the relation between fishing effort and time density distributions (Table 13). Scores tended to be lower when the commercial fleet harvested a relatively smaller fraction of total abundance during each fishing period and larger when relatively large fractions of total abundance were harvested on one or a few days. Smallest scores were associated with years of little or no fishing (1979, 1980 Black Lake) and largest scores occured when sporadic commercial harvests took large fractions of total abundance (1978 Chignik Lake).

Intraseason Forecasting

Average Performance Curve

Average performance curves are shown for the Black Lake stock in Figure 16 and for the Chignik Lake stock in Figure 17. Proportions of the curves, given in Appendix Tables 4 and 8 by stock, were used to allocate pre-season forecasts in Table 8 over the respective migrations. Resulting estimates of cumulative abundance were broken out by 5-d intervals for comparison with predictions from the IPF method.

Intraseason Period Forecast

The Black Lake and Chignik Lake stock migrations were divided into 5-d intervals beginning on day 152 (June 1) for the Black Lake stock and day 166 (June 15) for the Chignik Lake stock. Forecasts were possible for 8 periods during the Black Lake migration beginning on day 156, and for 10 periods of the Chignik Lake migration beginning on day 171.

The data requirements for intraseason period forecasts are summarized for the Black Lake stock in Table 14 and for the Chignik Lake stock in Table 15. The $\bar{N}_t$, $\bar{N}_{t+1}$, and b_{t+1} remain constant for each

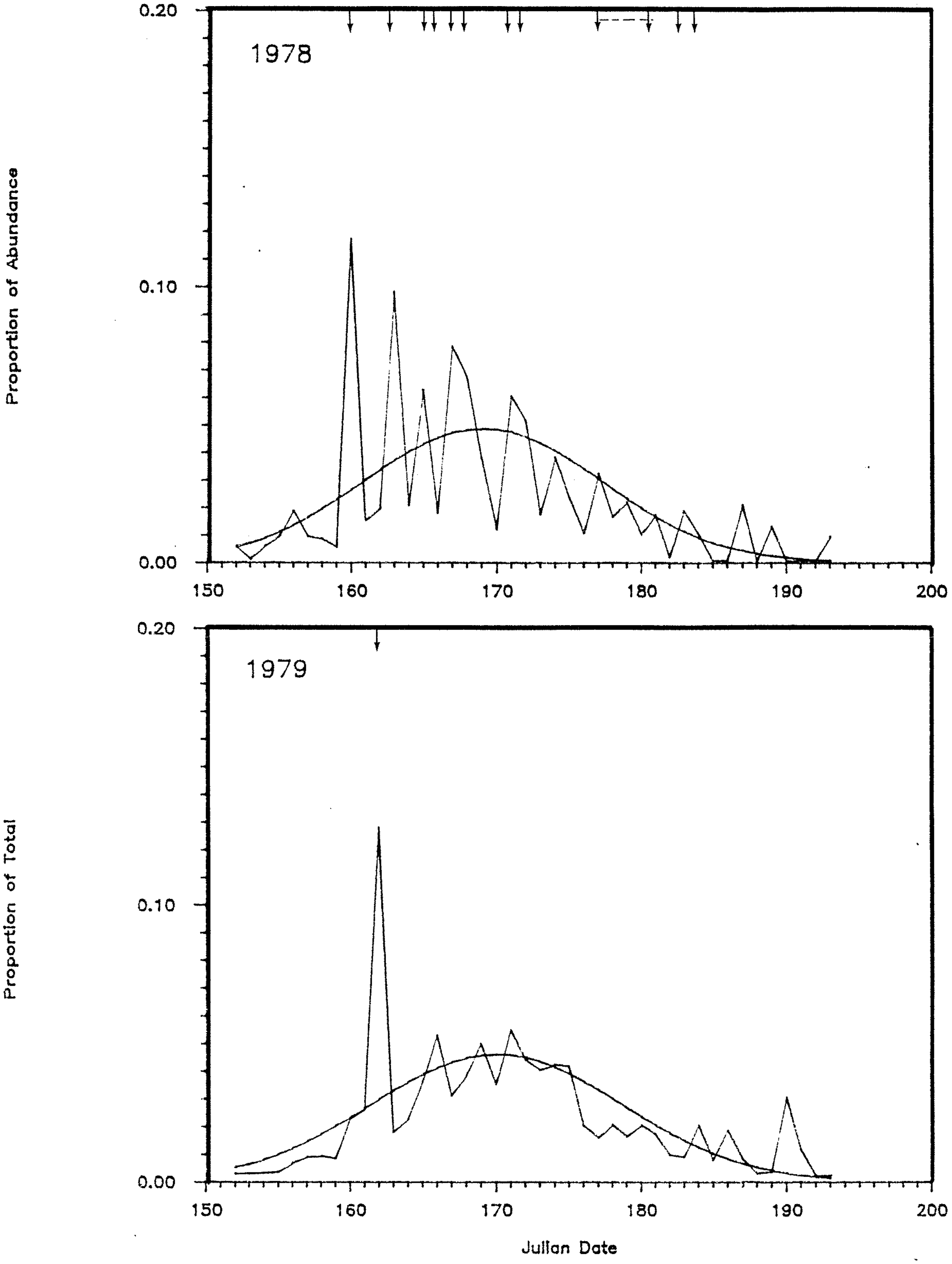


Fig. 14a-f. Comparisons of Black Lake stock time densities with normal distributions having identical parameter values. Arrows and dashed lines indicate fishing periods.

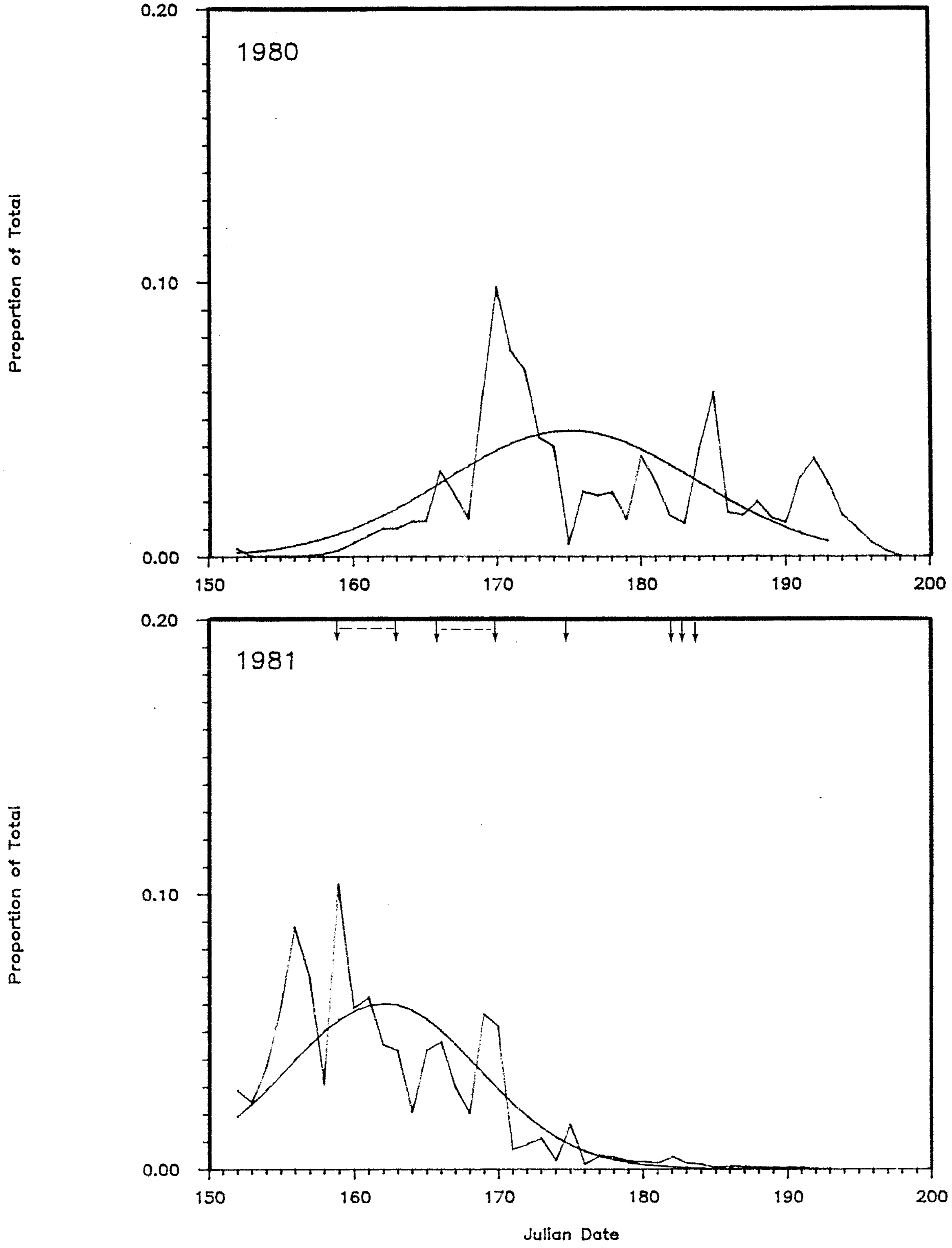


Fig. 14a-f. Continued.

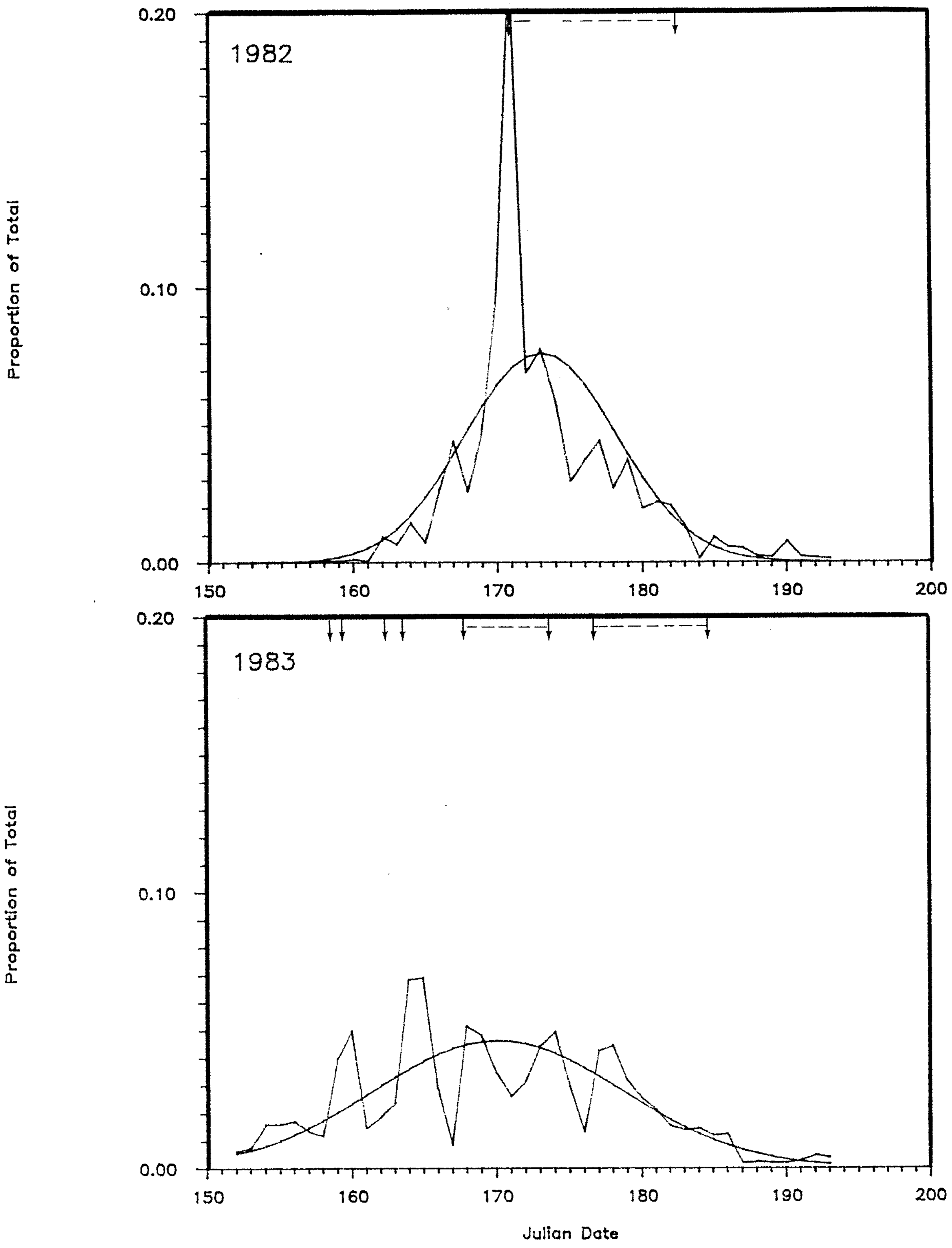


Fig. 14a-f. Continued.

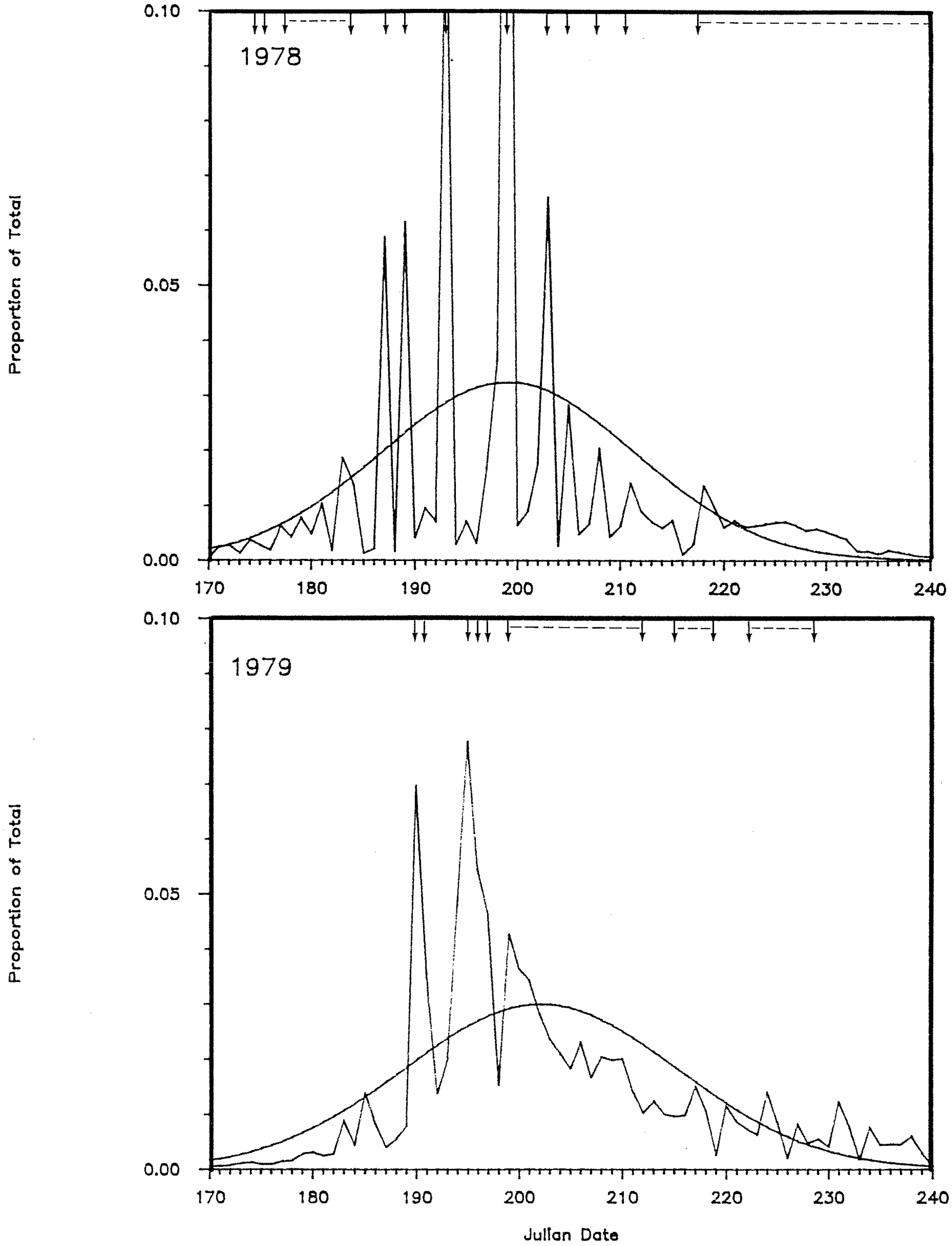


Fig. 15a-f. Comparisons of Chignik Lake stock time densities with normal distributions having identical parameter values. Arrows and dashed lines indicate fishing periods.

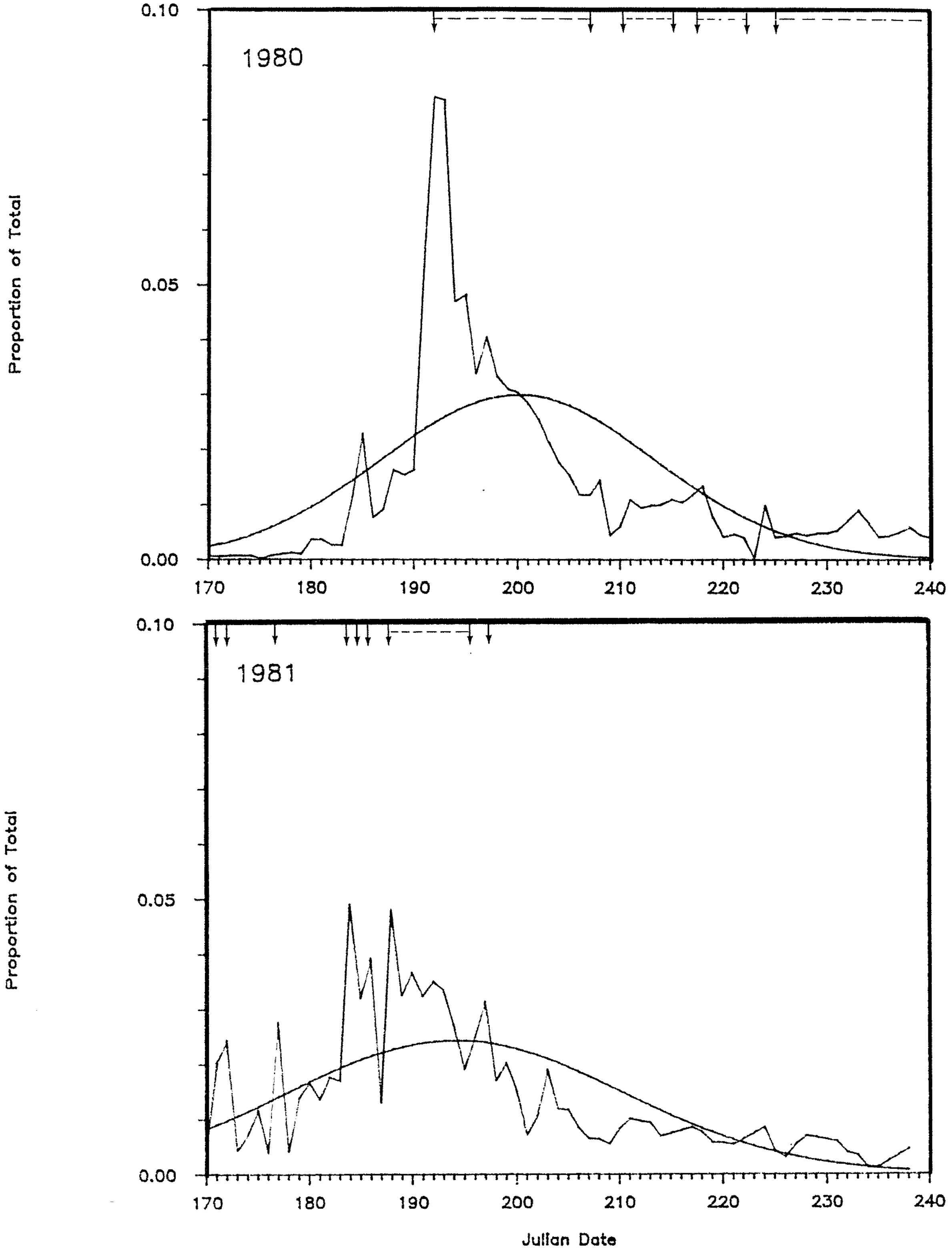


Fig. 15a-f. Continued.

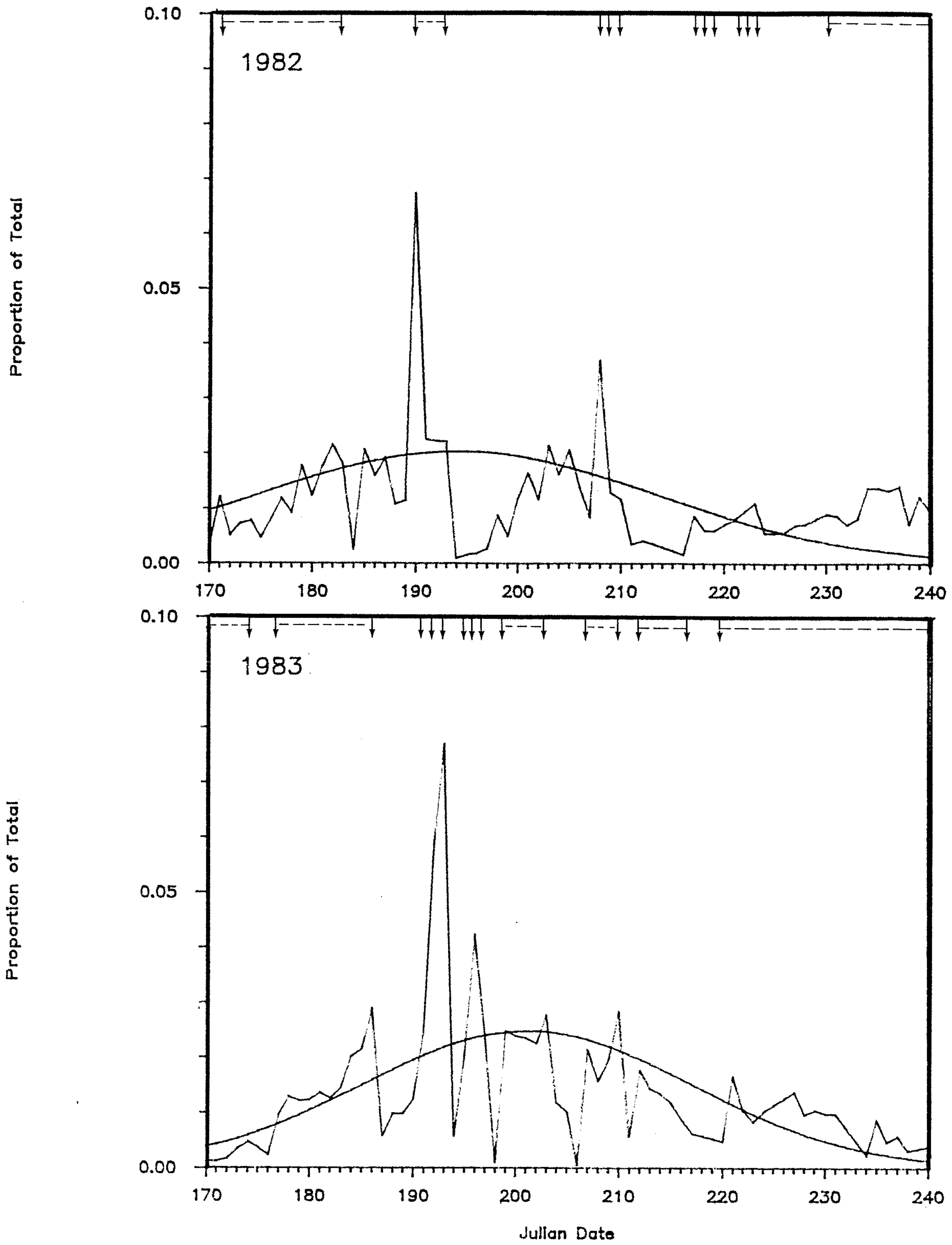


Fig. 15a-f. Continued.

Table 13. Likelihood scores for comparisons between empirical time density distributions and normal distributions having identical parameter values.

Year	Black Lake Stock	Chignik Lake Stock
1978	159518	293680
1979	37041	119144
1980	38112	115862
1981	77286	91534
1982	127578	64938
1983	50936	129386

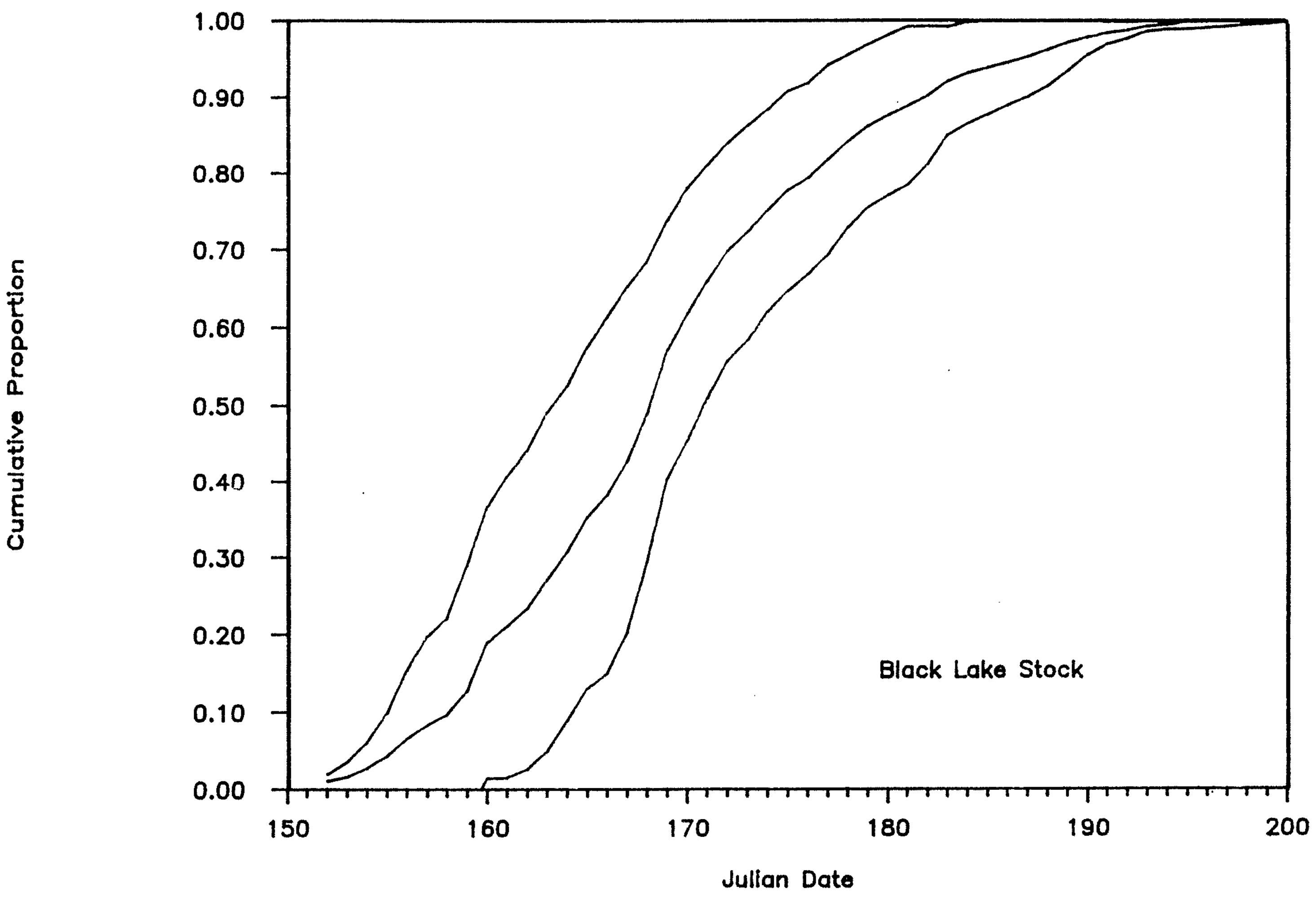


Fig. 16. Average (± 1 SD) performance curve of abundance for the Black Lake stock.

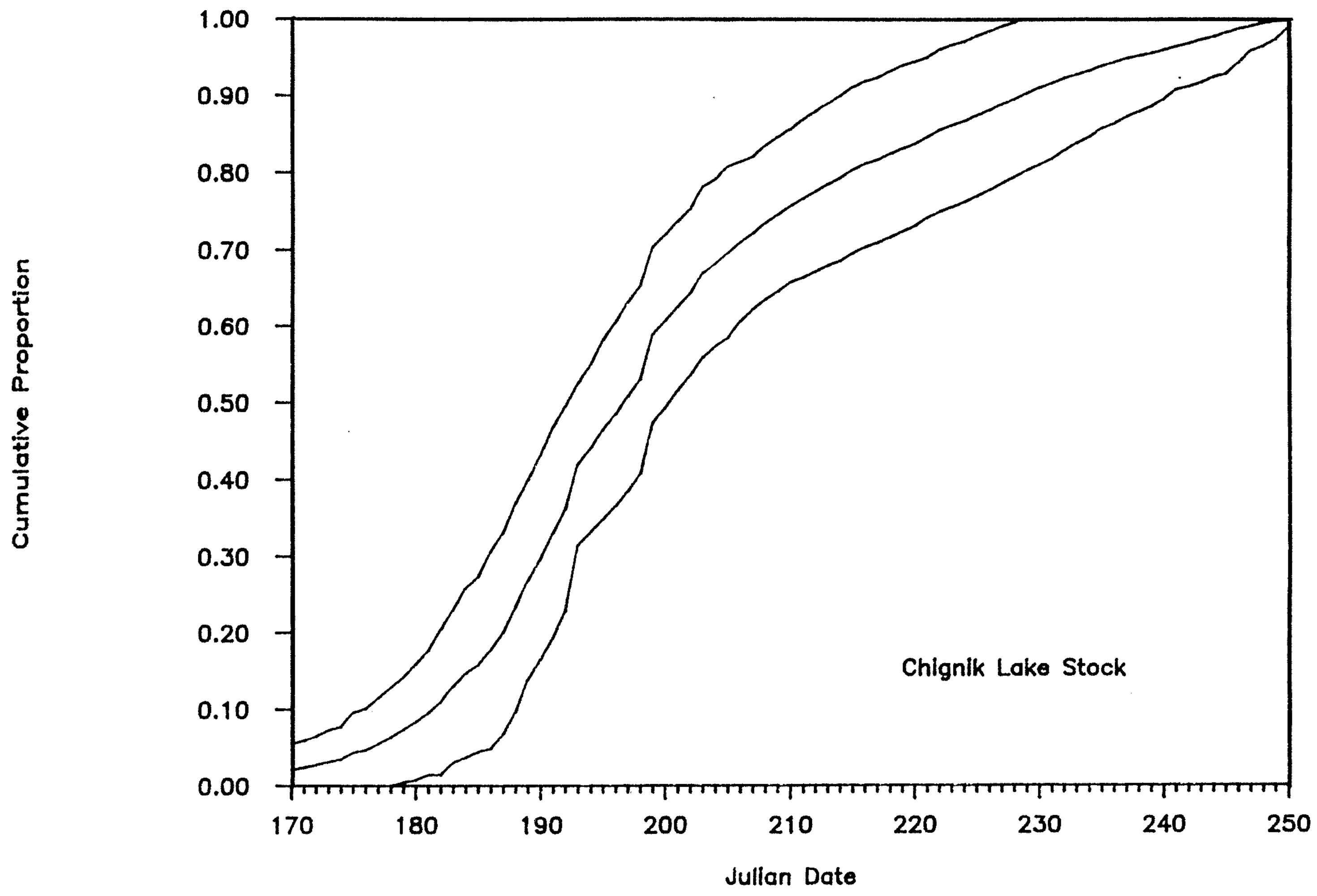


Fig. 17. Average (± 1 SD) performance curve of abundance for the Chignik Lake stock.

Table 14. Data set for the Black Lake stock intraseason period forecast model.

Calendar Date	Interval	$\bar{N}(t+1)$	b(t+1)	Cumulative Total	$\bar{N}(t)$
6/5	2	63848	7.903	*	8903
6/10	3	194579	2.519	*	63848
6/15	4	356123	1.535	Supplied	194579
6/20	5	630891	1.360	in	356123
6/25	6	761172	1.186	Season	630891
6/30	7	851359	1.127	*	761172
7/5	8	890903	1.036	*	851359
7/10	9	915631	1.021	*	890903

Table 15. Data set for the Chignik Lake stock intraseason period forecast model.

Calendar Date	Interval	$\bar{N}(t+1)$	b(t+1)	Cumulative Total	$\bar{N}(t)$
6/20	2	28146	3.029	*	7578
6/25	3	53604	1.651	*	28146
6/30	4	109406	1.677	*	53604
7/5	5	206872	1.809	Supplied	109406
7/10	6	372872	1.522	in	206892
7/15	7	557582	1.402	Season	372872
7/20	8	711550	1.234	*	557582
7/25	9	803406	1.120	*	711550
7/30	10	870939	1.086	*	803406
8/4	11	924295	1.063	*	870939

interval within a year and change only when the database is updated at the end of each season. The $N_{t,i}$ are year-specific and form the basis of predictions of $N_{t+1,i}$. To predict N for interval t+1 in year i, subtract cumulative abundance on interval t in the current year from the average cumulative abundance on interval t, multiply this total (positive or negative) by the appropriate interval coefficient b_{t+1}, and add the product to the average cumulative abundance on interval t+1.

The regression lines which relate cumulative abundance on a time interval with that on the next interval were strongly linear for all periods of the Black Lake and Chignik Lake stock migrations (Table 16). The intercepts of regression lines were not significantly different from 0 for any interval relationship (Student's "t", 95% confidence level), so the regressions were recalculated with intercepts forced through 0. Slopes were initially high, reflecting the rapid build-up of abundance in early periods, and decreased toward 1 as the rate of increase in successive periods lessened (Figs. 18 and 19).

Data for intervals 4 and 5 of the Black Lake stock migration in 1982 disrupted an otherwise strong correlation for other years and was dropped from that interval relationship (Fig. 20). Prolonged milling behavior in 1982, probably due to unusually cold river water temperatures, held early escapement counts to a trickle while the migration pooled in Chignik Lagoon. Consequently, the first commercial harvest of accumulated fish, which occured during interval 5, resulted in a 24-hr estimate of total abundance that distorted the normal relationship between intervals 4 and 5 in other years.

After discarding this data point, coefficients of determination (r^2) were uniformly high for all intervals. High r^2 values indicate that interval relationships were stable across years despite ranges in cumulative abundance that approach an order of magnitude (Appendix Table 3). The implication of this result is that the accumulation of abundance is a fairly constant function of time independent of abundance when accumulation is taken by 5-day intervals.

Performance of Intraseason Forecast Methods

The variability in abundance and migratory behavior of the stocks during 1978-83 provided good experimental conditions for evaluating the strengths and weaknesses of the intraseason forecasting systems. The IPF method showed generally better accuracy than did the APC method in predicting cumulative abundance for both stock migrations. Performance of the APC model in some years was limited by the accuracy of pre-season forecasts and in others by unusual migration timing. As expected, both models performed well in years of approximately average migration timing, but the IPF model was clearly superior in years of abnormal migration timing. Despite occasional large errors in some interval predictions, the recursive nature of the IPF model allowed subsequent predictions to converge with observed data. In contrast, the APC model

Table 16. Slope coefficients and coefficients of determination (r^2) for linear relationships between cumulative abundance in sequential time intervals for both stocks.

Interval	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11
Coefficient				Black Lake stock						
slope	7.903	2.519	1.535	1.36	1.186	1.127	1.036	1.021		
r^2	0.990	0.959	0.925	0.953	0.966	0.980	0.998	0.999		
				Chignik Lake stock						
slope	3.029	1.651	1.677	1.809	1.522	1.402	1.234	1.120	1.086	1.063
r^2	0.970	0.988	0.938	0.957	0.890	0.730	0.846	0.984	0.978	0.994

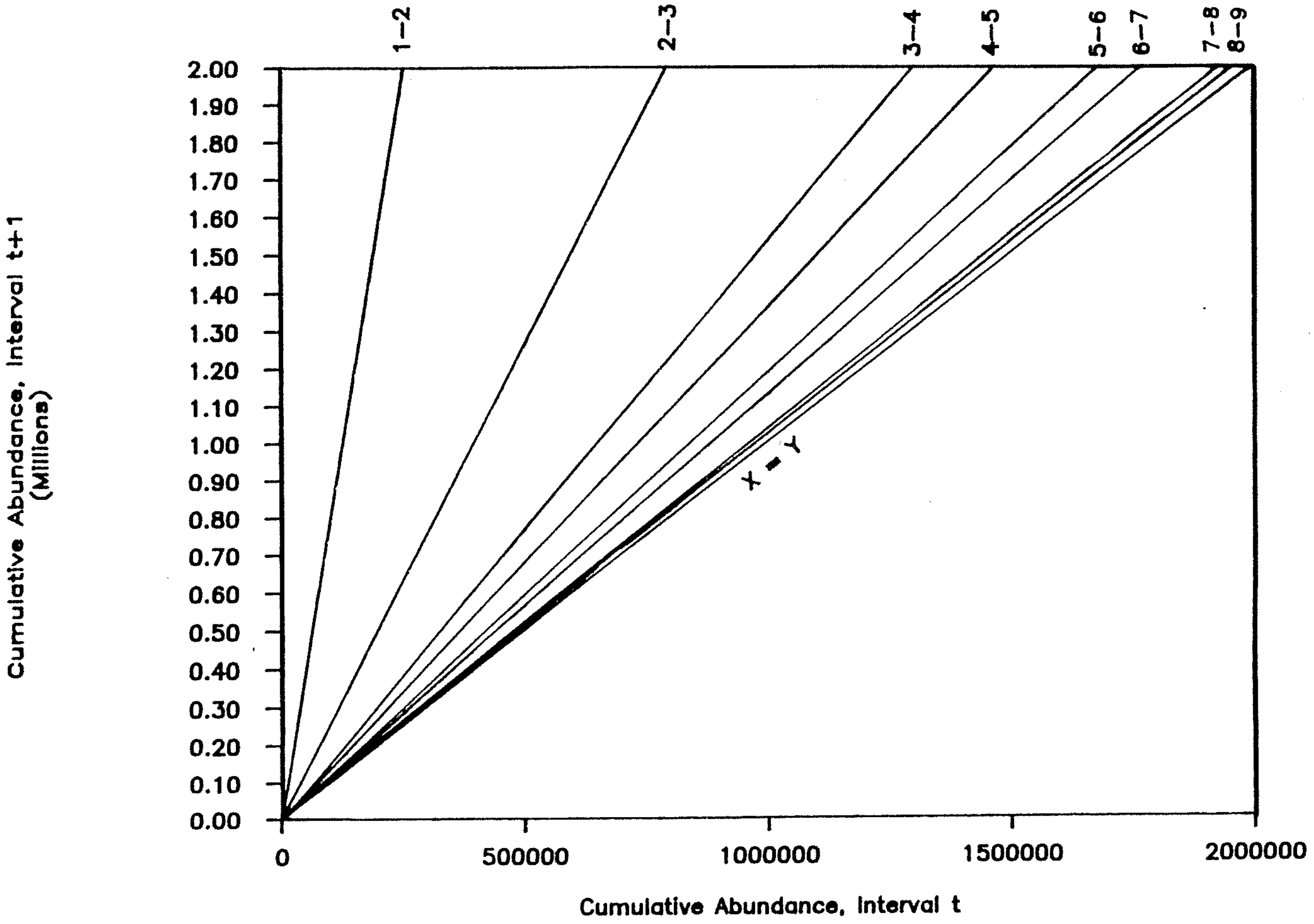


Fig. 18. Relationships between cumulative abundance on interval t with that on interval t+1 for Black Lake stock migrations. Numbers on perimeter refer to intervals.

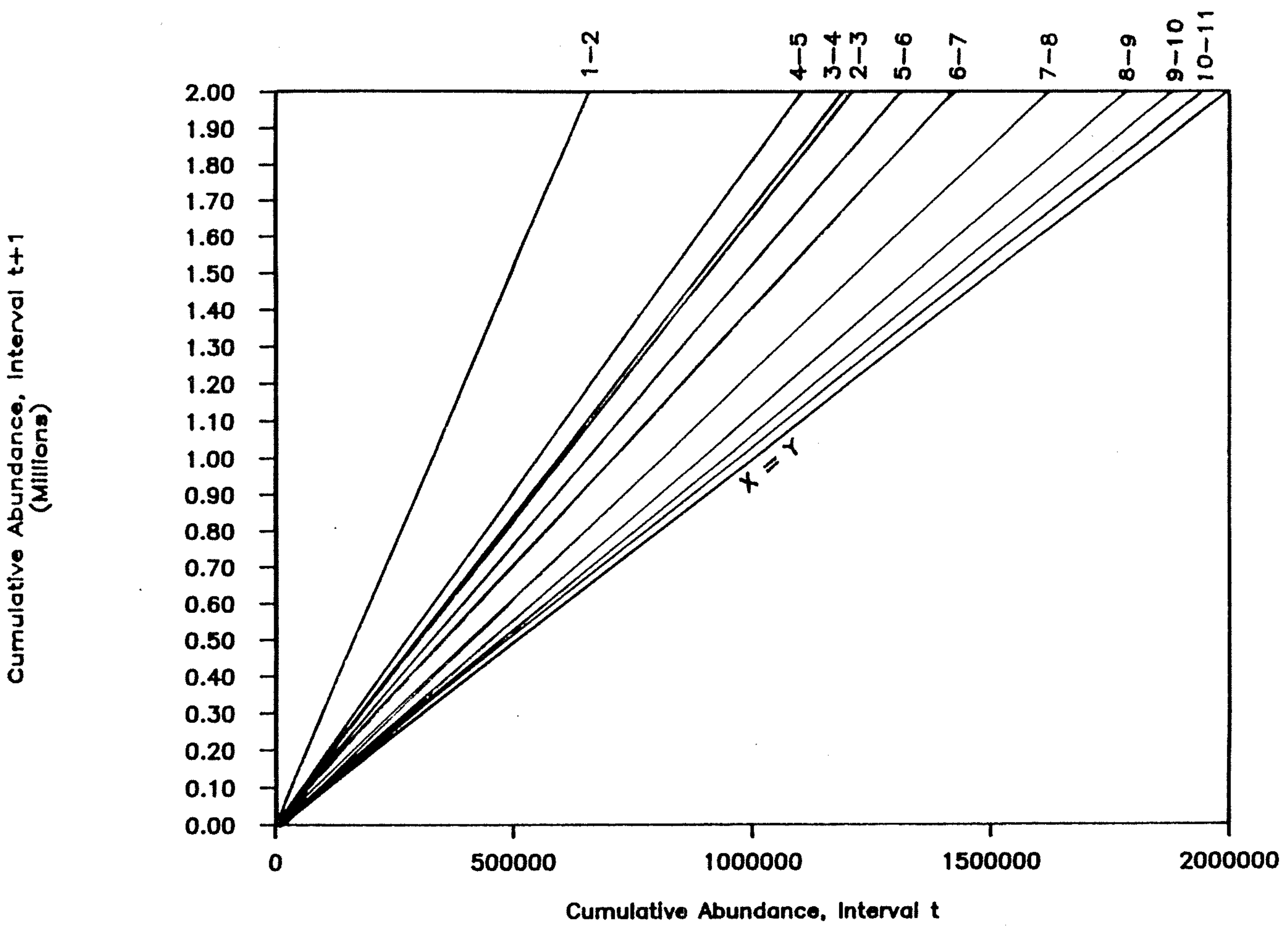


Fig. 19. Relationships between cumulative abundance on interval t with that on interval t+1 for Chignik Lake stock migrations. Numbers on perimeter refer to intervals.

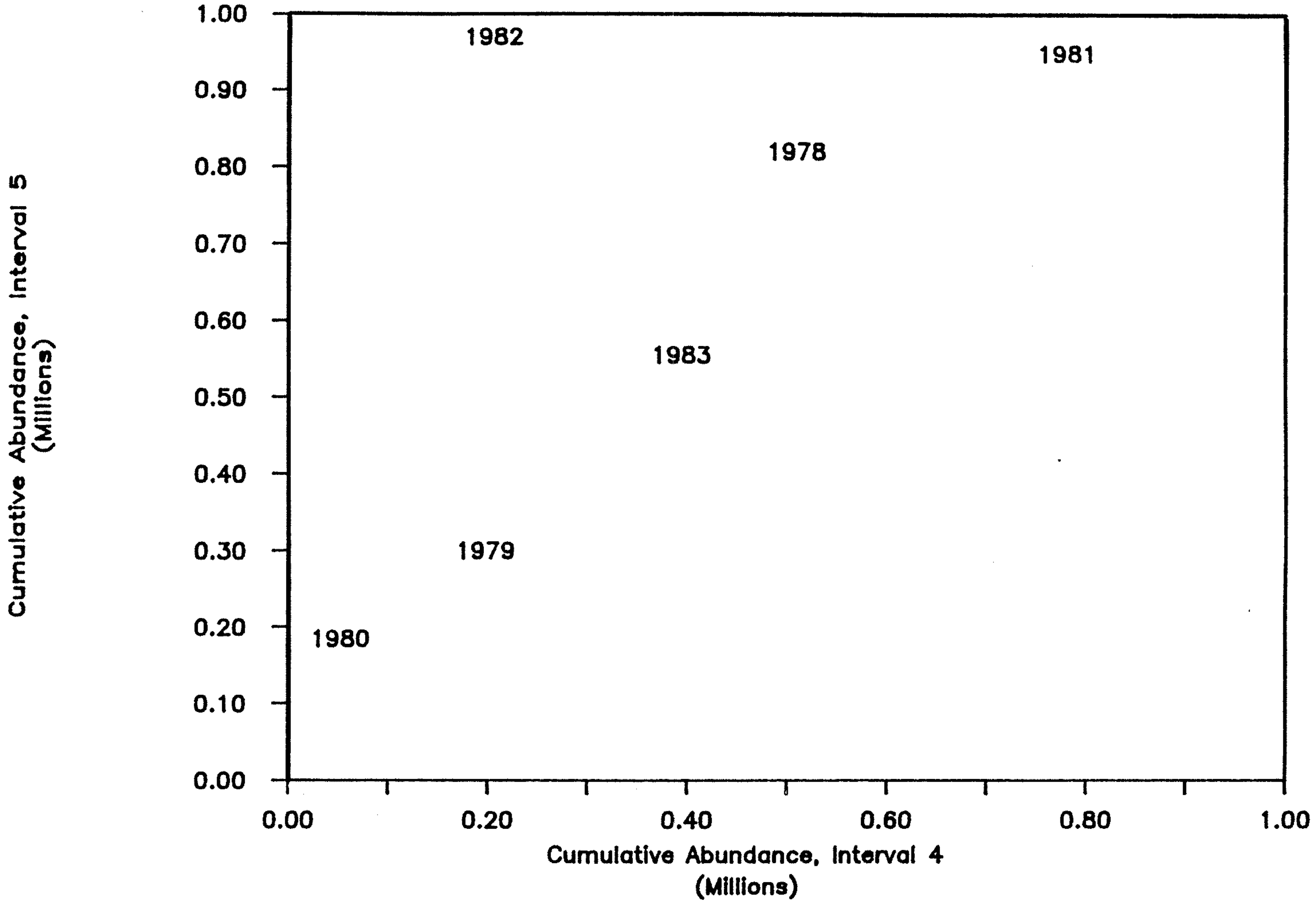


Fig. 20. Relationship between cumulative abundance on intervals 4 and 5 of Black Lake stock migrations, showing the 1982 outlier.

was inflexible to observed stock migrations that diverged from pre-season expectations of abundance or migration timing.

The stock migrations in 1978 were of nearly average timing in virtually every parameter (see Tables 9 and 10). The IPF model worked quite well for both stocks, with the exception of a single large error in interval 8 of the Chignik Lake stock migration (Figs. 21a,b). The APC model delivered relatively poor performance in reconstruction of the Black Lake stock migration owing to a highly inaccurate pre-season forecast. APC performance for the Chignik Lake stock was very good up to the midpoint of the migration period.

Differences in performance of the two models were not pronounced in the stock migrations of 1979 (Figs. 22a,b). Accuracy of interval predictions in early periods of the migrations was roughly equivalent for both methods, and in fact APC forecasts were slightly better for much of the Black Lake stock migration. Errors in the APC forecasts again were ascribable more to inaccurate pre-season forecasts than to deviation from expected migratory timing.

Note that the self-correcting feature of the IPF model was activated by forecast error only by interval 5 of the Black Lake stock migration. Systematic high predictions in previous intervals apparently result if cumulative abundance in each time interval of the observed migration is much smaller than the historical mean. The correction factor, $b_{t+1}[N_t - \bar{N}_t]$, is then small relative to N_{t+1} and has little influence on N_{t+1}. Use of proportional data would alleviate this difficulty by eliminating the effect of variable annual abundance, but the problem of determining true relative migratory timing would remain.

The 1980 migrations illustrated the case of asymmetric distributions of abundance over time (Fig. 23a,b). The Black Lake stock migration was the smallest and latest of the years considered. Poor performance of the APC model is explained by error in the pre-season forecast (even though the magnitude of error is quite small compared to other years), and by an unusual, somewhat truncated, migration pattern. Predictions from the IPF model tracked the accumulation of stock abundance over the duration of this atypical migration. The 1980 Chignik Lake migration was correctly forecasted and of average timing, yet APC predictions for the early periods were consistently higher than observation. APC errors in this case apparently resulted from negative skew in the temporal distribution of abundance, for which the IPF method mostly compensated.

Relative performance of the two intraseason forecasting methods in years of atypical migration timing was demonstrated in the 1981 migrations. The arrival of both stocks was noticeably early, but predictions from the APC method, being fixed to average timing, did not reflect this earliness (Fig. 24a,b). In years of normal timing, the APC method predicts that about 6.5% and 2.5% of cumulative total abundance will have arrived by interval 2 of the Black Lake and Chignik

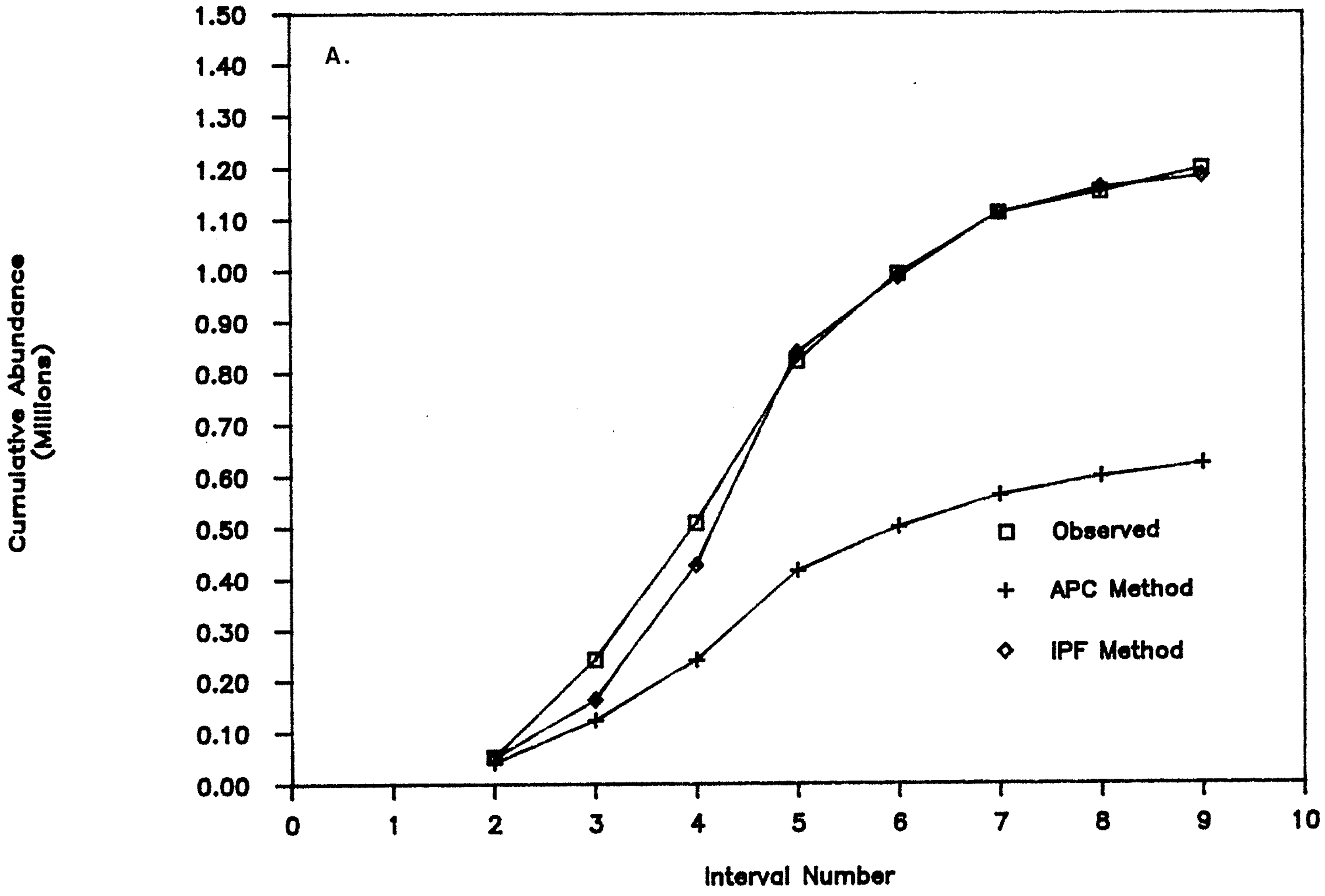
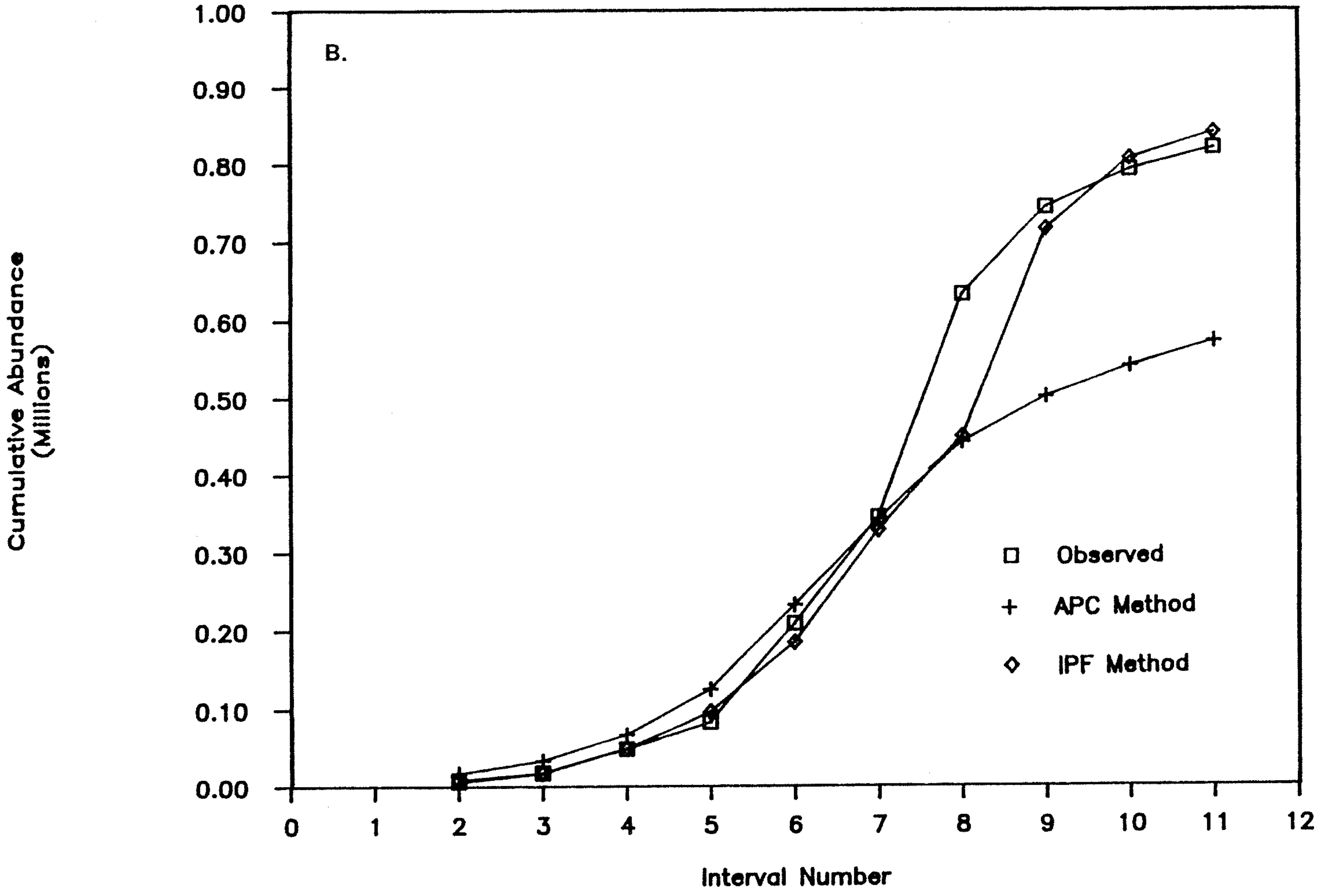


Fig. 21. Performance of APC and IPF models in reconstructing cumulative abundance by time period of the 1978 Black Lake (A) and Chignik Lake (B) stock migrations.



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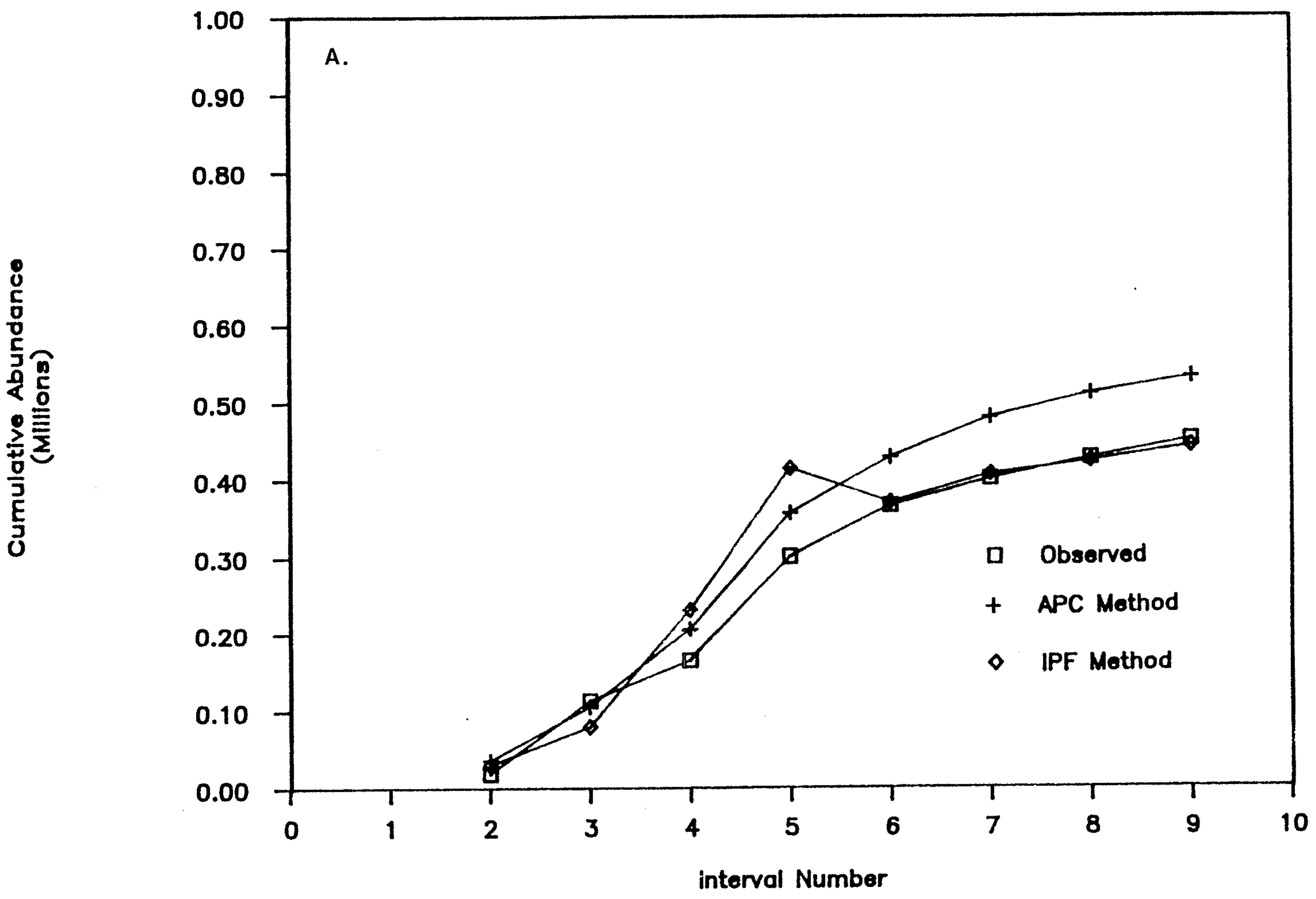
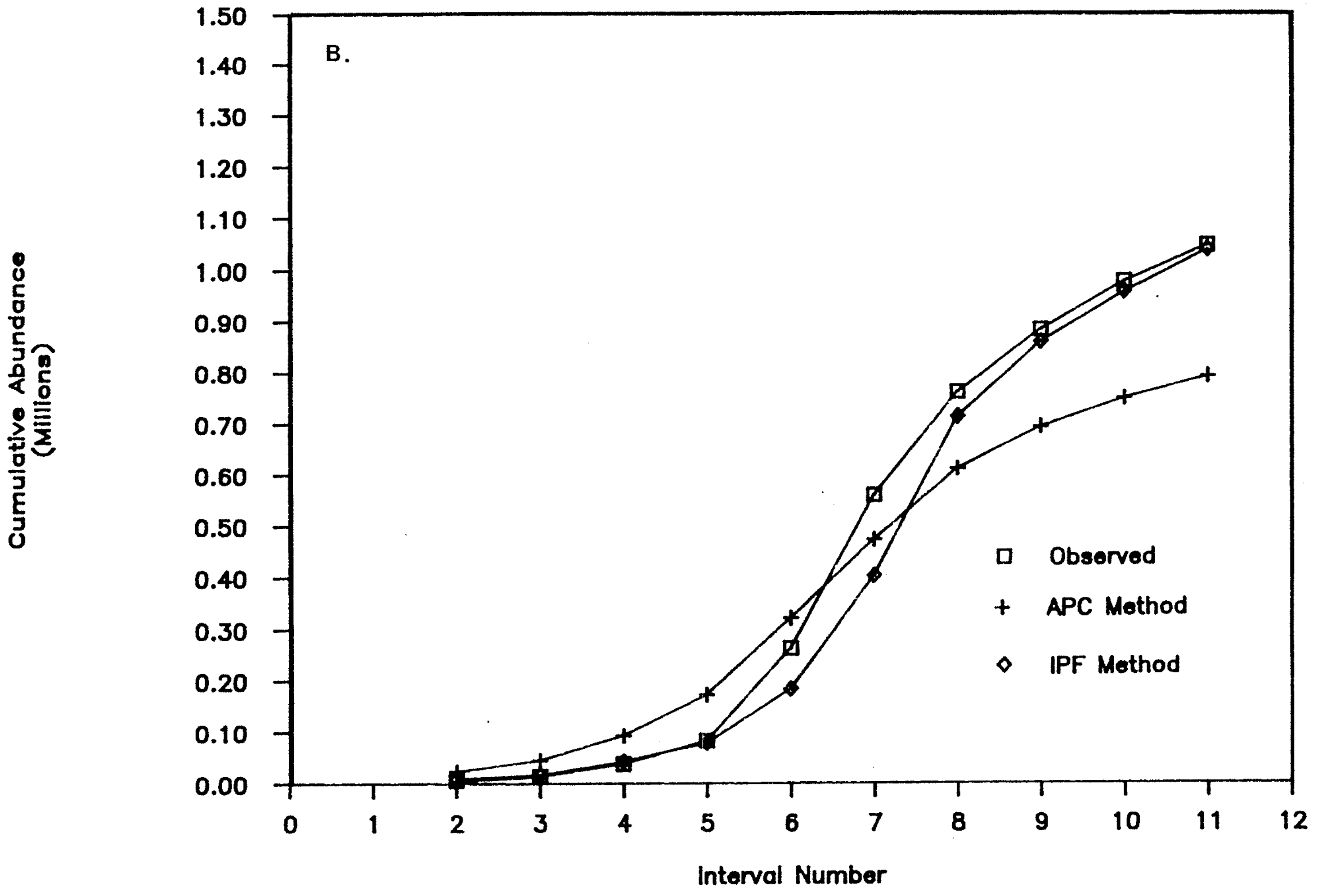


Fig. 22. Performance of APC and IPF models in reconstructing cumulative abundance by time period of the 1979 Black Lake (A) and Chignik Lake (B) stock migrations.



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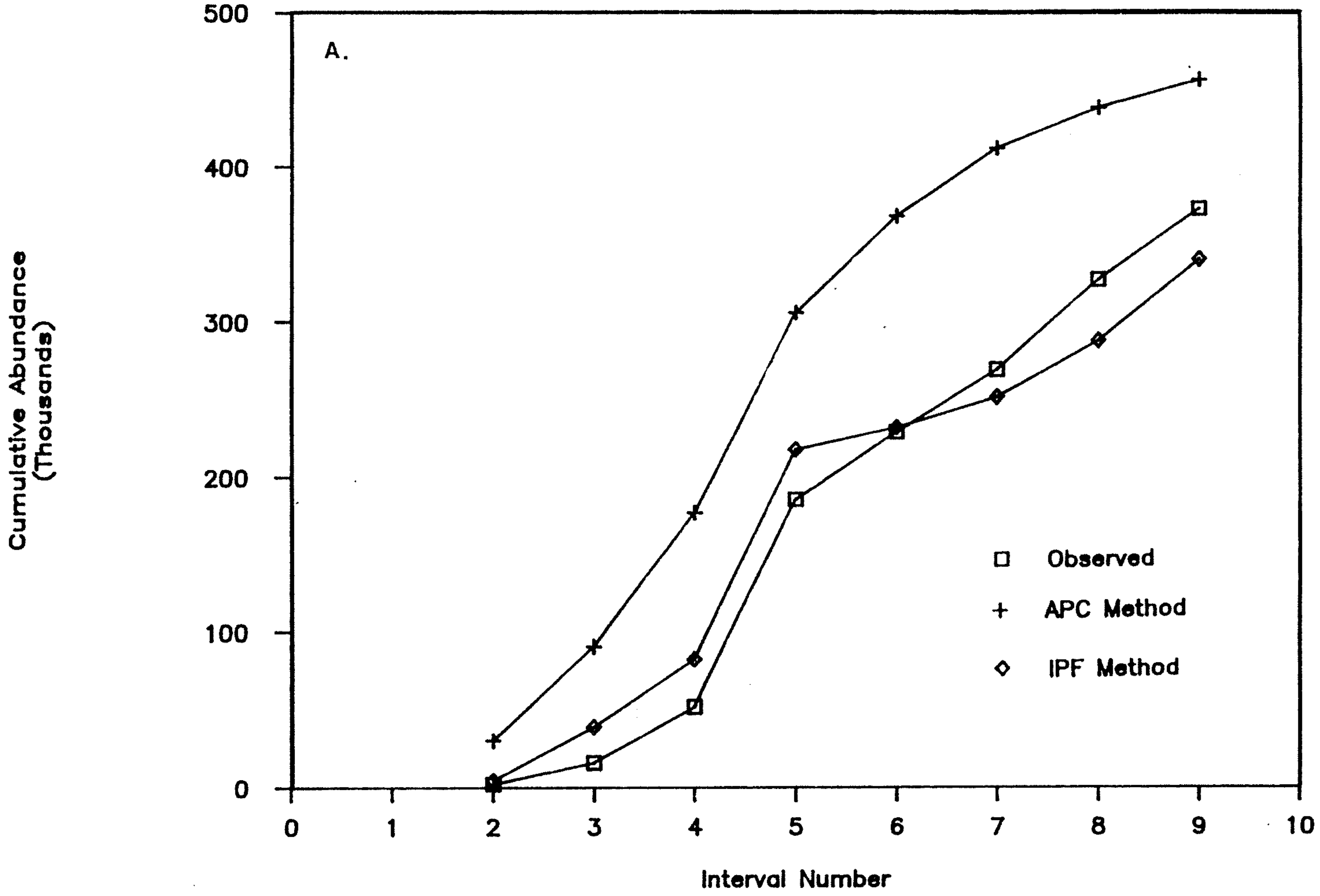
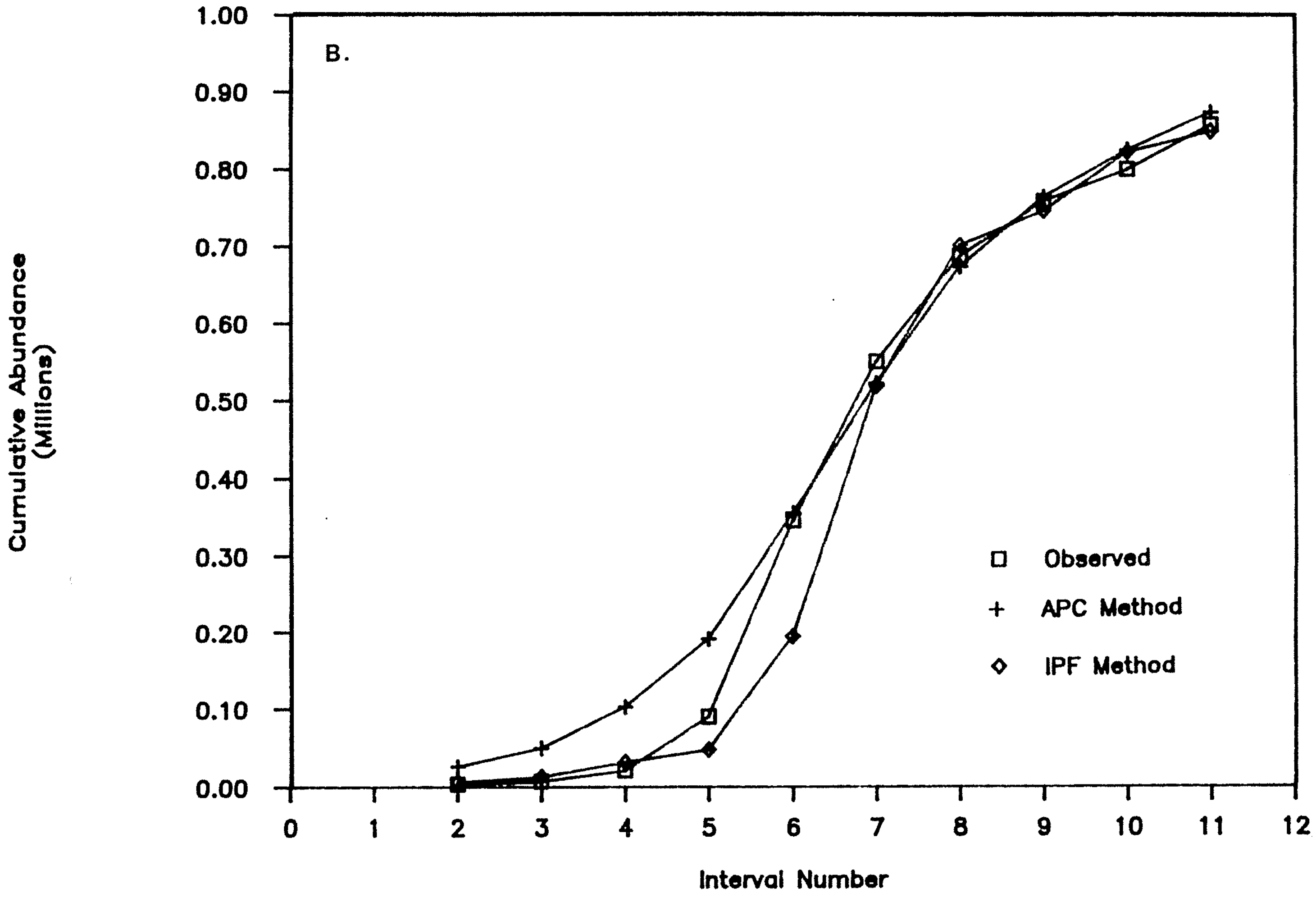


Fig. 23. Performance of APC and IPF models in reconstructing cumulative abundance by time period of the 1980 Black Lake (A) and Chignik Lake (B) stock migrations.



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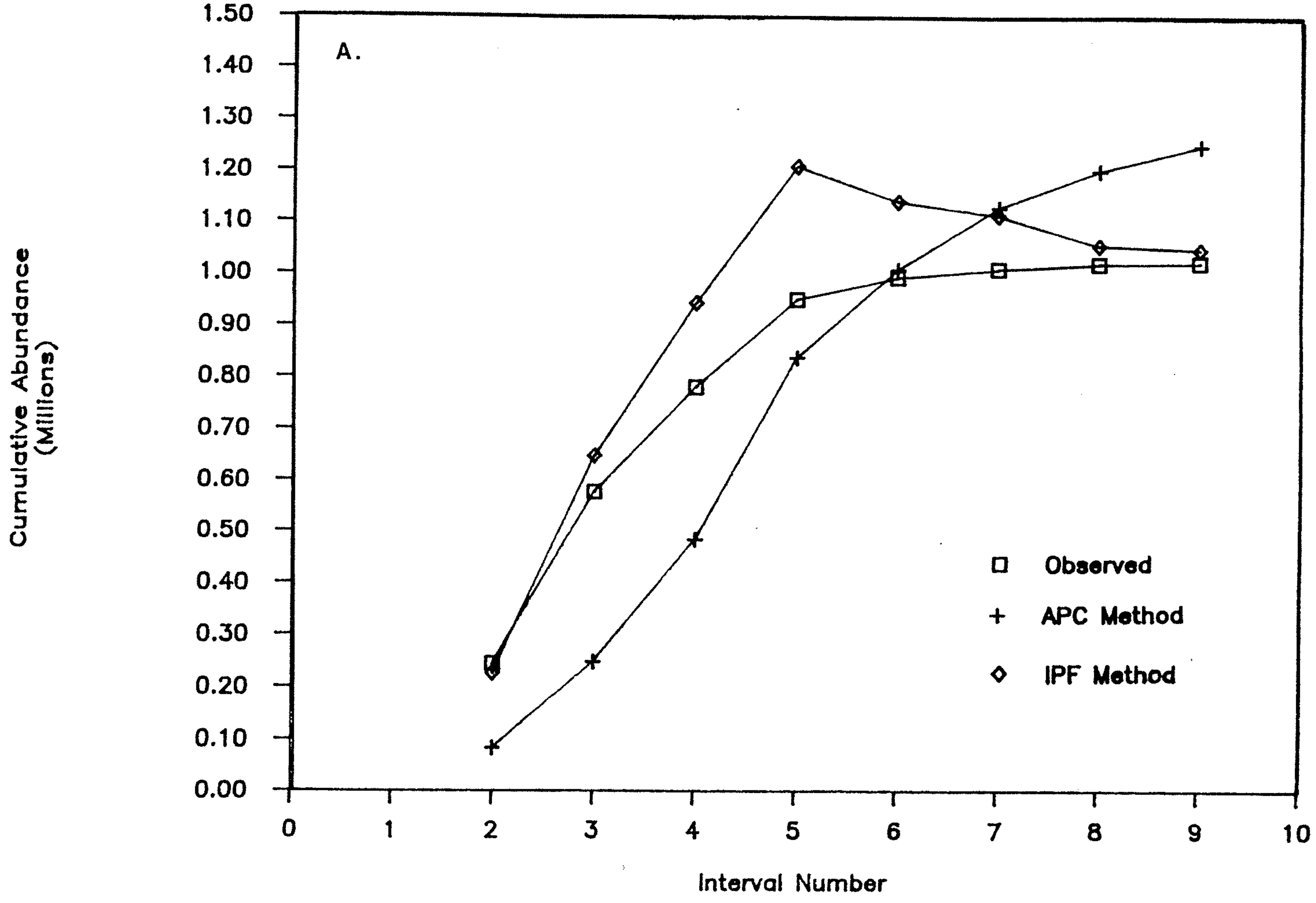


Fig. 24. Performance of APC and IPF models in reconstructing cumulative abundance by time period of the 1981 Black Lake (A) and Chignik Lake (B) stock migrations.

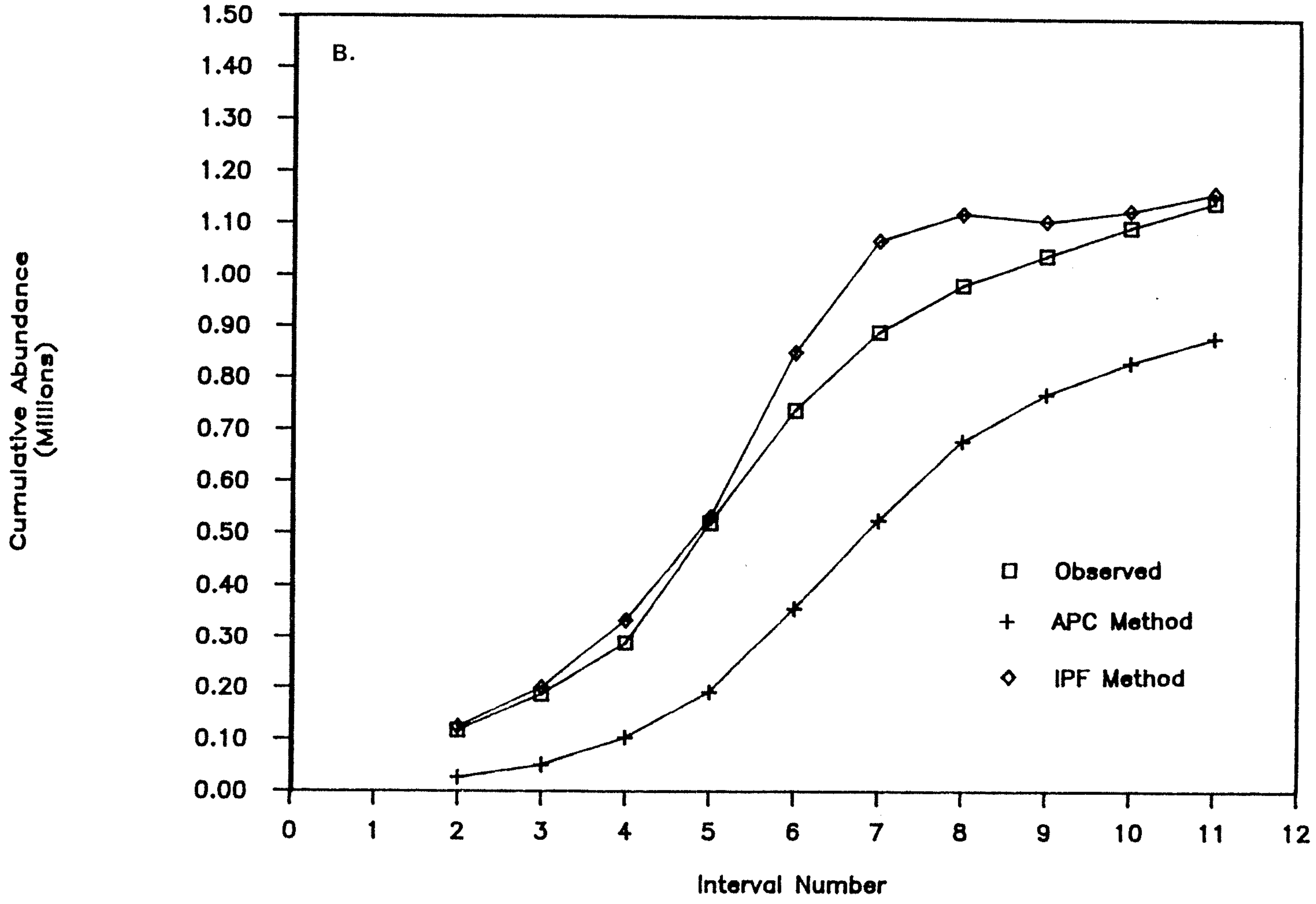


Fig. 24. Continued.

Lake stock migrations, respectively, rather than nearly 24% and 10% of the respective migrations that actually arrived by interval 2 in 1981. The IPF model produced interval forecasts that closely followed the actual trajectory of cumulative abundance in early intervals, but then systematically overestimated abundance near the peak of the migrations. The earliness of the migrations produced curves of cumulative abundance that were in decline during intervals at which maximum accumulation (near the inflection point) normally occurs. The IPF model overestimated the rate of accumulation based on observed data and the mean accumulation rate for these intervals. The advantage to the IPF method in this case was shown by the convergence of prediction with observation as the errors began to influence forecasts for subsequent intervals.

The 1982 season also demonstrated the flexibility of the IPF model to asymmetry in the cumulative abundance curve. The Black Lake stock migration appeared to be extremely late during the first time periods of the season because of a prolonged migration delay in Chignik Lagoon (Fig. 25a). The IPF accurately predicted cumulative abundance on each interval except 5, when a commercial harvest revealed that the trajectory of cumulative abundance on prior intervals had not accurately portrayed actual migration timing. Predictions from the APC model became more accurate in later periods as migration timing and stock abundance converged with pre-season forecasts. The Chignik Lake migration was of average timing and was modeled adequately in early periods by both models (Fig. 25b). The smooth accumulation of abundance proceeded as expected until interval 6, when the migration pattern became truncated by unexpectedly low numbers of fish. The IPF model produced a large forecast error only in interval 7, while the APC model produced large errors in all subsequent forecasts.

The relatively good performance of both intraseason forecasting systems in 1983 reflects the average timing of the migrations and the accuracy of pre-season forecasts (Fig. 26a,b). Migratory timing of both stocks was virtually average in all parameters (see Tables 9 and 10). The accumulation of abundance through time sufficiently resembled historical averages that no substantial forecast errors occurred. It is difficult to argue the superiority of either model in this year.

Relative performance of the models is illustrated by the behavior of MAPE over time periods of the migration. The IPF method showed substantially better performance in all intervals of Black Lake stock migrations, particularly in the early periods (Fig. 27). This result was repeated for the Chignik Lake stock migration (Fig. 28), but note that the scale of error is approximately half that of the Black Lake stock. The trend in MAPE for the APC model dropped sharply from high initial values as absolute forecast error became a smaller fraction of cumulative abundance in sequential time intervals, and reached a minimum value corresponding to the MAPE of pre-season abundance forecasts. The trend in MAPE for the IPF model was considerably less dramatic, and continued to decline over time periods of the migration as the precision of interval forecasts improved and abundance increased.

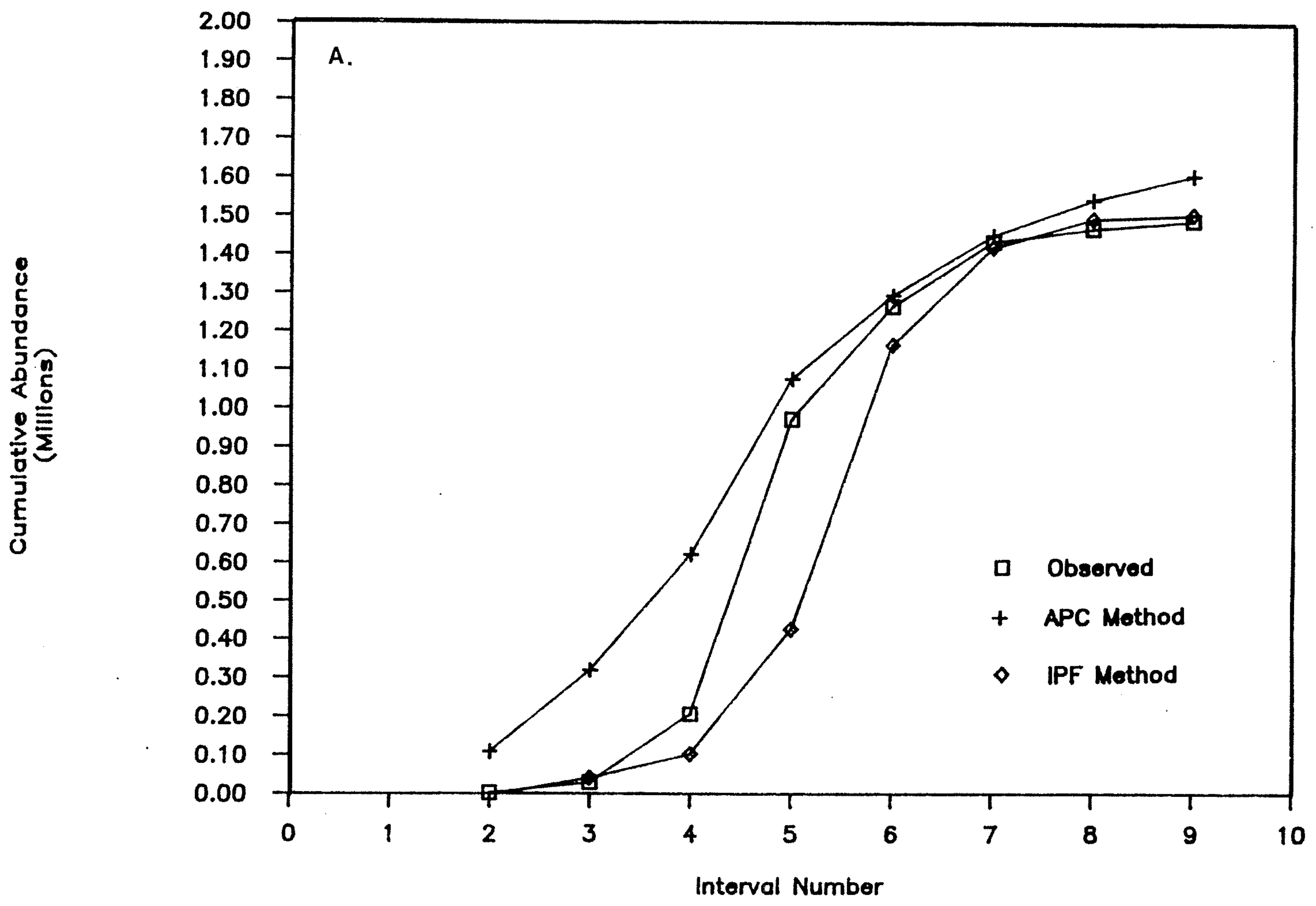
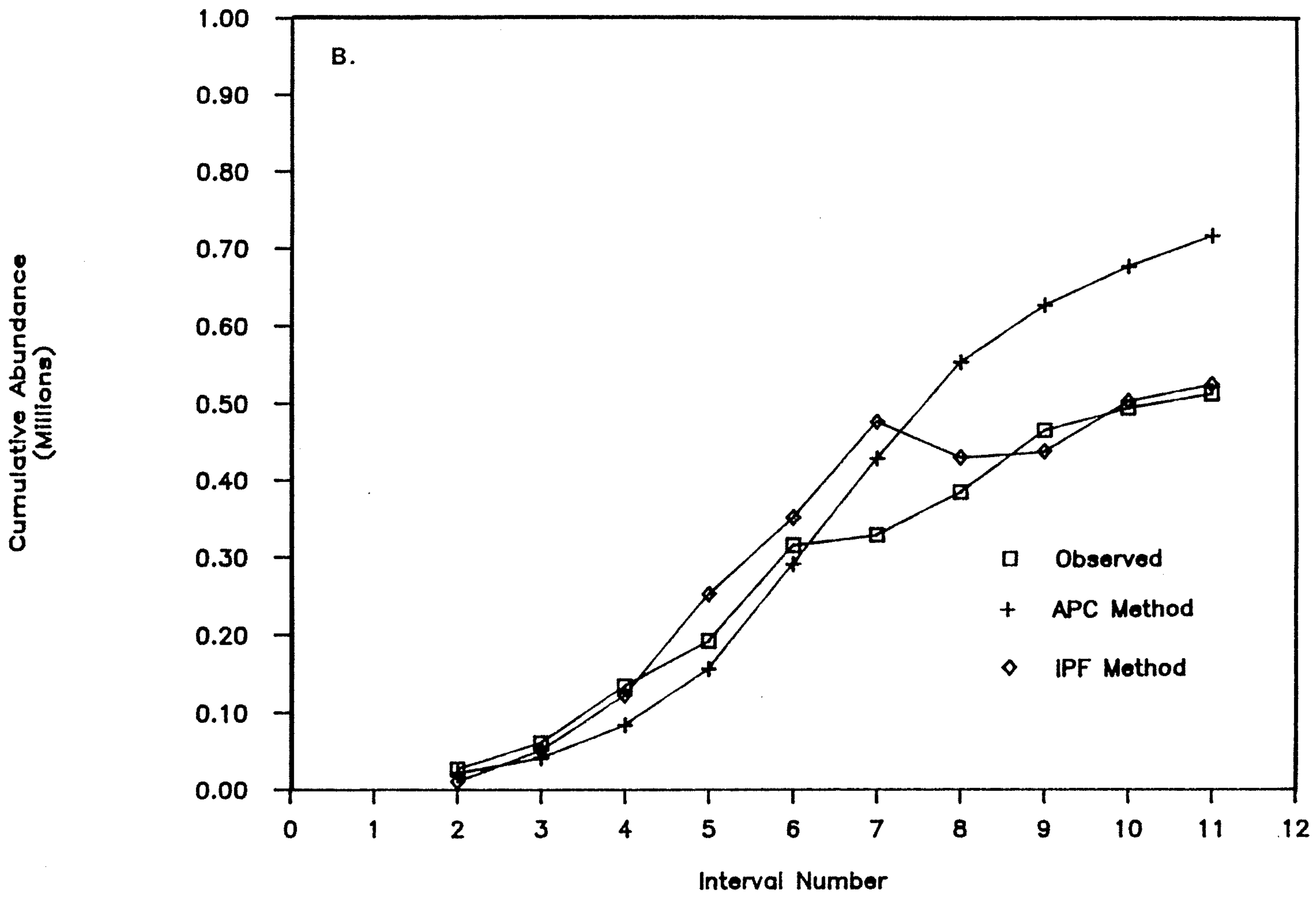


Fig. 25. Performance of APC and IPF models in reconstructing cumulative abundance by time period of the 1982 Black Lake (A) and Chignik Lake (B) stock migrations.



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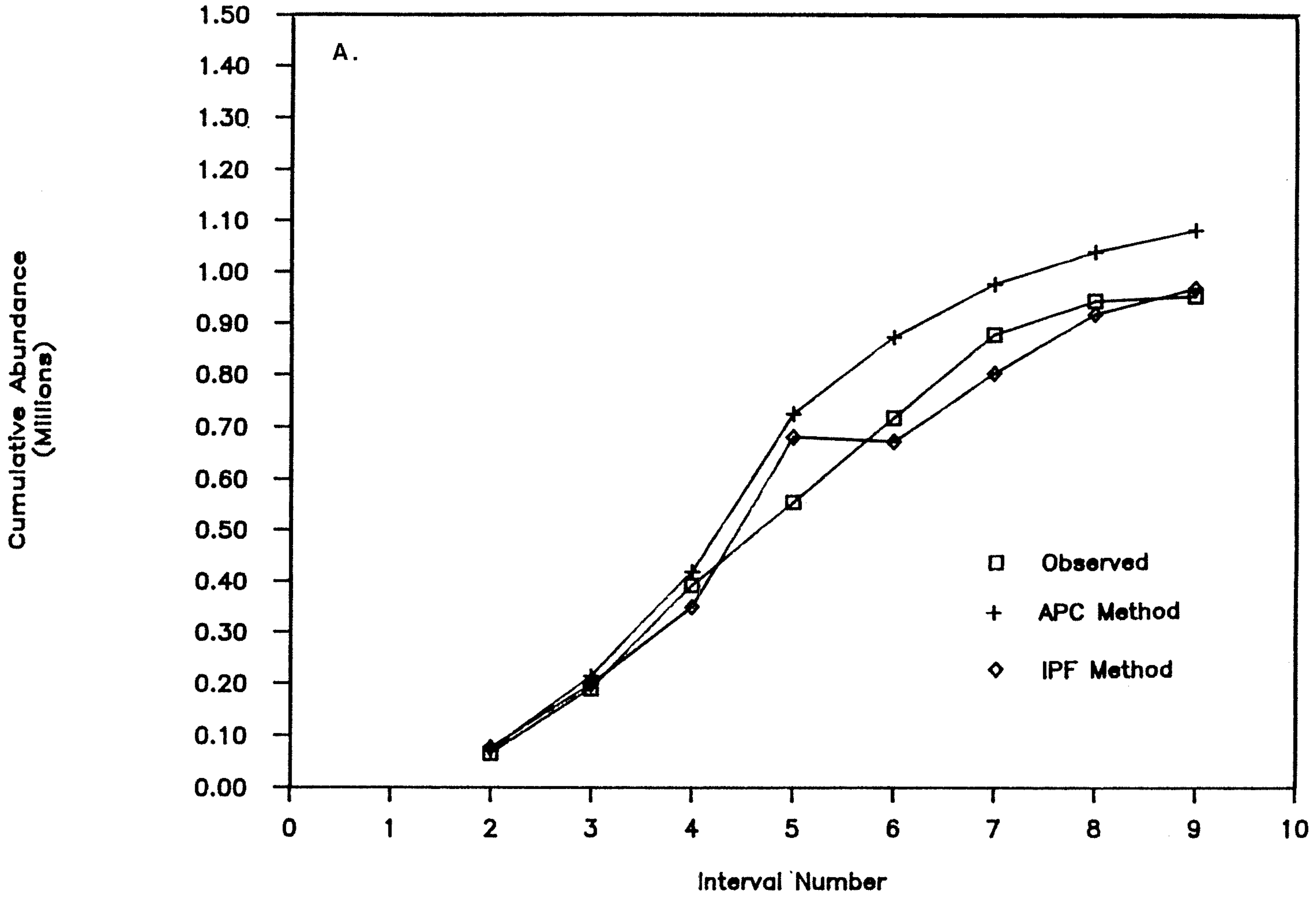
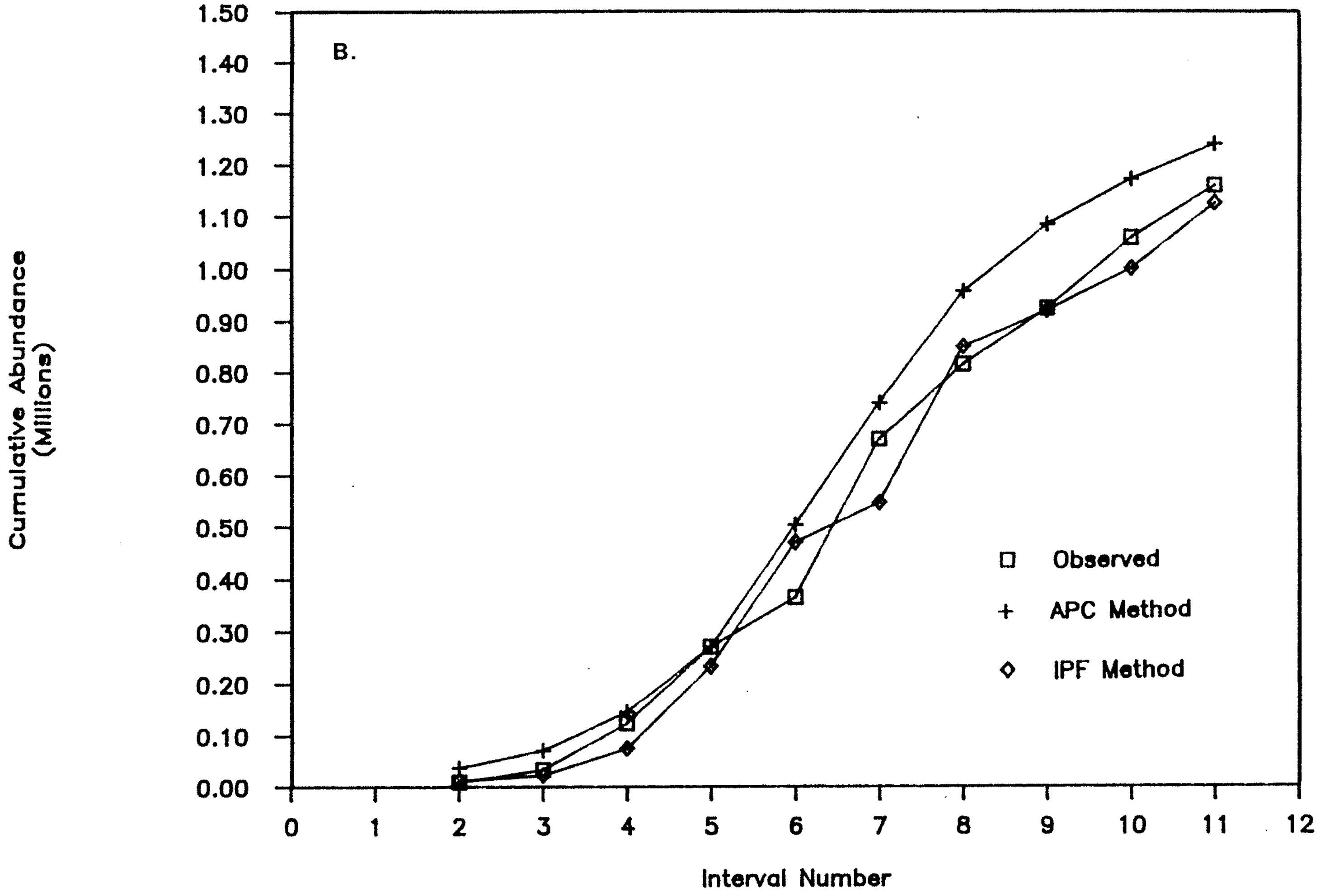


Fig. 26. Performance of APC and IPF models in reconstructing cumulative abundance by time period of the 1983 Black Lake (A) and Chignik Lake (B) stock migrations.



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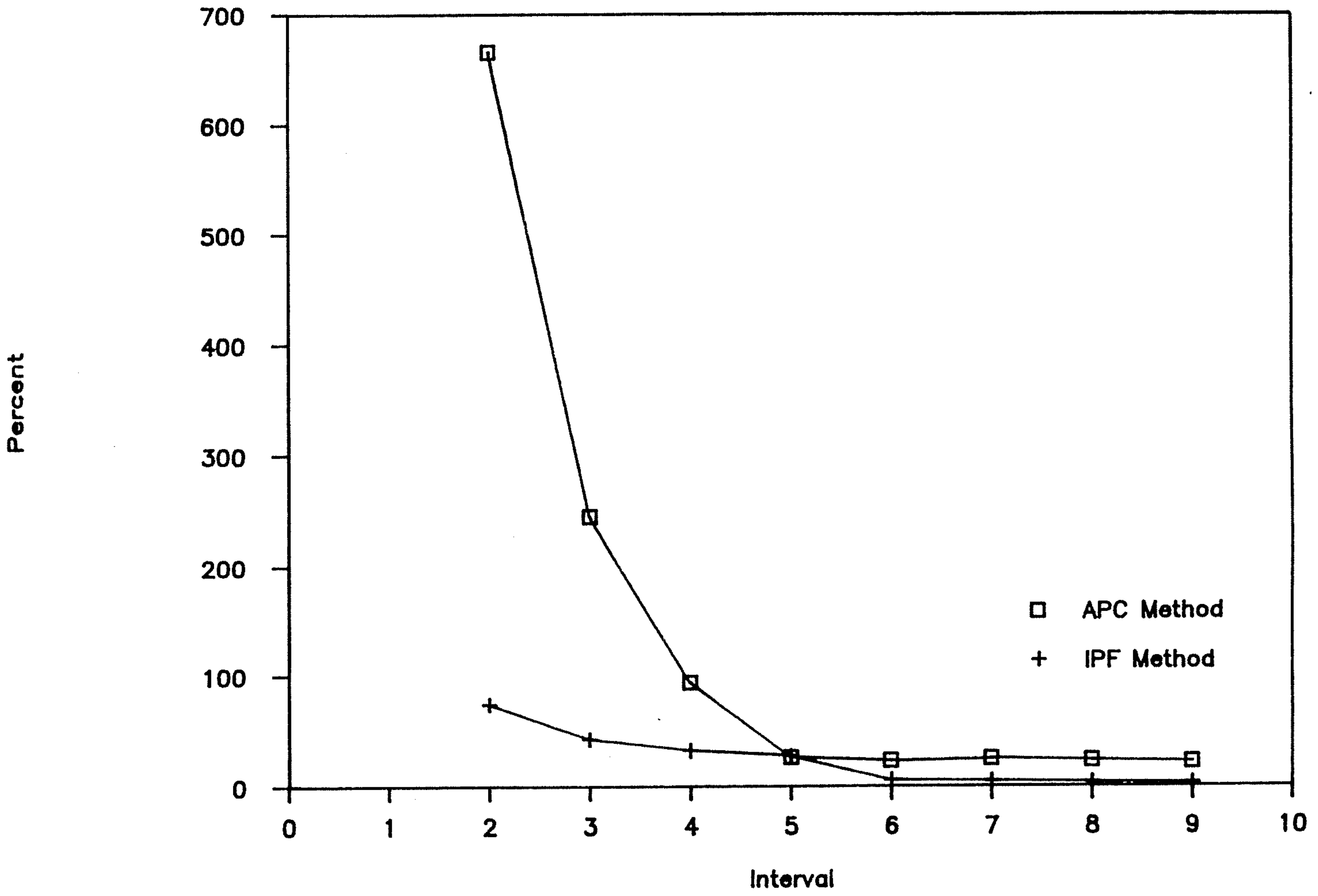

Fig. 27. Comparison of mean absolute percentage error of interval predictions for Black Lake stock migrations.

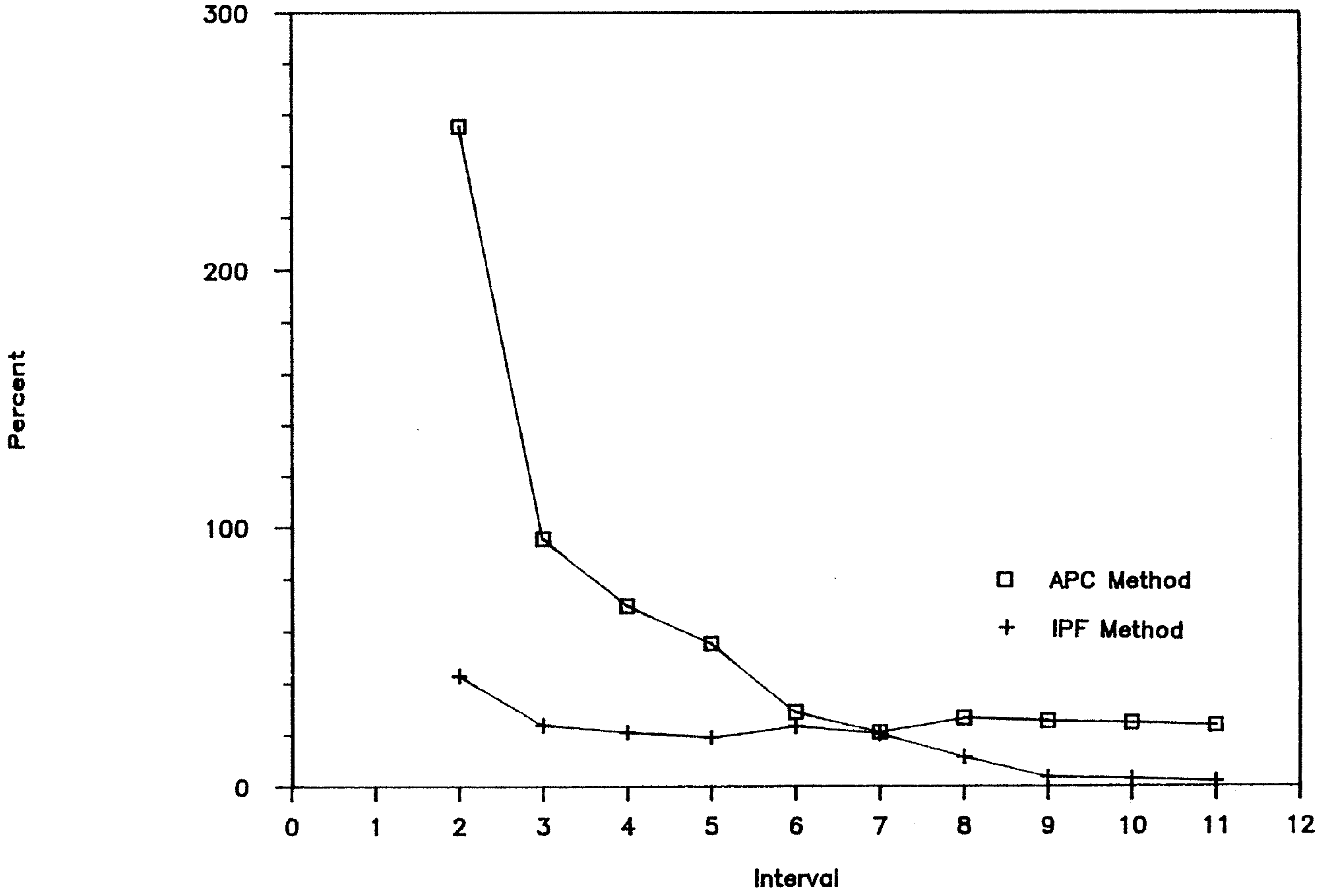

Fig. 28. Comparison of mean absolute percentage error of interval predictions for Chignik Lake stock migrations.

The accuracy of predictions for early migration periods was much better for the Chignik Lake stock than for the Black Lake stock, implying greater consistency in annual migration patterns. The MAPE for the first interval forecast was slightly over 40% and decreased to around 20% until the last few intervals. This stands in direct contrast to the rather dismal performance of the pre-season forecast model and offers some promise that the Chignik Lake stock abundance is predictable, if not in pre-season then at least as a function of time during the season.

DISCUSSION

The objective of this study was to develop and evaluate alternative methods for estimating the abundance of sockeye salmon in the Chignik fishery as a function of time. Two approaches to forecasting temporal trends in abundance were examained. The APC model represented the fixed forecast approach, wherein point estimates of cumulative abundance by time period were calculated in advance of the fishing season. The performance of this model depended entirely on the accuracy of pre-season forecasts of stock abundance and migration timing. The IPF model represented an adaptive approach to forecasting, wherein migration patterns in the year of interest were incorporated into the forecasting process. Information "learned" in developing stages of the migration influenced predictions for succeeding time periods.

Based on reconstructions of the sockeye migrations for 1978 through 1983, I conclude that the IPF method provides better performance in forecasting abundance in the fishery as a function of time. The APC forecasting model, being a composite of two independently derived predictions, obviously had twice the opportunity to fail. Although failure was due in some cases to unusual migration patterns (e.g. 1981 and 1982), performance of the APC model most often was limited by the accuracy of pre-season forecasts of abundance. It is clear that acceptable accuracy in point estimates of total abundance for the season is not necessarily acceptable accuracy for purposes of intraseason abundance estimation.

Pre-season Forecast Models

Multiple linear regression models have been correctly characterized as being site-specific and lacking general application (Barth 1984), but such models are useful in cases where causal relationships among the factors affecting the dependent variable cannot be confirmed even though circumstantial relationships may exist. Although biological dependence among variables in the model is desireable, regression models frequently are used solely as a means of predicting the value of a response variable (Zar 1974). A stepwise regression analysis was used in this study so that inclusion of variables could be examined at each step. This procedure allowed more analyst control over construction of a biologically realistic model.

The biological interpretation of the pre-season stock forecast models is straightforward. Independent variables are sensical parameters of stock production measured at various stages in the maturity of the dominant age class. Parent year escapements obviously index brood strength in terms of potential egg deposition. The abundance of 2-ocean age sockeye in the previous year provides a quantitative assessment of how the brood has fared up to that point in time, the inference being that ocean survival in the last year at sea is approximately constant over time. Data on the mean length of 2-ocean age sockeye are significant in determining whether the relative proportions of a brood returning after 2 yr at sea and after 3 yr at sea have been alterred by unusually favorable or unusually poor conditions for growth.

The absence of significant environmental predictors of stock abundance is not so surprising in view of the set of variables selected by the regression methods. The Black Lake stock forecast model incorporates data sampled chronologically through the development of ultimate brood strength. Environmental regulation of brood production at particular life history stages generally is correlated with abundance of 2-ocean age fish, and so does not contribute a great deal of additional information on variability of 3-ocean age abundance. The absence of environmental variables from the forecast models should not be interpreted as showing no environmental influence on production or maturity rates.

Several major differences exist between the specific stock forecast models, not the least being the disparity in performance. It is probable that differences in accuracy between the models relates to the quality of data available for each stock for the years prior to stock separation based on scale pattern analysis. Statistics for the Black Lake stock were calculated in this analysis from data obtained by routine sampling for age, length, and sex of spawners captured at the outlet of Black Lake prior to their movement onto the spawning grounds. These samples are reliably stock-specific as mixing between stocks at this location is highly improbable. Representative samples from the Chignik Lake stock are not easily obtained because the majority of spawners are inaccessible in the deeper waters off Hatchery Beach. Chignik Lake stock statistics consequently were calculated from data collected in the commercial fishery, but they cannot be considered reliably stock-specific for the years prior to scale pattern analysis because Black Lake and Chignik Lake stocks may be mixed in the catch during the sampling period. Therefore, error in stock production data probably is the principal source of variability in the relationships from which the Chignik Lake stock forecast model is developed.

Errors in stock production estimates arise primarily as a result of 1) inaccuracy in stock abundance estimates, or 2) misallocation of ages within stocks. Each stock data set contains error in stock abundance estimates attributable to yearly variations in timing and comparative magnitudes of the sockeye migrations relative to the placement in time of the average TOE curve. Errors of this sort are generated in estimates of stock abundance if the TOE curve is misplaced in time with respect to actual migration timing or if the migrations are not of equal magnitude. The frequency of occurence, size, and direction (to Black Lake stock or Chignik Lake stock) of such errors in the statistics are indeterminate for the years prior to 1978. Furthermore, estimates of Chignik Lake stock size are subject to a source of error which does not affect the Black Lake stock. Incomplete escapement counts after weir removal in early August may mask late season migration dynamics, and could account in part for the lack of significant relationships among Chignik Lake stock production variables.

Estimates of stock abundance in each year are apportioned to appropriate brood based on the age composition of the return. The accuracy of age composition statistics thus is a key factor in ascertaining overall brood production. As Burgner and Marshall (1974) pointed out, large discrepancies may exist between age composition estimates for each stock calculated from samples taken in the commercial fishery and from otoliths collected on the spawning grounds. Our use of age composition statistics for the Black Lake stock calculated from data taken in the Black Lake watershed rather than in the fishery almost certainly improves the accuracy of brood production estimates for years prior to 1978, in turn permitting a higher degree of accuracy in calculations based on brood production estimates. Conversely, the difficulty in obtaining reliable stock-specific Chignik Lake age composition data certainly impairs the reliability of brood production parameters calculated from the historical record for this stock.

The results clearly indicate a need for better measurements of basic population parameters for the Chignik Lake stock. The lack of strong relationships among stock production variables may be the result of (1) a real absence of such relationships in Chignik Lake stock production dynamics, or (2) masking of such relationships by measurement error in the data. It is suggested that (2) presently is the case, but the point is that (1) cannot be tested until (2) is resolved. Long-term efforts to enhance the Chignik Lake stock data base should include separation of stocks in the catch and escapement by scale pattern analysis (e.g., Conrad 1983, 1984) and estimation of late season sockeye escapements (Parker and Rogers 1984).

Intraseason Forecast Models

The accuracy of intraseason forecasts based on average migration characteristics is dependent on the consistency of annual time density distributions, with particular respect to their means and variances, but also with respect to symmetry. Although the Chignik sockeye stocks display remarkable consistency in central dates of migration timing, estimated variances of the migrations about their central dates are highly unstable. Exogenous influences on the symmetry of time density distributions may further alter the variance. Ironically, the perception of earliness or lateness of migration timing develops early in the season as a function of the variance. In the absence of quantitative information on timing and abundance early in the migration, control of the commercial harvest is likely to depend on this perception.

Underlying variances of migratory time densities probably are mediated by environmental factors such as climate (Mundy 1982; Clark 1983), but it is unclear to what extent the perception of variance of the time density distribution is due to asymmetry generated by the time distribution of fishing effort relative to the migratory behavior of the fish. Time density distributions calculated for nearly undisturbed migrations (1979, 1980 Black Lake stock) more closely approximated equivalent normal distributions than did those calculated for heavily exploited migrations. The magnitude of departure from expected migration patterns

(Mundy 1979) is probably related to the milling behavior of sockeye entering Chignik Lagoon.

The APC model was developed from a class of migratory time density models which rely on the assumption (probably valid in most cases) that the harvested stock exhibits a unidirectional and constant migration through the fishery. When this assumption is valid, then the distribution of catch plus escapement (time-lagged to the fishery) presents a true image of the migratory time density for the population. When the assumption is not true, the catch of a single time interval no longer reflects the abundance of fish accumulated only during that interval, but rather the abundance of fish accumulated over several time intervals corresponding to the "pool time" of fish and the time between harvests. The distribution of catch plus escapement in this case skews the outward appearance of the migration pattern.

It is apparent that the perceived time distribution of sockeye entering Chignik Lagoon actually represents the combined effects of both the behavior of the fish and that of the harvest community. If these behaviors and their effects occur at random, then it is unlikely that the time density of a single year will resemble that of other years. Eby and O'Neill (1977) advise limiting a time series forecasting horizon to the shortest feasible time period in such unstable forecasting conditions. The essential difference in the two intraseason forecasting models has to do precisely with this advice; the APC model is constrained to forecast all time periods of the migration in advance, before the behaviors of the fish and the fishing community can be known. The IPF model forecasts only five days into the future as the particular behavioral attributes of the migration become apparent.

In this study we have implicitly considered spawner escapements to be some part of the total abundance predicted for each time interval, but I have not addressed the question of how escapements could be obtained in real time. The present escapement schedule at Chignik is based on a salmon management theory which states there is an optimum spawner stock size determined by the carrying capacity of the nursery area for progeny. Narver (1966) and Dahlberg (1968) calculated optimal spawner stock sizes for Black Lake (about 400,000) and Chignik Lake (about 250,000) according to the prevailing philosopy of the time. If the IPF system were to be applied to the Chignik sockeye fishery, a fixed number of spawners would be withdrawn from each 5-day interval forecast of total abundance to determine the harvestable surplus in each interval. Fishing pressure would be adjusted in each interval to ensure attainment of the cumulative escapement goal.

However, the notion that there exists a single optimum spawner stock size for any nursery system has recently come under critical review (Walters and Hilborn 1976; Hilborn and Walters 1977; Walters 1981; Smith and Walters 1981). It has been suggested that rigid control of escapements reduces the variability in spawning stock sizes that provides valuable information on changes in stock productivity. These analysts argue that salmon rearing habitats are not environmentally or biologically static systems, and that it is fundamentally wrong to assume that a fixed spawner stock size is always (or usually) optimal for a given nursery area.

Walters (1981) recommmends regular "probing actions," whereby spawner stock size is deliberately varied to test for changes in stock productivity. Under this scenario, escapements could be regulated as a fixed fraction of forecasted total abundance in each time period of the migration. If the exploitation rate in the commercial fishery were held constant, then the time distribution of escapement naturally would follow that of total abundance in the fishery and ensure that all substocks contributed spawners in proportion to their relative abundance. The problem in this case would be in calculating an appropriate harvest level, particularly if the levels were different for each of the stocks mixing in the fishery.

The acceptability of the Walters and Hilborn (1976) style of "adaptive management" is of less relevance to this study than is the idea upon which it is based; namely, that the set of outcomes to complex biological processes is potentially infinite, always changing, and often unpredictable. In the context of the present study, it is useful to recognize that the parameters of migratory timing are in fact complex functions of biological and physical interactions, and are likely to be anything but constant over time. Indeed, the biological and environmental circumstances producing the migratory behavior of a given year might in no way resemble those in other years. Attempts to wrest simplicity from such complex situations often succeed only at the expense of flexibility in the resulting model. We submit that the IPF model is an acceptable compromise between simplicity and performance in meeting the needs of the Chignik sockeye salmon fishery manager.

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APPENDIX A

Appendix Table A1. Statistics for the distributions of daily abundance within and across years for the Black Lake stock.

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
152	7200	4596	1396	29389	312	10524	8903	10714	1.203
153	1680	1764	42	25104	260	7272	6020	9712	1.613
154	7435	3276	100	38075	414	15466	10794	14533	1.346
155	11929	4283	300	60592	251	15507	15477	22958	1.483
156	23094	4431	500	90053	1221	16618	22653	34239	1.511
157	11577	3906	1000	71478	699	12983	16941	27227	1.607
158	10435	10668	2000	31625	2012	11096	11306	10835	0.958
159	6720	12348	3000	106036	661	38402	27861	40664	1.460
160	143102	59339	4000	59937	14142	48489	54835	49230	0.898
161	18426	8372	4000	64262	9556	14119	19789	22344	1.129
162	24036	10650	5000	46305	21652	18246	20981	14288	0.681
163	119552	16761	5000	43989	10528	23109	36490	42871	1.175
164	25156	24588	12058	21228	39254	66241	31421	19176	0.610
165	76397	14416	8764	44393	65850	67069	46148	28804	0.624
166	21835	17854	5287	47851	38302	27893	26504	15124	0.571
167	95529	23132	22629	30523	72325	7996	42022	34071	0.811
168	82225	16376	38025	20730	147955	49892	59200	49510	0.836
169	46546	25465	29096	57825	327186	46543	88777	117417	1.323
170	14843	20418	26259	53126	102801	33411	41810	32696	0.782
171	73591	18710	16799	7405	116053	25196	42959	42739	0.995
172	62453	19740	15453	9379	87746	30668	37573	30940	0.823
173	21388	19372	1752	11777	44139	42849	23546	16925	0.719
174	46525	9450	9200	3102	55637	48053	28661	23765	0.829
175	28666	7390	8594	16671	66451	28468	26040	21844	0.839

Appendix Table A1. Statistics for the distributions of daily abundance within and across years for the Black Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
175	28666	7390	8594	16671	66451	28468	26040	21844	0.839
176	12990	9693	9134	1869	40386	12696	14461	13319	0.921
177	39256	7575	5220	5017	56220	41249	25756	22506	0.874
178	20167	9587	14172	4391	29423	43208	20158	14236	0.706
179	26844	7944	10527	2833	33003	30802	18659	13051	0.699
180	12422	4581	5757	2804	30915	24592	13512	11674	0.864
181	21305	4176	4579	2144	19833	20576	12102	9326	0.771
182	2643	9568	15240	4735	2087	14795	8178	5919	0.724
183	23009	3670	23235	2153	13688	13365	13187	9056	0.687
184	12937	8817	6171	1554	8202	14201	8647	4603	0.532
185	956	3855	5733	516	7614	11402	5013	4150	0.828
186	1238	1465	7763	1257	3176	12220	4520	4525	1.001
187	25658	1801	5444	848	2739	1777	6378	9577	1.502
188	498	14226	4696	474	11640	2409	5657	5902	1.043
189	16111	5399	11006	418	3078	1813	6304	6072	0.963
190	772	1040	13841	453	2311	1847	3377	5173	1.531
191	1436	1120	10427	431	1835	2820	3012	3718	1.235
192	799	1273	4684	0	62	4625	1907	2180	1.143
193	11609	4254	3670	0	73	3557	3861	4233	1.096
Mean	28833	10758	8886	2556	35513	22954	10565	9003	0.945
St. Dev.	32744	10358	8538	3764	57570	17353			
CV	1.136	0.963	0.961	1.473	1.621	0.756			

Appendix Table A2. Statistics for the distributions of proportion of daily abundance within and across years for the Black Lake stock.

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
152	0.0059	0.0032	0.0032	0.0076	0.0000	0.0059	0.0043	0.0027	0.6304
153	0.0014	0.0032	0.0002	0.0110	0.0001	0.0075	0.0039	0.0044	1.1324
154	0.0061	0.0034	0.0002	0.0102	0.0001	0.0160	0.0060	0.0062	1.0327
155	0.0098	0.0038	0.0001	0.0245	0.0002	0.0160	0.0091	0.0098	1.0745
156	0.0190	0.0071	0.0003	0.0372	0.0003	0.0172	0.0135	0.0141	1.0468
157	0.0095	0.0093	0.0008	0.0592	0.0002	0.0134	0.0154	0.0221	1.4365
158	0.0086	0.0096	0.0013	0.0881	0.0008	0.0115	0.0200	0.0336	1.6858
159	0.0055	0.0084	0.0026	0.0699	0.0005	0.0397	0.0211	0.0279	1.3235
160	0.1175	0.0230	0.0052	0.0309	0.0013	0.0501	0.0380	0.0428	1.1259
161	0.0151	0.0267	0.0077	0.1037	0.0004	0.0146	0.0280	0.0381	1.3575
162	0.0197	0.1282	0.0103	0.0586	0.0095	0.0189	0.0409	0.0464	1.1367
163	0.0981	0.0181	0.0103	0.0628	0.0064	0.0239	0.0366	0.0363	0.9911
164	0.0206	0.0230	0.0129	0.0453	0.0145	0.0685	0.0308	0.0218	0.7082
165	0.0627	0.0362	0.0129	0.0430	0.0071	0.0693	0.0385	0.0253	0.6573
166	0.0179	0.0531	0.0311	0.0208	0.0263	0.0288	0.0297	0.0125	0.4212
167	0.0784	0.0311	0.0226	0.0434	0.0441	0.0083	0.0380	0.0240	0.6305
168	0.0675	0.0386	0.0136	0.0468	0.0257	0.0516	0.0406	0.0192	0.4718
169	0.0382	0.0500	0.0583	0.0298	0.0485	0.0481	0.0455	0.0100	0.2196
170	0.0122	0.0354	0.0980	0.0203	0.0991	0.0345	0.0499	0.0387	0.7752
171	0.0604	0.0550	0.0750	0.0565	0.2192	0.0260	0.0820	0.0691	0.8419
172	0.0513	0.0441	0.0677	0.0519	0.0689	0.0317	0.0526	0.0142	0.2694
173	0.0176	0.0404	0.0433	0.0072	0.0778	0.0443	0.0384	0.0246	0.6392
174	0.0382	0.0426	0.0398	0.0092	0.0588	0.0497	0.0397	0.0168	0.4224
175	0.0235	0.0418	0.0045	0.0115	0.0296	0.0294	0.0234	0.0135	0.5772

Appendix Table A2. Statistics for the distributions of proportion of daily abundance within and across years for the Black Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
176	0.0107	0.0204	0.0237	0.0030	0.0373	0.0131	0.0180	0.0119	0.6614
177	0.0322	0.0160	0.0222	0.0163	0.0445	0.0426	0.0290	0.0128	0.4409
178	0.0166	0.0209	0.0235	0.0018	0.0271	0.0447	0.0224	0.0140	0.6236
179	0.0220	0.0164	0.0135	0.0049	0.0377	0.0318	0.0210	0.0121	0.5757
180	0.0102	0.0207	0.0365	0.0043	0.0197	0.0254	0.0195	0.0114	0.5830
181	0.0175	0.0172	0.0271	0.0028	0.0221	0.0213	0.0180	0.0083	0.4611
182	0.0022	0.0099	0.0148	0.0027	0.0207	0.0153	0.0109	0.0074	0.6777
183	0.0189	0.0090	0.0118	0.0021	0.0133	0.0138	0.0115	0.0056	0.4891
184	0.0106	0.0207	0.0393	0.0046	0.0014	0.0147	0.0152	0.0137	0.8982
185	0.0008	0.0079	0.0599	0.0021	0.0092	0.0118	0.0153	0.0223	1.4571
186	0.0010	0.0190	0.0159	0.0015	0.0055	0.0126	0.0093	0.0077	0.8264
187	0.0211	0.0083	0.0148	0.0005	0.0051	0.0018	0.0086	0.0080	0.9258
188	0.0004	0.0032	0.0200	0.0012	0.0021	0.0025	0.0049	0.0075	1.5216
189	0.0132	0.0039	0.0140	0.0008	0.0018	0.0019	0.0059	0.0060	1.0152
190	0.0006	0.0307	0.0121	0.0005	0.0078	0.0019	0.0089	0.0116	1.3009
191	0.0012	0.0117	0.0284	0.0004	0.0021	0.0029	0.0078	0.0109	1.4028
192	0.0007	0.0022	0.0357	0.0004	0.0015	0.0048	0.0076	0.0139	1.8342
193	0.0095	0.0024	0.0269	0.0004	0.0012	0.0037	0.0074	0.0101	1.3717
Mean	0.0237	0.0232	0.0229	0.0238	0.0238	0.0236	0.0235	0.0183	0.8970
St. Dev.	0.0269	0.0224	0.0220	0.0267	0.0386	0.0180			
CV	1.1357	0.9628	0.9608	1.1213	1.6211	0.7640			
Mean(t)	169	170	175	164	173	170	171		
SD(t)	8.2	8.6	8.7	6.6	5.2	8.6	8.7		

Appendix Table A3. Statistics for the distributions of cumulative abundance within and across years for the Black Lake stock.

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
152	7200	4596	1396	29389	312	10524	8903	10714	1.2034
153	8880	6360	1438	54493	572	17796	14923	20355	1.3640
154	16315	9636	1538	92569	986	33262	25718	34841	1.3547
155	28244	13919	1838	153161	1237	48769	41195	57708	1.4009
156	51338	18350	2338	243214	2458	65387	63848	91601	1.4347
157	62915	22256	3338	314692	3157	78370	80788	118733	1.4697
158	73350	32924	5338	346317	5169	89466	92094	129284	1.4038
159	80070	45272	8338	452353	5830	127868	119955	169235	1.4108
160	223172	104611	12338	512289	19972	176357	174790	185221	1.0597
161	241598	112983	16338	576551	29528	190476	194579	206785	1.0627
162	265634	123633	21338	622856	51180	208722	215560	219835	1.0198
163	385186	140394	26338	666845	61708	231830	252050	240762	0.9552
164	410342	164982	38396	688073	100961	298071	283471	239760	0.8458
165	486739	179398	47161	732465	166811	365140	329619	251829	0.7640
166	508575	197252	52447	780316	205113	393032	356123	262605	0.7374
167	604104	220384	75077	810839	277438	401028	398145	269550	0.6770
168	686329	236759	113102	831570	425393	450920	457345	268590	0.5873
169	732875	262224	142198	889394	752578	497463	546122	297139	0.5441
170	747718	282643	168457	942520	855379	530874	587932	314709	0.5353
171	821309	301352	185256	949926	971432	556069	630891	336688	0.5337
172	883762	321092	200708	959305	1059178	586737	668464	354892	0.5309
173	905151	340464	202461	971081	1103317	629586	692010	363214	0.5249
174	951676	349913	211661	974183	1158954	677639	720671	376332	0.5222
175	980342	357304	220254	990854	1225405	706107	746711	393390	0.5268

Appendix Table A3. Statistics for the distributions of cumulative abundance within and across years for the Black Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
176	993332	366997	229389	992723	1265790	718803	761172	400529	0.5262
177	1032588	374572	234608	997740	1322010	760052	786928	416394	0.5291
178	1052755	384159	248780	1002131	1351433	803260	807086	420784	0.5214
179	1079599	392104	259307	1004964	1384435	834062	825745	428407	0.5188
180	1092022	396684	265065	1007768	1415350	858654	839257	435916	0.5194
181	1113327	400860	269644	1009912	1435183	879229	851359	441981	0.5191
182	1115970	410428	284884	1014646	1437269	894024	859537	437426	0.5089
183	1138979	414098	308118	1016799	1450958	907389	872724	437338	0.5011
184	1151916	422916	314290	1018353	1459160	921590	881371	437991	0.4969
185	1152872	426771	320022	1018869	1466774	932992	886383	438087	0.4942
186	1154110	428236	327785	1020126	1469950	945212	890903	437123	0.4907
187	1179768	430037	333229	1020973	1472688	946989	897281	439348	0.4896
188	1180266	444263	337924	1021447	1484328	949398	902938	438349	0.4855
189	1196376	449662	348931	1021865	1487406	951210	909242	437339	0.4810
190	1197149	450703	362772	1022318	1489717	953058	912619	434365	0.4760
191	1198585	451822	373199	1022749	1491552	955877	915631	432248	0.4721
192	1199384	453095	377883	1022749	1491614	960503	917538	431010	0.4697
193	1210993	457349	381553	1022749	1491687	964060	921399	430804	0.4676
Mean	705449	419709	309855	1014382	1437072	541976	555739	309267	0.7485
St. Dev.	446826	28807	50035	9536	65768	347345			
CV	0.6334	0.0686	0.1615	0.0094	0.0458	0.6409			

Appendix Table A4. Statistics for the distributions of cumulative proportion of abundance within and across years for the Black Lake stock.

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
152	0.0059	0.0099	0.0036	0.0287	0.0002	0.0109	0.0099	0.0101	1.0178
153	0.0073	0.0137	0.0037	0.0533	0.0004	0.0184	0.0161	0.0193	1.1993
154	0.0134	0.0208	0.0040	0.0905	0.0007	0.0344	0.0273	0.0333	1.2194
155	0.0232	0.0301	0.0047	0.1498	0.0008	0.0504	0.0432	0.0552	1.2796
156	0.0421	0.0396	0.0060	0.2378	0.0016	0.0676	0.0658	0.0878	1.3338
157	0.0516	0.0481	0.0086	0.3077	0.0021	0.0810	0.0832	0.1138	1.3682
158	0.0602	0.0711	0.0138	0.3386	0.0035	0.0925	0.0966	0.1234	1.2770
159	0.0657	0.0978	0.0215	0.4423	0.0039	0.1322	0.1272	0.1614	1.2690
160	0.1832	0.2259	0.0318	0.5009	0.0134	0.1823	0.1896	0.1757	0.9265
161	0.1983	0.2440	0.0421	0.5637	0.0198	0.1969	0.2108	0.1954	0.9270
162	0.2180	0.2670	0.0550	0.6090	0.0343	0.2158	0.2332	0.2070	0.8877
163	0.3162	0.3032	0.0679	0.6520	0.0413	0.2397	0.2700	0.2206	0.8167
164	0.3368	0.3563	0.0990	0.6728	0.0676	0.3081	0.3068	0.2180	0.7107
165	0.3995	0.3874	0.1216	0.7162	0.1118	0.3775	0.3523	0.2225	0.6316
166	0.4174	0.4260	0.1352	0.7630	0.1374	0.4063	0.3809	0.2322	0.6097
167	0.4958	0.4760	0.1936	0.7928	0.1859	0.4146	0.4264	0.2253	0.5283
168	0.5633	0.5113	0.2916	0.8131	0.2850	0.4661	0.4884	0.1960	0.4014
169	0.6015	0.5663	0.3666	0.8696	0.5042	0.5143	0.5704	0.1671	0.2929
170	0.6137	0.6104	0.4343	0.9216	0.5731	0.5488	0.6170	0.1629	0.2641
171	0.6741	0.6508	0.4776	0.9288	0.6508	0.5748	0.6595	0.1504	0.2281
172	0.7254	0.6935	0.5175	0.9380	0.7096	0.6065	0.6984	0.1410	0.2019
173	0.7429	0.7353	0.5220	0.9495	0.7392	0.6508	0.7233	0.1398	0.1933
174	0.7811	0.7557	0.5457	0.9525	0.7765	0.7005	0.7520	0.1318	0.1753
175	0.8047	0.7717	0.5679	0.9688	0.8210	0.7299	0.7773	0.1307	0.1682
176	0.8153	0.7926	0.5914	0.9706	0.8480	0.7431	0.7935	0.1251	0.1576

Appendix Table A4. Statistics for the distributions of cumulative proportion of abundance within and across years for the Black Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
176	0.8153	0.7926	0.5914	0.9706	0.8480	0.7431	0.7935	0.1251	0.1576
177	0.8475	0.8090	0.6049	0.9755	0.8857	0.7857	0.8181	0.1240	0.1515
178	0.8641	0.8297	0.6414	0.9798	0.9054	0.8304	0.8418	0.1132	0.1344
179	0.8861	0.8468	0.6686	0.9826	0.9275	0.8622	0.8623	0.1068	0.1239
180	0.8963	0.8567	0.6834	0.9854	0.9482	0.8876	0.8763	0.1051	0.1199
181	0.9138	0.8657	0.6952	0.9874	0.9615	0.9089	0.8888	0.1040	0.1170
182	0.9160	0.8864	0.7345	0.9921	0.9629	0.9242	0.9027	0.0903	0.1001
183	0.9349	0.8943	0.7944	0.9942	0.9721	0.9380	0.9213	0.0710	0.0770
184	0.9455	0.9134	0.8103	0.9957	0.9776	0.9527	0.9325	0.0662	0.0710
185	0.9463	0.9217	0.8251	0.9962	0.9827	0.9645	0.9394	0.0619	0.0659
186	0.9473	0.9249	0.8451	0.9974	0.9848	0.9771	0.9461	0.0561	0.0593
187	0.9684	0.9288	0.8591	0.9983	0.9867	0.9789	0.9534	0.0519	0.0545
188	0.9688	0.9595	0.8713	0.9987	0.9945	0.9814	0.9624	0.0470	0.0489
189	0.9820	0.9711	0.8996	0.9991	0.9965	0.9833	0.9720	0.0369	0.0380
190	0.9826	0.9734	0.9353	0.9996	0.9981	0.9852	0.9790	0.0236	0.0241
191	0.9838	0.9758	0.9622	1.0000	0.9993	0.9881	0.9849	0.0145	0.0147
192	0.9845	0.9786	0.9743	1.0000	0.9993	0.9929	0.9883	0.0108	0.0110
193	0.9940	0.9877	0.9837	1.0000	0.9994	0.9966	0.9936	0.0066	0.0066
Mean	0.5981	0.9064	0.7989	0.9918	0.9628	0.5742	0.5877	0.1128	0.4596
St. Dev.	0.3597	0.0622	0.1290	0.0093	0.0441	0.3524			
CV	0.6015	0.0686	0.1615	0.0094	0.0458	0.6091			

Appendix Table A5. Statistics for the distributions of daily abundance within and across years for the Chignik Lake stock.

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
155	0	0	0	1251	0	0	209	511	2.4495
156	0	0	0	910	0	0	152	371	2.4495
157	0	0	0	1459	0	0	243	596	2.4495
158	0	0	0	645	0	0	108	263	2.4495
159	0	0	0	3279	0	0	547	1339	2.4495
160	0	0	0	2497	0	0	416	1020	2.4495
161	0	0	0	3382	0	0	564	1381	2.4495
162	0	169	0	3485	0	184	640	1397	2.1830
163	0	248	0	3825	106	233	736	1517	2.0630
164	0	146	122	2624	397	669	659	992	1.5035
165	772	182	89	6633	665	677	1503	2529	1.6827
166	221	472	53	9114	387	569	1803	3587	1.9895
167	965	338	229	8114	1476	163	1881	3096	1.6460
168	831	796	776	7284	3019	1543	2375	2555	1.0759
169	950	860	594	25979	10119	1939	6740	10104	1.4991
170	303	1006	812	31201	4283	1758	6561	12153	1.8524
171	2276	1502	700	5587	6108	1896	3011	2264	0.7517
172	2602	1741	813	9379	6605	2667	3968	3308	0.8336
173	1126	1195	132	14988	3838	5296	4429	5522	1.2466
174	3502	1144	800	5060	6876	7180	4094	2761	0.6744
175	2493	1963	1062	35427	9929	5422	9383	13161	1.4026
176	1606	2150	1365	5318	7692	3375	3584	2483	0.6927
177	5866	3612	994	17788	14944	14493	9616	6977	0.7255
178	3841	3909	3767	21437	10338	19412	10451	8151	0.7799
179	7136	2973	3699	17403	14827	18090	10688	6899	0.6455
180	4365	3591	2587	22685	18156	18552	11656	9076	0.7787

Appendix Table A5. Statistics for the distributions of daily abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
181	9572	10873	2689	21678	14961	20576	13391	7186	0.5366
182	1552	5409	11497	62905	2087	18830	17047	23394	1.3723
183	17358	17083	23235	40903	17422	21805	22968	9165	0.3990
184	12937	10082	7855	50240	13382	30177	20779	16456	0.7919
185	1216	4928	9353	16680	16180	32452	13468	11118	0.8255
186	2020	6877	16496	61586	9039	43325	23224	23829	1.0260
187	54524	9774	15493	41531	9709	8678	23285	19747	0.8481
188	1416	85671	16648	46912	56829	14796	37046	31729	0.8565
189	57120	43685	53737	41365	18909	14665	38247	17694	0.4626
190	3770	16934	85026	44839	18695	18679	31324	29503	0.9419
191	8824	24556	84366	42713	18554	37463	36079	26684	0.7396
192	6467	58720	47361	34748	823	87883	39333	32807	0.8341
193	117381	95326	48759	24404	1388	115007	67044	49188	0.7337
194	2662	66774	34131	31717	1593	8442	24220	25262	1.0431
195	6629	56777	40901	40146	2298	30344	29516	21218	0.7189
196	2846	18684	33616	21734	7402	63300	24597	21869	0.8891
197	15371	52385	31337	25992	4137	36627	27641	16807	0.6080
198	33617	44522	30663	19646	9927	1406	23297	16016	0.6875
199	225519	42115	28632	9177	13830	37182	59409	82381	1.3867
200	5912	34587	25690	13675	9763	35722	20891	12890	0.6170
201	8328	28929	21569	24309	18087	35154	22729	9226	0.4059
202	16403	25771	17843	15290	13631	33608	20424	7717	0.3778
203	61305	22414	15435	14966	17374	41410	28817	18745	0.6505
204	2376	28365	11936	10845	11696	17593	13802	8645	0.6264
205	26255	20457	11821	8333	7003	15011	14813	7413	0.5004

Appendix Table A5. Statistics for the distributions of daily abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
206	4362	25084	14557	8187	31084	719	13999	11984	0.8561
207	6240	24361	4497	7061	10793	32161	14186	11366	0.8012
208	18948	24749	6246	10749	9689	23588	15662	7806	0.4984
209	3954	17485	11084	13015	2935	29394	12978	9754	0.7516
210	5856	12612	9456	12377	3517	42553	14395	14253	0.9901
211	13093	15282	10022	12026	2995	8459	10313	4300	0.4169
212	8290	12368	10218	8931	2425	26538	11462	8097	0.7064
213	6535	11766	11139	9657	1856	21484	10406	6538	0.6283
214	5438	12239	10482	10382	1286	20009	9973	6361	0.6378
215	6846	18527	11998	11108	7222	17640	12224	4986	0.4079
216	972	13182	13588	9770	4998	13244	9292	5236	0.5635
217	2832	3218	7756	7400	5007	9353	5928	2646	0.4464
218	12600	14265	4207	7358	6051	8587	8845	3875	0.4381
219	9090	10688	4772	7008	6777	7820	7693	2039	0.2650
220	5522	8947	3889	8362	8026	7054	6967	1927	0.2765
221	6770	7670	315	9715	9274	24843	9765	8127	0.8323
222	5555	17217	9915	11070	4671	15717	10691	5123	0.4792
223	5857	10766	4077	5551	4672	12431	7226	3485	0.4824
224	6161	2456	4410	3850	4851	15240	6161	4610	0.7483
225	6463	10216	4943	7074	5964	17061	8620	4504	0.5225
226	6546	5770	4410	8972	6135	18883	8453	5322	0.6296
227	5898	6890	4927	8527	6908	20704	8976	5869	0.6539
228	5019	4940	4866	8081	7683	14419	7501	3685	0.4912
229	5449	15194	5483	7636	7308	15745	9469	4738	0.5004
230	4806	9695	7217	5125	5986	14558	7898	3714	0.4702

Appendix Table A5. Statistics for the distributions of daily abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
231	4164	2237	9159	4398	6962	14621	6924	4477	0.6466
232	3521	9444	6771	1555	11612	10870	7296	4087	0.5602
233	1501	5474	4154	1758	11591	7117	5266	3773	0.7166
234	1680	5636	4448	3187	11099	3366	4903	3311	0.6754
235	1096	5514	5045	4617	11924	13058	6876	4635	0.6741
236	1747	7523	6025	6046	6071	6966	5730	2045	0.3569
237	1410	3638	4565	3511	10268	8692	5347	3400	0.6359
238	1075	707	4013	1840	8005	4664	3384	2767	0.8175
239	738	3009	3213	1698	8566	5252	3746	2813	0.7510
240	652	1795	4705	0	12709	5838	4283	4718	1.1016
241	237	1723	3893	0	15944	6426	4704	6015	1.2788
Mean	10657	13941	11252	14552	8150	16492	12609	9691	0.9513
St. Dev.	28285	18653	16219	14441	7928	18440			
CV	2.6541	1.3381	1.4414	0.9924	0.9728	1.1181			

Appendix Table A6. Statistics for the distributions of proportions of daily abundance within and across years for the Chignik Lake stock.

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
155	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0002	0.0004	2.4495
156	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0001	0.0003	2.4495
157	0.0000	0.0000	0.0000	0.0011	0.0000	0.0000	0.0002	0.0005	2.4495
158	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0001	0.0002	2.4495
159	0.0000	0.0000	0.0000	0.0026	0.0000	0.0000	0.0004	0.0010	2.4495
160	0.0000	0.0000	0.0000	0.0020	0.0000	0.0000	0.0003	0.0008	2.4495
161	0.0000	0.0000	0.0000	0.0026	0.0000	0.0000	0.0004	0.0011	2.4495
162	0.0000	0.0001	0.0000	0.0027	0.0000	0.0001	0.0005	0.0011	2.1957
163	0.0000	0.0002	0.0000	0.0030	0.0001	0.0002	0.0006	0.0012	2.0439
164	0.0000	0.0001	0.0001	0.0020	0.0005	0.0004	0.0005	0.0008	1.4334
165	0.0008	0.0001	0.0001	0.0052	0.0008	0.0005	0.0012	0.0020	1.5626
166	0.0002	0.0004	0.0001	0.0071	0.0005	0.0004	0.0014	0.0028	1.9360
167	0.0010	0.0003	0.0002	0.0063	0.0018	0.0001	0.0016	0.0024	1.4742
168	0.0009	0.0006	0.0008	0.0057	0.0036	0.0010	0.0021	0.0021	0.9871
169	0.0010	0.0007	0.0006	0.0203	0.0120	0.0013	0.0060	0.0083	1.3869
170	0.0003	0.0008	0.0008	0.0244	0.0051	0.0012	0.0054	0.0094	1.7383
171	0.0025	0.0012	0.0007	0.0044	0.0073	0.0013	0.0029	0.0025	0.8744
172	0.0028	0.0014	0.0008	0.0073	0.0078	0.0018	0.0037	0.0031	0.8487
173	0.0012	0.0010	0.0001	0.0117	0.0046	0.0035	0.0037	0.0043	1.1581
174	0.0038	0.0009	0.0008	0.0040	0.0082	0.0048	0.0037	0.0027	0.7312
175	0.0027	0.0016	0.0011	0.0277	0.0118	0.0036	0.0081	0.0104	1.2848
176	0.0017	0.0018	0.0014	0.0042	0.0091	0.0023	0.0034	0.0030	0.8777
177	0.0063	0.0029	0.0010	0.0139	0.0177	0.0097	0.0086	0.0064	0.7501
178	0.0041	0.0032	0.0037	0.0167	0.0123	0.0130	0.0088	0.0059	0.6625
179	0.0077	0.0024	0.0037	0.0136	0.0176	0.0121	0.0095	0.0059	0.6248
180	0.0047	0.0029	0.0026	0.0177	0.0216	0.0124	0.0103	0.0081	0.7898

Appendix Table A6. Statistics for the distributions of proportions of daily abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
181	0.0103	0.0089	0.0027	0.0169	0.0178	0.0138	0.0117	0.0057	0.4829
182	0.0017	0.0044	0.0114	0.0491	0.0025	0.0126	0.0136	0.0180	1.3216
183	0.0187	0.0139	0.0230	0.0319	0.0207	0.0146	0.0205	0.0066	0.3228
184	0.0139	0.0082	0.0078	0.0392	0.0159	0.0202	0.0175	0.0116	0.6626
185	0.0013	0.0040	0.0093	0.0130	0.0192	0.0217	0.0114	0.0081	0.7124
186	0.0022	0.0056	0.0163	0.0481	0.0107	0.0290	0.0187	0.0172	0.9233
187	0.0587	0.0080	0.0153	0.0324	0.0115	0.0058	0.0220	0.0204	0.9266
188	0.0015	0.0698	0.0165	0.0366	0.0675	0.0099	0.0336	0.0295	0.8769
189	0.0615	0.0356	0.0532	0.0323	0.0224	0.0098	0.0358	0.0191	0.5343
190	0.0041	0.0138	0.0842	0.0350	0.0222	0.0125	0.0286	0.0292	1.0187
191	0.0095	0.0200	0.0835	0.0334	0.0220	0.0251	0.0323	0.0263	0.8149
192	0.0070	0.0478	0.0469	0.0271	0.0010	0.0589	0.0314	0.0237	0.7532
193	0.1265	0.0777	0.0483	0.0191	0.0016	0.0770	0.0584	0.0452	0.7748
194	0.0029	0.0544	0.0338	0.0248	0.0019	0.0057	0.0206	0.0211	1.0252
195	0.0071	0.0463	0.0405	0.0313	0.0027	0.0203	0.0247	0.0177	0.7167
196	0.0031	0.0152	0.0333	0.0170	0.0088	0.0424	0.0200	0.0150	0.7508
197	0.0166	0.0427	0.0310	0.0203	0.0049	0.0245	0.0233	0.0129	0.5520
198	0.0362	0.0363	0.0304	0.0153	0.0118	0.0009	0.0218	0.0146	0.6697
199	0.2430	0.0343	0.0283	0.0072	0.0164	0.0249	0.0590	0.0906	1.5354
200	0.0064	0.0282	0.0254	0.0107	0.0116	0.0239	0.0177	0.0092	0.5200
201	0.0090	0.0236	0.0214	0.0190	0.0215	0.0235	0.0196	0.0055	0.2799
202	0.0177	0.0210	0.0177	0.0119	0.0162	0.0225	0.0178	0.0037	0.2089
203	0.0660	0.0183	0.0153	0.0117	0.0206	0.0277	0.0266	0.0201	0.7542
204	0.0026	0.0231	0.0118	0.0085	0.0139	0.0118	0.0119	0.0068	0.5665
205	0.0283	0.0167	0.0117	0.0065	0.0083	0.0101	0.0136	0.0080	0.5883

Appendix Table A6. Statistics for the distributions of proportions of daily abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
206	0.0047	0.0204	0.0144	0.0064	0.0369	0.0005	0.0139	0.0134	0.9624
207	0.0067	0.0198	0.0045	0.0055	0.0128	0.0215	0.0118	0.0075	0.6333
208	0.0204	0.0202	0.0062	0.0084	0.0115	0.0158	0.0137	0.0060	0.4375
209	0.0043	0.0142	0.0110	0.0102	0.0035	0.0197	0.0105	0.0061	0.5840
210	0.0063	0.0103	0.0094	0.0097	0.0042	0.0285	0.0114	0.0087	0.7649
211	0.0141	0.0125	0.0099	0.0094	0.0036	0.0057	0.0092	0.0040	0.4344
212	0.0089	0.0101	0.0101	0.0070	0.0029	0.0178	0.0095	0.0049	0.5173
213	0.0070	0.0096	0.0110	0.0075	0.0022	0.0144	0.0086	0.0041	0.4772
214	0.0059	0.0100	0.0104	0.0081	0.0015	0.0134	0.0082	0.0041	0.5022
215	0.0074	0.0151	0.0119	0.0087	0.0086	0.0118	0.0106	0.0029	0.2726
216	0.0010	0.0107	0.0135	0.0076	0.0059	0.0089	0.0079	0.0043	0.5362
217	0.0031	0.0026	0.0077	0.0058	0.0059	0.0063	0.0052	0.0020	0.3774
218	0.0136	0.0116	0.0042	0.0057	0.0072	0.0058	0.0080	0.0037	0.4663
219	0.0098	0.0087	0.0047	0.0055	0.0080	0.0052	0.0070	0.0021	0.3027
220	0.0059	0.0073	0.0039	0.0065	0.0095	0.0047	0.0063	0.0020	0.3173
221	0.0073	0.0062	0.0003	0.0076	0.0110	0.0166	0.0082	0.0054	0.6612
222	0.0060	0.0140	0.0098	0.0086	0.0055	0.0105	0.0091	0.0031	0.3457
223	0.0063	0.0088	0.0040	0.0043	0.0055	0.0083	0.0062	0.0020	0.3193
224	0.0066	0.0020	0.0044	0.0030	0.0058	0.0102	0.0053	0.0029	0.5508
225	0.0070	0.0083	0.0049	0.0055	0.0071	0.0114	0.0074	0.0023	0.3162
226	0.0071	0.0047	0.0044	0.0070	0.0073	0.0126	0.0072	0.0030	0.4134
227	0.0064	0.0056	0.0049	0.0067	0.0082	0.0139	0.0076	0.0033	0.4303
228	0.0054	0.0040	0.0048	0.0063	0.0091	0.0097	0.0066	0.0023	0.3544
229	0.0059	0.0124	0.0054	0.0060	0.0087	0.0105	0.0081	0.0029	0.3528
230	0.0052	0.0079	0.0071	0.0040	0.0071	0.0097	0.0068	0.0020	0.2962

Appendix Table A6. Statistics for the distributions of proportions of daily abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
231	0.0045	0.0018	0.0091	0.0034	0.0083	0.0098	0.0061	0.0033	0.5404
232	0.0038	0.0077	0.0067	0.0012	0.0138	0.0073	0.0067	0.0042	0.6292
233	0.0016	0.0045	0.0041	0.0014	0.0138	0.0048	0.0050	0.0045	0.9028
234	0.0018	0.0046	0.0044	0.0025	0.0132	0.0023	0.0048	0.0043	0.8917
235	0.0012	0.0045	0.0050	0.0036	0.0142	0.0087	0.0062	0.0046	0.7434
236	0.0019	0.0061	0.0060	0.0047	0.0072	0.0047	0.0051	0.0018	0.3612
237	0.0015	0.0030	0.0045	0.0027	0.0122	0.0058	0.0050	0.0038	0.7755
238	0.0012	0.0006	0.0040	0.0014	0.0095	0.0031	0.0033	0.0033	1.0014
239	0.0008	0.0025	0.0032	0.0013	0.0102	0.0035	0.0036	0.0034	0.9506
240	0.0007	0.0015	0.0047	0.0000	0.0151	0.0039	0.0043	0.0056	1.2985
241	0.0003	0.0014	0.0039	0.0000	0.0189	0.0043	0.0048	0.0072	1.4935
Mean	0.0017	0.0035	0.0050	0.0020	0.0124	0.0053	0.0050	0.0042	0.8717
St. Dev.	0.0013	0.0022	0.0017	0.0015	0.0034	0.0024			
CV	0.7397	0.6392	0.3292	0.7402	0.2735	0.4516			
Mean(t)	199	201	198	192	195	201	198		
SD(t)	12.3	13.3	13.3	16.4	19.6	16.0	15.5		

Appendix Table A7. Statistics for the distributions of cumulative abundance within and across years for the Chignik Lake stock.

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
155	0	0	0	1251	0	0	209	511	2.4495
156	0	0	0	2161	0	0	360	882	2.4495
157	0	0	0	3619	0	0	603	1478	2.4495
158	0	0	0	4265	0	0	711	1741	2.4495
159	0	0	0	7544	0	0	1257	3080	2.4495
160	0	0	0	10042	0	0	1674	4099	2.4495
161	0	0	0	13424	0	0	2237	5480	2.4495
162	0	169	0	16909	0	184	2877	6875	2.3895
163	0	418	0	20734	106	418	3613	8390	2.3224
164	0	563	122	23358	503	1087	4272	9358	2.1905
165	772	745	210	29991	1168	1764	5775	11875	2.0562
166	992	1218	264	39106	1555	2334	7578	15460	2.0402
167	1957	1555	492	47219	3031	2497	9459	18519	1.9579
168	2788	2351	1268	54503	6050	4040	11833	20968	1.7719
169	3738	3211	1862	80482	16170	5979	18574	30765	1.6564
170	4041	4217	2674	111683	20453	7737	25134	42900	1.7069
171	6317	5719	3374	117270	26561	9634	28146	44455	1.5795
172	8919	7460	4188	126649	33166	12301	32114	47447	1.4775
173	10045	8655	4319	141637	37004	17597	36543	52768	1.4440
174	13546	9798	5119	146698	43880	24777	40636	53772	1.3233
175	16039	11762	6182	182124	53810	30199	50019	66931	1.3381
176	17645	13911	7546	187443	61502	33574	53604	68361	1.2753
177	23511	17524	8541	205231	76446	48067	63220	73792	1.1672
178	27352	21433	12308	226668	86784	67479	73671	80322	1.0903
179	34488	24406	16007	244071	101612	85569	84359	85511	1.0137
180	38852	27997	18593	266756	119768	104121	96015	93456	0.9734

Appendix Table A7. Statistics for the distributions of cumulative abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
181	48424	38870	21282	288434	134729	124697	109406	99384	0.9084
182	49976	44279	32779	351339	136816	143527	126453	120290	0.9513
183	67334	61363	56014	392242	154237	165332	149420	128418	0.8594
184	80271	71445	63868	442483	167619	195509	170199	144174	0.8471
185	81487	76373	73222	459163	183799	227961	183668	149673	0.8149
186	83507	83251	89718	520749	192838	271286	206892	171517	0.8290
187	138031	93025	105211	562280	202548	279964	230177	176891	0.7685
188	139447	178695	121860	609192	259377	294760	267222	180586	0.6758
189	196568	222380	175596	650558	278286	309426	305469	176335	0.5773
190	200338	239314	260622	695397	296981	328104	336793	181208	0.5380
191	209161	263870	344988	738109	315535	365568	372872	187723	0.5035
192	215628	322590	392349	772857	316358	453450	412205	193920	0.4704
193	333009	417915	441108	797261	317746	568457	479249	179875	0.3753
194	335670	484689	475238	828978	319339	576899	503469	186847	0.3711
195	342300	541466	516139	869124	321637	607243	532985	199944	0.3751
196	345145	560150	549756	890858	329039	670543	557582	210363	0.3773
197	360516	612535	581093	916850	333176	707170	585223	218921	0.3741
198	394133	657057	611756	936496	343102	708576	608520	217419	0.3573
199	619652	699172	640388	945673	356933	745758	667929	191825	0.2872
200	625564	733758	666078	959348	366696	781480	688821	195997	0.2845
201	633892	762687	687647	983657	384783	816634	711550	200539	0.2818
202	650295	788458	705489	998947	398414	850242	731974	203513	0.2780
203	711600	810872	720924	1013913	415788	891652	760792	203342	0.2673
204	713976	839237	732860	1024758	427484	909245	774594	205326	0.2651
205	740231	859694	744681	1033091	434487	924256	789407	206346	0.2614

Appendix Table A7. Statistics for the distributions of cumulative abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
206	744593	884778	759238	1041278	465571	924975	803406	198759	0.2474
207	750833	909139	763735	1048339	476364	957136	817591	202431	0.2476
208	769781	933888	769981	1059088	486053	980724	833253	205649	0.2468
209	773735	951373	781065	1072103	488988	1010118	846231	212630	0.2513
210	779591	963985	790521	1084480	492505	1052671	860626	221210	0.2570
211	792684	979267	800543	1096506	495500	1061130	870939	223974	0.2572
212	800974	991635	810761	1105437	497925	1087668	882400	229520	0.2601
213	807509	1003401	821900	1115094	499781	1109152	892806	234615	0.2628
214	812947	1015640	832382	1125476	501067	1129161	902779	239991	0.2658
215	819793	1034167	844380	1136584	508289	1146801	915003	243515	0.2661
216	820765	1047349	857968	1146354	513287	1160045	924295	246607	0.2668
217	823597	1050567	865724	1153754	518294	1169398	930223	247737	0.2663
218	836197	1064832	869931	1161112	524345	1177985	939067	248821	0.2650
219	845287	1075520	874703	1168120	531122	1185805	946760	249386	0.2634
220	850809	1084467	878592	1176482	539148	1192859	953726	249804	0.2619
221	857579	1092137	878907	1186197	548422	1217702	963491	253545	0.2632
222	863134	1109354	888822	1197267	553093	1233419	974182	257750	0.2646
223	868991	1120120	892899	1202818	557765	1245850	981407	260053	0.2650
224	875152	1122576	897309	1206668	562616	1261090	987569	261692	0.2650
225	881615	1132792	902252	1213742	568580	1278151	996189	264686	0.2657
226	888161	1138562	906662	1222714	574715	1297034	1004642	267951	0.2667
227	894059	1145452	911589	1231241	581623	1317738	1013617	271497	0.2678
228	899078	1150392	916455	1239322	589306	1332157	1021119	273269	0.2676
229	904527	1165586	921938	1246958	596614	1347902	1030588	276318	0.2681
230	909333	1175281	929155	1252083	602600	1362460	1038486	278541	0.2682

Appendix Table A7. Statistics for the distributions of cumulative abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
231	913497	1177518	938314	1256481	609562	1377081	1045409	279587	0.2674
232	917018	1186962	945085	1258036	621174	1387951	1052705	278850	0.2649
233	918519	1192436	949239	1259794	632765	1395068	1057970	277315	0.2621
234	920199	1198072	953687	1262981	643864	1398434	1062873	275234	0.2590
235	921295	1203586	958732	1267598	655788	1411492	1069749	275526	0.2576
236	923042	1211109	964757	1273644	661859	1418458	1075478	276361	0.2570
237	924452	1214747	969322	1277155	672127	1427150	1080826	275805	0.2552
238	925527	1215454	973335	1278995	680132	1431814	1084210	274499	0.2532
239	926265	1218463	976548	1280693	688698	1437066	1087956	273503	0.2514
240	926917	1220258	981253	1280693	701407	1442904	1092239	271024	0.2481
241	927154	1221981	985146	1280693	717351	1449330	1096943	267952	0.2443
Mean	922171	1205508	963220	1270615	662248	1416068	1073305	275060	0.2564
St. Dev.	4485	14932	15431	9846	33762	23932			
CV	0.0049	0.0124	0.0160	0.0077	0.0510	0.0169			

Appendix Table A8. Statistics for the distributions of cumulative proportion of abundance within and across years for the Chignik Lake stock.

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
155	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0002	0.0004	2.4495
156	0.0000	0.0000	0.0000	0.0017	0.0000	0.0000	0.0003	0.0007	2.4495
157	0.0000	0.0000	0.0000	0.0028	0.0000	0.0000	0.0005	0.0012	2.4495
158	0.0000	0.0000	0.0000	0.0033	0.0000	0.0000	0.0006	0.0014	2.4495
159	0.0000	0.0000	0.0000	0.0059	0.0000	0.0000	0.0010	0.0024	2.4495
160	0.0000	0.0000	0.0000	0.0078	0.0000	0.0000	0.0013	0.0032	2.4495
161	0.0000	0.0000	0.0000	0.0105	0.0000	0.0000	0.0017	0.0043	2.4495
162	0.0000	0.0001	0.0000	0.0132	0.0000	0.0001	0.0022	0.0054	2.3926
163	0.0000	0.0003	0.0000	0.0162	0.0001	0.0003	0.0028	0.0066	2.3205
164	0.0000	0.0005	0.0001	0.0182	0.0006	0.0007	0.0034	0.0073	2.1732
165	0.0008	0.0006	0.0002	0.0234	0.0014	0.0012	0.0046	0.0092	2.0032
166	0.0011	0.0010	0.0003	0.0305	0.0018	0.0016	0.0060	0.0120	1.9871
167	0.0021	0.0013	0.0005	0.0369	0.0036	0.0017	0.0077	0.0143	1.8708
168	0.0030	0.0019	0.0013	0.0426	0.0072	0.0027	0.0098	0.0162	1.6578
169	0.0040	0.0026	0.0018	0.0628	0.0192	0.0040	0.0158	0.0240	1.5210
170	0.0044	0.0034	0.0026	0.0872	0.0243	0.0052	0.0212	0.0334	1.5751
171	0.0068	0.0047	0.0033	0.0916	0.0315	0.0064	0.0241	0.0347	1.4430
172	0.0096	0.0061	0.0041	0.0989	0.0394	0.0082	0.0277	0.0372	1.3432
173	0.0108	0.0071	0.0043	0.1106	0.0439	0.0118	0.0314	0.0414	1.3178
174	0.0146	0.0080	0.0051	0.1145	0.0521	0.0166	0.0351	0.0424	1.2072
175	0.0173	0.0096	0.0061	0.1422	0.0639	0.0202	0.0432	0.0528	1.2216
176	0.0190	0.0113	0.0075	0.1464	0.0730	0.0225	0.0466	0.0543	1.1660
177	0.0253	0.0143	0.0085	0.1602	0.0908	0.0322	0.0552	0.0593	1.0741
178	0.0295	0.0175	0.0122	0.1770	0.1030	0.0452	0.0641	0.0643	1.0042
179	0.0372	0.0199	0.0158	0.1906	0.1206	0.0573	0.0736	0.0689	0.9361
180	0.0419	0.0228	0.0184	0.2083	0.1422	0.0697	0.0839	0.0760	0.9058

Appendix Table A8. Statistics for the distributions of cumulative proportion of abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
181	0.0522	0.0317	0.0211	0.2252	0.1599	0.0835	0.0956	0.0808	0.8449
182	0.0538	0.0361	0.0325	0.2743	0.1624	0.0961	0.1092	0.0944	0.8646
183	0.0725	0.0500	0.0555	0.3063	0.1831	0.1107	0.1297	0.0995	0.7675
184	0.0865	0.0582	0.0632	0.3455	0.1990	0.1309	0.1472	0.1104	0.7498
185	0.0878	0.0622	0.0725	0.3585	0.2182	0.1526	0.1586	0.1143	0.7202
186	0.0900	0.0678	0.0888	0.4066	0.2289	0.1816	0.1773	0.1286	0.7254
187	0.1487	0.0758	0.1042	0.4390	0.2405	0.1874	0.1993	0.1313	0.6588
188	0.1502	0.1456	0.1207	0.4757	0.3079	0.1973	0.2329	0.1363	0.5852
189	0.2118	0.1812	0.1739	0.5080	0.3304	0.2071	0.2687	0.1302	0.4845
190	0.2158	0.1950	0.2580	0.5430	0.3526	0.2196	0.2973	0.1327	0.4464
191	0.2254	0.2150	0.3416	0.5763	0.3746	0.2447	0.3296	0.1373	0.4166
192	0.2323	0.2628	0.3885	0.6035	0.3756	0.3035	0.3610	0.1336	0.3701
193	0.3588	0.3405	0.4367	0.6225	0.3772	0.3805	0.4194	0.1046	0.2495
194	0.3617	0.3949	0.4705	0.6473	0.3791	0.3862	0.4399	0.1083	0.2462
195	0.3688	0.4411	0.5110	0.6786	0.3818	0.4065	0.4647	0.1166	0.2508
196	0.3719	0.4564	0.5443	0.6956	0.3906	0.4489	0.4846	0.1198	0.2471
197	0.3884	0.4990	0.5754	0.7159	0.3955	0.4734	0.5079	0.1233	0.2427
198	0.4246	0.5353	0.6057	0.7312	0.4073	0.4743	0.5298	0.1229	0.2320
199	0.6676	0.5696	0.6341	0.7384	0.4237	0.4992	0.5888	0.1151	0.1956
200	0.6740	0.5978	0.6595	0.7491	0.4353	0.5231	0.6065	0.1132	0.1866
201	0.6830	0.6214	0.6809	0.7681	0.4568	0.5467	0.6261	0.1108	0.1770
202	0.7006	0.6424	0.6985	0.7800	0.4730	0.5692	0.6439	0.1091	0.1694
203	0.7667	0.6606	0.7138	0.7917	0.4936	0.5969	0.6705	0.1119	0.1669
204	0.7692	0.6837	0.7256	0.8002	0.5075	0.6086	0.6825	0.1089	0.1596
205	0.7975	0.7004	0.7373	0.8067	0.5158	0.6187	0.6961	0.1120	0.1609

Appendix Table A8. Statistics for the distributions of cumulative proportion of abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
206	0.8022	0.7208	0.7517	0.8131	0.5527	0.6192	0.7100	0.1039	0.1463
207	0.8089	0.7407	0.7562	0.8186	0.5655	0.6407	0.7218	0.0995	0.1378
208	0.8294	0.7609	0.7624	0.8270	0.5770	0.6565	0.7355	0.0999	0.1358
209	0.8336	0.7751	0.7733	0.8371	0.5805	0.6762	0.7460	0.0998	0.1338
210	0.8399	0.7854	0.7827	0.8468	0.5847	0.7047	0.7574	0.0988	0.1305
211	0.8540	0.7978	0.7926	0.8562	0.5882	0.7103	0.7665	0.1023	0.1334
212	0.8630	0.8079	0.8028	0.8632	0.5911	0.7281	0.7760	0.1033	0.1331
213	0.8700	0.8175	0.8138	0.8707	0.5933	0.7425	0.7846	0.1049	0.1337
214	0.8759	0.8275	0.8242	0.8788	0.5949	0.7559	0.7928	0.1068	0.1347
215	0.8832	0.8426	0.8360	0.8875	0.6034	0.7677	0.8034	0.1071	0.1333
216	0.8843	0.8533	0.8495	0.8951	0.6094	0.7765	0.8113	0.1073	0.1322
217	0.8873	0.8559	0.8572	0.9009	0.6153	0.7828	0.8166	0.1067	0.1307
218	0.9009	0.8675	0.8613	0.9066	0.6225	0.7885	0.8246	0.1076	0.1305
219	0.9107	0.8762	0.8661	0.9121	0.6305	0.7938	0.8316	0.1075	0.1293
220	0.9167	0.8835	0.8699	0.9186	0.6401	0.7985	0.8379	0.1063	0.1269
221	0.9240	0.8898	0.8702	0.9262	0.6511	0.8151	0.8461	0.1039	0.1228
222	0.9299	0.9038	0.8800	0.9349	0.6566	0.8256	0.8552	0.1051	0.1229
223	0.9363	0.9126	0.8841	0.9392	0.6622	0.8340	0.8614	0.1051	0.1220
224	0.9429	0.9146	0.8884	0.9422	0.6679	0.8442	0.8667	0.1042	0.1202
225	0.9499	0.9229	0.8933	0.9477	0.6750	0.8556	0.8741	0.1038	0.1188
226	0.9569	0.9276	0.8977	0.9547	0.6823	0.8682	0.8812	0.1032	0.1172
227	0.9633	0.9332	0.9026	0.9614	0.6905	0.8821	0.8888	0.1023	0.1151
228	0.9687	0.9372	0.9074	0.9677	0.6996	0.8917	0.8954	0.1008	0.1126
229	0.9745	0.9496	0.9128	0.9737	0.7083	0.9023	0.9035	0.1003	0.1110
230	0.9797	0.9575	0.9200	0.9777	0.7154	0.9120	0.9104	0.0997	0.1095

Appendix Table A8. Statistics for the distributions of cumulative proportion of abundance within and across years for the Chignik Lake stock (continued).

Julian Date	1978	1979	1980	1981	1982	1983	Mean	Standard Deviation	CV
231	0.9842	0.9593	0.9290	0.9811	0.7237	0.9218	0.9165	0.0979	0.1069
232	0.9880	0.9670	0.9357	0.9823	0.7374	0.9291	0.9233	0.0941	0.1020
233	0.9896	0.9715	0.9399	0.9837	0.7512	0.9339	0.9283	0.0897	0.0966
234	0.9914	0.9761	0.9443	0.9862	0.7644	0.9361	0.9331	0.0856	0.0918
235	0.9926	0.9806	0.9493	0.9898	0.7785	0.9449	0.9393	0.0813	0.0866
236	0.9945	0.9867	0.9552	0.9945	0.7857	0.9495	0.9444	0.0802	0.0849
237	0.9960	0.9897	0.9597	0.9972	0.7979	0.9553	0.9493	0.0764	0.0805
238	0.9972	0.9902	0.9637	0.9987	0.8074	0.9585	0.9526	0.0732	0.0768
239	0.9980	0.9927	0.9669	1.0000	0.8176	0.9620	0.9562	0.0698	0.0730
240	0.9987	0.9942	0.9716	1.0000	0.8327	0.9659	0.9605	0.0642	0.0669
241	0.9989	0.9956	0.9754	1.0000	0.8516	0.9702	0.9653	0.0571	0.0592
Mean	0.9935	0.9821	0.9537	0.9921	0.7862	0.9479	0.9426	0.0791	0.0841
St. Dev.	0.0048	0.0122	0.0153	0.0077	0.0401	0.0160			
CV	0.0049	0.0124	0.0160	0.0077	0.0510	0.0169			