A probabilistic analysis of decision-making about trip duration by Strait of Georgia sport anglers

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Abstract: Since 1984, an access-point creel survey of the Strait of Georgia, British Columbia, sport fishery has generated data on catch, effort, and attributes of effort from thousands of interviews of salmon anglers completing a daily boat-trip. I present a maximum-likelihood model for this daily bag limit (DBL) constrained fishery that estimates catch rate and variance for various angling fleets (as defined by boat-trip attributes such as the number of angling lines), estimates the probability that a boat-trip ends after a certain number of hours angling, and measures how angling success influences that probability. Most anglers targeting either chinook salmon (*Oncorhynchus tshawytscha*) or coho salmon (*Oncorhynchus kisutch*) became more likely to end a boat-trip in response to angling success, i.e., they were satiated by angling success before reaching a DBL. However, autumn and winter chinook salmon anglers tended to extend a boat-trip in response to angling success, i.e., they were motivated by angling success. Variability in angling success could not be attributed to variability in angler skill. Coho salmon catch rates increased by about 42% with each additional angling line per boat-trip up to three. The model can be used to judge the effectiveness of a DBL in reducing daily catch.

Résumé : Depuis 1984, une enquête menée aux points d'accès auprès des pêcheurs sportifs dans le détroit de Géorgie (Colombie-Britannique), a fourni des données sur les prises, l'effort de pêche et les attributs de ce dernier. Des milliers d'entrevues de pêcheurs sportifs de saumon effectuant des sorties en bateau d'une journée ont été réalisées. Je présente un modèle fondé sur le maximum de vraisemblance pour cette pêche restreinte par des limites quotidiennes de prises, modèle qui estime le taux de capture et la variance des captures pour diverses flottilles (définies selon les attributs des sorties, comme le nombre de lignes) et la probabilité qu'une sortie se termine après un certain nombre d'heures de pêche, et qui mesure comment le succès de la pêche influe sur cette probabilité. Chez la plupart des pêcheurs de quinnat (*Oncorhynchus tshawytscha*) ou de coho (*O. kisutch*), le succès de la pêche tend à motiver l'arrêt de la sortie, c'est-à-dire que ces pêcheurs se jugent satisfaits avant d'atteindre la limite quotidienne de prises. Cependant, le succès de la pêche tend à motiver les pêcheurs de quinnat d'automne et de printemps à prolonger leur sortie. La variabilité du succès de la pêche ne pouvait pas être attribuée à la variabilité de l'habileté des pêcheurs. Pour chaque ligne additionnelle par sortie, et jusqu'à trois lignes, les taux de capture du coho augmentaient d'environ 42 %. Le modèle peut être utilisé pour juger l'efficacité des limites quotidiennes de prises pour réduire les captures quotidiennes.

[Traduit par la Rédaction]

Introduction

One view of fisheries science sees fishers and fish as defining a predator–prey system. This paradigm can be useful in that it facilitates the testing of ecological models for evaluating fishers' behaviour and foraging success. Two prominent ecological models concern a predator's functional and numerical responses to prey abundance. However, for several reasons, there are few studies of fishers as predators (Hilborn and Ledbetter 1979, 1985; Peterman and Steer 1981). Perhaps the main reason that studies of the predatory behaviour of fishers are rare is that fishers are highly constrained predators. Complex management regimes that include quotas, area and seasonal closures, size limits, bag limits, etc., preclude the testing of simple hypotheses concerning the behaviour of fishers as freely foraging and competitive predators. Different designs and powers of fishing gear also complicate the calibration of the predatory skills of any one fisher or fishing vessel (Hilborn and Ledbetter 1985).

On the other hand, the information requirements of managing fisheries for conservation and allocation have led to large expenditures to measure the parameters of some fisheries. The large-scale access-point creel survey (Pollock et al. 1994, 1997) ongoing in the Strait of Georgia, British Columbia, is motivated by the need for estimates of the total number of five species of salmon and some groundfish caught by the sport fishery (e.g., Collicutt and Shardlow 1992). Those totals form a component of a Canadian Department of Fisheries and Oceans (DFO) stock assessment program whose mandate is to provide quantitative information central to the harvest management of salmon and groundfish and to assure that salmon escapement goals are achieved. Confidence in estimates of the total number of fish caught and kept, or caught and released, comes from appropriately designed and executed statistical surveys of fishing activities and out-

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Table 1. Annual sport angling regulations directly or indirectly affecting the retainable daily catch by a licensed angler who targeted and caught exclusively either chinook salmon or coho salmon in the Strait of Georgia from 1984 to 1993.

	Chinook salmon				Coho salmon			
Year	DBL	Minimum retainable size (cm)	Annual bag limit	% released	DBL	Minimum retainable size (cm)	Annual bag limit	% released
1984	4, 2[a]	45	30	25	4	30.5	None	23
1985	2	45	20	17	4	30.5	None	16
1986	2	45	20	17	4	30.5	None	4
1987	2	45	20	14	4	30.5	None	15
1988	2	62[b]	8	37	4	30.5	None	16
1989	2	62	15	50	4	30.5	None	15
1990	2	62	15	53	4	30.5	None	24
1991	2	62	15	52	4	30.5	None	7
1992	2	62	15	49	4	30.5	None	28
1993	2	62	15	52	4	30.5	None	26

Note: The DBL for the total of all salmon species caught is four fish. The percentage of chinook salmon or coho salmon caught and subsequently released by anglers targeting each species is also tabled.
[a]Only for 1 December until 31 March or within Howe Sound.
[b]Introduced 1 December 1988.

comes. The Strait of Georgia creel survey was designed to estimate, with 95% confidence, catch and effort within 20% of their true values by sampling at least 5% of boat-trips.

By the end of 1993, the Strait of Georgia creel survey database contained several hundred thousand records of access-point interviews of sport anglers. These interviews were conducted by posing questions to anglers at an access point (e.g., a launch ramp) regarding the number of salmon and groundfish they caught (then either kept or released), their effort (in hours spent angling), and some attributes of effort for their just completed boat-trip. The angling power of a daily boat-trip can be defined by measured attributes of effort such as the number of licensed anglers or the number of angling lines. This allows subsets of boat-trips to be segregated into specific angling fleets defined by those attributes shared by all boats in that fleet.

The Strait of Georgia sport fishery for chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon (*Oncorhynchus kisutch*) is a year-round saltwater fishery prosecuted by anglers who fish from shore or a boat. Both serious and casual anglers participate in this fishery because of its adjacency to the urbanised lower mainland of British Columbia (greater Vancouver) and southern Vancouver Island. Anglers are also entitled to catch sockeye salmon (*Oncorhynchus nerka*), pink salmon (*Oncorhynchus gorbusha*), chum salmon (*Oncorhynchus keta*), as well as groundfish. For management purposes the daily bag limits (DBL's) for the salmon species differ, e.g., four for all salmon except chinook salmon, two chinook salmon, and no more than four salmon in total (Table 1). In this study of decision-making by salmon sport anglers, I eliminated the analytical complication associated with calculating various DBL combinations that would arise from anglers catching more than one species of salmon by dealing with only those two species preferred by sport anglers, chinook salmon and coho salmon.

Motivated in part by Hilborn (1985), I address both conceptual and practical considerations related to the angling success of fleets of anglers targeting exclusively either chinook salmon or coho salmon. For various angling fleets defined by their attributes, I (1) define a unit of effort for an angling fleet given the attributes (e.g., number of angling lines, number of licensed anglers) of the boats in the fleet, (2) estimate catch rates, their variance, and the rate at which boats of an angling fleet quit a daily boat-trip, (3) question if angling success affects the length of a daily boat-trip, (4) question if angler skill affects angling success, and (5) evaluate the effectiveness of DBL's in reducing total catch per daily boat-trip. These considerations deal with the functional response of anglers to angling success (Peterman and Steer 1981). That is, once having made the decision to take a sport angling boat-trip, how is a decision to continue the boat-trip affected by angling success? By modelling the probability of catching a certain number of fish after a certain number of hours angling, and the probability of a boat ending its angling trip as a function of time and angling success, I produce bivariate probability mass distributions for the proportion of boats in an angling fleet that quit angling as a function of catch and effort. These probabilities indicate if angling success tends to encourage or discourage continuation of a boat-trip. They are also informative of how often achieving the DBL affects the length of a boat-trip and how daily catch rates are affected by the DBL. These probabilities can also be indicative of how variability in angler skill contributes to observed variability in angler success. I test, using a general linear model (GLM), if the number of anglers per boat, or the number of angling lines per boat, affects angling success and anglers' tendencies to either extend or shorten a boat-trip in response to their angling success.

Analytical model

Model development

I developed a model that captures the dynamics of a fleet of boats making daily angling trips that conforms to the following considerations: (1) only one species is targeted and caught during the boat-trip, (2) total catch for a boat-trip can be constrained by a DBL rule, (3) all boat-trips end, but after variable amounts of time angling, (4) the length of a boat-trip can be a function of angling success (i.e., anglers quit angling because they are (dis)satisfied with the number of fish they have caught), and (5) the expected mean hourly catch rate and catch rate variance can (*i*) remain constant for a fleet ($\rho = 0$), (*ii*) be determined by the catch rate of those anglers still angling ($\rho = 1$), or (*iii*) be a function of both hypotheses ($0 < \rho < 1$). These considerations led to the conceptualisation of a bivariate probability mass distribution describing the probability that a boat-trip will end after a certain number of hours angling, and with a certain total catch. Specifically, the probability mass for each cell of the distribution can be described by

$$(1) \qquad p[Q_{C,h}] = p[C_h] \times p[E_h | S_{h-1}]$$

which reads as follows. The probability that a boat-trip will end in hour h with catch C ($p[Q_{C,h}]$) equals the probability that C fish were caught after h hours of angling ($p[C_h]$) times the probability that the boat-trip will end in hour h on the condition that the boat-trip lasted at least h – 1 hours ($p[E_h|S_{h-1}]$). Given models for calculating $p[C_h]$ and $p[E_h|S_{h-1}]$, their parameters can be adjusted to fit the observed data for a particular angling fleet using a criterion such as maximum-likelihood.

Useful parametric models exist for defining $p[C_1]$, $p[E_h|S_{h-1}]$ and, as a consequence, $p[C_h]$. If angling success, when measured as total catch after 1 h of angling (C_1), is treated as a discrete random variable with its variance attributable to random sampling error plus other sources of random variability (e.g., variability in fish distribution or in angler skill), then $p[C_1]$ can be modelled using the negative binomial distribution (Mood et al. 1985) with $r = \dfrac{\mu_1^2}{\sigma_1^2 - \mu_1}$ and $q = \dfrac{\mu_1}{\sigma_1^2}$, where μ_1 and σ_1 represent the mean and SD of the hourly catch rate, respectively:

$$(2a) \qquad p[C_*] = \frac{(r + C - 1)!}{C!(r-1)!} q^r (1-q)^C \quad \text{when } C < \text{DBL}$$

$$(2b) \qquad p[C_*] = 1 - \sum_{X=0}^{\text{DBL}-1} p[X_*] \quad \text{when } C = \text{DBL}$$

where the asterisk helps to conceptually distinguish hourly catch rate probabilities from the probable catches after 1 h of angling ($h = 1$), although $p[C_1] = p[C_*]$ in eq. 2. This hypothesis of a constant mean hourly catch rate and catch rate variance (i.e., $\rho = 0$) is premised upon catch rate being proportional to fish abundance and fish abundance not changing perceptibly during a boat-trip.

I base the parametric model for $p[E_h|S_{h-1}]$ on the attenuated Weibull probability distribution with parameters $\alpha > 0$ and $\beta > 0$:

$$(3) \qquad p[S_h] = e^{-\alpha h^{\beta}}.$$

The Weibull distribution has its genesis in failure analysis (Walpole et al. 1998) and is well suited to model the probability of a boat-trip ending as a function of time. Here, I modify the Weibull distribution to render an attenuated distribution that can be used to describe the probability of a boat-trip ending as a function of both time (h) and total catch (C):

$$(4) \qquad p[S_h] = e^{-\alpha h^{\beta^{(C+1)^{\zeta}}}}.$$

The ζ in eq. 4 is a dimensionless parameter that modifies the influence of discrete catches C = 0, 1, 2,..., DBL on the rate of attenuation. This modified distribution is still Weibull in form with a new parameter $\beta' = \beta^{(C+1)^{\zeta}}$ for fixed values of C and ζ. If $\zeta = 0$, then $\beta' = \beta$ and it can be said that the probability of a boat-trip ending is independent of total catch.

Using eq. 4, I define the probability of a boat-trip ending in hour h conditional on the boat-trip having lasted at least h – 1 hours and as a function of total catch C, $p[E_h|S_{h-1}]$, as

$$(5a) \qquad p[E_h | S_{h-1}] = \frac{e^{-\alpha(h-1)^{\beta^{(C+1)^{\zeta}}}} - e^{-\alpha h^{\beta^{(C+1)^{\zeta}}}}}{e^{-\alpha(h-1)^{\beta^{(C+1)^{\zeta}}}}} \quad \text{when } C < \text{DBL}$$

$$(5b) \qquad p[E_h | S_{h-1}] = 1 \quad \text{when } C = \text{DBL}$$

starting with $p[S_0] = 1$.

In practice, an analyst must choose a maximum value for h that is greater than the length of most, if not all, boat-trips. For this final hour, which I designate by h_f:

$$(5c) \qquad p[E_{h_f} | S_{h_f - 1}] = 1.$$

I used h_f = 10 h for the analyses presented in this paper.

The models for $p[C_1]$ and $p[E_h|S_{h-1}]$ allow the probable catches in any hour h ($p[C_h]$ in eq. 1) to be calculated sequentially in time by convolving ($\otimes$) the probable catches of boat-trips that lasted h – 1 hours with the negative binomial distribution of probable catch rates in hour h ($p[C_*]$), i.e.:

$$(6) \qquad p[C_h] = (p[C_{h-1}] \times (1 - p[E_{h-1} | S_{h-2}])) \otimes p[C_*]$$

using the moments μ_* and σ_*^2 where

$$(7a) \qquad \mu_* = \rho \mu_{h-1} + (1-\rho)\mu_1$$

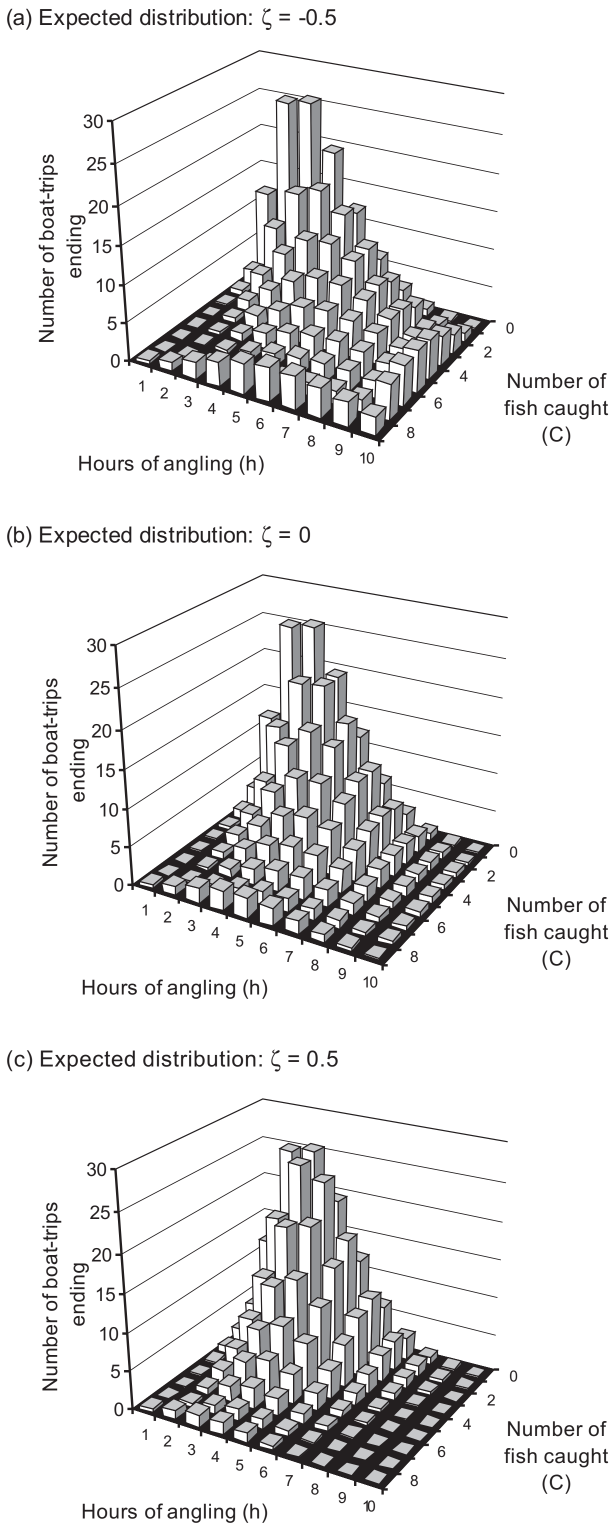
$$(7b) \qquad \sigma_*^2 = \rho^2 \sigma_{h-1}^2 + (1-\rho)^2 \sigma_1^2$$

subject to the constraint that $\sigma_*^2 \geq \mu_*$. In eq. 7, μ_{h-1} and σ_{h-1}^2 refer to the mean hourly catch rate and catch rate variance, respectively, for those boats still angling after h – 1 hours. The ρ estimates the proportion of the hourly catch rate distribution attributable to the competing hypotheses of a constant hourly catch rate and a catch rate determined by the angling success of those anglers still angling.

The model is now fully stated. One way to conceptualize this model is to view Fig. 1, which demonstrates how different values for ζ (–0.5, 0, 0.5) influence the appearance of ideal (i.e., no sampling error) bivariate probability mass distributions. The mean hour of a boat-trip ending is independent of catch when $\zeta = 0$ (Fig. 1*b*). If $\zeta < 0$, then angling success tends to lengthen a boat-trip (Fig. 1*a*), while if $\zeta > 0$, then angling success tends to shorten a boat-trip (Fig. 1*c*).

The magnitude of estimated values for ζ is inherently scaled to the catch expectations of a particular fleet. To allow comparisons of values for ζ among fleets, I scaled ζ in

Fig. 1. Simulated bivariate distributions of the number of boats ending a daily boat-trip as a function of catch (C) and hours of angling (h) and for three values of ζ: (*a*) –0.5, (*b*) 0, and (*c*) 0.5. Expected distributions are shown for a mean hourly catch rate (μ_1) of 0.5 fish·h^{-1}, an SD of hourly catch rates (σ_1) of 1.0 fish·h^{-1}, a mean trip length (when ζ = 0) of 4.0 h, an SD in trip length (when ζ = 0) of 2.0 h, h_f = 10 h, ρ = 0, and the three values of ζ. The fleet size (N) is 400 boats and the DBL for a boat-trip is eight fish.



order to express it relative to the catch expectation of a reference fleet ($\overline{C}_R$). I chose the fleet composed of two licensed anglers and two angling lines (2-A, 2-L) predominant in all years as the reference fleet. Scaling sets $e^{\alpha h \beta^{(\overline{C}_R+1)^{\zeta'}}}$ (eq. 4) equivalent to $e^{\alpha h \beta^{(\overline{C}_F+1)^{\zeta}}}$ such that scaled values (ζ') are defined by

$$(8) \qquad \zeta' = \zeta\left(\frac{\ln(\overline{C}_F + 1)}{\ln(\overline{C}_R + 1)}\right)$$

where the catch expectation of each fleet is defined as $\overline{C}_F = \mu_1 \overline{h}$, $\overline{h}$ being the expected mean trip length (hours) when ζ = 0. Scaling does not change the sign of ζ.

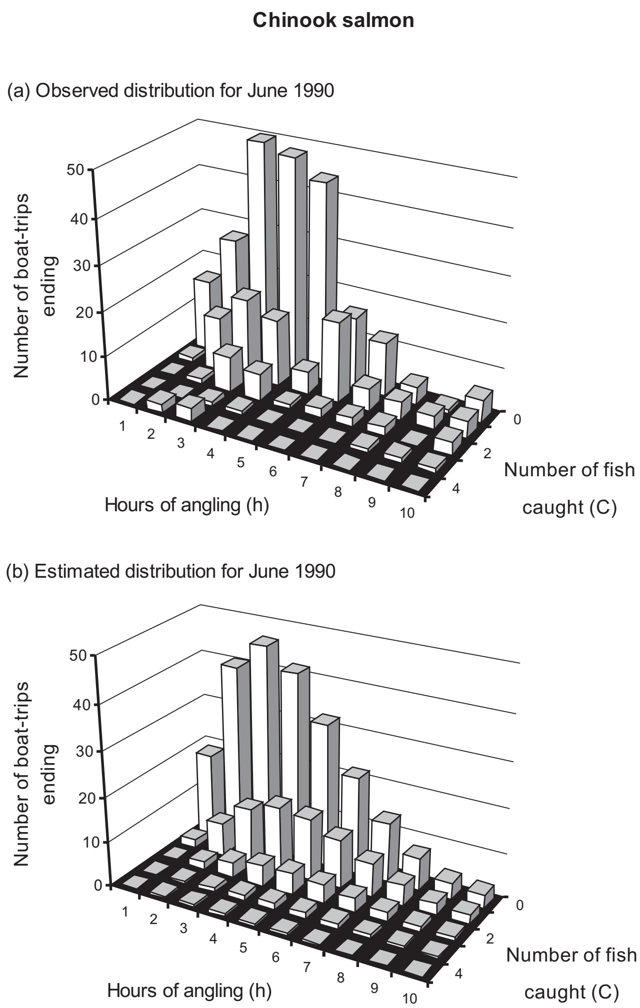
Data preparation

I had available for analysis data from the Strait of Georgia creel survey for the years 1984–1993. One important detail of these data is that the total number of chinook salmon or coho salmon caught and retained, or caught and released, by anglers on a daily boat-trip was assigned to the boat-trip, not to individual anglers. Therefore, the DBL applicable to any boat-trip is the single angler regulatory DBL times the number of licensed anglers. This implicitly assumes that licensed anglers made only one boat-trip per day.

Anglers may have caught and released other salmon and groundfish species while targeting either chinook salmon or coho salmon. I did not investigate any possible effect of the number of chinook salmon or coho salmon caught and released on an angler's perception of his or her angling success because the release of salmon smaller than a minimum legal size limit is mandated by sport angling regulations and is not a decision made by the angler (Table 1). A change in a DBL regulation might also influence the length of a daily boat-trip or an angler's perception of his or her angling success. The DBL's for both chinook salmon and coho salmon remained unchanged during this study after 1984 (Table 1), eliminating this concern.

I organized individual boat-trips into fleets where exclusively either chinook salmon (26 687 records) or coho salmon (27 361 records) was both the target species and the only species caught, subject to some other data-refining criteria. Thus, for each species, a single data record corresponding to one daily boat-trip was accepted for analysis if and only if (1) the targeted and caught species was exclusively either chinook salmon or coho salmon, (2) the number of licensed anglers was three or fewer, (3) the number of angling lines was three or fewer, (4) the anglers were residents of British Columbia, (5) the boat-trip was not guided, (6) the number of chinook salmon or coho salmon caught and retained did not exceed the DBL for the species and corresponding fleet definition, and (7) the time targeting exclusively either chinook salmon or coho salmon (measured to the nearest 0.5 h) was no more than 10 h. The first three define categorical data that facilitate the definition of an angling fleet (e.g., all boat-trips where only one angling line was used). This definition can be extended to time periods (e.g., all boat-trips in a particular year or month). Only the last two refer to the data required to evaluate the dynamics

Fig. 2. (*a*) Observed and (*b*) estimated bivariate frequency distributions of the number of boats ending a daily boat-trip as a function of catch (C) and hours of angling (h) for the most well sampled (N = 344) monthly chinook salmon angling fleet (two licensed anglers and two angling lines (2-A, 2-L) in June 1990). For this example, μ_1 = 0.12 fish·h^{-1}, σ_1 = 0.16 fish·h^{-1}, $\bar{h}$ = 3.8 h, $\overline{C_F}$ = 0.44 fish, ζ = 0.12, and ρ = 0 (p = 0.05).



of catch rate and the decision of anglers to continue or discontinue a boat-trip, i.e., total catch and total hours spent angling.

One deficiency of the data concerns the type of angling gear and bait. The former is particularly relevant to chinook salmon angling, since some anglers would have chosen to use downriggers (Argue et al. 1983) with one or more of their lines. The use of downriggers allows an angler to precisely choose an angling depth. Any difference in catch rate between lines with and without downriggers will contribute to variance in catch rates. The influences of tides, currents, time of day, fish distribution, and choice of bait can also contribute to overall variability in angling success (see Holtby et al. 1992), but these specific factors are not investigated in this paper.

Parameter estimation

Fitting the model to the data organized for this study requires that values be estimated for the six parameters introduced in eq. 2 (μ_1, σ_1), eq. 4 (α, β, ζ), and eq. 7 (ρ). Maximum-likelihood estimates for these parameters are those obtained by maximising Θ_1:

$$(9)\qquad \Theta_1(\mu_1, \sigma_1, \alpha, \beta, \zeta, \rho) = \prod_{h=1}^{h_f} \prod_{C=0}^{\mathrm{DBL}} p[Q_{C,h}]^{n_{C,h}}$$

where $n_{C,h}$ is the number of boat-trips ending with catch C in hour h. The total number of boats in the fleet, N, is

$$(10)\qquad N = \sum_{h=1}^{h_f} \sum_{C=0}^{\mathrm{DBL}} n_{C,h}.$$

I found it more expedient to minimise the following separation statistic:

$$(11)\qquad \Theta_2(\mu_1, \sigma_1, \alpha, \beta, \zeta, \rho) = 2\sum_{h=1}^{h_f} \sum_{C=0}^{\mathrm{DBL}} O_{C,h} \ln\left[\frac{O_{C,h}}{P_{C,h}}\right] \text{ for all } O_{C,h} > 0$$

(Schnute and Fournier 1980) rather than maximise eq. 9 to obtain maximum-likelihood estimates, although both Θ_1 and Θ_2 lead to identical estimates and their SE's. Equation 11 measures the discrepancy between the observed ($O_{C,h}$) and predicted ($P_{C,h}$) number of boat-trips ending within each frequency cell defined by C and h. The objective function Θ_2 is twice the negative ln-likelihood for a multinomial distribution, without the additive constant. The value for Θ_2 at the maximum-likelihood estimates is always zero or positive, is conveniently zero only when $P_{C,h} = O_{C,h}$ in all cells, and approximates the χ^2 statistic when N is large and the fit is good.

I used the software of Mittertreiner and Schnute (1985) to minimise Θ_2. SE's of the maximum-likelihood parameter estimates were calculated using their numerical method. The quality of model fit was diagnosed based on χ^2 probabilities (p) precisely calculated using simulation (Roff and Bentzen 1989). The χ^2 diagnostic evaluates the probability of the observed data given the model and parameter estimates; thus, higher values of p will be associated with more likely models. This diagnosis is the antithesis to null hypothesis testing where one generally tests to reject the null model.

Parameter estimates and their SE's for μ_1, σ_1, α, β, ζ, and ρ were obtained from nearly 420 analyses of various chinook salmon and coho salmon angling fleets (three anglers (A) × three lines (L) × 10 years plus the predominant "2-A, 2-L" fleet × 12 months × 10 years) where there were sufficient data. I judged a fleet to have sufficient data if N exceeded 50 boats (maximum N = 1811 for chinook salmon and N = 2862 for coho salmon). Typical chinook salmon and coho salmon data sets, and the maximum-likelihood fits to these data, are illustrated in Figs. 2 and 3, respectively. The maximum-likelihood estimate for ρ was zero in 90 and 81% of the analyses of chinook salmon and coho salmon fleets, respectively. On the basis of this strong statistical support for ρ = 0 and the simulations reported below, all analyses were redone with ρ fixed at zero.

Parameter accuracy and precision

One concern I had was that the intrinsic nonlinearity (Ratkowsky 1983; Bates and Watts 1988) of eq. 4 in particular

Fig. 3. (*a*) Observed and (*b*) estimated bivariate frequency distributions of the number of boats ending a boat-trip as a function of catch (C) and hours of angling (h) for the most well sampled (N = 796) monthly coho salmon angling fleet (two licensed anglers and two angling lines (2-A, 2-L) in June 1992). For this example, μ_1 = 1.09 fish·h^{-1}, σ_1 = 3.62 fish·h^{-1}, $\bar{h}$ = 2.9 h, $\overline{C_F}$ = 3.21 fish, ζ = 0.10, and ρ = 0 (p = 0.133).

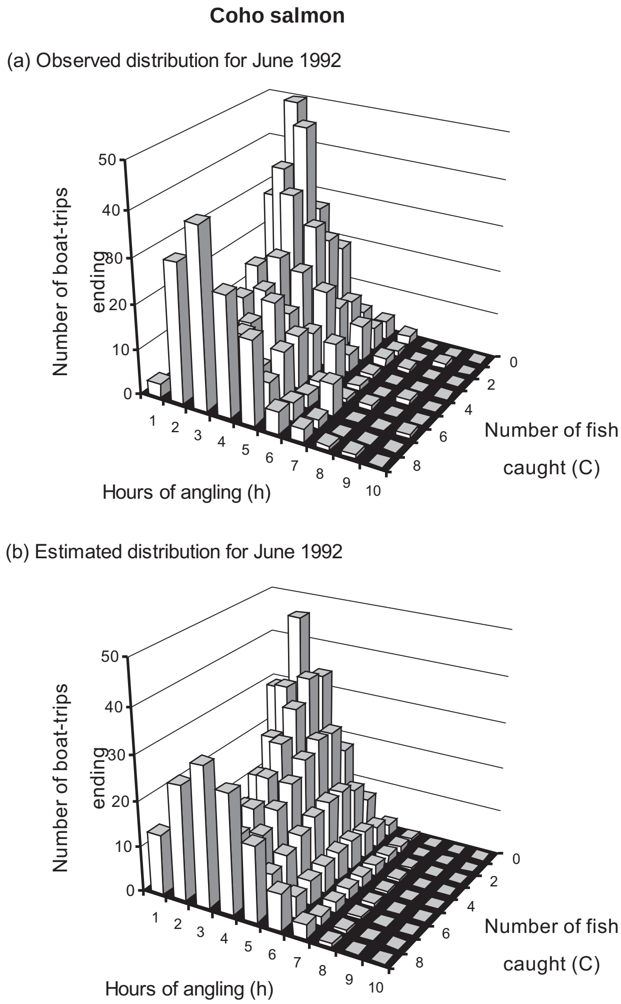
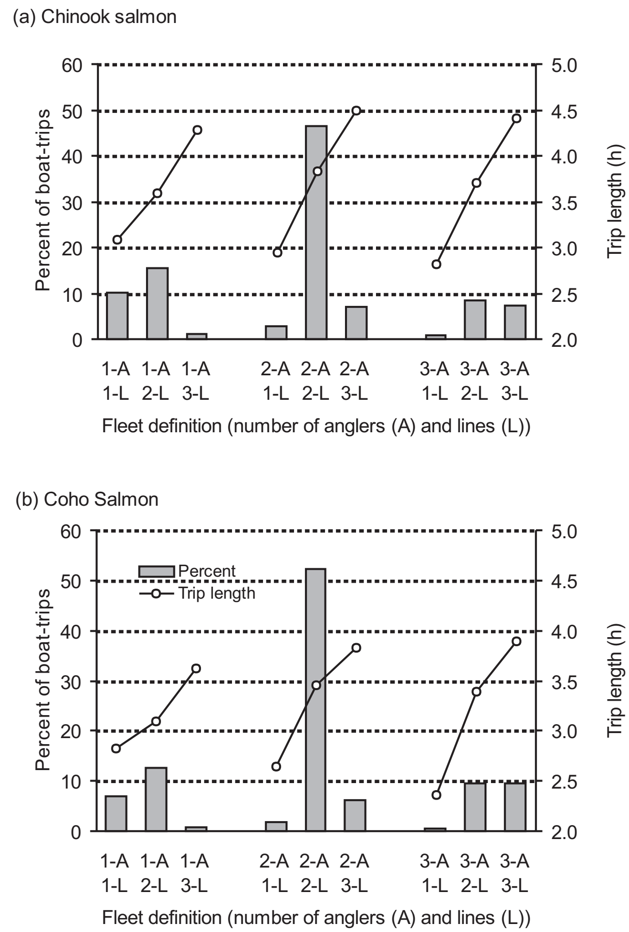


Fig. 4. Percent and mean trip lengths of boat-trips targeting (*a*) chinook salmon (N = 26 687, overall mean trip length is 3.7 h) or (*b*) coho salmon (N = 27 361, overall mean trip length is 3.2 h) for all years from 1984 to 1993 and according to fleet. A fleet is defined by the number of licensed anglers (A) and the number of angling lines (L).



could lead to seriously biased parameter estimates and their SE's, particularly for ζ. Such bias could result in parameter values that badly misrepresent fleet dynamics and lead to incorrect qualitative conclusions of fleet behaviour. To address these concerns, I performed an extensive set of analyses of data simulated using values for the six model parameters. These simulated values were generated by randomly sampling Gaussian distributions whose means and SD's were calculated using the approximately 420 parameter estimates (for ζ), or the natural logarithm of parameter estimates (for μ_1, σ_1, α, and β) obtained by analysing the chinook salmon or coho salmon angling data of this study. Natural logarithms of μ_1, σ_1, α, and β were taken to accommodate the skewness in their sample distributions, which, by definition, is always positive. Sequential predictive regressions (i.e., ln[σ_1] regressed on ln[μ_1], then ln[α] regressed on ln[σ_1], etc.) among the parameter domains were used to assure that the correlations among the simulated parameter values represented the correlations among the parameter estimates obtained from real data. Since the maximum-likelihood estimate for ρ was zero for nearly all analyses, the simulated values for ρ were obtained by randomly sampling the uniform distribution 0–1.

Simulations were performed for fleet sizes (N) of 30, 60, 120, 240, 480, and 960 boats and for DBL's of two, four, and six fish, using parameters values typical of the chinook salmon fleet, and four, eight, and 12 fish, using parameters values typical of the coho salmon fleet (Table 1). Sixty replicates for each of these simulations were performed. The parameter values estimated from these simulated fleets had undetectable bias. Mittertreiner and Schnute's (1985) numerical method usually produced reliable SE's for those estimates, with the exception of the estimates for ρ. The SE's were statistically indistinguishable from the SD's of the parameter estimates of the 60 replicates for each simulation when samples sizes were judged to be adequate (N > 50). These very acceptable results are due to the high ratio of data to parameters resulting in the model's behaviour being close to linear (Ratkowsky 1983; Bates and Watts 1988) at the maximum-likelihood parameter estimates. The simulations revealed that sample sizes greater 480 boats were re-

Fig. 5. Annual patterns in anomalies from mean trip length and ζ′ for (*a*) chinook salmon and (*b*) coho salmon angling trips with two licensed anglers and two angling lines (2-A, 2-L). Error bars indicate 1 SE. Note that the minimum retainable size for chinook salmon was increased from 45 to 62 cm in December 1988 (Table 1). For chinook salmon, mean trip length is 3.8 h and N = 12 411; for coho salmon, mean trip length is 3.5 h and N = 14 304.

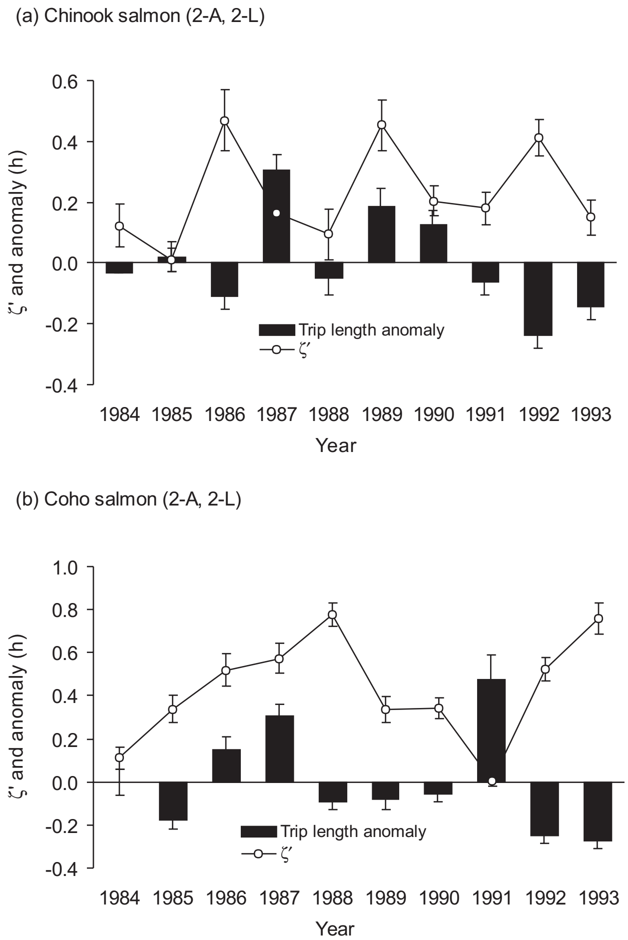
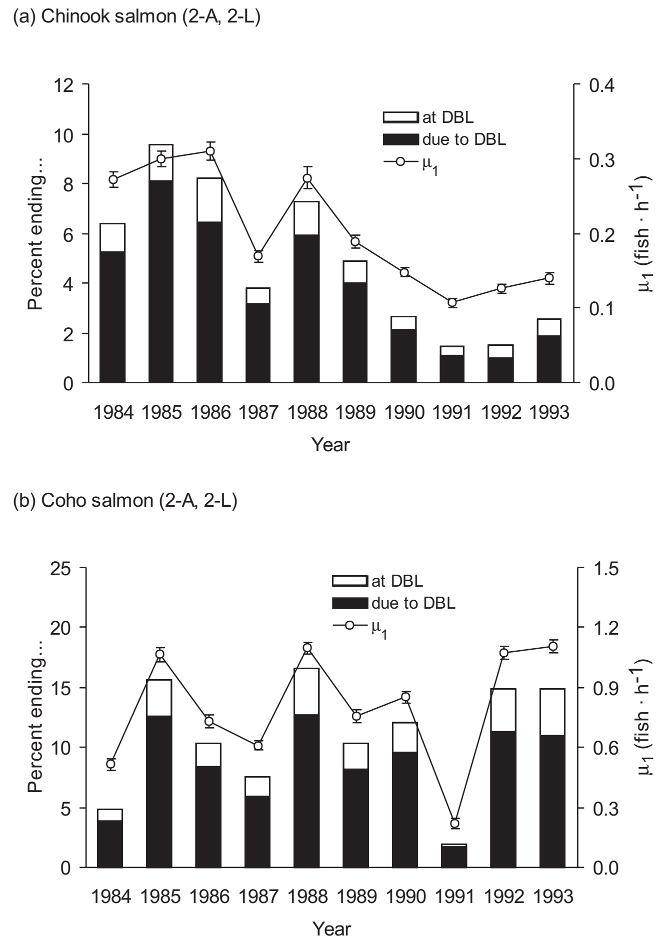


Fig. 6. Annual patterns in (*a*) chinook salmon (N = 12 411) and (*b*) coho salmon (N = 14 304) mean hourly catch rate (μ_1) and the percentage of boat-trips ending at, and due to, the DBL for angling trips with two licensed anglers and two angling lines (2-A, 2-L). Error bars indicate 1 SE. The percentage of boat-trips ending due to the DBL is that percentage of trips where the expected catch would have exceeded the DBL. Note that the minimum retainable size for chinook salmon was increased from 45 to 62 cm in December 1988 (Table 1).



quired to obtain estimates of ρ whose 95% confidence interval excluded the extreme hypotheses ρ = 0 and ρ = 1 when ρ = 0.5. Thus, precise values for ρ could not be estimated in most analyses, and the hypothesis ρ = 0 upon which all analyses were conditioned could not be rejected.

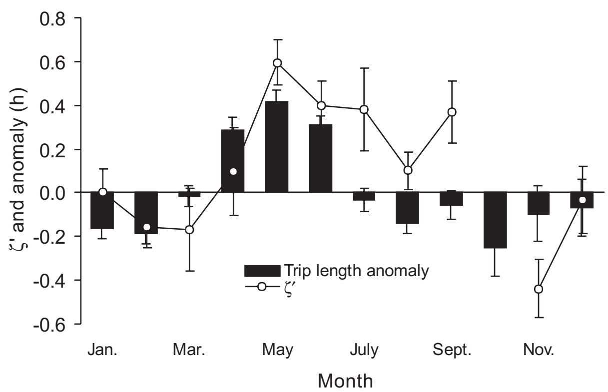
Results

The fleet most characteristic of Strait of Georgia chinook salmon and coho salmon anglers from 1984 to 1993 was composed of two licensed anglers and two angling lines (2-A, 2-L, Fig. 4). Anglers of this fleet who targeted chinook salmon invested significantly (p < 0.0001) more time angling (3.8 h) than did coho salmon anglers (3.5 h), likely reflecting the generally lower catch rate for chinook salmon (see Fig. 6). For anglers targeting either species, the number of angling lines significantly influenced the length of a boat-trip, whereas the number of anglers onboard did not. Each additional angling line tended to increase the length of a boat-trip by 30–45 min. The shortest trips occurred for the most ill-equipped fleet, i.e., three anglers and one line (3-A, 1-L).

Trips targeting both chinook salmon and coho salmon varied in length according to year (Fig. 5). Although mean annual chinook salmon catch rates (Fig. 6*a*) for years before 1988 are not directly comparable with those after 1988 because of a dramatic increase in the minimum retainable size from 45 to 62 cm in 1988 (Table 1), the following interpretation can be made. Before 1988, a poor annual catch rate tended to increase the length of a boat-trip (Fig. 5*a*), whereas poorer annual catch rates in the latter years correspond to shorter trip lengths and fewer trips ending due to anglers having reached the DBL (Fig. 6*a*). An almost three-fold increase in the percentage of chinook salmon caught and released after 1988 (Table 1) suggests that the catch rate for chinook salmon 45 cm and larger after 1988 might have been somewhat higher than the rate for fish 62 cm and larger. Poorer annual catch rates for coho salmon generally

Fig. 7. Monthly patterns in anomalies from mean trip length and ζ′ for (*a*) chinook salmon and (*b*) coho salmon angling trips with two licensed anglers and two angling lines (2-A, 2-L). Error bars indicate 1 SE. For chinook salmon, mean trip length is 3.8 h and N = 12 374; for coho salmon, mean trip length is 3.3 h and N = 14 256. Insufficient data are available to confidently estimate ζ′ for chinook salmon in October and for coho salmon during November through February.

(a) Chinook salmon (2-A, 2-L)



(b) Coho salmon (2-A, 2-L)

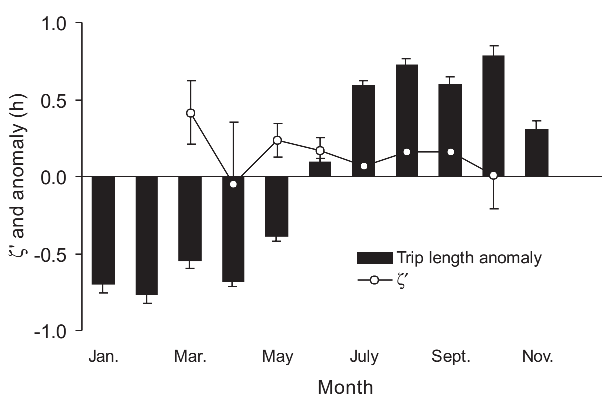
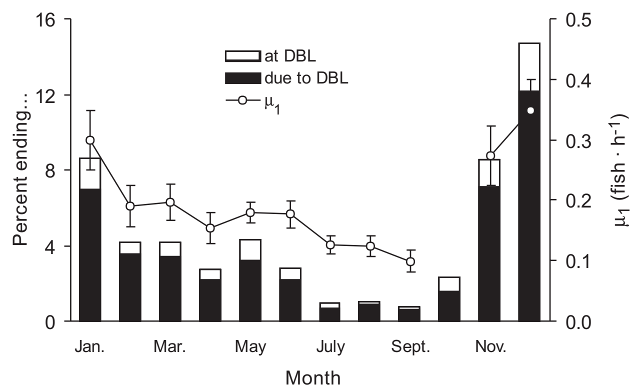
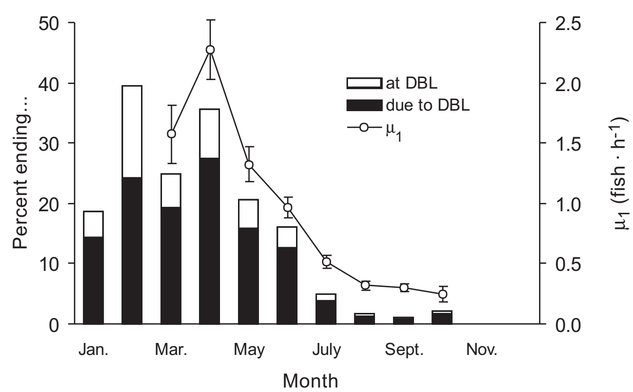


Fig. 8. Monthly patterns in (*a*) chinook salmon (N = 12 374) and (*b*) coho salmon (N = 14 256) mean hourly catch rate (μ_1) and the percentage of boat-trips ending at, and due to, the DBL for angling trips with two licensed anglers and two angling lines (2-A, 2-L). Error bars indicate 1 SE. The percentage of boat-trips ending due to the DBL is that percentage of trips where the expected catch would have exceeded the DBL. Insufficient data are available to confidently estimate μ_1 for chinook salmon in October and for coho salmon during November through February.

(a) Chinook salmon (2-A, 2-L)



(a) Chinook salmon (2-A, 2-L)



resulted in longer trip lengths (Fig. 5*b*) and fewer trips ending due to anglers having reached the DBL (Fig. 6*b*).

Monthly trip lengths for both chinook salmon and coho salmon vary with the season, the longer trips tending to occur in the more pleasant spring (chinook salmon) and summer (coho salmon) months (Fig. 7). The highest seasonal catch rates for chinook salmon occurred in the autumn and winter months (Fig. 8*a*) when the mean sizes of ocean-age-2 and ocean-age-3 fish (Argue et al. 1983) surpass the minimum retainable sizes of 45 and 62 cm, respectively (Table 1). The highest seasonal catch rates for coho salmon occurred in the spring months (Fig. 8*b*) when growth is rapid (Groot and Margolis 1991) and the mean size of ocean-age-2 fish rapidly surpasses the minimum retainable size of 30.5 cm (Argue et al. 1983).

The positive values for ζ′ for all years (except 1991 for coho salmon, Fig. 5) indicate that anglers targeting chinook salmon or coho salmon tend to shorten their boat-trips as a result of angling success. Notwithstanding 1991, a year of particular low coho salmon abundance, there is a slight tendency for ζ′ to increase over the years, but unexplained high interannual variability is a dominant feature. Figure 7 illustrates that interpretation of ζ′ is independent of mean trip length; summer boat-trips targeting chinook salmon are about an hour longer than autumn and winter boat-trips, yet summer trips tend to be shortened by angling success, while autumn and winter trips are lengthened. Arguably, chinook salmon anglers who brave uncomfortable autumn and winter conditions are keen anglers who are motivated to continue angling when they have some angling success. The high catch rate of coho salmon in the spring (Fig. 8*b*) results in rapid angling success and correspondingly shorter trip lengths (Fig. 7*b*) as anglers are satisfied, reach their DBL (Fig. 8*b*), or find spring weather less comfortable than summer weather.

Using a GLM, I found the mean hourly catch rate (μ_1) of boat-trips targeting chinook salmon to be dependent on the number of anglers, with boat-trips having two and three an-

Table 2. GLM ($\ln[\mu_{ijy}] = \gamma_i + \kappa_j + \lambda_y + \varepsilon_{ijy}$) of $\ln[\mu_{ijy}$, fish·h$^{-1}]$ for chinook salmon and coho salmon (Fig. 6) as a function of the number of angling lines (i = 1,..., 3), the number of licensed anglers (j = 1,..., 3), and the year (y = 1984,..., 1993).

Chinook salmon (n = 69, error df = 55, r^2 = 0.83, p < 0.0001)										
No. of lines (i)	1	2	3							
γ_i	0.000	0.045	–0.059							
SE of γ_i	—	0.056	0.067							
No. of anglers (j)	1	2	3							
κ_j	0.000	0.358*	0.442*							
SE of κ_j	—	0.056	0.066							
Year (y)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
λ_y	–1.671*	–1.511*	–1.660*	–2.151	–1.752*	–2.087	–2.067	–2.347*	–2.423*	–2.329*
SE of λ_y	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.087
Coho salmon[a] (n = 62, error df = 48, r^2 = 0.85, p < 0.0001)										
No. of lines (i)	1	2	3							
γ_i	0.000	0.374*	0.603*							
SE of γ_i	—	0.065	0.079							
No. of anglers (j)	1	2	3							
κ_j	0.000	–0.027	0.037							
SE of κ_j	—	0.062	0.072							
Year (y)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
λ_y	–1.017*	–0.475*	–0.679	–0.896	–0.433*	–0.819	–0.629	–1.728*	–0.288*	–0.321*
SE of λ_y	0.091	0.085	0.091	0.085	0.085	0.085	0.085	0.122	0.091	0.091

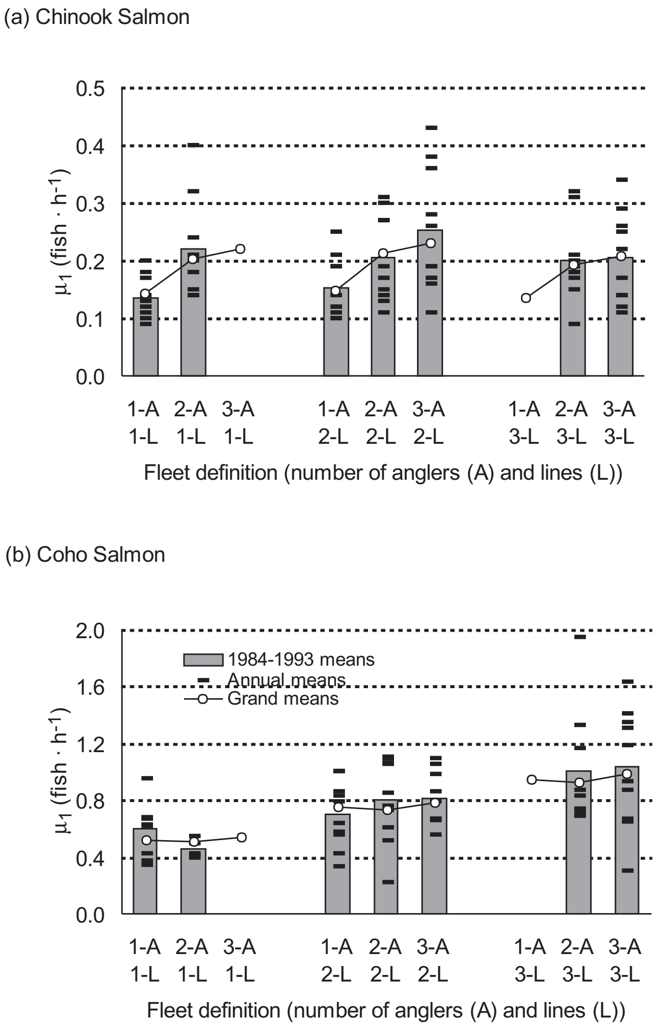
Note: The model uses fewer than 90 observations (see Fig. 9) because the analyses were restricted to estimates of μ_{ijy} based on fleets with more than 50 boat-trips to assure that the variance was normal and homogeneous. Reconstructing the relationship $\overline{\mu_{ijy}} = e^{\gamma_i + \kappa_j + \lambda_y}$ allows multiplicative comparisons of mean hourly catch rates ($\overline{\mu_{ijy}}$) according to the number of angling lines, the number of anglers, or the year. Asterisks within the number of lines or number of anglers classes indicate values statistically different from the value for one line or one angler, respectively (p < 0.05). Asterisks within the year-class indicate values statistically different from the mean value for all years.

[a]For coho salmon the estimated hourly catch rate ($\overline{\mu_{ijy}}$) of two lines is 1.45 (e^{γ_2}) times that of one line, while the hourly catch rate of three lines is 1.83 (e^{γ_3}) times that of one line. These differences in hourly catch rates are strongly statistically significant (p < 0.0001) (Fig. 9).

glers onboard tending to be more successful regardless of the number of angling lines (Table 2; Fig. 9*a*). Having more anglers onboard would allow more attention to be paid to each line, with perhaps more success in landing a chinook salmon attracted to a line. Angling success was equal regardless of the number of lines used, suggesting that one, two, or three lines have essentially the same effective area fished relative to the distribution and effective foraging area of chinook salmon (Shardlow 1993). This occurs despite that many boat-trips with two or three lines would have used lines with and without downriggers to angle the extensive depth range of chinook salmon (Orsi and Wertheimer 1995; Candy et al. 1996). On the other hand, there was no difference in mean hourly catch rate (μ_1) of coho salmon for boat-trips with one, two, or three anglers onboard (Table 2; Fig. 9*b*). However, the estimated hourly catch rate of two lines is 1.45 times that of one line, while the hourly catch rate of three lines is 1.83 times that of one line. This suggests that more lines result in a larger effective area fished relative to the distribution and effective foraging area of coho salmon (Shardlow 1993).

A GLM also revealed that boat-trips targeting coho salmon tended toward smaller, but positive, values of ζ' as the number of anglers onboard increased (Table 3; Fig. 10*b*). This result is intuitive in that with more anglers onboard, the focus of a boat-trip could be distracted from angling to include other social considerations such as camaraderie (Holland and Ditton 1992; Spencer 1993; Fisher 1997). Also, the need to accommodate the personal and domestic responsibilities of each angler means that it becomes more likely that a boat-trip will end for reasons independent of angling success as the number of anglers increases. The potential catch of a boat-trip with two or three anglers exceeds that of one angler, since the DBL would be double or triple that for a single angler. This increased catch potential would tend to lengthen boat-trips using two or three lines, while ill-equipped boat-

Fig. 9. Means for all years from 1984 to 1993, mean annual values, and means predicted by a GLM (Table 2) for hourly catch rates (μ_1) of (*a*) chinook salmon and (*b*) coho salmon. Annual means are shown for fleets of more than 50 boat-trips. A fleet is defined by the number of licensed anglers (A) and the number of angling lines (L). There were 50 or fewer boat-trips of the fleets 1-A, 3-L and 3-A, 1-L in all years; ergo, no annual mean values for μ_1 were available for analysis from these two categories.



trips, e.g., three anglers and one line (3-A, 1-L), would tend to be shortened when a DBL constrains catch (Fig. 4*b*).

As the number of lines for boat-trips targeting coho salmon increases from one to three, the values of ζ' also tend to increase (Table 3; Fig. 10*b*). This could be a result of the increased catch rate of coho salmon for two and three lines, relative to one line (Fig. 9*b*), leading to boat-trips ending earlier than they would have otherwise ended. Notwithstanding this dynamic, and further illustrating that ζ' is independent of mean trip length, boat-trips targeting coho salmon tended to increase in length as the number of lines increased (Fig. 4*b*). This implies that anglers using more lines are prepared to commit relatively more time to angling.

Boat-trips targeting chinook salmon may have similar dynamics for ζ' in relation to the number of anglers and number of lines, but this dynamic is not clearly revealed in the data that I analysed (Table 3; Fig. 10*a*). However, as for coho salmon, boat-trips with three lines had the highest values for ζ'. It might be that the smaller DBL for chinook salmon and an hourly catch rate generally only 20–25% of that for coho salmon preclude the statistical identification of such a dynamic, given the relatively low sample sizes for those fleets other than the 2-A, 2-L fleet (Fig. 4*a*). Consider also that the chinook salmon DBL for a single angler is two fish and that the low hourly catch rate for chinook salmon (Figs. 6*a* and 8*a*) means most anglers will be unsuccessful. This results in bivariate probability mass distributions that lack enough information to precisely determine the value of ζ (compare Figs. 2 and 3).

Discussion

The results presented address both conceptual and practical considerations of fisheries managers. The concept that time invested in angling is influenced by angling success is intuitive to biologists and managers of recreational fisheries. Although the functional response of anglers to the abundance of their prey is often measured by creel survey methodology, to my knowledge, no study has quantitatively measured anglers' response, in terms of time invested in angling, to angling success. On the other hand, sociological studies, usually based on questionnaire methods (Duttweiler 1976), suggest that anglers appreciate the angling experience for "fun" and "relaxation" values (Smith 1980). They are said to be less interested in actual angling success, although they are no doubt partly motivated by anticipation of successful angling (Fisher 1997).

My analyses refine these qualitative interpretations in that I show quantitatively that anglers can react in two ways to angling success. Anglers in the majority of fleets tended to use angling success to shorten an angling trip ($\zeta > 0$). An exception was autumn and winter chinook salmon anglers who seem to use angling success to lengthen a boat-trip ($\zeta < 0$, Fig. 7*a*). Holland and Ditton (1992) used sociological terminology to categorize certain aspects of angler behaviour. They defined seven categories of anglers, and among them, they included a group of anglers who rate angling success as an important component of their angling experience. These anglers need to be aroused/excited by angling success and need to have a sense of competency as anglers. My results suggest that anglers can be further categorized as anglers that are either motivated (i.e., I am catching fish, so I will keep angling) or satiated (i.e., I caught fish, so I will go home now) by their angling success. Neither behaviour contradicts the qualitative interpretations of Smith (1980) or Fisher (1997) mentioned above, but with most fleets tending to shorten a boat-trip as a result of angling success, it seems that anglers generally want to be rewarded with fish and will increase angling time to achieve that reward.

If the assumptions of the model developed here are judged appropriate for a fishery, then it can be used by a fishery manager to estimate catch rate and its variance and measure the feedback of angling success on angling effort. If, as was typical of the data that I analysed, anglers tend to end a boat-trip as a result of angling success ($\zeta > 0$), then longer boat-trips will be associated with less successful anglers who will disproportionately contribute to total effort. Ratios

Table 3. GLM ($\zeta'_{ijy} = \gamma_i + \kappa_j + \lambda_y + \varepsilon_{ijy}$) of ζ' for chinook salmon and coho salmon (Fig. 5) as a function of the number of angling lines (i = 1,..., 3), the number of licensed anglers (j = 1,..., 3), and the year (y = 1984,..., 1993).

Chinook salmon (n = 69, error df = 55, r^2 = 0.38, p = 0.011)										
No. of lines (i)	1	2	3							
γ_i	0.000	–0.018	0.314*							
SE of γ_i	—	0.098	0.118							
No. of anglers (j)	1	2	3							
κ_j	0.000	0.126	–0.119							
SE of κ_j	—	0.098	0.115							
Year (y)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
λ_y	0.101	0.291	–0.071*	0.175	0.366	0.272	0.324	0.162	0.198	0.437
SE of λ_y	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.152
Coho salmon (n = 62, error df = 48, r^2 = 0.49, p = 0.001)										
No. of lines (i)	1	2	3							
γ_i	0.000	0.375*	0.583*							
SE of γ_i	—	0.121	0.146							
No. of anglers (j)	1	2	3							
κ_j	0.000	–0.148	–0.342*							
SE of κ_j	—	0.116	0.132							
Year (y)	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
λ_y	–0.014	0.228	0.333	0.387	0.690*	0.316	0.304	–0.431*	0.586	0.412
SE of λ_y	0.168	0.156	0.168	0.156	0.156	0.156	0.156	0.226	0.168	0.168

Note: The model uses fewer than 90 observations (see Fig. 10) because the analyses were restricted to estimates of ζ' based on fleets with more than 50 boat-trips to assure that the variance was normal and homogeneous. Asterisks within the number of lines or number of anglers classes indicate values statistically different from the value for one line or one angler, respectively (p < 0.05). Asterisks within the year-class indicate values statistically different from the mean value for all years.

of variance to mean greater than 1 for the fleets targeting chinook salmon (≈1.8) and coho salmon (≈4.6) confirm that variability in angling success is due to factors in addition to sampling variability. However, despite successful anglers tending to quit angling after having had some angling success, this decision alone will not bias appropriate sample statistics used to estimate hourly catch rate. The reason for this is that all anglers, whether successful or not, have the same expected hourly catch rate (μ_1). So although a boat-trip may have ended because the anglers were successful, their success cannot be attributed to them being better anglers, given the strong statistical support for $\rho = 0$ (eq. 7). This is not to say that there is no variation in skill among anglers, rather that angler skill is not a factor required to explain catch rate and catch rate variance for this fishery. The statistical conclusion of a constant mean hourly catch rate and catch rate variance ($\rho = 0$) seems reasonable for this easy-access open-water fishery where information on fish location, abundance, bait effectiveness, etc., moves rapidly among anglers.

Unlike the model estimators for mean hourly catch rate (μ_1) and catch rate variance (σ_1^2), the simulations showed that the unbiased stratified sample statistics

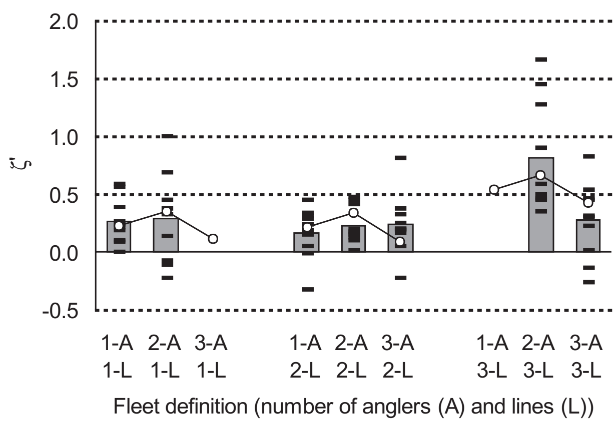
$$(12)\qquad \mu_1' = \frac{1}{N}\sum_{h=1}^{h_f}\frac{1}{h}\sum_{i=1}^{N_h} C_i = \frac{1}{N}\sum_{i=1}^{N}\frac{C_i}{h_i}$$

$$(13)\qquad \sigma_1'^2 = \frac{1}{N}\sum_{h=1}^{h_f}\frac{1}{h(N_h-1)}\left(\sum_{i=1}^{N_h} N_h C_i^2 - \left(\sum_{i=1}^{N_h} C_i\right)^2\right)$$

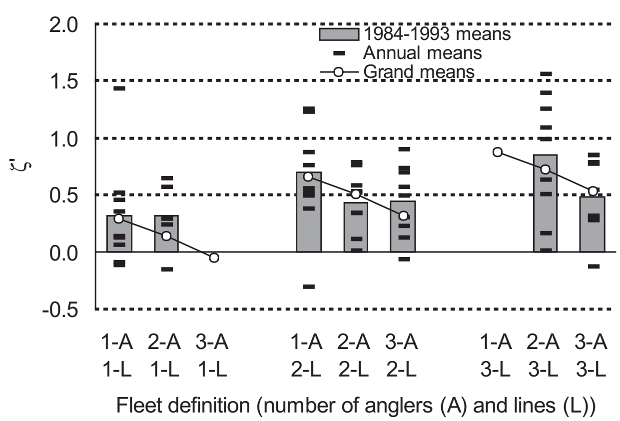
tended to underestimate their true values as DBL's were lowered, thus forcing more boats to quit angling at that lower DBL. Also, true catch rate variance tended to be underestimated when true $\zeta \neq 0$. These tendencies are probably partly due to these two estimators being more sensitive to a loss of resolution associated with time being measured in discrete units than were their corresponding model estimators. Short boat-trips with low catches provide poor information for accurately calculating catch rates and their variances using sample statistics. Note that these two estimators (eqs. 12 and 13) treat hours (h) as strata, since, if unfettered, cumulative catch should progress as a Poisson ($\mu_1 = \sigma_1^2$) or negative binomial ($\sigma_1^2 > \mu_1$) process where both catch rate

Fig. 10. Means for all years from 1984 to 1993, mean annual values, and means predicted by a GLM (Table 3) for ζ′. Annual means are shown for fleets of more than 50 boat-trips targeting (*a*) chinook salmon or (*b*) coho salmon. A fleet is defined by the number of licensed anglers (A) and the number of angling lines (L). There were 50 or fewer boat-trips of the fleets 1-A, 3-L and 3-A, 1-L in all years; ergo, no annual mean values for ζ′ were available for analysis from these two categories.

(a) Chinook Salmon



(b) Coho Salmon



and catch rate variance increase in proportion to the number of hours angled.

I caution that the estimator of mean catch rate (μ_1) introduced in this paper and those of Pollock et al. (1994, 1997) could be seriously biased indices of fish abundance if an important amount of variability in angling success was due to variability in angler skill, this difference affected trip lengths, and there is no statistical mechanism to account for this variability. Consequently, variability in fleet dynamics from time to time or place to place could invalidate the use of mean hourly catch rate as an index to compare fish abundance among those times and places. On the basis of χ^2 goodness-of-fit (α = 0.05), the hypothesis that all anglers have the same catch expectation (ρ = 0) was sufficient to explain the observed bivariate distributions for 79% of chinook salmon fleets and 75% of coho salmon fleets in the Strait of Georgia. The χ^2 diagnostic tended to fail for the largest fleet sizes, since sample distributions are rarely as ideal as predicted distributions. Goodness-of-fit tests are pessimistic in that they assume that the only source of random variability in an observed distribution is sampling error; thus, outliers can be heavily penalized in a χ^2 calculation for observed data.

The effectiveness of a DBL in reducing daily catch of one boat-trip can also be evaluated with this model structure. For example, I show in Fig. 6*a* that the chinook salmon DBL has become steadily less effective over time. In 1984, about 6% of boat-trips ended due to the DBL, while in 1993, only about 2% of boat-trips ended due to the DBL. Once model parameters are estimated for a particular fleet, then those parameter values can be used to project total effort and total catch for different DBL scenarios, thereby assisting a manager to judge the potential effectiveness of a DBL. These projections would of course be conditional on the debatable assumption that the parameters describing a fleet remain relatively unchanged in the face of changing DBL regulations (see Porch and Fox 1991). Careful use of the model to evaluate DBL effectiveness would include a sensitivity analysis of the model's parameters to such changes and of the impact of changing catch rates on the abundance of the targeted population.

Consider the following examples for the well-sampled two-angler and two-angling-line (2-A, 2-L) fleets targeting chinook salmon and coho salmon in 1990. For chinook salmon the predicted catch of those boats interviewed (N = 1811) was 1027 fish with the current DBL of four fish (two licensed anglers × a DBL of two fish per angler). Without that DBL rule the projected catch would have been 1063 fish. The DBL thus reduces the daily catch only by about 4%. About 3% of boats ended their trip due to the DBL. With the parameter values estimated for that chinook salmon fishery (μ_1 = 0.15 fish·h^{-1}, σ_1 = 0.52 fish·h^{-1}, $\bar{h}$ = 3.9 h, $\overline{C_F}$ = 0.58 fish, ζ = 0.29, ρ = 0), a new, lower DBL of one fish per angler would achieve about a 15% reduction in daily catch. The equivalent result for coho salmon (N = 1977) at the current DBL of four fish per angler is a 16% reduction in catch with 12% of boats ending their trip due to the DBL. With the parameter values estimated for that coho salmon fishery (μ_1 = 0.85 fish·h^{-1}, σ_1 = 2.23 fish·h^{-1}, $\bar{h}$ = 3.5 h, $\overline{C_F}$ = 2.95 fish, ζ = 0.31, ρ = 0), a new, lower DBL of two fish per angler would achieve about a 23% reduction in daily catch. For these two examples the values for ζ of about 0.3 indicate reductions in the mean length of boat-trips targeting chinook salmon and coho salmon of about 11 and 32%, respectively, relative to ζ = 0.

The above calculations would be less tractable for fleets that targeted and (or) caught both chinook salmon and coho salmon, or the other salmon species, because of complications in calculating the DBL's. Nevertheless, the results for this subset of the Strait of Georgia sport angling community imply that only modest reductions in the daily catch by individual boats might be achieved by DBL rules because too few anglers achieve the DBL. Given these particular catch rate and effort dynamics, it would appear that dramatic reductions in total harvest can only be achieved by reducing the number of anglers. My suspicion for this fishery is that a

DBL might be more effective in reducing the number of anglers than it is in reducing the daily catch of a boat-trip. This could occur because anglers feel that their opportunity for a satisfying angling experience has been compromised or they may have been made more conscientious of a conservation concern by the imposition of a more restrictive DBL regulation.

In support of my suspicion, I am aware that in 1995, DFO decreased the summer DBL for chinook salmon in the tidal waters of Barkley Sound (DFO Statistical Area 23B on the west coast of Vancouver Island) from four fish per day to one fish per day for conservation reasons. The number of boat-trips by anglers targeting either chinook salmon or coho salmon in 1995 was estimated at 36 500, down from a mean of 49 600 (range 43 100 to 58 200) for the preceding 5 years, 1990–1994 (DFO, unpublished data). More generally, the relative importance of the functional and numerical responses of anglers to angling success will depend on the characteristics of particular fisheries, the magnitude of the DBL's, and anglers' propensities to reach the DBL. A satisfactory understanding of sport angler dynamics for a particular fishery will require that both numerical and functional responses to angling success be studied and then evaluated in the context of the impact of angling on the targeted population (Porch and Fox 1991).

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