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THE CARRYING CAPACITY FOR JUVENILE SALMONIDS IN SOME NORTHERN CALIFORNIA STREAMS[1]

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Standing crops of juvenile coho (silver) salmon (*Oncorhynchus kisutch*), steelhead rainbow trout (*Salmo gairdneri*), and coast cutthroat trout (*Salmo clarki*) were examined in seven coastal streams to define the natural carrying capacity of these streams, and to develop methods of population comparison and prediction which could be used to determine the effects of road construction and logging on salmon and trout production.

Biomass per unit of surface area was the best method of expressing carrying capacity, because biomass was better correlated with stream surface area than with other parameters tested. Volume of streambed sediments, total dissolved solids, alkalinity, and total phosphate in six streams were not satisfactory predictors of carrying capacity. only living-space variables correlated significantly with biomass. Not all streams reached carrying capacity in the summer and salmonid biomass was highly variable. Even with 3 years of prelogging study, it would be difficult to attribute a change in carrying capacity under 50% to anything but natural variation.

INTRODUCTION

Standing crops of juvenile coho (silver) salmon, steelhead rainbow trout, and coast cutthroat trout were examined in seven coastal streams. The goals of this investigation were to define the natural salmonid carrying capacity of these streams, and to develop methods of population comparison and prediction which could be used to determine the effects of road construction and logging on salmon and trout production.

The most direct way to assess the impact of logging on anadromous salmonids is to compare numbers of juvenile outmigrants before and after logging. This method is generally impractical in California, because characteristic extreme seasonal. fluctuations in streamflow make construction and maintenance costs of weirs and traps prohibitive (Burns, 1966). As an alternative, the juvenile carrying capacity of streams before and after logging was compared. Valid comparisons required a reliable, standardized sampling method. I reasoned that during minimum streamflow in the summer, juvenile salmonids would be at their greatest weight density (biomass per unit of living space), a density that would remain fairly constant from year to year and would be regulated by available living space. Any adverse effects of logging should decrease the stream's salmonid carrying capacity and be indicated by a decrease in the weight density of salmonids during summer. However, before this method was used, I had to test two hypotheses: (i) salmonid carrying capacity in coastal streams is attained during the summer, and (ii) the biomass of salmonids remains relatively con

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stant from one summer to the next. The relationship of minimum streamflow and water quality to salmonid density was determined, since these variables also affect salmonid abundance and therefore carrying capacity.

Carrying capacity is defined as the greatest weight of fishes that a stream can naturally support during the period of least available habitat. It should be considered a mean value, around which populations fluctuate (Moyle, 1949). Spawning salmonids in coastal streams are thought to produce enough progeny to fill streams to carrying capacity. This assumption is supported by observations of high rates of emigration and mortality of fry shortly after emergence from the spawning bed (Shapovalov and Taft, 1954). Since a section of stream can accommodate only a limited number of territories, surplus fish are displaced (Allen, 1969). Displacement distributes fish to parts of the system remote from the spawning grounds, thus insuring that most of the area and productivity of the system is utilized. Even in the absence of excess fry production, receding summer streamflow limits habitat and practically insures that streams are filled to carrying capacity. Survival and growth of fishes in these streams are density dependent, or have density dependent components (McFadden, 1969). The stream's carrying capacity limits the number and weight of salmonid smolts ultimately produced.

METHODS

Sections of seven streams were studied during the summers of 1966 through 1969. The streams are located in the coastal redwood (*Sequoia sempervirens*) belt between Crescent City and Fort Bragg, California. Three northern streams, Bummer Lake Creek, Godwood Creek, and South Fork Yager Creek, were in virgin, old growth forests (never logged) and four southern streams, North Fork James Creek, Little North Fork Noyo River, North Fork Caspar Creek and South Fork Caspar Creek, were in second-growth forests (logged about 100 years ago). Four of these streams (Bummer Lake Creek, South Fork Yager Creek, Little North Fork Noyo River, and South Fork Caspar Creek) were logged by 1968 (Burns, 1970); however, this report considers only prelogging conditions (Table 1). Postlogging conditions are the subject of a future report (James W. Burns, MS). Only one stream had been recently logged (North Fork James Creek) and logging was completed there in 1962. This stream was surveyed once. Unlogged streams (Godwood Creek, an upstream section of South Fork Yager Creek, and North Fork Caspar Creek) were studied for 3 years. More detailed descriptions of the streams are given by Burns (1970) and Fredric R. Kopperdahl, James W. Burns and Gary E. Smith (MS). Fishing pressure for juvenile salmonids on these strealins was negligible.

Stream dimensions were determined by standard sampling procedures (Welch, 1948 and Lagler, 1956) using permanent transect stations. The number of transect stations ranged from 30 in stream sections less than 1 km long, to 101 in longer sections. Fish were captured with a, battery-powered DC back-pack shocker, and populations estimated by the Petersen single census mark and recovery method (Davis, 1964) or by the removal method (Seber and LeCren, 1967). Age classes of trout were separated by length frequency methods. Fish less than 1 year

TABLE 1-**Habitat Dimensions and Teleost Biomass in Seven Northern California Streams**

		Dimensions of sections at time of survey						Absolute biomass, kg (lb)				
				Surface area, hectares (acres)								
	Survey date	Discharge, m^3/sec (cfs)	Length, km (mi)	Pools	Riffles	Total	Volume, m^3 (acre-ft)	Coho salmon	Trout	Total salmonids	Non-salmonids	Total teleosts
Bummer Lake Cr	Sept. 1967	0.015	1.524	0.459	0.270	0.729	1.444	1.12	28.90*	30.02	0.98$	31.00
Del Norte County		(0.521)	(0.521)	(1.135)	(0.667)	(1.802)	(1.171)	(2.46)	(63.71)	(66.17)	(2.15)	(68.32)
Godwood Cr.,	July 1967	0.036	1.098	0.214	0.111	0.325	445	3.56	1.86*	5.42	0.17§	5.59
Humboldt County		(1.270)	(0.682)	(0.529)	(0.273)	(0.802)	(0.361)	(7.84)	(4.09)	(11.93)	(0.37)	(12.30)
S.Fk. Yager Cr.,	Aug. 1967	0.017	1.119	0.420	0.163	0.583	752	____	25.621	25.62	0.68$	26.30
Humboldt County		(0.598)	(0.695)	(1.038)	(0.403)	(1.441)	(0.610)	____	(56.48)	(56.48)	(1.51)	(57.99)
N. Fk. James Cr.,	Oct. 1966	0.003	0.039	0.005	0.003	0.008	10	____	0.521	0.52	0.091	0.61
Mendocino County		(0.100)	(0.024)	(0.012)	(0.007)	(0.019)	(0.008)	____	(1.15)	(1.15)	(0.20)	(1.35)
Little N. Fk. Noyo R.,	Oct. 1966	0.002	0.396	0.041	0.019	0.060	92	1.26	0.221	1.48	0.10$	1.58
Mendocino County		(0.077)	(0.248)	(0.102)	(0.048)	(0.150)	(0.075)	(2.77)	(0.49)	(3.26)	(0.21)	(3.47)
N. Fk. Caspar Cr.,	June 1967	0.012	2.451	0.263	0.215	0.478	291	0.84	5.211	6.05	____	6.05
Mendocino County		(0.415).	(1.523)	(0.650)	(0.531)	(1.181)	(0.236)	(1.86)	(11.48)	(13.34)	____	(13.34)
S. Fk. Caspar Cr.,	June 1967	0.013	3.092	0.295	0.308	0.603	367	9.59	13.311	22.90	0.15#	23.05
Mendocino County		(0.447)	(1.921)	(0.730)	(0.760)	(1.490)	(0.298)	(21.15)	(29.34)	(50.49)	(0.32)	(50.81)

* Steelhead rainbow trout *(Salmo gardneri)* and coast cutthroat trout *(Salmo clarki).*
t Steelhead rainbow trout.
$ Sculpin *(Gottus spp.).*
§ Sculpin and threespine stickleback *(Gasterosteus aculeatus).*
\# Threespine stickleback.

old were designated as Age +, and yearling and older fish were lumped as a single group, Age 1+. Coho salmon juveniles were also combined as a single group, Age +, since few spend more than 1 year in stream residence. Biomass was determined by multiplying mean individual weight by the population estimate for each species. Population estimates were presented in two forms: (i) absolute, referring to the estimated population of fish in the stream section (e.g., kilograms or numbers), and (ii) relative, referring to the population of fish per unit of living space (e.g., kilograms per hectare or number per square meter).

RESULTS AND DISCUSSION

Methods of Expressing Carrying Capacity

Carrying capacity is expressed either as the number of fish in the population, or more commonly, as the total weight of the population (biomass). Living space is also considered when measuring carrying capacity, since changes in biomass may be due to changes in available habitat. Living space parameters include stream surface area, volume, length, and flaw. To determine which variables best expressed relative biomass,correlation coefficientsfor fish biomass and each of these living space parameters were calculated. Since these seven streams varied considerably in the length of stream surveyed and in their biomass (Table 1), 1 thought that some unmeasured factors could influence the correlations tested. Therefore, correlation coefficients for both the seven streams and a single stream were calculated (Table 2), thereby eliminating some of the unmeasured factors. The best correlation for the seven streams was absolute biomass with surface area (Table 3). For North Fork Caspar Creek, biomass per surface area was also superior, with streamflow also having a significant correlation with absolute biomass. These results pointed to kilograms per hectare or pounds per acre as superior to other expressions of biomass. Coho production in Oregon streams also correlated more strongly with available stream area than with other stream parameters (Mason and Chapman, 1965).

Changes in Biomass

Salmonid biomass in the unlogged streams changed considerably during the study. North Fork Caspar Creek's mean biomass of salmonids was 5.56 kg. (Table 2). The 95% confidence limits were ±27.5% of the mean. The confidence limits of the mean kilogram per hectare were ±16.9% (y = 15.54). The mean in South Fork Yager Creek was 8.67 kg (Table 4), with 95% confidence limits of ±13.0%. The confidence limits of the mean kilograms per hectare were ±47.8% (y = 34.59). Changes in biomass in Godwood Creek were greater than in the other two streams (Table 5) . The mean biomass of salmonids was 4.06 kg, with 95% confidence limits of ±75.2%. The confidence interval of the mean kilograms per hectare were ±81.2% (y = 12.54).

Weakness in the Biomass/Surface Area Expression

Density expressions of biomass (kg/ha) did not reflect well the real changes in total fish populations. They commonly increased in late summer when the total biomass actually decreased. Absolute biomass in North Fork Caspar Creek, for example, usually decreased as the stream's surface area decreased (Table 2) . Relative biomass increased,

TABLE 2-**Stream Dimensions and ieleost Biomass in North Fork Caspar Creek, Mendocino County**

	Stream dimensions at time of survey						Absolute biomass, kg (lb)			Relative Biomass
			Surface area, hectares (acres)							
Survey date	Discharge, m^3/sec (cfs)	length, km (mi)	Pools	Riffles	Total	Volume, m^3 (acre-ft)	Coho salmon	Steelhead rainbow trout	Total salmonids	Total salmonids, kg/ha (lb/acre)
June 1967_______	0.012 (0.415)	2.451 (1.523)	0.263 (0.650)	0.215 (0.531)	0.478 (1.181)	291 (0.236)	0.84 (1.86)	5.21 (11.48)	6 05 (134)	12.64 (11.29)
Oct. 1967_______	0.007 (0.237)	2.326 (1.445)	0.195 (0.482)	0.195 (0.481)	0.390 (0.963)	178 (0.144)	0.57 (1.26)	5.70 (12.57)	6.27 (13.83)	16.08 (14.36)
June 1968_______	0.007 (0.242)	2.458 (1.527)	0.191 (0 .47 j)	0.169 (0.417)	0.360 (0.888)	219 (0.178)	0.45 (0.99)	4.18 (9.21)	4.63 (10.20)	12.87 (11.49)
Oct.1968_______	0.001 (0.038)	1.984 (1.233)	0.163 (0.403)	0.067 (0.165)	0.230 (0.568)	105 (0.085)	0.44 (0.98)	3.32 (7.32)	3.76 (8.30)	16.36 (14.61)
June 1969_______	0.013 (0.446)	2.458 (1.527)	0.242 (0.598)	0.252 (0.623)	0.494 (1.221)	301 (0.244)	2.99 (6.59)	4.85 (10.69)	7.84 (17.28)	15.85 (14.15)
Oct. 1969_______	0.001 (0.044)	1.975 (1.227)	0.148 (0.366)	0.099 (0.244)	0.247 (0.610)	150 (0.122)	2.00 (4.40)	2.79 (6.16)	4.79 (10.56)	19.39 (17.31)

TABLE 3-**Correlation Coefficients for Living Space Parameters and Biomass**

variables tested	Correlation coefficient	Statistically significant at 5% level
Seven northern California streams		
Stream surface area (ha) vs. salmonid biomass (kg)	0.898	yes
Stream surface area (ha) vs. teleost biomass (kg)	0.895	yes
Stream volume (m^3) vs. salmonid biomass (kg)	0.837	yes
Stream volume (m^3) vs. teleost biomass (kg)	0.844	yes
Streamflow (m^3/sec) vs. salmonid biomass (kg/km)	0. 003	no
Streamflow (m^3/sec) vs. teleost biomass (kg/km)	0.020	no
North Fork Caspar Creek, Mendocino County		
Wetted stream length (m) vs. salmonid biomass (kg)	0.656	no
Stream surface area (ha) vs. salmonid biomass (kg)	0.868	yes
Stream volume (m^3) vs. salmonid biomass (kg)	0.790	no
Streamflow (m^3/sec) vs. salmonid biomass (kg)	0.836	yes
Streamflow (m^3/sec) vs. salmonid biomass (kg)	0.622	no

however, because the fish were forced into a smaller area. Steelhead may have adjusted to greater population densities by reducing territory size. Accommodation by steelhead has been reported from British Columbia streams (Hartman, 1965). Another possible explanation for the, increase is that the stream was not at carrying capacity in June because of low fry production resulting from small spawning escapements. Decreasing living space may have brought these fish to densities at or near the carrying capacity in October. To describe accurately changes in fish populations and carrying capacity it is best to present the absolute along with the relative values.

Carrying Capacity Studies

Salmonid biomass in Godwood Creek was exceptionally low, ranging from 16.68 kg/ha in 1967 to 8.48 in 1969 (Table 5). Prairie Creek, to which Godwood Creek is a tributary, had a salmonid biomass of 21.95 kg/ha in 1969, suggesting that Godwood Creek probably wasn't at carrying capacity. Low population densities in Godwood Creek in 1968 and 1969 apparently reduced competition, for fish attained greater average lengths than in 1967, when densities were greater (Table 6). Increased growth, however, apparently did not compensate for lowered density and carrying capacity was not reached in 1968 and 1969. To test if Godwood Creek was at carrying capacity in 1969, I transplanted the salmonids captured in Prairie Creek in July into a 366-m section of Godwood Creek in sufficient numbers to increase the biomass to 27.98 kg/ha. Two months later the same section of Godwood Creek was censused to determine if the biomass had remained above the July 1969 value of 7.36 kg/ha. It was 18.08 kg/ha at the second census. This :experiment demonstrated that the stream had been below carrying capacity before transplanting the Prairie Creek fish. There were no obvious reasons for the low number of salmonids in 1968 and 1969,except that young-of-the-year coho were exceptionally scarce then, suggesting that the spawning run had not seeded the stream to carrying capacity. There were no significant changes in spawning bed sediments (Burns, 1970) to explain reduced survival of incubating embryos and fry.

TABLE 4--**Stream Dimensions and Teleost Biomass in South Fork Yager Creek, Humboldt County**

	Stream dimensions at time of survey						Absolute biomass, kg(lb)		Relative biomass
			Surface area, hectares (acres)						
Survey date	Discharge, m^3/sec (cfs)	Length, km(mi)	Pools	Riffles	Total	Volume, m^3(acre-ft)	Steelhead rainbow trout	Non-salmonids*	Total salmonids, kg/ha (lb/acre)
Aug.1967----------	0.017 (0.598)	0.560 (0.348)	0.205 (0.506)	0.068 (0.168)	0.273 (0.674)	374 (0.303)	8.80 (19.39)	0.02 (0.05)	32.22 (28.77)
Aug. 1968----------	0.015 (0.527)	0.560 (0.348)	0.110 (0.271)	0.105 (0.260)	0.215 (0.531)	229 (0.186)	9.05 (19.95)		42.08 (37.57)
Aug.1969----------	0.020 (0.719)	0.560 (0.348)	0.192 (0.474)	0.086 (0.213)	0.278 (0.687)	381 (0.309)	8.18 (18.03)		29.39 (26.24)

* Sculpin (*Cottus* spp.).

TABLE 5-**Stream Dimensions and Teleost Biomass in Godwood Creek, Humboldt County**

	Stream dimensions at time of survey						Absolute biomass, kg (lb)				Relative biomass
			Surface area, hectares (acres)								
Survey date	Discharge, m^3/sec (cfs)	Length, km(mi)	Pools	Riffles	Total	Volume, m^3(acre-ft)	Coho salmon	Trout*	Total salmonids	Non-salmonids	Total salmonids, kg/ha (lb/acre)
July 1967------	0.036 (1.270)	1.098 (0.682)	0.214 (0.529)	0.110 (0.273)	0.324 (0.802)	445 (0.361)	I 3.56 (7.84)	1.86 (4,09)	5.42 (11.93)	0.17 (0.37)	16.68 (14.88)
July 1968------	0.029 (1.039)	1.098 (0.682)	0.157 (0.388)	0.150 (0.372)	0.307 (0.760)	375 (0.304)	2.32 (5.12)	1.51 (3.33)	3.83 (8.45)	0.02 (0.05)	12.45 (11.12)
July 1969------	0.031 (1.080)	1.098 (0.682)	0.228 (0.564)	0.123 (0.304)	0.351 (0.868)	428 (0.347)	1.20 (2.64)	1.78 (3.93)	2.98 (6.57)	0.03 (0.07)	8.48 (7.57)

* Steelhead rainbow trout (*Salmo gairdneri*) and coast cutthroat trout (*Salmo clarki*).
t Sculpin (*Cottus* spp) and threespine stickleback (*Gasterosteus aculeatus*).

TABLE 6-**Population Densities, Mean Fork Lengths, and Absolute Numbers of Salmonids in Godwood Creek, Humboldt County ***

	Steelhead rainbow and coast cutthroat trout								
	Young of the year			Yearling and older			Coho salmon		
Survey date	No. /m^2 (kg/ha)	Mean fork length, mm	Number	No. /m^2 (kg/ha)	Mean fork length, mm	Number	No. /m^2 (kg/ha)	Mean fork length, mm	Number
July 1967-------------	0.14 (1.40)	41(40-42)	455 (374-536)	0.04 (4.32)	97(90-104)	121 (72-170)	0.37 (10.96)	55(54-56)	1,186 (1,051-1,321)
July 1968-------------	0.11 (1.17)	45(44-46)	325 (274-376)	0.03 (3.74)	102(97-107)	88 (65-111)	0.31 (7.56)	56(55-57)	961 (922-998)
July 1969-------------	0.07 (1.34)	54(53-55)	248 (198-299)	0.02 (3.73)	105(101-109)	88 (64-111)	0.10 (3.41)	64(63-65)	352 (338-366)

* 95%o confidence intervals in parentheses unless indicated otherwise.

TABLE 7-**Population Densities, Mean Fork Lengths, and Absolute Numbers of Steelhead Rainbow Trout in South Fork Yager Creek, Humboldt County**

	Young-of-the-year			Yearling and older		
Survey date	No./m^2 (kg/ha)	Mean fork length, mm	Number	No./m^2 (kg/ha)	Mean fork length, mm	Number
Aug. 1967-------------	0.60 (10.22)	46 (45-48)	1,641 (1,470-1,812)	0.11 (22.01)	117 (111-124)	299 (193-405)
Aug.1968-------------	0.92 (18.35)	54 (53-56)	1,973 (1,695-2,251)	0.13 (23.77)	115 (110-119)	284 (208-360)
Aug.1969-------------	0.86 (11.14)	47 (46-48)	2,385 (2,244-2,526)	0.10 (18.27)	115 (112-119)	289 (268-310)

* 95% confidence intervals in parentheses unless indicated otherwise.

Predation by oligochaete worms may have contributed to low survival, since Briggs (1953) found that the average mortality in Godwood Creek was about 56% and sometimes as high as 100% in salmon redds infested with oligochaetes. Oligochactes were abundant in the benthos samples taken in July 1961; however, benthos was not examined in 1968 and 1969, when coho populations were lowest. Briggs also indicated that the spawning rubs in Godwood Creek were usually small, with only about seven redds resulting from coho spawning in 3.2km of stream. This experiment shows that artificially seeding streams with fry could bring them up to carrying capacity.

Yearling-and-older steelhead in South Fork Yager Creek were similar in population density and average length in all years (Table 7). Age + steelhead, on the other hand, attained the greatest average length in 1968, when population density for this age group was greatest. In 1967 and 1969, densities were less and mean lengths were shorter, indicating that either carrying capacity changed or that the stream was not at carrying capacity in these 2 years.

Except for the seasonal. increase that usually accompanies a decrease in surface area, the density of salmonids in North Fork Caspar Creek was similar in 1967 and 1968 (Table 8). In 1969, however, the density increased 22% over the 1967-68 average. Coho were scarce in 1967-68 and then became abundant in 1969. Apparently interspecific competition was less influential than intraspecific competition in determining this stream's carrying capacity. These observations support the contentions of Nilsson (1956) , Hartman (196.5) , and Fraser (1969) that two or more species use the habitat more efficiently than does one species alone. The similarity of biomasses in 1967 and 1968 suggests that the stream was at or near carrying capacity for the existing species combination. The change in species ratio apparently increased the carrying capacity in 1969. Territorially in stream salmonids is food-linked;when food is abundant,aggression decreases and territories become smaller (Chapman, 1966). A higher population density could therefore result from an increased food supply. An increase in food did not occur in North Fork Caspar Creek,since the biomass of benthos was similar in all years of study (James W. Burns and Gary E. Smith, MS).

Young-of-the-year salmonids in North Fork Caspar Creek in June were largest when stock densities were lowest, suggesting a density dependent relationship (Table 8). Growth increments for salmonids in North Fork Caspar Creek from June to October, however, did not show any trend and therefore did not support a hypothesis of density dependent growth. Over-summer mortality did not indicate density dependence either. Decreasing availability of living space caused the greatest mortality, with total mortality highest in the summer of low est streamflow. Mortality of Age + steelhead from June to October averaged 73% (range 71 to 80%). Mortality of Age I or older steel head averaged 44% (range 6 to 66%). For Age + coho, average mortality was 58% (range 46 to 61%).

North Fork Caspar Creek was relatively unproductive. Besides supporting a low biomass per surface area of salmonids, it had low summer production (Table 9) . Production of salmonids from June to October ranged from 0.29 to 0.38 g/m^2/month. This was considerably

TABLE 8-**Population Densities, Mean Fork Lengths, and Absolute Numbers of Salmonids in North Casper Creek, Mendocino County**

	Steelhead rainbow trout								
	Young-of-the-year			Yearling and older			Coho salmon		
Survey date	No. /m^2 (kg/ha)	Mean fork length, mm	Number	No. /m^2 (kg/ha)	Mean fork length, min	Number	No. /m^2 (kg/ha)	Mean fork length, mm	Number
June 1967-------------	1.37 (9.59)	39 (38-40)	6 558 (6 370-6,746)	0.02 (1.30)	77 (73-80)	93 (3-196)	0.07 (1.76)	54 (54-60)	313 (261-365)
Oct.1967-------------	0.52 (10.33)	54 (52-55)	2,015 (1,897-2,133)	0.02 (4.29)	123 (84-163)	69 (19-119)	0.03 (1.47)	71 (69-73)	122 (110-134)
June 1968-------------	1.61 (9.68)	38 (37-39)	5,801 (5,723-5,879)	0.02 (1.94)	86 (80-93)	82 (41-113)	0.10 (1.26)	47 (46-48)	359 (335-381)
Oct.1968-------------	0.51 (8.66)	51 (50-52)	1.172 (1,107-1,237)	0.03 (5.77)	117 (109-124)	77 (54-100)	0.08 (1.94)	52 (47-57)	194 (185-203)
June 1969-------------	0.81 (5.67)	40 (39-41)	4,005 (3,896-4,114)	0.04 (4.14)	92 (86-97)	211 (158-264)	0.55 (6.11)	45 (44-46)	2,724 (2,675-2,771)
Oct. 1969-------------	0.47 (6.98)	52 (51-53)	1,151 (1,101-1,201)	0.03 (4.34)	108 (100-115)	71 (46-96)	0.45 (8.08)	53 (52-54)	1,105 (1,079-1.127)

' 95% confidence intervals in parentheses unless indicated otherwise.

TABLE 9-**Production of Salmonids in North Fork Caspar Creek, Mendocino County, California**

	Steelhead rainbow trout				Coho salmon			
	Young of the year		Yearling and older		Young of the year		Total	
Period	g/m^2/month	g/month	g/m^2/month	g/month	g/m^2/montb	g/month	g/m^2/month	g/month
June to Oct. 1967	0.2627	1,140.0	0.0860	373.1	0.0270	117.0	0.3757	1,630.1
June to Oct. 1968	0.2616	770.6	0.0662	194.9	0.0262	77.0	0.3540	1,042.5
June to Oct. 1969	0.1358	503.2	0.0543	201.4	0.0966	357.9	0.2867	1,062.5

lower than the coho production of 0.56 g/m^2/month reported for the same season for Oregon's salmonid streams (Chapman, 1965).

Relationships of Physical-Chemical Factors to Carrying Capacities

The relationship of water chemistry and morphoedaphic characteristics of lakes to fish production and standing crop have been investigated by Moyle (1946, 1956), Hayes and Anthony (1964), and Ryder (1965); however, little is known of the relationships of these factors to the carrying capacity of streams. A positive correlation between brown trout (*S. trutta*) biomass and conductivity in six Pennsylvania streams was reported by McFadden and Cooper (1962) ; however, this relationship was not statistically significant. LeCren (1969) found no apparent correlation between brown trout and Atlantic salmon (*S. salar*) production and calcium content of English streams. I failed to find any significant correlations between relative biomass and either total dissolved solids, total phosphate, or total alkalinity (Table 10). In addition, biomass was not significantly correlated with the volume of fine sediments in the streambed.

CONCLUSIONS

Biomass per unit of surface area was an acceptable method of expressing carrying capacity in small coastal streams. This expression did not always reflect trends in the absolute biomass, however. If lower surface area accompanied lower biomass, the kilograms per hectare of salmonids could remain the same or even increase, leading to erroneous conclusions about changes in fish populations. For this reason, it is necessary to include an absolute value when making such comparisons. The absolute value could be the number of fish in each age class for each species. The two values compliment each other; one considers changes in living space, while both reflect changes in fish abundance.

The hypotheses that streams reach carrying capacity in the summer, and that biomass per unit of living space is constant from 1 year to the next, must be rejected. Because of natural variation, comparing biomass from 1 summer month or year to the neat was adequate for indicating gross changes only. In Godwood Creek the maximum change in relative biomass from the first to the third year was 49% and in North Fork Caspar Creek, the change from June to October of the same year

TABLE 10-**Salmonid Biomasses and Some Physical and Chemical Parameters of Six Streams**

Stream	Salmonid biomass, kg/ha	Total dissolved solids, ppm*	Total alkalinity., ppm*	Total phosphate, ppm*	Percentage mean volume of sediments smaller than 0.8 mm diametert
Bummer Lake Cr.	41.13	57	26	0.30	10.2
Godwood Cr.	16.67	80	30	0.45	17.3
S. Fk. Yager Cr.	43.90	109	56	0.43	16.4
Little N. Fk. Noyo R.	24.35	112	51	0.36	20.0
N. Fk. Caspar Cr.	12.64	124	57	0.34	18.4
S. Fk. Caspar Cr.	37.95	149	68	0.43	20.6

* Value from Fredric R. Kopperdahl. James W. Burns, and Gary E. Smith (MS).
t Values from Burns (1970).

was as much as 25%. The 95% confidence limits of the mean kilograms per hectare of salmonids in South Fork Yager Creek were ±48% of the mean. These results demonstrate that even with 3 years of prelogging measurements it would be difficult to attribute a change in carry ing capacity to anything but natural variation unless the change exceeded about 50%. These extremes in natural variation are probably due to variable spawning escapement and, in the case of juvenile steelhead, to variable time spent in fresh water.

It does not appear that physical and chemical factors will prove to be useful factors for predictiiig carrying capacity, as only living space variables correlated significantly with biomass.

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