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AN EVALUATION OF BIG CHICO CREEK, LINDO CHANNEL, AND MUD CREEK AS SALMONID NONNATAL REARING HABITATS

A LITERATURE REVIEW

by

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INTRODUCTION

Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) are two anadromous salmonid species of particular concern in the Big Chico River watershed. The historical distribution of Chinook salmon was once copious throughout the Central Valley, with steelhead present to a lesser degree (Yoshiyama et al, 1996). In recent years, the Sacramento River has experienced a decline in optimal rearing habitat for salmonids. Turbidity and high flows, combined with flood and erosion control have minimized slow reaches and eddies, thus decreasing suitable habitat (Maslin et al, 1996b).

Researchers have suggested that smaller intermittent tributaries such as Big Chico Creek, Lindo Channel, and Mud Creek provide and contribute to nonnatal rearing habitats in the Big Chico watershed and may become increasingly important as the Sacramento River habitat declines (Maslin et al, 1996b; Phipps, 1988). Faster growth and earlier smolting characteristic of juvenile salmonids in intermittent tributaries might increase their survival rates (Moore, 1997; Maslin et al, 1999).

California's Central Valley steelhead have been designated a threatened species (NMFS). Central Valley spring-run Chinook have been designated as a threatened species (NMFS) and the Sacramento River winter-run Chinook as an endangered species (Flosi et al, 1998; NMFS). Both the Central Valley fall- and late-fall-run Chinook have been proposed as threatened (NMFS).

The purpose of this literature review is to assess and quantify the present and future suitability of the Big Chico Creek Watershed – specifically Big Chico Creek, Lindo Channel, and Mud Creek – as nonnatal rearing habitats for the Chinook salmon and steelhead.

BACKGROUND

Steelhead Trout and Chinook Salmon

Both Chinook and steelhead are identified by "races" or "runs," determined by the time of year adults appear in the river system to begin their upstream migration (Flosi et al, 1998). California's Sacramento River experiences fall-, and winter-run steelhead; and spring-, fall-, late-fall-, and winter-run Chinook (Flosi et al, 1998; IEPSPWT, 1998).

Although Chinook salmon experience four runs, only the fall- and spring-runs are clearly identified – the late-fall and winter-run Chinook are specific to the Sacramento River system (Flosi et al, 1998). Fall-run Chinook begin their migration between late August and September and spawn from October through January. Spring-run Chinook begin their migration at the onset of spring-runoffs, spend the summer in the streams, and spawn prior to the fall-run through to mid-October (Flosi et al, 1998). Winter-, spring-, fall- and late-fall-run Chinook have lost 70 – 90% of their historical spawning and rearing habitats (NMFS).

Steelhead in the Central Valley migrate during late summer through October (Flosi et al, 1998) and spawn from December through April (IEPSPWT). Prior to emigration most natural Central Valley steelhead rear in freshwater for approximately two years (IEPSPWT).

Steelhead are almost always present in waters that contain Chinook (IEPSPWT). Nonetheless, estimates suggest that steelhead have lost 80 - 90% of their historical spawning and rearing habitats (NMFS). Further, our understanding of steelhead is often muddied by behavioral, physiological, genetic, geographical and taxonomic classifications (IEPSPWT).

Big Chico Creek Watershed

The Big Chico Creek watershed (Figure 1) encompasses Big Chico Creek, Lindo Channel, and three additional drainages: Mud, Rock and Sycamore Creek (Flosi et al, 1998). The Big Chico Creek watershed drainage covers approximately 72 square miles (CH2M Hill, 1993). All fish species represented in the watershed are included in Table 1.

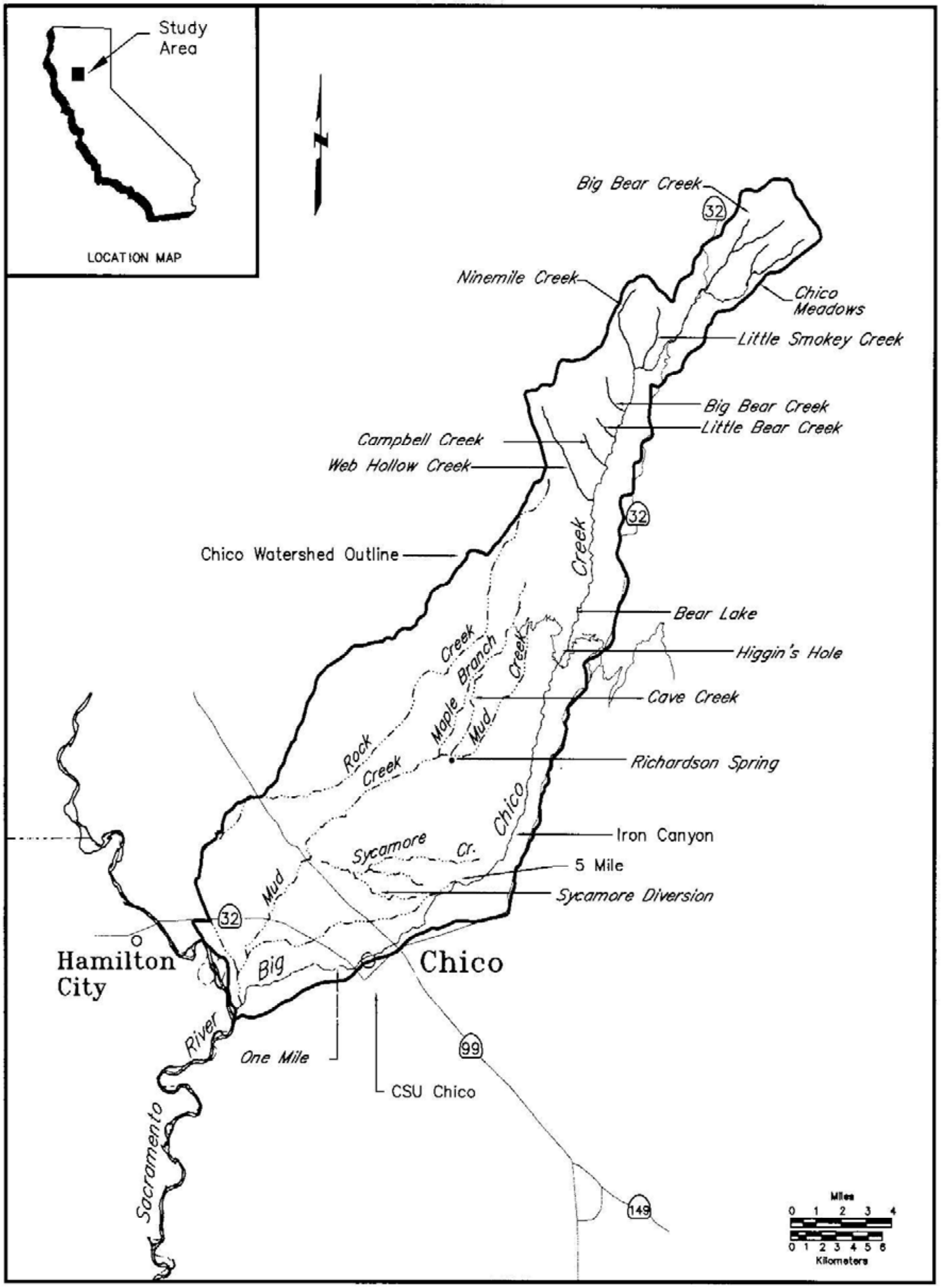

Figure 1. Big Chico Creek Watershed.

Table 1. Fish Species in the Big Chico Watershed.

Common Name	Scientific Name
PETROMYZONTIDAE Lamprey family	
Pacific Lamprey	***Lampetra tridentatus***
River Lamprey	***Lampetra ayrsi***
SALMONIDAE Salmon and Trout family	
Chinook Salmon	***Oncorhynchus tshamytscha***
Rainbow Trout (including Steelhead)	***Oncorhynchus mykiss***
Brown Trout	***Salmo trutta***
CYPRINIDAE Minnow family	
Carp	***Cyprinus carpio***
Goldfish	***Carassius auritus***
Golden Shiner	***Notemigonus crysoleucas***
Sacramento Blackfish	***Orthodon microlepidotus***
Hitch	***Lavinia exilicauda***
Hardhead	***Mylopharodon conocephalus***
Sacramento Splittail	***Pogonichthys macrolepidotus***
Sacramento Squawfish	***Ptychocheilus grandis***
California Roach	***Lavinia symmetricus***
Speckled Dace	***Rhinichthys osculus***
CATOSTOMIDAE Sucker family	
Sacramento Sucker	***Catostomus occidentalis***
ICTALURIDAE Catfish family	
White Catfish	***Ameiurus catus***
Channel Catfish	***Ictalurus punctatus***
Brown Bullhead	***Ameiurus nebulosus***
Black Bullhead	***Ameiurus melas***
POECILIEDAE Livebearer family	
Mosquitofish	***Gambusia affinis***
GASTEROSTEIDAE Stickleback family	
Threespine stickleback	***Gasterosteus aculeatus***
PERCICHTHYIDAE Temperate Bass family	
Striped Bass	***Morone saxatilis***
CENTRARCHIDAE Sunfish and Black bass family	
Bluegill	***Lepomis macrochirus***
Redear Sunfish	***Lepomis microlophus***
Green Sunfish	***Lepomis cyanellus***
Warmouth	***Lepomis gulosus***
White Crappie	***Poinoxis annularis***
Black Crappie	***Poinoxis nigromaculatus***
Largemouth Bass	***Micropterus salmoides***
Smallmouth Bass	***Micropterus dolomieui***
EMIBIOTOCIDAE Surfperch family	
Tule Perch	***Hysterocarpus traski***
COTTUDAE Sculpin family	
Prickly Sculpin	***Cottus asper***
Riffle Sculpin	***Cottus gulosus***

(from BCCECR Appendix A)

Big Chico Creek - The main channel of Big Chico Creek begins in Chico Meadows, fed by a number of springs that originate off Colby Mountain, and flows 45 miles to its confluence with the Sacramento River. Big Chico Creek's primary tributaries include Cascade Creek, Little Smokey Creek, Nine-mile Creek, Big Bear Creek, Little Bear Creek, Campbell Creek, and Web Hollow (BCCECR).

Approximately 4 miles downstream of Web Hollow is Higgins Hole, a considerable waterfall thought to be the uppermost barrier to anadromous fish migrations. Farther downstream lies Iron Canyon, a deep, narrow stretch characterized by sizable boulders within the steam channel (Maslin, 1997; CH2M Hill, 1993). Upon reaching the City of Chico, Big Chico Creek flows through Lower Bidwell park; One Mile dam; the California State University, Chico campus; and Bidwell Golf Course, before joining up with Mud Creek, Rock Creek, Lindo Channel, and ultimately the Sacramento River (BCCECR).

Big Chico Creek can be broken down into three zones. The upper zone between the headwaters and Higgin's Hole; the middle zone between Higgin's Hole and Iron Canyon; and the lower zone between Iron Canyon and the Sacramento River (Maslin, 1997).

Lindo Channel - Lindo channel, formerly Sandy Gulch (Flosi et al, 1998), serves as a seasonal flood control channel for the Chico area to help alleviate flows in Big Chico Creek. Lindo channel was modified for flood control purposes in the early 1960's (Phipps, 1988). The channel diverts flows from Big Chico Creek at the Five Mile Recreation Area (Phipps, 1988; Pella-Donnelly, 1999) for approximately eight miles before merging again with Big Chico Creek (Phipps, 1988) two miles upstream of the Sacramento River (CH2M Hill, 1993). During flood flows, Lindo Channel can absorb more than 60% of the total flows from Big Chico Creek (Phipps, 1988), but outside of flood events, the channel relieves approximately 40% of the flows (Pella- Donnelly, 1999).

Lindo Channel is characterized by wide, shallow reaches and areas of reduced shade; in some locations, armoring rock has replaced natural stream bank vegetation to prevent erosion (CH2M Hill, 1993; Pella-Donnelly, 1999). The unnatural physical characteristics of Lindo Channel have been shaped by tree removal, land development, roads, grazing, soil compaction, and channelization (Pella-Donnelly, 1999).

Mud Creek - Mud Creek is a spring fed stream that acts as one of the primary tributaries in the Big Chico Creek watershed. Mud Creek is fed by a number of springs and its two main tributaries, Maple Creek and Cave Creek, which join Mud Creek near Richardson Springs (BCCECR). An overflow weir at Lindo Channel diverts excess flows through a diversion channel to Sycamore Creek, where it then flows into Mud Creek (Maslin, Analysis of the Sycamore).

Mud Creek flows 26 miles before its confluence with Big Chico Creek. Richardson Springs acts as a primary barrier to all upstream migrations (BCCECR).

OPTIMAL SALMONID HABITAT

When salmon fry emerge from their redds, they seek suitable rearing habitats in side-sloughs, channels, tributaries, along quiet water side-margins, and the outer edges of streams. As juveniles grow, they substitute quiet shallows with deeper, faster stretches of stream, a response often tied to low water inputs, and thus a minimization of available habitat (WSCC).

Storm events are a common catalyst of instream migration towards protective tributaries (Maslin et al, 1997). Murray and Rosenau (1989) suggests that young salmonid movements towards rearing areas consist of complex, genetically and environmentally controlled local upstream and/or downstream migrations (in Maslin et al, 1998). High sediment levels and cold temperatures might also provoke juvenile Chinook to seek out nonnatal tributaries to feed and clear their gills of sediment (Scrivener et al, 1994 in Maslin et al, 1998).

Water chemistry, water flow, and the physical stream components of a system are critical elements of optimal salmonid habitat. These components include water quality, water quantity/flow, stream and river physical features, riparian zones, stable upland terrestrial conditions, and overall ecosystem interactions (WSCC).

Clean, cool, well oxygenated waters at optimal flow rates are important to all stages of the salmonid freshwater lifecycle – low flows can increase water temperatures, decrease the amount of dissolved oxygen, and concentrate toxic materials (WSCC). The temperature requirements of Chinook and steelhead vary depending on their life stage (Table 2).

Table 2. Temperature Requirements (°F) for various salmonid life stages.

Species	Adult Migration	Spawning	Incubation	Juvenile Rearing	Smoltification
Chinook					
Fall	51-67[1]	42-57[1]	41-58[1]	45-58[1]	✕
Spring	38-56[1]	42-57[1]	41-58[1]	57-67[1]	✕
Steelhead	46-52[2]	39-49[1]	48-52[2]	45-58[1]	<57[2]

✕ = data not available

[1] = (Flosi et al, 1998)
[2] = (Taylor, 1997)

The riparian zone is the transition area between the stream and the upper watershed. Riparian zones provide and effect nutrients and invertebrate food sources; supply large woody debris for habitat and flow control; filter runoff; enhance stream bank cohesion; and provide shade to both regulate water temperatures and productivity (WSCC; BCCECR; CH2M Hill, 1993) and extend the usable season for smaller, intermittent streams (Maslin et al, 1997).

Large woody debris is an important component in stream morphology, biotic composition and biological productivity (BCCECR). Woody debris and overhead cover provides food, nutrients and protection from predators (WSECR). Reductions in riparian vegetation can lead to stream bank instability, increases in channel width, and a reduction in fish habitat (BCCECR).

Sediments share a delicate, dynamic relationship with instream fish habitat. The natural equilibrium in undisturbed watersheds provides sorted and evenly distributed gravel and cobble for spawning grounds and protection. Excess loads of fine sediment can be detrimental to eggs and embryo, and an absence of larger cobble interstices can leave juveniles unexposed (BCCECR). An unnatural loss or overabundance of sediment input may impact water quality (WSCC) resulting in streambed aggradation, bank instability, a rise in the substrate surface level, an increase in channel width, and warmer temperatures due to greater surface areas exposed to the sun (Flosi et al, 1998).

Turbidity is an optical property of water that decreases water clarity and the infiltration of light (Moore, 1997). In being visual predators, an abundant food source is essential to salmonids for growth and reproduction (Keeley & Slaney, 1996) – high turbidity might interfere with juvenile food consumption (Maslin et al, 1996a).

Heavy grazing, fires, excavations, road systems (BCCECR), mining, construction, and logging (Maslin et al, 1997) might also contribute to sedimentation by accelerating erosion in the form of landslides, gullies, new stream channels (BCCECR) and high gravel bars instream (Maslin et al, 1997).

Keeley & Slaney (1996) proposed that streams with greater food abundance might increase the production of salmonids. Since habitat characteristic preferences change with the age class of salmonids, Keeley & Slaney suggested that microhabitat velocity and depth in salmonid rearing habitats be taken into consideration when rehabilitating degraded streams.

SUITABILITY OF BIG CHICO CREEK, LINDO CHANNEL, AND MUD CREEK AS NON-NATAL REARING HABITATS

The Sacramento River has degraded over the years as an optimal rearing habitat for salmonids. Large sections of the river have experienced devegetation and the introduction of riprap (Maslin et al, 1996a). Schaffter et al's (1983) comparisons of bank modification found that riprap areas increased species diversity – often of species known to compete with or predate on Chinook – at higher densities and in areas where they were not characteristically found. Turbidity and high flows, combined with flood and erosion control – which decreases sinuosity and braiding of the river – have minimized slow reaches and eddies, thus decreasing suitable habitat (Maslin et al, 1996b; Moore, 1997).

Intermittent tributaries such as Big Chico Creek, Lindo Channel, and Mud Creek, have proven to be optimal nonnatal rearing habitats in the Big Chico watershed (Maslin et al, 1996b). Records dating back to 1938 indicate that Big Chico Creek and Mud Creek once supported runs of steelhead and salmon (BCCECR). However, by the time studies were conducted in the 1980s to assess steelhead and Chinook runs, populations were low and distorted by hatchery plantings (BCCECR).

Since 1995, Maslin et al has documented the nonnatal rearing of juvenile Chinook salmon (1996a; 1996b; 1997; 1998; 1999) in as many as 26 tributaries to the Sacramento River (Maslin et al, 1998). In particular, Maslin has determined the stretch of Big Chico between the confluence of Lindo Channel and its mouth, and the tributaries Mud and Rock Creek between their mouths and Chico, as excellent nonnatal rearing habitats (pers. comm.).

Of the streams visited, all with a near-mouth gradient of less than 1% supported nonnatal Chinook rearing (Maslin et al, 1997). In all years, Maslin et al (1996a; 1996b; 1997; 1998; 1999) found that Chinook rearing in these tributaries were in good or better condition, and experienced consistently higher growth rates than their similarly-sized counterparts rearing in the Sacramento River.

Moore (1997) had similar results of mean optimal conditions of juvenile Chinook being higher in neighboring tributaries like Blue Tent Creek and Dibble Creek than in the Sacramento River. The findings of these two studies were attributed to several possible characteristics of intermittent tributaries; warm water temperatures, diel temperature fluctuations, low turbidity, rich food sources, and lack of an established predator population (Maslin et al, 1996a; Moore, 1997).

The distance juvenile Chinook traveled upstream while rearing in tributaries was dependent on race, and on variable stream characteristics; size, gradient, habitat quality (Maslin et al, 1999).

Big Chico Creek/Lindo Channel – The lower reaches of Big Chico Creek and parts of Lindo Channel are subject to nonnatal rearing of fall-, late-fall-, spring- (Maslin et al, 1999) and winter-run Chinook (Maslin, pers. comm.), with more recent observations of steelhead (Tables 3, 4) (Maslin, pers. comm.; Brown, 1999).

In comparison with other east-side tributaries of the Sacramento River, Big Chico Creek is the fourth most significant spring-run salmon stream. Neighboring creeks that exceed Big Chico include Butte, Deer, and Mill Creek (Brown, 1994).

In particular, Maslin (1997) considers Big Chico Creek's middle zone to be crucial to the survival of steelhead and spring-run Chinook, especially the former since on occasions of high flows late in the year, individuals migrating upstream can pass through Iron Canyon.

Brown's (1996) stream habitat inventory disclosed a variety of habitats with good cover, suitable gravel reaches, and adequate water temperatures for rearing Chinook.

Table 3. Adult salmonid presence by run in Big Chico Creek & Lindo Channel from 1956-1999.

	Big Chico Creek & Lindo Channel Adults				
	Chinook Salmon				Steelhead
Year	Winter	Spring	Fall	Late Fall	
1956	X	500[1]	X	X	X
1957	X	100[1]-248[2]	X	X	X
1958	X	1,000[1]	X	X	X
1959	X	200[1]	X	X	X
1960	X	X	X	X	X
1961	X	X	X	X	X
1962	X	200[1]	X	X	X
1963	X	500[1]	X	X	X
1964	X	100[1]	X	X	X
1965	X	50[1]	X	X	X
1966	X	50[1]	X	X	X
1967	X	150[1]	X	X	X
1968	X	175[1]	X	X	X
1969	X	200[1]	X	X	X
1970	X	0[1]	X	X	X
1971	X	0[2]	X	X	X
1972	X	X	X	X	X
1973	X	50[1]	X	X	X
1974	X	100[1]	X	X	X
1975	X	X	X	X	X
1976	X	X	X	X	X
1977	X	100[1]-332[2]	X	X	X
1978	X	X	X	X	X
1979	X	X	X	X	X
1980	X	X	X	X	X
1981	X	X	X	X	X
1982	X	X	X	X	X
1983	X	X	500[1]	X	X
1984	X	0[2]	200[1]	X	X
1985	X	0[2]	25[1]	X	X
1986	X	X	X	X	X
1987	X	X	X	X	X
1988	X	X	X	X	X
1989	X	7[2]	X	X	X
1990	X	0[2]	X	X	X

X = data not available

[1] = (CH2M Hill, 1993)
[2] = (BCCECR)
[3] = (Brown, 1999)

Cont.

Table 3. *cont.* Adult salmonid presence by run in Big Chico Creek & Lindo Channel from 1956-1999.

	Big Chico Creek & Lindo Channel Adults (*cont.*)				
	Chinook Salmon				Steelhead
Year	Winter	Spring	Fall	Late Fall	
1991	X	X	X	X	X
1992	X	0[2]	X	X	X
1993	X	35[3]-38[2]	X	X	X
1994	X	2[3]	X	X	X
1995	X	200[3]	X	X	X
1996	X	2[3]	X	X	X
1997	X	2[3]	X	X	X
1998	X	369[3]	X	X	X
1999	X	63[3]	X	X	1[3]

X = data not available

[1] = (CH2M Hill, 1993)
[2] = (BCCECR)
[3] = (Brown, 1999)

Table 4. Juvenile salmonid presence by run in Big Chico Creek & Lindo Channel from 1990-1999.

	Big Chico Creek & Lindo Channel Juveniles				
	Chinook Salmon				Steelhead
Year	Winter	Spring	Fall	Late Fall	
1990	X	X	X	X	X
1991	X	X	X	X	X
1992	X	X	X	X	X
1993	X	X	X	X	X
1994	X	X	X	X	X
1995	X	X	X	X	X
1996	X	X	X	X	X
1997	X	X	75[˜]	X	X
1998	X	X	X	X	X
1999	13[˚]	31[˚]	943[˚]	2[˚]	10[ˆ]

X = data not available

[˚] = (Maslin et al, 1999)
[˜] = (Maslin et al, 1997)
[ˆ] = (Maslin, 2001)

Mud Creek - Maslin et al's (1996a; 1996b; 1997; 1998; 1999) ongoing study has documented Chinook salmon's substantial use of – and steelhead's irregular use of – the intermittent Mud Creek as a nonnatal rearing habitat (Table 5). Listed winter-run Chinook tended to use tributaries in their study area for rearing proportionally more than did spring-, fall-, and late-fall runs (Maslin et al, 1998).

Table 5. Juvenile salmonid presence by run in Mud Creek from 1990-1999.

	Mud Creek Juveniles				
	Chinook Salmon				Steelhead
Year	Winter	Spring	Fall	Late Fall	
1990	~650[1]	~600[1]	~370[1]	0[1]	✕
1991	✕	~200[1]	~100[1]	0[1]	✕
1992	✕	✕	✕	✕	✕
1993	✕	~470[1]	~300[1]	0[1]	✕
1994	~2,200[1]	~2,100[1]	~1,300[1]	0[1]	✕
1995	~1,170[1]	~1,050[1]	~600[1]	0[1]	✕
1996	✕	✕	✕	✕	✕
1997	35[2]	365[2]	975[2]	0[2]	✕
1998	189[3]	280[3]	711[3]	2[3]	6[˜]
1999	53[˚]	27[˚]	151[˚]	0[˚]	1[˜]

✕ = data not available

[1] = (Maslin et al, 1995)
[2] = (Maslin et al, 1997)
[3] = (Maslin et al, 1998)
[˚] = (Maslin et al, 1999)
[˜] = (Maslin, 2001)

For 1996, Maslin et al estimated the presence of 5.9 Chinook per linear meter of stream in Mud Creek (1996), and an estimated 32,000 total juveniles present in March of 1997 (Maslin et al, 1997). Mud Creek Chinook's growth rate was 1.14mm/day, more than double that of the 0.48mm/day obtained from Sacramento River Chinook (Maslin et al, 1996b). Stomach contents revealed that tributary individuals were consuming Diptera, Epemeroptera, Plecoptera, terrestrial insects and cyprinoid fry – an average of 41 food items per fish in the tributaries sampled, compared to an average of 22 food items per fish in the Sacramento River (Maslin et al, 1996b).

DISCUSSION

Despite the presence of threatened and endangered species, there are a number of stakeholders with invested interests in the Big Chico Watershed that must be considered: Farmers, timber companies, and local governments are concerned about water access, regulations costs, and flooding/water quality issues, respectively. Also of importance are private landowners, businesses that cater to recreational fishing, hunting and bicycling, and those who visit, enjoy, or study the Big Chico Watershed (BCCECR).

While it is apparent from population estimates that Chinook and steelhead regularly utilize tributaries within the Big Chico Creek watershed, it is equally apparent that these streams are faced with or are experiencing threats to sensitive habitats. To maintain the Big Chico Creek watershed – Big Chico Creek, Lindo Channel and Mud Creek in particular – as suitable nonnatal rearing habitats, a balance must be struck between stakeholders and the watershed.

A number of issues and concerns have been raised regarding the water quality in the Big Chico Creek watershed – mainly, increased sediment loads and turbidity; fecal coliform contamination; urban stormwater runoff; groundwater contamination; agricultural runoff; siltation-, pollutant- and garbage-related contamination tied to the Minnehaha Mine; sediment-, erosion-, and septic-related contamination tied to the Boy Scouts of America Camp at Chico Meadows; and the potential threat of petroleum contamination along Highway 32 (BCCECR).

Water flows throughout the Big Chico Creek/Lindo Channel system severely decrease between March and June – paradoxically, this is the same time that salmonids migrate downstream through the system (Pella-Donnelly, 1999). In March, flows were high enough to support salmon movement through Lindo Channel 75% of the time; in April and May, only 50% of the time (Pella-Donnelly, 1999). As such, there have been a number of reported strandings of salmonids in the Big Chico Creek/Lindo Channel system (Phipps, 1988; Pella-Donnelly, 1999).

Maslin et al (1996b) noted that as maximum daily temperatures approached lethal levels – by the end of April –, juvenile Chinook avoided entering the tributaries, and rearing resident juveniles smolted and emigrated. Both the lack of rainfall late in the season and receding waters have incurred juveniles in some years to become trapped in smaller tributaries' low waters (Maslin et al, 1997; Maslin et al, 1998; Maslin et al, 1999).

During low flow periods, water quality deteriorates as well. Brown (1994) found low levels of oxygen, high levels of nitrates and sodium, and unhealthy water temperatures during the summer months.

Habitat preservation, restoration and revitalization are key to ensuring that these nonnatal rearing habitats don't become obsolete. Past studies show that habitat loss is not irreversible. Throughout the John Day subbasin, an increase in habitat diversity, shade, cover and bank stability, and the restoration of fish passages helped restore the spawning and rearing habitat of Chinook and steelhead salmon (Bonneville, 1997). Enhanced instream diversity, the exclusion of livestock, and riparian vegetation resulted in improved habitat quality, an increase in carrying capacity, lower summer stream temperatures and stable banks. Bonneville also found that riparian revegetation proved to be more effective than introducing instream structures.

Instream boulder structures in Hurdygurdy Creek, California helped revitalize habitat components such as water velocity and depth, amount of cover, and stream substrate distribution – newly emerged Chinook and steelhead juveniles took advantage of low velocity habitat and thalweg zones created by introduced wing deflectors (Gomes, 1990).

However, single species management might be detrimental to stream communities. Fuller and Lind (1993) addressed the complexity of watershed management, noting that in the three years following the introduction of instream structures in Hurdygurdy Creek, they were unable to find foothill yellow-legged frogs (*Rana boylii*) breeding in the study area. Consequently, the western aquatic garter snake (*Thamnophis atratus*), a common predator of frogs, experienced a decrease in numbers and shifted its diet to accommodate the possible change in prey availability.

CONCLUSION

Based on the findings of recent studies, the Big Chico watershed provides a number of optimal nonnatal rearing habitat for salmonids. In particular, Big Chico Creek, Lindo Channel and Mud Creek are important nonnatal rearing habitats for all runs of Chinook and steelhead. It is critical in our role as stewards that we safeguard the watershed to ensure that it will continue to contribute to future salmonid stocks.

All elements of natural stream physiology – water chemistry, water flow, water quality, water temperature, riparian zones, sedimentation and pollution – must be considered in the context of a complex ecosystem, not individual elements. The integrity of the watershed and the ecosystem as a whole for all stakeholders must be considered in future restoration efforts.

Maslin et al concluded that "all the streams we investigated could be enhanced by changes in the way humans attempt to manage them… The safest and most conservative approach would be to ensure preservation of existing natural habitat and begin restoration of degraded habitat to mimic historical conditions wherever possible" (1997).

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