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Effects of Fluctuating Flows on the Population Dynamics of Rainbow Trout in the Spokane River of Idaho

Abstract

Rainbow trout (*Oncorhynchus mykiss*) were studied in 1985 and 1986 in the Spokane River, Idaho, to evaluate possible factors limiting abundance and survival. A mark and recapture estimate made in the fall 1985 was 19,029 fish and standing crop was estimated at 5.2 g/m^2 in a 7.9 km reach. Rainbow trout growth rates were above average for the region with fish averaging 140-155 mm in length by the end of the first year. Estimates of total instantaneous rate of mortality (Z) were 1.35 using catch curves and 1.13 to 1.44 based on tag returns. Exploitation corrected for nonresponse was 8.9 percent making instantaneous rates of fishing mortality (F) 0.16 and natural mortality (M) 1.19. Annual survival for recruited fish was less than 30 percent. Post spawning, over winter mortality, high zinc concentrations, high summer temperatures and/or low summer flows may have contributed to the high natural mortality. Spawning commenced in the Idaho reach about 1 April. Variable year-class strengths appeared to correlate with river flow between the spawning period (early spring) and establishment of feeding territories (1 July) during the first summer. Fry production was minimal in 1986. Sampling young-of-the-year trout in the fall and examination of the hydrograph could provide fishery managers with two years advance planning to supplement weak year-classes.

Introduction

The Spokane River, Idaho, has sustained a popular wild rainbow trout (*Oncorhynchus mykiss*) fishery for many years. Recently, however, fishermen have reported declines in the size and number of trout. Excessive harvest, lack of spawning habitat and dam operations have been suggested as possible causes (Idaho Department of Fish and Game 1985). Despite the introduction of brown trout (*Salmo trutta*) rainbow trout remain the principal game fish (Bennett and Underwood 1988). In Idaho, the Spokane River has been managed under a general six fish creel limit whereas downstream in Washington, restrictive terminal gear and creel limits have been imposed.

Some angler groups in Idaho have requested more restrictive regulations, such as lower creel limits and/or size limits. Additional data are needed on abundance, mortality, growth and recruitment. Our objectives were: 1) to investigate the population dynamics of rainbow trout in the Spokane River; and 2) to evaluate factors affecting rainbow trout survival and abundance.

Study Site

The Spokane River forms at Post Falls Dam (Figure 1), the outflow of Lake Coeur d'Alene (10,121 hectares, 648.6 m elevation). Lake Coeur d'Alene

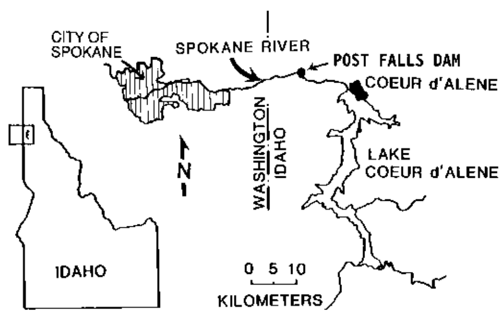

Figure 1. The Spokane River located at the outfall of Coeur d'Alene Lake, in northern Idaho and the study area from Post Falls Dam downstream to the Idaho-Washington border.

and the Post Falls Dam are separated by a long (14.5 km) shallow arm that restricts outflow to the lake's surface water. The river flows west from the lake, through the city of Spokane, Washington, and joins the Columbia River at Lake Roosevelt. At Post Falls Dam the river drains approximately 958,300 hectares including both highly developed and roadless areas.

The study area was the 10 km reach between Posts Falls Dam and the Idaho-Washington border. The river in the study area is bordered by agricultural land and expanding residential developments. Mean river width was 58.8 m and mean high and low instantaneous flows were 623 m^3/s and 14 m^3/s. During spring runoff the lake fills and river flow is normally uncontrolled whereas during summer, flow equals lake intake (minus

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evaporation) and is augmented by lake storage for hydroelectric generation in late August or September. At low flow the river follows a riffle-pool-run sequence with a gradient of approximately 1.8 m/km. The channel is generally large cobble with bedrock exposed in scoured pools. Water temperatures during this study ranged from 2 to 24 C. River conductivity typically ranges from 50 to 80 umhos (Funk *et al.* 1975).

Methods

Fish collections were made in March, June, September, and October 1985 and June and October 1986 from drift boats equipped with boom-type electrofishing equipment. Each boat was equipped with two arrays of anodes and cathodes, a 3,500 or 2,900 watt generator, livecar, and was operated by a crew of two or three (one oarsman plus netters). Pulsed DC current was provided via a Coffelt VP-15 pulsator unit. Fish were usually captured and processed in the same riffle-pool segment of stream from which they were captured.

Fish were measured for fork length (nearest mm) and a subsample weighed to the nearest gram. Trout <170 mm were considered too small for tagging. Captured fish (>170 mm) were measured (fork length), tagged with serially numbered jaw tags and released. A stratified subsample (Ricker 1975) of up to 20 scale samples (n = 10 in 1986) per 25 mm length group was taken in the fall 1985 and 1986. Back-calculated length at annulus was determined by direct proportions, and corroborated by length-frequency distributions (Tesch 1978). Reward tags worth $5.00 were placed on 4 to 20% of the jaw tagged fish to estimate angler non-response (Henny and Burnham 1976).

Abundance estimates of Age-1+ and older fish (>130 mm) were made in the fall of 1985 using a modified Petersen mark and recapture estimate (Ricker 1975). Fish were marked using an adipose fin clip, released and recaptured 12 days later to allow for redistribution (Vincent 1983). Also, we jaw tagged 378 trout to assess movement to evaluate the assumption of a closed population. Catch efficiency curves were used to divide fish into size groups for more accurate population estimates (Vincent 1983). Average weights were calculated for the size groups and multiplied by the population estimates to estimate standing crop. Formulas for each estimator are listed in Table 1.

Total instantaneous rate of mortality and fishing and natural mortalities were estimated by catch curves (Everhart and Youngs 1981) and annual tag returns (Ricker 1975; Table 2). Trout were captured, tagged and released in March, June and September 1985 and June 1986. Tag return data was then available for two years from the March and June 1985 releases and one year from the September 1985 and June 1986 releases. Instantaneous fishing mortality (F) was calculated from annual exploitation (E) based on tag returns. Instantaneous natural mortality (M) was calculated as the difference between total and fishing mortality (Table 2).

The study area was stratified into upper, middle and lower sections and north and south banks to estimate the abundance of Age-0 fish along the river margin. We snorkeled randomly selected transects (35 per stratum each 10 m long and 2 m wide) once in July 1986 (Everhart and Youngs 1981; Schaeffer *et al.* 1986).

The relative strengths of the 1984, 1985 and 1986 year-classes were evaluated qualitatively by snorkeling the same reaches of river in July 1985 and 1986 and by comparing length frequency distributions from electrofishing data. Discharges from Post Falls Dam between 1 March and 30 June for 1984, 1985 and 1986 were examined to determine if any relationship existed between year-class strength and discharge during the spawning and incubation seasons.

Results

Abundance and Mortality

We estimated 19,029 (95% C.I. = 15,786 and 22,271) Age-1 and older rainbow trout (>130 mm) were present in the study area in the fall of 1985 based on 1,014 marked fish released and 111 recaptures of 1,950 fish examined for marks. The standing crop was estimated to be 5.2 g/m^2.

Estimates of total instantaneous rate of mortality from catch curves were 1.35 for pooled data (Figure 2), 1.27 and 2.10 for 1985 and 1986, respectively. Estimates of total instantaneous rate of mortality using single lots of tagged fish were 1.44 (March 1985 release) and 1.28 (June 1985 release) and the pooled estimate from releases in June 1985 and 1986 was 1.13.

Returns from fish tagged in March and June 1985, and June 1986 were similar whereas returns from those tagged in September 1985 were lower

TABLE 1. Formulas used for population estimates of rainbow trout in the Spokane River, Idaho.

Population estimate Age 1+ and older:

$$N = \frac{(M + 1) \cdot (C + 1)}{(R + 1)}$$

where,

N = estimated number of fish in the study area,
M = the number of fish marked,
C = the number of fish examined for marks,
R = number of recaptured marked fish.

$$V_{(N)} = N^2 \left[\frac{(N - M) \cdot (N - C)}{M \cdot N \cdot (N - 1)} \right]$$

where,

$V_{(N)}$ = the variance of the estimate population.

Population estimate Age-0 fish:

$$N = \frac{A}{a} \cdot \Sigma Ni$$

where,

A = the number of possible quadrats,
a = the number of quadrats sampled,
Ni = the number of fry observed in the ith quadrat.

$$V_{(N)} = \frac{A^2 - (aA)}{a} \cdot \frac{(a\, Ni^2 - (\Sigma Ni^2))}{a\,(a - 1)}$$

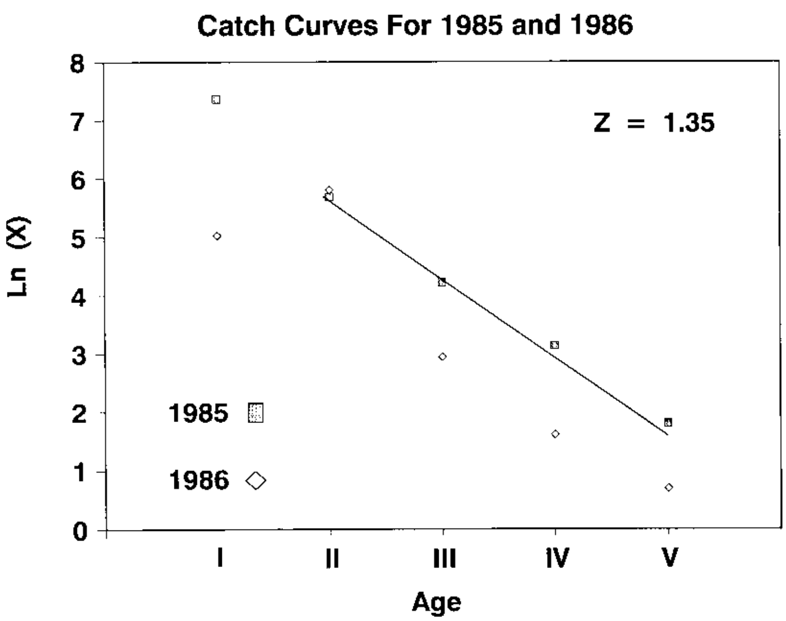

Figure 2. Plot of the natural logarithm of the electrofishing catch of rainbow trout from fall 1985 and 1986 collections, from the study area. The instantaneous rate of mortality (Z) is the slope (absolute value) of the regression line. The line represents mortality for the pooled data for 1985 and 1986.

TABLE 2. Formulas used to estimate survival and mortality statistics of the rainbow trout population in the Spokane River, Idaho.

Symbols:

A = total annual mortality
E = annual fishing mortality
F = instantaneous fishing mortality
M = instantaneous natural mortality
S = annual survival
Z = total instantaneous mortality
$V_{(s)}$ = variance of the estimate

Chapman-Robson estimate of survival:

$$S = T/n + T - 1$$

where,

S = the estimate of annual survival,
T = the sum of the coded age multiplied by their frequencies,
n = the sample size.

$$V_{(S)} = S[S - (T - 1)]/(n + T - 2)$$

Estimate of survival from tag returns (Ricker 1975):

$$S = R_2/R_1$$

where,

S = the estimate of annual survival,
R_1 = recaptures during the first year,
R_2 = recaptures during the second year.

$$V_{(s)} = [S(1 - S)]/R_1$$

and

$$S = R_{12} (M_2/M_1)R_{22}$$

where,

M_1 = number of fish marked the first year,
M_2 = number of fish marked the second year,
R_{12} = first year fish recaptured the second year,
R_{22} = second year fish recaptured the second year.

$$V_{(s)} = S^2 (1/R_{12} + 1/R_{22} - 1/M_1 - 1/M_2)$$

than the releases in spring and summer (Table 3). Nonresponse was similar to that observed in other systems (Rieman 1987) based on the return of reward tags (mean = 42%). The mean annual exploitation rate weighted by the number of tagged fish was 9.2 percent (reward tags) or 8.9 percent (regular tags corrected for non-response). The highest estimate of instantaneous fishing mortality was 0.34 based on the pooled catch curve estimate of tagged fish which was equivalent to an exploitation rate of 18.8 percent, and this was the rate used to avoid overharvest and be consistent with a conservative management style. With the 18.8 percent

TABLE 3. Summary of Monel jaw tagged fish released in the Spokane River, Idaho.

		Regular tags		Reward tags	
Month	Year	Number released	Percent returned	Number released	Percent returned
March	1985	331	6.3%	32	9.4%
June	1985	303	6.3%	38	7.9%
Sept.	1985	362	2.2%	16	18.8%
June	1986	274	5.1%	70	7.1%

exploitation rate, the instantaneous natural mortality was 1.01, about 75 percent of the total annual mortality (Table 4).

TABLE 4. Summary of annual and instantaneous rates as related to levels of exploitation in the Spokane River, Idaho. Symbols used were: S = annual survival; A = annual mortality; E = annual exploitation; F = instantaneous fishing mortality; M = instantaneous natural mortality; and Z = total instantaneous mortality.

	Rates				
Method of estimation	S	A	F	M	Z
Catch curves (W/E = 0.092)					
1985	0.279	0.720	0.162	1.11	1.27
1986	0.122	0.877	0.218	1.87	2.09
Pooled	0.260	0.740	0.167	1.18	1.35
Chapman-Robson (W/E = 0.092)					
1985	0.253	0.747	0.168	1.20	1.37
1986	0.324	0.676	0.153	0.97	1.13
Pooled	0.216	0.784	0.179	1.35	1.53
Catch Curves (W/E = 0.188)					
1985			0.330	0.94	
1986			0.447	1.64	
Pooled			0.342	1.01	
Chapman-Robson (W/E = 0.188)					
1985			0.344	1.03	
1986			0.313	0.82	
Pooled			0.366	1.29	

[1]18.8% estimated from reward tags released in September 1985, 9.2% is the average return of reward tags weighted for the number released.

Age and Growth

Five age classes were present in the electrofishing catch. Growth rates were above average for rivers in this area (T. Bjornn, Idaho Cooperative Fish and Wildlife Research Unit, Personal Communication), with fish averaging 140-155 mm in length by the end of the first year (Table 5). The least-squares regression equation best describing the length (L) – Weight (W) relationship for 1985 was $\mathrm{Log_e}(W) = -10.77 + 2.90\mathrm{Log_e}(L)$; $\mathrm{Log_e}(W) = -9.95 + 2.76\mathrm{Log_e}(L)$ for 1986; ($r^2 = 0.97$ for both years).

Year-class Strength

The 1984 year-class was the most abundant cohort in all samples collected in 1985 and 1986 (Figure 3). Fish of the 1985 year-class were collected in June 1986 far less abundantly than the 1984 year-class at the same age. Underwater observations indicated that fry densities of the 1986 year-class were lower than those of the 1985

TABLE 5. Back-calculated fork length (mm) at annulus for rainbow trout captured by electrofishing in the Spokane River, Idaho, in September 1985 and October 1986.

		Age				
1985	n	1	2	3	4	5
	72	153				
	70	153	244			
	28	148	242	305		
	15	164	257	311	355	
	4	166	227	307	354	396
Average		154	245	307	354	396
1986	19	134				
	45	140	218			
	18	140	232	305		
	2	157	227	319	371	
Average		139	222	306	371	

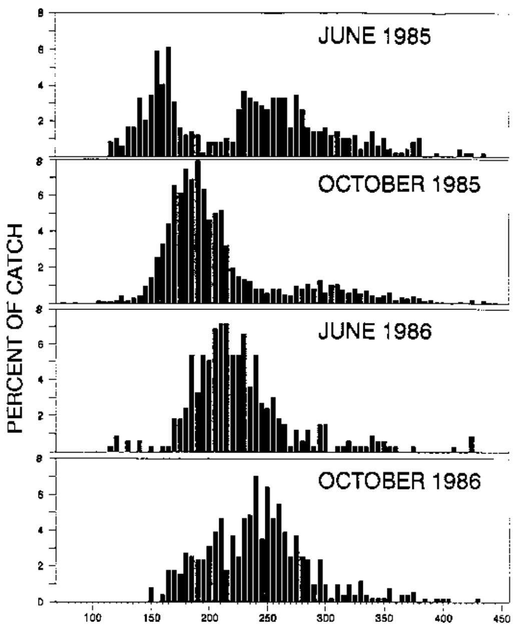

Figure 3. Length-frequency distributions of rainbow trout collected in June and October 1985 and 1986.

year-class. Areas that supported fry in 1985 did not contain fry in 1986. In 1986, 37 fry were observed in 22 of 210 quadrats (12%) out of 1694 possible quadrats. An estimate of 315 Age-0 fish (95% C.I. $158 \leq N \leq 471$) was calculated for the study area in June 1986. Length-frequency data for October 1985 and 1986 corroborated our snorkel data that young-of-the-year were present in the electrofishing sample in October 1985, but not in October 1986 (Figure 3).

Discussion

We estimated over 1,900 fish/km in the Idaho section of the Spokane River, a larger rainbow trout population than an earlier estimate of less than 425 fish/km (Bailey and Saltes 1982). The fall biomass of 5.2 g/m^2 (rainbow trout >130 mm) was similar to that of a self-sustaining rainbow trout population in Virginia (3.13 to 4.30 g/m^2, Neves *et al.* 1985), for a tailwater fishery in the Green River of Wyoming (4.96 g/m^2, Wiley and Dufek 1980), and a combined population biomass of brown and rainbow trout (>198 mm) in the Madison River of Montana (5.9 g/m^2, Vincent 1969). Standing crops for Age-0 and Age-1 fish were estimated as high as 10.4 and 16.0 g/m^2 in a productive rainbow-steelhead stream in eastern Idaho (Bjornn 1978). In other studies on trout summarized by Lorz (1975), estimated standing crops ranged between 0.2 and 22.4 g/m^2.

Growth rates of rainbow trout in the study area were good. Annual growth increments during the first year were similar to other populations in the same latitude (Wydoski and Whitney 1979).

Annual mortality in the lower Spokane River was 74 percent per year. Estimates of total mortality (Z) from catch curves and tag returns were similar and exploitation estimates were similar to those previously reported (4-9%) for the river (Bailey and Saltes 1982). In comparison, instantaneous rates of mortality ($Z = 1.35$; $F = 0.34$; $M = 1.01$) for rainbow trout in the Spokane River were slightly higher, but in the same proportions as those reported by Wiley and Dufek (1980) for rainbow trout in the Green River ($Z = 1.12$; $F = 0.20$; $M = 0.92$). Petrosky and Bjornn (1988) reported total instantaneous mortality rates of 1.93-2.06 for yearlings and older rainbow trout over a three year period for Big Springs Creek, Idaho, a productive stream in eastern Idaho. Based on these studies, we do not believe the mortality of rainbow trout in the Spokane River in Idaho is uncommonly high. Populations in other streams that produce quality fisheries exhibit even higher mortality rates. The low fishing mortality was a surprise. Although fishing effort was not quantified, the close proximity of the cities of Coeur d'Alene and Spokane led us to expect higher fishing mortality. Natural mortality composed a major proportion of total annual mortality since mortality due to fishing was low (<20%). Nonetheless, perceived declines in the Spokane River fishery are difficult to assess with the limited historical data base. The decline in fishing quality could be the difference between even lower fishing mortality years ago and the present rate.

Recruitment during 1986 was lower than expected. The estimate of Age-0 rainbow trout in the 10 km study area was only 315 fish. Based on our mortality calculations (Figure 2), we estimate there should have been about 10,000 Age-0 fish to produce the abundance of older fish observed in 1985 and 1986. The low number of Age-0 fish suggests that recruitment of young-of-the-year fish was poor in 1986 despite the moderate standing crop of older fish. The low number of Age-0 fish observed in 1986 is one indication that recruitment can be more variable among years, although examination of the catch curves (Figure 2) for Ages 2-5 rainbow trout suggests that recruitment was reasonably stable in the early 1980s.

Size and age structures of the rainbow trout population in the Spokane River were strongly correlated with growth and mortality. Growth and fishing mortality are similar to other quality trout fisheries, but natural mortality reduces the population up to 64 percent annually allowing few fish to reach large size (older age classes). A combination of high natural mortality and low recruitment can shift the structure of the population (Figure 3). Substantial year-class variations occur in the Idaho section of the Spokane River under conditions of high natural mortality and variable recruitment.

The source of natural mortality in the Spokane River is unknown. Possible causes include: overwinter mortality (Shetter 1967) as indicated by the low return of fish tagged September 1985 (Table 3); high zinc concentration (0.12-0.62 mg/l, Funk *et al.* 1975); post-spawning mortality (Ferguson and Rice 1980); high (24 C) summer water temperatures (Kaya 1978; Hokanson *et al.* 1977); and water level fluctuations (Mundie 1969; Holden 1979). It is unlikely that natural mortality could be easily reduced and therefore, the quality of the fishery depends upon recruitment and spawning success. Strong year-classes are necessary to maintain abundance and provide enough fish to survive to trophy size.

Factors affecting recruitment seem to occur between spawning (around 1 April; Figure 4) and some time shortly after emergence (15-25 June). The estimate of young-of-the-year rainbow trout was conducted in July 1986 and year-class strength was established prior to our sampling. The 1984 year-class, first sampled as Age-1 fish in 1985, remained strong throughout the study (Figure 3).

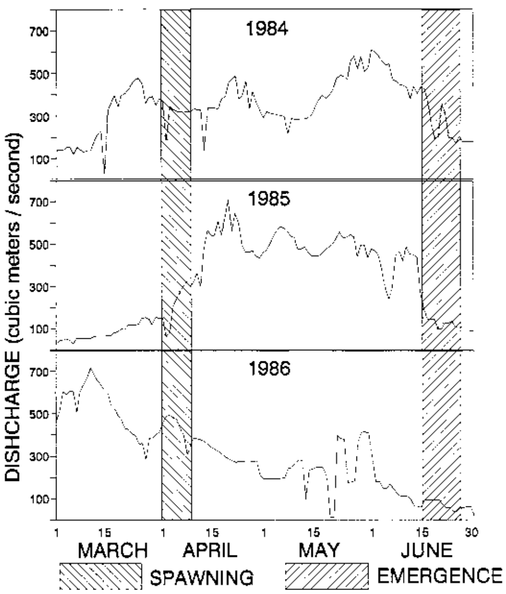

Figure 4. Minimum daily discharges (m^3/sec) in the Spokane River from Post Falls Dam from 1 March through 30 June 1984, 1985 and 1986. Spawning and emergence times of rainbow trout are also shown.

Year-class strength for 1984, 1985 and 1986 was variable and correlated with their respective spring hydrographs (Figure 4). The strong 1984 year-class was associated with high, relatively constant flows between 1 April and 25 June. Spring runoff continued into late June and minimum daily discharge fluctuated less during embryo incubation in 1984 than in 1985 and 1986. The 1985 year-class, intermediate in abundance, occurred with intermediate flows during spawning, but serious reductions in flows occurred near emergence time. The weak 1986 year-class developed in a year of fluctuating, low flows. Spring runoff subsided late in May 1986 and flows fluctuated greatly especially in May when alevins were most vulnerable. Nonetheless, the link between water levels and recruitment is still unclear in this section of the Spokane River. However, our cursory observations indicate that spawning gravels are only inundated above flows of 200-300 m^3/sec. Flow fluctuations cause mortality to embryos and alevin through reduced oxygen levels, stranding and desiccation (Fraser 1972; Reiser 1981; Neitzel and Becker 1985). Becker *et al.* (1983) found that dewatering became more critical as embryo development progressed and especially between hatching and emergence.

We found that quadrat sampling is a technique to assess year-class strength in the Spokane River and other rivers that experience similar fluctuation in flows. Snorkel transects should be conducted shortly after emergence to assess the relative strength of the year-class. Cursory predictions of year-class strength from the examination of the hydrograph and an index based on transect sampling of young-of-the-year could provide enough information for a manager to anticipate stocking or other corrective management action to stabilize recruitment and ultimately, the fishery. Similar information on year-class strength has been used to predict catch rates (Engstrom-Heg 1986). Since rainbow trout in the Idaho section of the Spokane River generally are not available to the fishery until their third summer, such a strategy would allow up to two years lead time for implementation of the appropriate management action (i.e., stocking, season closure, etc.).

In summary, we suggest that the quality of the fishery in the Idaho section of the Spokane River will fluctuate depending on climatic conditions and spawning success. Strong year-classes are necessary to offset the high natural mortality to produce a quality fishery and will probably only occur with high, relatively constant flows between April and late June.

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