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Influence of Stream Corridor Parameters on Fish Populations in the Clearwater River, ID, USA

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ABSTRACT

This study presents the results of a statistical analysis performed at the micro scale (stream corridor) level in the South Fork of the Clearwater River (SFCR) watershed which is located in North central Idaho. Using multivariate techniques along with factor analysis, relationships between Fish Indicators and man-made disturbances, watershed landscape, water discharge and geometry, channel morphology, river water depth and temperature were established. At the micro scale level, this analysis was performed for 4 tributaries of the SFCR, namely, Newsome, Crooked, American and Red River, where a significant amount of recent data existed. Results show that data at the micro scale level were more important for establishing quantitative relations between sediment and channel morphology parameters with Fish Indicators than at the watershed wide level. The findings of this investigation clearly illustrate that micro scale analyses should be considered in modeling habitat restoration techniques. It allows the development of more refined relationships between Fish Indicators and stream corridor parameters occurring at different life stages of fish populations.

Key words: Watershed wide parameters, stream corridor parameters, fish indicators, factor and redundancy statistical analysis, south fork clearwater

INTRODUCTION

In response to fish decline in the inland Northwest, many federal and state agencies (e.g., National Marine Fisheries Service (NMFS), United States Department of Agriculture (USDA, 2000), United States Bureau Reclamation (USBR), United States Forest Service (USFS), Department of Fish and Wildlife (DFW), United States Geological Survey (USGS), Columbia River Inter-Tribal Fish Commission (CRITFC), Bonneville Power Administration (BPA) and United States Army Corps of Engineers (USACE)) have employed management plans in the last twenty to thirty years to augment stream habitat population.

Most of the restoration efforts have focused on the impairment of the stream corridors to restore habitat variables (e.g., pool-riffle sequence, depth, shade) and river geomorphologic characteristics (e.g., sinuosity and slope) within a stream corridor (microscale), without considering the overall effects of watershed wide (macroscale) parameters on the stream-corridor parameters over a period (Richardson *et al*., 2011; Zalba *et al*., 2010).

Lack of understanding of the complex interaction between watershed-wide parameters with stream corridor parameters has caused in some cases the unsuccessful implementation of these management plans in forest, rangeland, urban and agriculture (cropland) areas to adequately improve habitat ecosystems (Upstream: Salmon and Society in the pacific Northwest (NRC, 1996).

Recent study in watershed and stream ecology (Kumar *et al*., 2011; Li *et al*., 2001) has raised the question of the effect of scale (microscale vs., macroscale) in the overall performance of different monitoring and restoration approaches. It was concluded that monitoring approaches based on limited spatial information could hinder restoration efforts by over-or under-estimating the impact of different variables on the productivity of fish populations and yield to inconclusive results (Upstream: Salmon and Society in the pacific Northwest (NRC, 1996).

While a well-developed body of literature describes qualitatively the hierarchy of the watershed wide and stream corridor parameters, as they relate to the productivity of fish populations, there are very few studies that assess the influence of these parameters on fish populations operating at different temporal and spatial scales (Aravindan *et al*., 2011; Shaw and Cooper, 2008).

The objective of this research was to develop expressions that quantitatively describe Fish Indicators as a function of stream corridor parameters and account for the interdependence of these parameters with macro scale parameters. For this purpose, multivariate techniques such as factor analysis and multiple regression, were employed first to quantitatively relate stream corridor parameters to different Fish Indicators for the South Fork of the Clearwater River (SFCR) watershed (Argyrous, 2002).

At present, there are two schools of thought in habitat modeling: (1) The first, believes that macroscale approaches are the most appropriate for examining the interdependence of fish populations (or assemblages) with various watershed-wide parameters such as land use, canopy and human-made disturbances (Barbour *et al*., 1992; Richards *et al*., 1996; Wang *et al*., 1997, 2000). (2) The second school believes that microscale approaches should be considered which strictly focus on the modeling of the stream corridor parameters as it relates to fish assemblage.

MATERIALS AND METHODS

For the purpose of this study, data that were provided by several agencies for the South Fork of Clearwater have been assembled and analyzed in order to: (1) Demonstrate the influence of micro scale parameters on Fish Indicators, (2) Develop empirical prediction models for fish species using the multivariate analysis approach by identifying stream corridor parameters that are strong predictors for Fish Indicators and (3) Qualitatively address the issue of integration of micro-and macroscale models in order to provide a complete picture of the parameters affecting Fish Indicators. Next, a description of the study area, available data, design and statistical analysis of data for the SFCR and Newsome, Crooked, American and Red Rivers is provided.

Study area: The South Fork Clearwater River subwatershed is located in North central Idaho encompassing an area of approximately 1175 square miles (Fig. 1: South Fork Clearwater River Basin, USDA Forest Service, 1998a). The subbasin extends from the headwaters above Elk City and Red River to the confluence with the middle fork of the Clearwater River at Kooskia. The soils, landforms and streams in the South Fork Clearwater subbasin are the result of geologic and climatic events including several episodes of glaciation and climatic change. The annual precipitation is between 25-50 inches, the dominant land use is forested and elevation is moderate to high. The dominant anthropogenic disturbances are timber harvest, roads, mining and grazing. (USDA Forest Service, 1998b).

Fig. 1: South Fork Clearwater River Basin, Idaho, USA

Included in the area are 14 major subunits. The subunits of the American River, Red River, Crooked River and Newsome Creek are considered here since these rivers are major tributaries in the upper reaches of the South Fork Clearwater (hereafter, these tributaries are referred as ARCN). ARCN rivers contain substrate of gravel and cobble and are historically associated with some of the highest potential anadromous spawning and rearing habitat in the South Fork of Clearwater. ARCN rivers have a runoff regime very similar to the mainstem of the South Fork of Clearwater. They each drain a large area of rolling upland terrain. Because of the elevation of ARCN, climate, relatively deep soils and moderate topography, they typically do not have a flashy response to storms (USDA, 2000).

Red River, Crooked River (the upper part only of the river) and Newsome Creek have been historically found with high productivity to Spring Chinook Species and they are known as "Strongholds" (USDA, 2000). These areas still support Spring Chinook Species and still would rank as moderate to high in existing habitat capability. However, the population resilience and potential of this area as population source for the subbasin, is believed to have been significantly reduced.

Finally, fine sediments are typically derived from upland contributing watersheds (macroscale effects) as well as from lower-elevation streamside zones and banks (microscale effects) (Mani *et al*., 2008). The increased fine sediments found in channels have reduced riffle and pool frequencies (e.g., Red River), increased water temperature and reduced base flows causing a deterioration of the in stream water quality. Current sediment yield within the Red River subunit has exceeded by 20% the natural base sediment yield for this subunit while for the other three subunits it is found to be within 5-10% higher than the natural based sediment yield.

Data sets: The set of data contains information on twenty-two microscale variables for the ARCN subunits including Fish Indicators for Steel head and Chinook at different life stages, in-stream hydraulics parameters, habitat substrate, sediment and temperature during the period of 1995-2008. Table 1 provides the definitions for the microscale variables employed in the statistical analysis.

Table 1: Variables used in the micro scale analysis, their definitions and the corresponding stream corridor property for those variables that are potential fish density predictors

Variable	Definition	Stream corridkor property
Sthd_012	Density for Steel head, ages 0, 1 and 2 years old	
Sthd_0	Density for Steel head, age 0 years old	
Sthd_12	Density for Steel head, ages 1 and 2 years old	
Chin_01	Density for Chinook, ages 0 and 1 years old	
Chin_0	Density for Chinook, age 0 years old	
Chin_1	Density for Chinook, age 1 years old	
Total_FD	Total fish density	
Temp	Water temperature	Water quality
Length	length of river reach	Stream geometry
Width	Mean width	Stream geometry
Area	SEC area	Stream geometry
Gradient	Gradient	Stream geometry
Depth	Mean depth	Stream hydrology
Q	Discharge	Stream hydrology
Pool	Percentage of area within river reach that is pool	Stream habitat
Run	Percentage of area within river reach that is run	Stream habitat
Pocket	Percentage of area within river reach that is pocket	Stream habitat
Riffle	Percentage of area within river reach that is riffle	Stream habitat
Backw	Percentage of area within river reach that is backwater	Stream habitat
Sand	Percentage of area within river reach that is sand	Stream sediment
Gravel	Percentage of area within river reach that is gravel	Stream sediment
Rubble	Percentage of area within river reach that is rubble	Stream sediment
Boulder	Percentage of area within river reach that is boulder	Stream sediment
Bedrock	Percentage of area within river reach that is bedrock	Stream sediment

Study design

Fish indicators for the micro scale analysis: In the present study biological indicators such as Fish assemblages or Fish indicators are adopted to quantitatively describe the biotic integrity, abundance of fish, as an indication of the hygiene of the fish ecosystem. As such, well-established Fish indicators have been employed to describe the temporal and spatial distributions of Fish populations throughout the SFCR subbasin in terms of historic and current ontogeny, population density and hydraulic and physical habitat characteristics. These indicators have been developed based on the hypothesis that fish density or habitat use are similar (Hadi, 2010; McCain, 1992; Richards *et al.*, 1996). To quantitatively describe species richness and abundance, different multimetric Indices have been introduced in the literature.

The Fish density parameter is employed to represent the fish population along the stream corridors. The Fish density parameter in the present study is defined as the number of fish species in stream reach per 100 m^2 of a stream area. An alternative definition for fish density is the number of fish species per km or ha, however, the latter definition is useful when fish surveying occurs only within a stream of a constant width. In this study, the fish density data provided by the Department of Fisheries of the Nez Perce Tribe were available in the form of number of fish species in stream reach per 100 m^2.

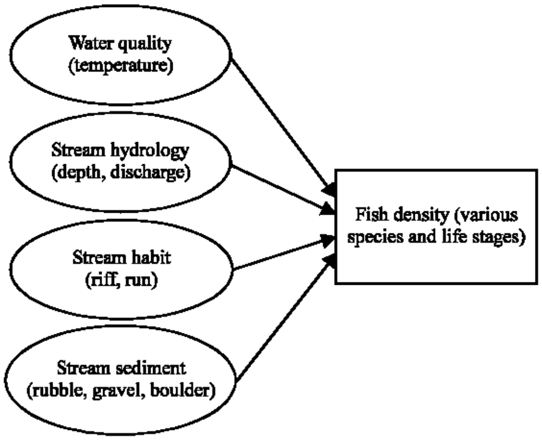

Fig. 2: Conceptual model for the micro-scale (stream-wide) environmental characteristics that influence fish density

Predicting fish density using micro-scale variables as predictors: Besides the general environmental factors that were studied in the previous sections, fish populations are known to exhibit habitat preferences based on the local characteristics of a stream reach. The water temperature may vary from one reach of the same stream to another, by as much as 11°C Celsius, making certain reaches more favorite to fish than others, especially at different stages of the fish life cycle. The presence of sand or gravel at the stream sediment may have an effect on making a stream desirable as a fish habitat. Extremely high stream discharge may create turbulence which disturbs the sediment, making the particular reach less favorite for egg-laying purposes. Figure 2 shows the conceptual model that defined the purpose of this particular study: to examine and attempt to establish statistically significant relationships among various stream characteristics as predictors for the density of fish population. Such stream characteristics include water quality, stream hydrology, stream habitat and stream sediment.

In order to study the effects of such micro-scale stream properties on fish population density, we sampled fish density data from four small streams that are part of the South Fork of the Clearwater River, Idaho. The selected streams were American River, Crooked River, Newsome Creek and Red River. American River was divided into 8 reaches, Crooked River into 23, Newsome Creek into 15 and Red River into 17. For all these reaches, data on the 17 micro-scale variables shown on Table 2 were obtained from the GPM Physical Habitat Data, 1985-1994, made available by the Idaho Department of Fish and Game (Gove *et al.*, 2001). These micro-scale variables were related to corresponding fish densities for Steelheads and Chinooks separated by age, as shown on Table 1, for the same reaches.

RESULTS AND DISCUSSION

In order to investigate the effects of the micro-scale variables on the fish densities, we fitted 28 linear multiple regression models, using the seven variables, Sthd_012, Sthd_0, Sthd_12, Chin_01, Chin_0, Chin_1 and Total_FD, as response variables for all four streams. Table 2 summarizes the findings. For each of the 28 models, the significant predictor variables are listed, together with the corresponding significance levels (p-values).

Next, an example of the output which was produced using multiple regression analysis.

Model 1: Steel head density

STE012 = 19.6169 - 0.166146*PER_RUBBLE - 0.569846*PER_BOULD-0.157686*PER_POOL

Multiple regression analysis

Dependent variable: STE_012

Parameter	Estimate	Standard T error	Statistic	p-value
Constant	-53.482800	19.6188000	-2.72610	0.0722
PER_GRAVEL	-0.733451	0.1893090	-3.87436	0.0304
TEMP	8.921370	1.6254000	5.48872	0.0119
PER_RUN	-0.358148	0.0850848	-4.20931	0.0245
PER_BOULD	-0.876275	0.2312210	-3.78978	0.0322

Analysis of variance

Source	Sum of squares	Df	Mean square	F-ratio	p-value
Model	1182.4600	4	295.616	10.51	0.0413
Residual	84.3728	3	28.1243		
Total (Corr.)	1266.84 7				

R^2 = 93.3399 percent

Unusual residuals

Row	Y	Predicted Y	Residual	Studentized residual
3	3.74	10.6993	-6.95932	-3.68
7	4.03	0.3655	3.6645	3.52

Table 2: Predictor variables for Fish Density at various life stages of summer Steel head and spring chinook with their corresponding significance, as indicated by their p-values (refer to Table 1 for definitions of the variables) variable definition stream corridor

	Sthd_012	Sthd_0	Sthd_12	Chin_01	Chin_0	Chin_1	Total_FD
American river	(+)temp** (-)run** (-)gravel** (-)boulder**	(+)temp** (-)run** (-)boulder** (-)gravel*	(-)gravel** (+)riffle* (+)temp (-)boulder				(+)rubble*** (+)gravel*** (-)riffle**
Rsq, Rsq-adj	0.93, 0.84	0.92, 0.82	0.81, 0.56	(no model)	(no model)	(no model)	0.87, 0.77
Crooked river	(-)boulder** (-)pool** (-)rubble*	(+)gravel* (-)pocket (-)pool	(-)boulder** (+)pocket**	(+)backw*** (+)temp*** (-)riffle*** (-)run** (-)run**	(+)backw*** (+)temp*** (-)riffle***	(+)temp***	(+)backw*** (+)pocket** (+)pool* (-)boulder
Rsq, Rsq-adj	0.47, 0.38	0.25, 0.13	0.34, 0.28	0.65, 0.55	0.65, 0.56	(no model)	0.66, 0.52
Newsome creek	(-)riffle* (+)gravel (-)backw	(-)riffle (-)temp	(+)pocket*** (-)depth*** (+)pool*** (+)rubble*** (+)Q*** (-)backw*** (+)temp*	(+)gravel*** (-)backw** (-)riffle** (-)temp			(-)riffle* (-)backw* (+)gravel
Rsq, Rsq-adj	0.34, 0.16	0.35, 0.22	0.98, 0.96	0.68, 0.52	(no model)	(no model)	0.40, 0.22

Table 2: Continue

	Sthd_012	Sthd_0	Sthd_12	Chin_01	Chin_0	Chin_1	Total_FD
Red river	(-)boulder**	(-)run	(-)boulder***	(+)temp**	(+)temp**	(-)sand***	(+)temp**
	(-)gravel**	(+)pool	(-)gravel***	(-)rubble*	(+)boulder**	(-)gravel***	(-)rubble
	(-)sand**	(-)gravel	(+)riffle***	(+)depth*	(+)depth**	(-)rubble**	(+)depth
	(-)rubble*		(-)rubble***	(-)gravel	(+)sand*	(-)boulder**	(-)gravel
	(+)riffle*		(+)run**			(+)pool**	
			(-)sand**			(+)temp	
Rsq, Rsq-adj	0.54, 0.33	0.56, 0.46	0.75, 0.61	0.43, 0.24	0.51, 0.35	0.72, 0.55	0.44, 0.25

0.10<p-value<0.20 low significance, *0.05<p-value<0.10, **0.01<p-value<0.05, ***p-value<0.01

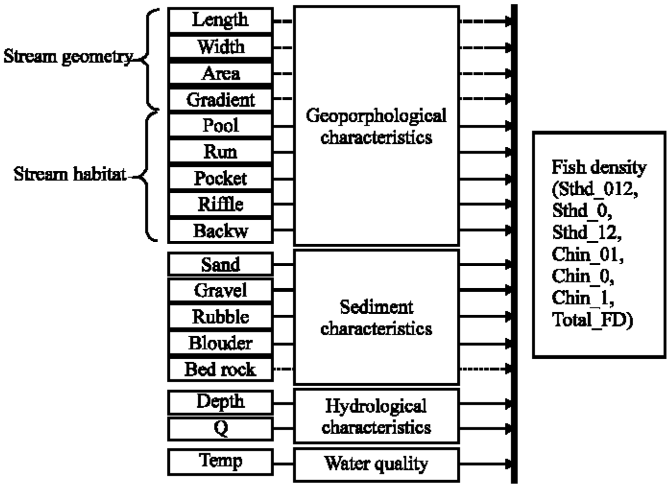

Fig. 3: Stream properties that affect fish density of a river at the micro-scale. The dashed lines show those variables that could not be established as significant predictors for any of the fish density-related variables

For each of the 28 models, the regression coefficient of determination (R^2) is listed on Table 2. This is the amount of fish density variability explained by each model. The R-squared values are typically around 50%, with some of them as small as 25% and some as large as 98%. The corresponding adjusted R^2 (Rsq-adj) values are also listed for each model. These are adjusted for the number of predictors, i.e., if a regression model has a large explained variability (Rsq) but, in order to achieve that, uses a large number of predictors, some of which are not worth the added model complexity, the Rsq-adj value will be much smaller than the corresponding Rsq. In most of the cases, Rsq and Rsq-adj have a good correspondence (are quite similar). In some others, the Rsq-adj seems much smaller. This is mainly because we decided to include in Table 1 variables with small significance, since our main purpose was to explore the fish density predictors. All 28 regression models exhibited a reasonably satisfactory statistical behavior, with the usual regression assumptions to either hold or show mild and unimportant violations. Figure 3 summarizes the relationships between fish densities and stream-wide characteristics that were established with our statistical analysis. Figure 4 summarizes the multiple regression results for the relationship between various types of fish species and fish density.

According to in-stream parameters were better predictors of fish assemblages than watershed-wide land use practice. On the other hand, Roth *et al.* (1996) found that watershed-wide

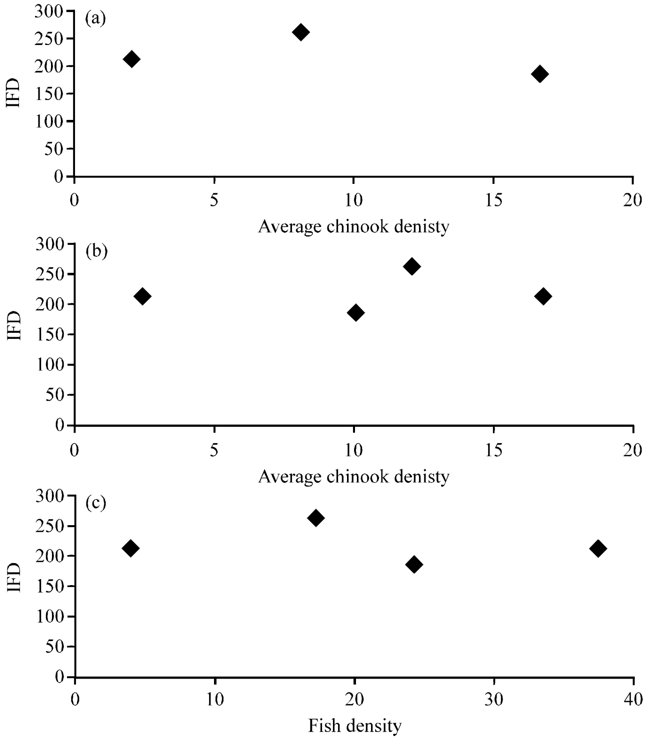

Fig. 4: Multiple regression results for the relationship between various types of fish species and fish density

land use practices are a strong predictor of fish assemblages than local in-stream parameters. There are several reasons for the latter discrepancy with the most prominent one being the absence of a well-defined methodology that incorporates both micro-and macroscale approaches.

As a result, micro scale approaches have strictly focused on the hydraulic and/or channel bed stability variables without examining the effects of watershed-wide variables on habitat variables and in-stream living organisms. At the most, river channel restoration has focused on the development of buffer zones (to minimize sediment delivery from the watershed within the stream) based on empirical rules without knowing the interrelationship between several watershed-wide parameters with stream-side parameters. On the other hand, while watershed-wide land use patterns (macroscale approaches) work better than riparian (micro scale) scale parameters for coarser scales, macroscale approaches cannot provide consistent predictions of the interdependence between fish assemblage and watershed-wide parameters due to different spatial and temporal scales (Shaw and Cooper, 2008).

CONCLUSION

The above differences highlight the fact that scale (spatial and temporal) of study significantly affects the predictive ability of models and an integrated methodology should be developed based on statistical sound methods that links the macroscale and microscale approaches. Such methodology will utilize the strengths of both methods and will help us to establish quantitative expressions between several watershed-wide and stream corridor parameters which in turn can be used to assess the relation between the productivity of fish populations with these parameters.

The findings of this investigation clearly illustrates that micro scale analyses should be considered in modeling habitat restoration techniques. It is concluded that the scale of a study (spatial and temporal) significantly affects the predictive ability of such models and an integrated methodology should be developed in the future that links the macroscale and microscale approaches. It is expected that such methodology will utilize the strengths of both methods and will help us to establish the missing links between several watershed-wide and stream corridor parameters which in turn can be used to assess the relation between the productivity of fish populations with these parameters.

This analysis will not only generate valuable predictive tools of statistical significance but it will assist the field watershed managers to focus only on the collection of those parameters that have adverse effects on fish habitats. When the microscale studies are not only focused on river restoration work from the engineering point of view but incorporate stream water quality as well biological integrity they can become a powerful tool for guiding channel “habitat restoration” work in the future.

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REFERENCES

Aravindan, S., K. Shankar and S.S. Mini, 2011. Integrated geohydrological studies in the sedimentary part of Gadilam River Basin, Cuddalore District, Tamil Nadu. Asian J. Earth Sci., 43: 183-192.

Argyrous, G., 2002. Statistics for Research: With a Guide to SPSS. SAGE, London, ISBN: 1-4129-1948-7.

Barbour, M.T., C.G. Graves, J.L. Plafkin, R.W. Wisseman and B.P. Bradley, 1992. Evaluation of EPA`s rapid bioassessment benthic metrics: Metric redundancy and variability among reference stream sites. Environ. Toxicol. Chem., 11: 437-449.

Gove, N.E., R.T. Edwards and L.L. Conquest, 2001. Effects of scale on land use and water quality relationships: A longitudinal basin-wide perspective. J. Am. Water Resour. Assoc., 37: 1721-1734.

Hadi, N.S., 2010. The research on water quality of water area around drain outlets of Longwangzui sewage plant in China. Asian J. Applied Sci., 3: 166-185.

Kumar, B., R. Gaur, G. Goel, M. Mishra and D. Prakash *et al*., 2011. Distribution of pesticides in sediments from municipal drains in Delhi, India. Asian J. Sci. Res., 4: 271-280.

Li, J., A. Herlihy, W. Gerth, P. Kaufmann, S. Gregory, S. Urquhart and D.P. Larsen, 2001. Variability in stream macroinvertebrates at multiple spatial scales. Freshwater Biol., 46: 87-97.

Mani, E.P., B. Ravikumar, P.J. Antony, P.S. Lyla and S.A. Khan, 2008. Impact of physical disturbance on the community structure of estuarine Benthic Meiofauna. Asian J. Sci. Res., 1: 239-245.

McCain, M., 1992. Comparison of habitat use and availability for juvenile fall chinook salmon in a Tributary of the Smith River. CA R-5 Fish Habitat Relationship Technical Bulletin, No. 7.

NRC, 1996. Upstream Salmon Society in The Pacific Northwest. National Academy Press, Washington, DC.

Richards, C., L.B. Johnson and G.E. Host, 1996. Landscape-scale influences on stream habitats and biota. Can. J. Fish. Aqua. Sci., 53: 295-311.

Richardson, C.J., N.E. Flanagan, M. Ho and J.W. Pahl, 2011. Integrated stream and wetland restoration: A watershed approach to improved water quality on the landscape. Ecol. Eng., 37: 25-39.

Roth, N.E., J.D. Allen and D.L. Erickson, 1996. Landscape influences on stream biotic integrity assessed at multiple spatial scales. Landscape Ecol., 11: 141-156.

Shaw, J.R. and D.J. Cooper, 2008. Linkages among watersheds, stream reaches and riparian vegetation in dryland ephemeral stream networks. J. Hydrol., 350: 68-82.

USDA Forest Service, 1998a. South fork clearwater river landscape assessment. Volume I-Narrative. United States Department of Agriculture.

USDA Forest Service, 1998b. South fork clearwater river landscape assessment. Volume II-Map. United States Department of Agriculture.

USDA, 2000. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins. General Technical Report, United States Department of Agriculture Portland, OR.

Wang, L., J. Lyons, P. Kanehl and R. Gatti, 1997. Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams. Fisheries, 22: 6-12.

Wang, L., J. Lyons, P. Kanehi, R. Bannerman and E. Emmons, 2000. Watershed urbanization and changes in fish communities in Southeastern Wisconsin streams. J. Am. Water Resour. Assoc., 36: 1173-1189.

Zalba, P.E., M. Morosi, M. Manassero and M.S. Conconi, 2010. Microscale diagnostic diagenetic features in neoproterozoic and ordovician units, tandilia basin, Argentina: A review. J. Applied Sci., 10: 2754-2772.