Review Article

Factors affecting stream fish community composition and habitat suitability

Abstract

The objective of this review was to provide an overview of the major biotic and abiotic factors that determine the composition of stream fish communities. Fish communities often consist of discrete and nonrandom species assemblages. Stream fish communities are all structured none randomly in space. In a meta-community framework, local fish communities may be structured by both spatial and environmental factors. Most fish in small, stable streams are most probably habitat specialists that have evolved various morphological and behavioral adaptations to exploit specific habitat types. Over large geographical and habitat scales, environmental filtering and anthropogenic effects are generally the most important determinants of assemblage variability. Streams are important habitats, providing shelter and feeding opportunities for a wide range of organisms like fish, insects, plants, mollusks, birds and mammals.

Fish community structure depends on biotic interactions and abiotic variables. Predation is a major determinant of ecological patterns in fresh water fish communities. Resource partitioning among fishes suggest that competition may play an important role in the local organization of communities. Most studies are based on field observations, and many suggest that niche segregation rather than competitive exclusion is the predominant outcome resulting from competitive interactions. Finally, we saw that, fish community composition was negatively affected by human impact, Climate change, introduction of exotic spices and tourism or sports on streams.

Keywords: Fish communities, Fish assemblage, Biotic, Abiotic, Meta-community, Climate change, Exotic spices

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Introduction

Various studies have been shown that fish communities often consist of discrete and nonrandom species assemblages[1-3] of which the community characteristics are to a large extent determined by a combination of due biotic and abiotic factors.[4-6]

Depending on the aim of the study, fish communities can be described or classified in different ways. Fish communities or species assemblages have been named on the basis of ecological and numerical dominance of a particular species or group of species that are of economic value.[7] This approach is particularly convenient for resource managers, as the identified species are generally those of management interest. Stream fish community analysis has been designated using this approach.[8] Another approach to community analysis has been to classify species in to guilds, i.e., species sharing attributes, generally based on feeding or reproduction. This approach focuses on specific ecological attributes of the species. Feeding or trophic guilds classify species based on their diet or manner of feeding,[9] which works well for species with restricted and consistent diets. Another approach for classification of fish communities is through the use of multivariate statistical methods. Multivariate approaches provide an objective approach in identifying patterns in community composition and their relationships with environmental conditions.[10-14]

Various findings support the idea that stream fish communities are all structured nonrandomly in space.[15,16] In a meta-community framework, local fish communities may be structured by both spatial and environmental factors.[17-20] In addition to the abiotic environmental and spatial factors, stream fish communities are also locally structured by species interactions.[21]

Determining which factors are responsible for the structure of communities is a primary focus in ecology. Species distribution and abundance within a particular environment is determined both by tolerance to physical conditions and interactions with other organisms.[22] Research in community ecology has focused on biotic interactions and consequently, several models relating the relative importance of competition and predation to community structure have been developed.[23] Among biotic interactions, a debate continues over the relative importance of predation and competition in determining community structures .[24]

Freshwater ecosystem and their resources are indispensable part of human life and the health of those freshwater ecosystems is often reflected in the structure and characteristics of the fish communities they support.[25] The habitat requirements of fish in streams are in many ways similar to those of humans in our own environment. In essence, fish need suitable environmental conditions to live and reproduce. The existence of good fish habitat is dependent on a number of factors, such as water flow, water quality, the presence of sufficient food, and the lack of excessive numbers of predators and competitors.[26]

The importance of habitat characteristics on community structure and species distribution has long been recognized.[27,28] A fish's habitat includes all the required physical factors (temperature, water depth, current, waves, bottom types, cover, etc.) and chemical factors (oxygen levels, dissolved minerals, and other substances) in their environment. Habitat requirements for each stage of a fish's life cycle (egg, larvae, juvenile and adult) may also be quite different within the same water body. In areas where fish habitats have been changed or lost by humans, many important fish species have declined in numbers, become extinct, or have been replaced by other species more tolerant of the habitat changes.[26]

In general, habitat can be conceptualized as the physical and chemical characteristics of a stream that determine suitability for habitation and reproduction of stream organisms. The characteristics, volume, spatial arrangement, and variation of habitat over time can be fundamental controls that determine which organisms can survive or thrive in a stream and, therefore, may function also as preliminary controls on biotic interactions such as competition or predation.[17] Moreover, rivers and streams are essential for the exchange of energy, organic matter and nutrients between inland and coastal areas. They drive local as well as global biochemical cycles. Minor streams are dominant interfaces between any aquatic habitat and associated land.[29] Streams are also important habitats, providing shelter and feeding opportunities for a wide range of organisms like fish, insects, plants, mollusks, birds and mammals. Additionally, these species are dependent on running waters, using these waters for their whole or parts of their lifecycle. For example, there are some migratory fish species that use running water for foraging or as nursery areas for young stages. Among the fish species that use running waters for such purposes are salmon (*Salmo salar*) and trout (*Salmo trutta*).[30]

Habitat diversity influences the structure and composition of stream fish communities.[31,32] More diverse habitat conditions support a greater range of species and age classes than do simple habitats. It can also mediate biotic interactions such as competition.[33] and predation.[31] Besides this, hydrological and geomorphological conditions of streams are highly variable and dynamic, and provide diverse habitats for fish and other aquatic life. Langerhans et al.[34] and many other studies have indicated that the morphological characters of fish are related to their habitat preferences for lentic or lotic waters.

Most fish in small, stable streams are most probably habitat specialists that have evolved various morphological and behavioral adaptations to exploit specific habitat types.[32] Some studies indicated that many tropical stream fish specialize in habitat use and exhibit morphological segregation, with a close relationship between morphological and ecological characteristics. As a result, these ecomorphological specializations may serve to facilitate resource partitioning.[35]

On the other hand, disturbances such as floods or droughts are regarded by many stream ecologists as playing a central role in determining the structure of stream communities[36] Research on disturbance ecology in streams has concentrated on flow - generated disturbances, mostly high- flow events (floods), and has neglected low-flow events or droughts. Natural streams and rivers have stable flows for much of the time, mostly running at base flow levels.[36] Flow-generated disturbances that periodically disrupt such stable conditions may vary greatly in duration, spatial extent, and predictability. Both floods and droughts can destroy habitat patches and create new ones that are then colonized and inhabited by biota with the return of stable flow conditions. The size of patches created by disturbance can vary greatly. Different-sized patches are used by different biota. There may be a rich variety of habitat patches that supports the high diversity of lotic biota.

Effects on stream include changes in physical characteristics such as channel structure, sedimentation or sediment transport and thermal regime, and changes in biological characteristics such as species diversity, trophic structure, and community composition.[37,38] Likewise, fish communities can have a high degree of variability because of geographic distribution of species, human modifications of streams and the surrounding landscape, presence or absence of nonnative species, and natural effects. Natural variability in fish communities

can be attributed to differences in elevation, water temperature, physical habitat, water quality, and other important characteristics of the environmental setting. Low abundances and types of fish species may be a result of water quality and habitat that can be affected by the surrounding land use.[39]

Physical habitat change has been recognized as a key factor in degradation of stream ecosystems.[40] At the same time, the land-use changes that have caused physical-habitat degradation and disturbances of streams by activities such as channelization, aggregate mining, urbanization, livestock grazing, agriculture and dams have directly affected channel morphology and stream flow characteristics. Changes in runoff and sediment yield to streams and direct disturbances of channels can severely alter physical stream habitat; the template of temperature, turbidity, water depth, current velocity, channel substrate, and cover that supports the stream ecosystem. Cover, such as boulders, root wads, or submerged vegetation, provides concealment and protection to organisms in an aquatic system. Streams are also the subject of different anthropogenic impact, e.g. hydropower development. Hydropower development usually means lost connectivity, altered flow regimes and channelization.[41]

What motivated me to review this is that, fishes are not only diverse and important sources of food particularly proteins but also important bio-indicators. They can be used in the study of stream ecology to study ecological structures to evaluate the quality of an aquatic biota. In addition, like all animals, fish need a healthy living space, or habitat, to survive, grow, and reproduce. Since the quality and quantity of fish habitat in a water body directly affects fish populations they can tell us what is happening in our environment and the degree of anthropogenic impacts. As a result, ecologists, environmentalist and other concerned bodies can took measures on the improvement of stream fish habitats and water chemistry activities.

he objective of this review is to provide an overview of the major biotic and abiotic factors that determine the composition of stream fish communities. In addition to important natural biotic and abiotic factors, I also focus on the extent to which human impact may affect the ecological integrity of fish assemblages. The provided information is essential for a good understanding of the distribution patterns of fish species, and also provides important knowledge for the development of effective conservation programs.

Biotic and abiotic factors structuring fish communities

The distribution, occurrence, diversity and composition of fish communities are strongly determined by a combination of abiotic and biotic factors. Research to clarify the dynamics of fish communities has generally focused on either of these. Both factors may act jointly in structuring fish populations and communities.[42] A better understanding of patterns and processes that influence community structure is a continuing goal in ecology.[43] Abiotic factors, such as climatic factors, oxygen concentration, and other chemical variables,[44-46] are generally more important at the regional spatial scale, whereas biotic conditions may determine community characteristics at the local scale. The underlying mechanisms by which different factors affect fish communities are often complex and dynamic.[47]

Fish communities are structured by effects working at a regional scale, where abiotic factors limit the breadth of species distributions, and at a local scale, where biotic factors determine species survival within a system.[48] According to Degerman et al.,[49] fish populations may also be affected by predation and competition from various

types of organisms, including piscivorous fishes. However, in highly variable aquatic systems, abiotic factors appear to be more important in structuring communities at the local scale.[43]

Abiotic variables appear to gain importance in highly variable freshwater systems, such as tropical wetlands where a marked seasonal hydroperiod (dry and wet seasons) modifies water quality and quantity, differentially affecting fish survival and, consequently, modifying species richness and abundance.[50]

Biotic factors structuring fish communities

Predation: Predation is a major determinant of ecological local patterns in fresh water fish communities. Direct and indirect effects of predation influence a wide variety of individuals, population and community patterns, such as habitat selection, size distribution and species diversity.[51,47] Experimental studies indicate that habitat use by small stream fish is commonly constrained by risks associated with nearby to large predatory fish[52] and others. Predation risk is also a major component in predicting the distribution of prey fish among available habitats. Under experimental conditions, potential prey fish typically respond to the presence of predatory fish by restricting use to stream habitats that are shallow[53] or offer structural cover.[52]

The impact of predators on prey is not only dependent on ecological attributes of animals but also on attributes of the environment they inhabit. One such attribute, habitat complexity, is known to affect interactions between predators and prey.[54] Increased habitat complexity produces a greater potential niche space, which may allow coexistence of predators and prey.[53] Habitat complexity also acts to reduce predatory efficiency by providing refuges for prey.[47]

Stream-based studies have shown strong predation effects on fish communities.[5] Studies by Power et al.[53] and others have shown that predators can affect the choice of habitat by prey species within streams. This may lead to different assemblages being present in particular pools or riffles because prey species move to sites providing less risk of predation.[5] Prey species may move to areas where predators have difficulty in accessing them,[55] and these may be habitats different from those selected when predators are not present (e.g., piranha's (*Pygocentrus notatus*) effect on other species;[56,57] suggested that some of the structure attributed to stream fish assemblages is due to prey species' common avoidance of predators, i.e., species collectively assembles in habitats affording greater protection from predation.

While direct predation effects are often expressed strongly and quickly by the elimination of one or more prey species in the lake or stream system, there are additional, but less obvious, indirect effects by which predators may structure fish communities. When prey species alter their choice of habitat and foraging to reduce predation risk, they may experience corresponding changes in life history and fitness reduction. Hence, slower growth generally means that the individual and species remain vulnerable to predation for a longer time. As a result fecundity may be reduced if individuals mature at a smaller size, and individuals in poorer condition may experience increased mortality during environmentally stressful periods. For example, Shuter et al.[58] showed size-selective mortality in the overwinter survival of smallmouth bass. Therefore, predator avoidance may contribute to reduced growth that may be sufficient to prevent successful survival through the winter, thereby preventing the successful long-term survival of the species within such systems. Although the direct effect of smallmouth bass on cyprinids has been discussed, predation can lead to indirect biotic effects through competition.

Competition: Although there is no consensus regarding the role of interspecific competition in structuring stream fish communities, many literatures associated with resource partitioning among fishes suggest that competition may play an important role in the local organization of communities.[59] Most studies are based on field observations, and many suggest that niche segregation rather than competitive exclusion is the predominant outcome resulting from competitive interactions. Although there are few studies that compare the importance of different resource axes in separating species, habitat segregation appears to be the most prevalent resource-partitioning mechanism identified for lake and stream fishes.[60] However, most observational studies do not test directly whether competition is the most plausible mechanism responsible for the patterns observed or whether other uncontrolled factors could give rise to similar results. For example, allopatric speciation with posterior contact[61] can generate patterns equivalent to the competition hypothesis because of differential adaptation to distinct habitats.

In contrast to fish communities in lakes, the knowledge of the importance of competitive interactions in structuring stream fish communities remains somewhat superficial.[62] However, due to the environmental variability in stream systems, ecologists continuously debate whether behavioral, morphological, and physiological adaptations play a more important role than interactions such as competition.[60] The net increase of species richness along gradients environmental variability[63] and the fact that average population densities are often far below the maximum have been used to argue that competition is less important in shaping stream community structures. Streams simultaneously may have both "harsh conditions" where disturbance might play an important role and "benign environments" where interactions could be significant due to environmental stability.[64] According to Taylor et al.,[65] such controversy regarding the importance of competitive interactions in structuring stream fish communities may arise from different scales. So the importance of the range in habitat conditions and spatial scale is critical in whether competition is viewed as an important factor or not.

Abiotic factors structuring fish communities

Biotic factors, predation or competition, show comparable effects on the fish communities in both lake and stream/river systems. However, the abiotic influences in lakes and streams are quite different in their relative importance in determining the fish community composition. Many of the factors in lakes show variation principally in a vertical orientation whereas stream systems exhibit them in longitudinal arrangements, often semi replicated within pool–riffle pairings along the length of each stream.[14] Abiotic factors such as conductivity and pH are important factor for in fish community characteristics. It is suggested that abiotic factors affect fish abundance mainly by their effects on other species performance, particularly roach.[66] In general, the abiotic components of both systems can be divided into physical and chemical factors.[14]

Physical factors: The chemical characteristics of water combined with the physical features of the stream channel influence the presence or absence of particular aquatic organisms in a stream. Habitat features affect the species distribution at different spatial scales. For example, fish species distribution in a stream reach is affected by climate on a regional scale, channel gradient on a local scale, and particle size of substrate at a very small local scale. Other important factors such as stream meandering, steepness of banks, riparian vegetation, and variability of stream flow affect the habitat for fish in the stream. Not only does stream habitat have to be suitable for a particular species, it also has to support other biotas that are prey for the species.[67]

Temperature has been long recognized to limit the range of species both in a broad geographic scale[58] and at finer scales within particular lakes or streams.[60] High temperatures may produce high physiological demands and stress while also reducing the oxygen saturation levels of water. So the combination of increased metabolic demand and decreased oxygen availability can prove limiting or lethal.[68] Low temperatures may also limit the distribution of species and affect community composition.[13]

Stream morphology affects flow dynamics, both temporally and spatially. Geomorphology, soil development, and vegetative cover all affect the rates at which precipitation or snowmelt reaches the principal channel. Some studies show minimal effects on the adults in fish communities even after major floods.[69] The morphology of the streams varies such that some streams have well-developed pool–riffle patterns due to the underlying geology whereas other systems may have geologies that do not readily develop such patterns (e.g., recently glaciated Precambrian bedrock in north-temperate regions or alpine systems). Morphological features, such as depth, are often strongly related to community composition. Depth of streams is negatively correlated with the probability of winter freezing and oxygen depletion and with high water temperatures during summer periods.[52] Shallow streams are more variable with greater extremes in the range of conditions experienced by the associated communities in much the same way that shallow lakes experience greater extremes annually.

Structural complexity of the environment interacts with other characteristics of the abiotic and biotic environment and contributes to the community diversity. Substrate surface irregularities, such as rocks or woody material (i.e., necromass), alter the stream flow and deepen some regions through hydraulic scouring[70] with fish being attracted to the area because it is energetically less demanding than maintaining a position in the open water. In a similar way that hard surfaces enhance diversity, different assemblages may be found depending on the level of macrophyte cover provided, although this is not strictly an abiotic factor.

Stream flow or discharge, is the volume of water moving past a cross-section of a stream over a set period of time. It is usually measured in cubic feet per second (cfs). Stream flow is a function of the hydrology and geomorphology of an area and it controls important characteristics such as width, depth, current velocity and substrate composition and thus plays a central role in stream ecology.[71] Stream flow is affected by the amount of water within a watershed, increasing with rainstorms or snowmelt, and decreasing during dry periods. Flow is also important because it defines the shape, size and course of the stream. It is integral not only to water quality, but also to habitat. Food sources, spawning areas and migration paths of fish and other wildlife are all affected and defined by stream flow and velocity. Velocity and flow together determine the kinds of organisms that can live in the stream (some need fast-flowing areas; others need quiet, low-velocity pools). Different kinds of vegetation require different flows and velocities, too.[41,71]

The driving force of a stream, the current, is necessary for the respiration of many benthic invertebrates and reproduction of some fish species. Moreover, currents distribute nutrients and food down a river system, detritus for invertebrates and drifting insects for fish and birds and aid species dispersal.[72] As a result, many stream fishes and aquatic insects are adapted to either fast or slow currents. Streams that provide a variety of velocities usually support a more diverse aquatic community. Current velocity influences water quality and adds more diverse habitat types.[41] Stream velocities are not uniform in all parts of a traverse section but are reduced near the surface due to friction with the surface tension and along the bottom or sides of the channel due to friction with a solid surface .For this reason, in studies of organisms like fish and macro invertebrates that reside on the bottom, one may find velocities at the bottom interface are more important than the average velocity of the stream. Methods for current measurements very close to a surface are not well established and are often considered imprecise. However, for biological studies in streams such measurements may be critical.[73]

The effect of stream flow on fish communities has been studied on both spatial[74,31] and temporal scales.[60,75] Increased stream flow brings about an expansion of stream habitats and refugia, and increases the food available to stream fishes[75] although it may lead to the displacement of some species from their microhabitats and force them to increase their energy expenditure by living in sub-optimal environments.[60]

Fish can swim with amazing bursts of speed, but they may be unable to sustain this speed in high velocity waters throughout the entire length of a culvert. Swimming speeds vary with the species, size, and life stage of fish. Where fish are a concern, the velocity of water in the culvert (meter per second) should be based on the slowest sustained swimming speed for the fish in the stream.[72] For example, Species richness of fish in 15 prairie streams in Illinois and Ohio (USA) was correlated with flow variability with the highest species richness being found in headwater streams with a more constant flow while the downstream addition of species was greatest in streams with a relatively high constancy.[74] Using the coefficient of variation as a measure of assemblage stability and persistence, Oberdorff et al.[76] reported that flow variability had a negative influence on species richness by increasing assemblage variability. Environmental variability also had strong effects on recruitment and mortality,[74,76] which led to local extinctions, and immigration and emigration of individual fish.[11]

For many fishes, maintaining position in habitats with high current velocity is energetically costly.[77] Therefore these fishes, including catostomids, *Pomoxis spp.* and *Micropterus spp.*, use deep, slow-flowing pools.[78] However, some fishes, such as percids, cottids, *Noturus spp.* and *Campostama spp.* have a flattened or fusiform body shape that reduces current drag and allows these fishes to maintain position in fast-moving waters (e.g., races and riffles) with minimal energy expenditure.[77] As a result, these fishes are able to feed upon benthic invertebrates that occur in relatively high densities in these habitats.[79]

Depth and Water velocity are probably the most important requirements of spawning fish and depth is probably the most serious limitation fish passage during periods of reduced flow. Moreover there exists minimum and maximum depth for each species. Water level fluctuations related to flow variability are important signals for many tropical fish species and the onset of the rains induces flow in intermittent and seasonal streams leading to continuity of streams, inundation of floodplains and the flushing of terrestrial nutrients into the rivers thus expanding the food resources available to fish.[79] Many tropical fishes make extensive upstream spawning migrations at this time, or move into floodplains to spawn.[80]

Based on depth and velocity streams can be classified in to three major microhabitats as pools, runs and riffles. Fishes would be expected to choose sites where they are less likely to be destabilized by large velocity variations.[81] Large fish spend most of their time in deep pools and occasionally move to shallow areas (may be runs or

riffles) to feed. Small fish often use shallow habitats to feed or to avoid larger, predatory fish.[80] For example, to avoid predation by mammalian and avian predators, larger fish may use deeper habitats,[82,52] whereas small fishes may use shallow habitats to avoid predation by larger piscivores.[52] In addition, intraspecific competition influences habitat use, because larger individuals can force smaller conspecifics out of preferred habitats. For example, as smaller fishes aggregate in shallow habitats to avoid predation, these fishes may experience large overlap in resource use.[52]

Chemical variables: The chemical composition of the water in rivers varies strongly, depending on season, time of day, place, and depth.[83] Of all the chemical substances in natural waters, oxygen is one of the most significant. The annual cycle of oxygen in a stream is closely correlated with temperature. The principal chemical factors affecting community composition identified repeatedly in studies of lake and stream fish communities are dissolved oxygen levels.[66] They indicated the importance of oxygen and its relationship with water temperature (e.g., the capacity of water to hold oxygen decreases as temperature increases while metabolic demand typically increases). Large predatory species generally require higher levels of oxygen, and many smaller species have behavioral and physiological adaptations that allow them to survive even at low oxygen levels.[84] Therefore, periodic reductions in dissolved oxygen levels contribute to the loss of predatory species such as pike (*Esox sp.*) and bass (*Micropterus sp.*) whereas prey species may be relatively unaffected.[66]

Streams also exhibit variation in the level of oxygen present, perhaps without the availability of oxygen-rich counterparts (e.g., hypolimnetic waters) being available as a refuge. Shallow, slow-moving sections of streams are prone to temperature elevation and decreased oxygen levels due to high decomposition and respiration rates, thereby stressing fish and favoring different species. The combination of temperature and oxygen stress may eliminate intolerant species, such as salmonids, from stream systems. Tropical systems having low flow rates, or flood-plain ponds, frequently develop low oxygen levels due to high ambient temperatures and high respiration and decomposition rates. Tropical fishes exhibit a greater degree of air breathing relative to temperate fishes,[85] likely reflecting this selective pressure imposed on these communities due to anoxia.

Increases of stream water temperature stress aquatic organisms by reducing the dissolved oxygen concentration of the water, by disrupting the timing of thermal signals that trigger development stages, or by causing direct mortality.[72,86,87] In addition, the removal of riparian vegetation and channelization of streams can disrupt stream water temperature regimes, causing further disruption or mortality to aquatic organisms.[86]

Human impact on stream fish community composition

Generally, stream flow is affected by both forces of nature and by humans (such as urbanization and land use changes). In undeveloped watersheds, soil type, vegetation, and slope all play a role in how fast and how much water reaches a stream. In watersheds with high human impacts, water flow might be depleted by withdrawals for irrigation, domestic or industrial purposes. These activities influence both the velocity and depth of the streams which directly or indirectly affects for those stream dwelling fishes. Dams used for electric power generation may affect flow, particularly during periods of peak need when stream flow is held back and later released in a surge. Drastically altering landscapes in a watershed, such as with development, can also change flow regimes, causing faster runoff with storm events and

higher peak flows due to increased areas of impervious surface. These altered flows can negatively affect an entire ecosystem by upsetting habitats and organisms dependent on natural flow rates.[71]

Effects of land use on stream fish ecology

Land use, including agriculture, forest harvesting, and urbanization, can have profound impacts on receiving water bodies.[88] Land use changes often alter hydrologic flow regimes and hydrogeomorphology, which can adversely impact stream aquatic biota, reducing species diversity and richness.[89] It has major influences on stream ecosystems. Soil erosion associated with poor agricultural practices and forest clearing, which often precedes agricultural activity, can contribute significant amounts of sediment to streams.[2,88] The past effects of land uses such as deforestation or agriculture can have significant long term effects on fish and macro invertebrate communities that can persist long after that land use has ceased or has been replaced by another type of land use.[90,91]

Impacts of land use change can include alteration of stream flow (velocity and discharge), sediment, thermal regimes, stream geomorphology, aquatic and riparian habitat, the addition of pollutants and nutrients, and a reduction of aquatic species richness and diversity.[88] Agriculture can result in excess nutrient loading that can lead to eutrophication and anoxia.[92] In addition, habitat degradation associated with riparian forest clearing, channel straightening and sedimentation, is often present in agricultural streams, and can lead to substantially degraded fish and macro invertebrate community assemblages.[93] Aquatic communities can be affected by forest harvesting activities, which often leads to soil erosion and sedimentation of streams and increases in stream temperature.[94]

According to Dudgeon,[95] there are four main categories of human induced threats to fish: flow alteration or regulation, pollution, catchment alteration and overharvesting. These cause streams to lose integrity, frequently resulting in low levels of biodiversity and lower productivity of the ecological communities' involved.[96] Logging and deforestation is a form of catchment alteration, causing changes in water flow and dramatic increases in sedimentation.[97]

Agriculture is one of the main factors responsible for stream degradation in the United States.[98] Urban land use also has adverse effects on stream and water quality, especially when present in critical amounts and close to the stream channel.[99] Agriculture is the dominant land use feature of many southern Michigan basins, including the Raisin, while others, including the Huron, are in areas of high urban sprawl.[100] In addition, wetlands have been reduced to half or less of pre settlement estimates,[101] leading to changes in flow stability and aquatic habitat. Human activities reflected in altered land use have resulted in high levels of degradation in stream ecosystems in many areas.[88] Similarly, Land-use and physical habitat variables have been shown to be strongly related to biological metrics in other studies of the Raisin River.[102,103] Several studies report agriculture to have a strong influence on fish assemblages.[90,104,105] Agriculture increases run-off and sediment transfer to a stream[40,106] although the clearing of vegetation and the installation of structures such as drainage tiles.[106] Increased sediment loads limit fish habitat and are associated with poor biotic condition,[107] due to sediment deposition covering gravel, filling interstitial spaces, and burying logs.[107] Many fish require stream substrate relatively free of fine sediments for reproduction.[40] The increased sedimentation associated with agricultural practices decreases survival of eggs and larvae of fish, and the availability of food for fish[104,107,108] observed a reduction in substrate complexity in tributaries to the Chattahoochie River as a result of the sediment deposited in agricultural streams, and

Roth et al.,[102] reported a negative correlation between habitat metrics and fish biotic condition for sites within the Raisin River basin.

Land use throughout catchments and along stream margins can substantially influence in-stream physical, chemical, and biological habitat. Physical habitat for fish includes substrate, extent of pools versus riffles and runs, vegetation, undercut banks, flow amount and variability, and any other stream feature whose presence and quality can be important to the presence and abundance of fish species in a stream segment.[109] Physical habitat degradation can therefore have large effects on the fish assemblages present in a stream.

In relation to land use, change in stream morphology plays a critical role in the structure and function of streams in relation to habitat patch structure and hydraulic conditions. For example, at the reach scale, local geomorphic features influence patch dynamics and habitat complexity.[110] Local geomorphology is influenced by slope and sinuosity of the stream channel, which can vary based on the position of a reach longitudinally within a stream. In line with this, headwater streams tend to exhibit steeper slopes and straighter channel form and are typically characterized by coarser sediment. Furthermore, larger streams with well-developed floodplains are more prone to lateral meandering and have shallower gradients, and finer sediment.[111] Streams often exhibit corresponding longitudinal patterns of fish and macro invertebrate's assemblage structure associated with the progression of the stream from headwaters to mouth.[112] However, longitudinal progressions are not always continuous and localized geomorphic features are understood to exact greater influence over community composition at the scale of a single reach, riffle or pool.[110]

Effects of urbanization

Urban development affects stream hydraulics and sediment input, transported deposition and thereby, altering aquatic habitat and the resident community of aquatic organisms.[113,114] Urban development impacts the environment in a variety of ways, including reduction of fish and wildlife habitat, increased impervious surface area, introduction of exotic species and disruption of natural ecosystem processes.[115] Low levels of urbanization, with as little as 10% impervious surface area were shown to result in detectable changes in aquatic community composition.[116] Urbanization also has well documented effects on fish assemblages and runoff delivered to a stream increases markedly due to greater imperviousness of the basin,[99] causing increased flow variability and reduced base flows, which in turn alter the erosion and temperature in a stream.

Increasing urban populations, and the urban sprawl associated with the increase in population, are known to alter drainage basins and the streams that drain these urbanized catchments.[116] A growing human population accompanied by urbanization and industrialization have led to over exploitation and pollution of freshwater resources and have consequently impacted on aquatic ecosystem health[117-119] and increased demand for food.[120] These factors have consequently led to deterioration in water quality, a reduction in water quantity and degradation of freshwater biodiversity habitats.[121] For example, industrialization over the past half century has led to huge increases in the discharge of toxic chemicals into fresh water bodies, some of whose toxicity are partly or totally unknown. In addition, many of these chemicals are persistent and could transform into by products that may have adverse effects on water resources. As a result, the ability of freshwater ecosystems to provide clean and reliable sources of water, maintain the natural water cycle and the biological food web as well as provision of food and recycling of nutrients have been severely impaired. Additionally, these have limited the amount of useable water available for biodiversity, for further economic and social developments as well as natural ecosystems functioning.[121]

Given its high impact, urbanization is a major concern for water resource managers, engineers, geomorphologists and aquatic ecologists. Streams in urbanizing watersheds differ greatly from natural stream systems.[114] Urban stream ecosystems are subject to a variety of insults ranging from accelerated rates of sedimentation to bio-magnification of toxic chemicals to flash flooding. Even though urbanization brings drastic modification of landscape, it is generally thought to have limited negative effects on stream fish communities when its components are considered as single events. For example, the expansion of one road or the building of one bridge would likely have a negligible effect on the overall health of any given watershed. However, long-term cumulative effects of urbanization in a watershed can be comparable to those resulting from high intensity disturbance of streams, such as point source pollution or clear-cut logging.[122]

Stream flow regime alterations resulting from urbanization can include increased sediment load, a flashier hydrograph characterized by higher peak discharge and lower base flow, elevated water temperature, higher nutrient loading, increased algal biomass, and the addition of petroleum products, pesticides and other pollutants. In line to this, Water flowing over surfaces such as roads, sidewalks, parking lots and rooftops, can also contribute to increasing water temperature. Hot asphalt roads and other surfaces conduct heat to rainwater flowing in contact with it and the water carries that energy to the stream and the combined effect of these alterations is referred to as "The Urban Stream Syndrome".[114] Urban induced impacts of natural hydrologic flow regimes and additions of excess nutrients and anthropogenic pollutants can damage fish, macro invertebrates, algae, and macrophytes communities, reducing species richness and diversity Walsh et al.[123] Increases in impervious surfaces in urban areas can result in reduced infiltration and subsurface flow and increased surface runoff. Decreased infiltration can cause stream levels to rise faster during runoff events and can reduce sources of base flow from groundwater.[114] Higher stream velocity may increase bank erosion and streambed cut and result in declines of habitat diversity.[123]

Moreover, it has been well established that urbanization changes the hydrology, morphology, water quality and ecology of streams and the severity of these changes are directly linked to the degree of watershed imperviousness.[115] Studies have shown that fish community parameters (i.e. species diversity, index of biotic integrity (IBI) and species richness) decline with increasing impervious surface cover (ISC).[99,122] Generally, as Alberti[115] and others explained, as urbanization increases, the physical, biological and chemical degradation of streams increases, with the most dramatic changes occurring in the early stages of urbanization.

Effects of stream sedimentation

Sediment is the most known water quality pollutant worldwide. As a result, the issue of sediment in aquatic environments has been a topic of concern for many decades.[124] It affects most aspects of the food chain of aquatic environments and all freshwater stages of fish particularly the salmonid life cycle. In small streams, effects are more pronounced since juvenile salmonids that remain in these streams are wholly dependent on their natural stream for meeting their life cycle needs. Cloudiness due to turbidity reduces the volume or depth of the photic zone; reduces local primary production; and triggers a cascade of impacts, from one trophic level to the next, involving phytoplankton, zooplankton, insects, freshwater molluscs, and fish.[125] At each trophic level, excessive concentration of clay can cause direct effects (mortality, reduced physiological function, and habitat alienation) and indirect effects (decreased rates of growth, reproduction and recruitment) linked to reduced food supply.[124,125] In addition ,turbid water results in a stress response in salmonids,[126] which

may result in reduced growth, reduced ability to tolerate additional stressors, compromised immune system, impaired outmigration behaviour, reduced osmoregulatory competence, etc; all of which further decrease survival rates.[127]

According to Turner,[128] the loss of sediment from landscapes is influenced by many human activities and small sediment particles make their way into streams from sheet and rill erosion in the watershed or erosion of stream channels. Moreover, Characteristics of a watershed define the sedimentation of a stream and can be considered natural if human activities are not contributing to the sedimentation. Natural inputs of sediment are controlled by climate, soils, native vegetation, and watershed slope. These natural inputs of sediment have helped define the conditions from which the current biotic community has evolved. Conversely, a stream can be considered to be unnaturally or excessively impacted by sediment when human activities are contributing sediments. Human activity within a stream's watershed alters the natural sediment balance and can lead to detrimental effects on aquatic life. For example, some human activities like construction, urbanization, row cropping, overgrazing, livestock access to the stream, logging, riparian degradation, channelization and gravel mining can alter a stream's natural sediment regime (increases over the natural levels).

Accelerated sedimentation of riverine habitats due to human activities (e.g. agriculture, forest harvesting, urban development) is known to have wide-ranging impacts on river ecosystem health, particularly river biota and this accelerated accumulation of sediments in aquatic ecosystems leads to a decline in surface water quality and biodiversity.[40] For example, Sediment from soil erosion has long been considered the most serious threat to water quality in Illinois. Farm fields, mines, cut-over forests, and unpaved roads are sources of sediment in streams in rural areas. While in urban areas, ill-managed construction sites can greatly elevate sediment levels in streams. Excessive amounts of sediment in the water can destroy macro invertebrate habitats by filling the spaces between boulders and rocks in which many of these organisms live. Sediment can also harm the filter-feeding mechanisms of some aquatic organisms, clog the gills of others, or bury macro invertebrates entirely.[129]

Based on Waters[40] and other studies, there are adverse impacts on aquatic ecosystems that result from excessive sedimentation and turbidity. Sediments fill the interstices of gravel and cobble stream bottoms, greatly decreasing the spawning areas for many fish species and the habitat for macro invertebrates, which serve as food for many fish species. In addition, Sedimentation in stream channels reduces in-stream cover for fish and depresses their food supply by filling channel interstices and reducing the substrate's potential to produce food. Large amounts of fine sediment kill fish embryos incubating in the stream channel materials.[130] Large concentrations of fine sediment in spawning areas impede the intra-gravel subsurface water flow, causing embryos to receive less oxygen and allowing toxic metabolic wastes to accumulate. Also, fish need in-stream cover, especially during their early years of development and during winter.

Fine sediments filling the interstices reduce the amount of protective cover and force young salmonids to live in surface waters where they are more exposed to severe winter conditions. Salmonids are dependent on aquatic and terrestrial invertebrates for their food. Fine sediments can cover the food-producing rubble and gravel channel areas, reducing the quality of the aquatic insect's habitat; this, in turn, impairs the quantity of food available for salmonids.

High loads of fine sediment in rivers are known to impact fish, both through direct physical effects, and less directly as a result of

effects on habitat and food availability. Suspended sediments can scour and abrade fish, particularly the gill-rakers and gill filaments, making fish in turbid waters more susceptible to disease and even causing mortality in extreme cases.[131] Fish gills are delicate and easily damaged by fine sediment. As sediment accumulates in the gills, fish respond by excessively opening and closing their gills to try to remove the silt. If irritation continues, mucus is produced to protect the gill surface, which may impede the circulation of water over gills and hence interfere with respiration.[132] Under prolonged exposure to sediments, fish may actually die due to physically damaging and clogging their gills. For example, levels of 800mg/l over a prolonged period (i.e. 10 days) have caused mortality in rainbow trout.

Deposited fine sediments can cause a reduction in suitable spawning habitat, reducing survival or hindering development of eggs and fry, and can reduce habitat and cover for juvenile and adult fish. Growth rates of fish are also commonly decreased in rivers with high fine sediment loads, due to a reduction in the feeding efficiency of visual-feeders in low clarity waters, as well as reductions in the invertebrate food-supply for drift-feeders. In order to avoid the impacts of fine sediment, natural movements and migrations of some fish species may be modified, with some fish species exhibiting avoidance of highly turbid waters. As with benthic invertebrate communities, fish community composition may ultimately change as certain fish species are favored over others,[133] and diversity may decrease due to changes in migration patterns, avoidance behavior or reductions in suitable habitat.

A greater variety of microhabitats exist when large sediment fractions (i.e. gravel, cobble, and boulders) dominate the substrate than when fine sediment (i.e. sand, silt, and clay) dominates the substrate profile.[134] Young fish often use pools and the interstitial spaces between gravels, cobbles, and boulders for refuge. Sedimentation can fill up pools and inundate the interstitial spaces, thereby eliminating quality habitats.

Effects of climate changes

Climate change affects fish populations through its influence on physical environmental factors such as water chemistry and physical limnology. Warmer water contains less dissolved oxygen than colder water. Since fish metabolism increases with elevated water temperature, climate change will likely result in increased oxygen demand and reduced supply. Higher temperatures will tend to increase duration and strength of thermal stratification in temperate zones.[135]

In addition according to Swanston et al.[136] the two driving forces of climate change that affect water resources are increased temperature and shifting precipitation patterns. The combination of warmer temperatures and changing precipitation patterns suggests that we will see a significant increase in the amount of winter precipitation falling as rain rather than snow and that freezing rain is more likely to occur. The magnitude and frequency of precipitation are also projected to increase in spring and fall.

These changes in temperature and precipitation will affect water cycles, with major impacts on lakes, streams, groundwater and wetlands. Some of the physical responses we can expect to see include: Increased average surface water and groundwater temperatures, Shorter periods of ice cover on lakes and streams, Decreases in the thickness of lake ice cover, Increased evapotranspiration rates during the longer growing season, Increased number of freeze thaw events, More groundwater recharge due to increases in winter and spring precipitation, (Groundwater recharge refers to water that infiltrates and moves downward into the saturated zone of an aquifer), Changes

in recharge and discharge based on whether precipitation falls as rain or snow, (Groundwater discharge refers to groundwater that reaches the surface, such as springs, seeps, lakes or rivers) and Increased number of high water events causing flooding.[136]

Climate change affects the composition of aquatic species living in lakes and streams, including invasive species. Floods and droughts alter the physical conditions of lakes and streams, affecting the suitability for plant and animal species and in some cases making them better suited for invasive species. Unusual floods can connect water bodies and allow invasive species to enter waters that had typically been confined or isolated. Rising temperatures affect thermal thresholds of plant and animal species, and polluted runoff from increased precipitation or heavy storms affects many facets of aquatic ecosystems, such as algal communities.

Increased temperatures may lead to introductions and survival of aquatic invasive species not previously recorded in Wisconsin. Species not native to the area may be more likely to survive when temperatures rise because many species, such as hydrilla, water hyacinth or red swamp crayfish, will be able to overwinter.

These species are native or well established in the southern U.S. but thought to be limited by cold temperatures and ice cover; however, two recent findings of these species in small constructed ponds in Wisconsin have shown that over wintering is possible and will become even more likely with reduced or no ice cover. An example of a southern native fish species that could further invade due to warmer temperatures is the gizzard shad, a problem species in reservoirs in Ohio and other areas south of Wisconsin.

Effects of climate change on rivers and streams are its effect on fish habitat and its composition. Rising water temperatures, changes in groundwater recharge and stream base flow, and an increase in large runoff events from heavy storms may all affect stream channels or other habitat characteristics that fish require for survival.[136]

Effects of Introduction of Exotic Spices

Competition for food resources and habitat between native and introduced fish may result in reduced growth, survival and reproductive potential of native stocks. If introduced fish successfully occupy habitat and use resources that would otherwise be used by native fish then, over time, the characteristics and contribution of the native stocks may change. This issue of competition for food, and space, with both conspecifics and other species may be particularly problematic when unnaturally high densities of fish are released in restricted areas. This could potentially be realized within the native stock in terms of overall size of the spawning stock, or the size or age at first maturity of the native fish. Furthermore, the increased energetic costs resulting from competition for food and territory may result in reduced growth and reproductive capacity of native stocks. The repeated injection of fish into fisheries negates the effects of mortality (natural and fishery), and could potentially minimize the chances of native fish maturing and occupying these niches. Ultimately, this has the potential to impact negatively on the spawning stock.[137]

There is a strong belief that introduced species frequently outcompete indigenous species to the point of causing a considerable reduction in abundance, or even their complete disappearance. Brown[138] trout are reported to have competed with, and displaced, indigenous salmonids in North America, and are actively excluded from some locations to facilitate the rehabilitation of populations of indigenous salmonids, including brook trout, *Salvelinus fontinalis*, and Atlantic salmon, *Salmo salar*.[139]

Effects of tourism or sports on streams

Sport fishing of wild and stocked game fishes in lakes, rivers, and along coasts has become one of the most popular recreational activities internationally.[140] Intimate contact with nature while fishing is claimed to be one of the major incentives for sport fishing.[141] The increasing demand for game fish and suitable fishing and swimming areas, is in conflict with the decreasing water quality owing to other human activities.[142]

Fish are sensitive to many stresses from parasites or diseases to acidification. Furthermore, due to such factors as rapid growth rates, large body sizes, habitat choice, and trophic level, many fish have the capacity to bioaccumulate toxic substances. It has also been suggested that response by fish to stress at the population level can be identified before changes at the ecosystem level.[143] These features make many fishes suitable as early warning signals of anthropogenic stress on natural ecosystem dynamics, or conversely, as indicators of ecosystem recovery,[144,145] and of resilience.[146] In addition to the physical condition of fish, fish species richness and composition, trophic composition, and abundance can be used for monitoring human influence on water quality (cf. Index of Biotic Integrity, e.g. Fore and Karr.[147]

Summary

Determining which factors are responsible for the structure of communities is a primary focus in ecology. Species distribution and abundance within a particular environment is determined both by tolerance to physical conditions and interactions with other organisms. Freshwater ecosystem and their resources are indispensable part of human life and activity, and health of those freshwater ecosystems is visible in the wellbeing of the fish assemblage they support. Knowledge of spatial and temporal patterns of fish assemblage structure and their associated environmental factors is a fundamental requirement for understanding aquatic ecosystem functioning and evaluating ecosystem health for environmental management. Over large geographical and habitat scales, environmental filtering (the survival or elimination of species in the community in response to environmental constraints), and anthropogenic effects are generally the most important determinants of assemblage variability.

Streams are important habitats, providing shelter and feeding opportunities for a wide range of organisms like fish, insects, plants, mollusks, birds and mammals. Natural variability in fish communities can be attributed to differences in elevation, water temperature, physical habitat, water quality, and other important characteristics of the environmental setting.[148] Low abundances and types of fish species may be a result of water quality and habitat that can be affected by the surrounding land use.

Fish community structure depends on biotic interactions and abiotic variables. Predation is a major determinant of ecological patterns in fresh water fish communities. The impact of predators on prey is not only dependent on ecological attributes of animals but also on attributes of the environment they inhabit. Competition is a basic principle of modern ecology and population biology which tries to explain community and species composition in terrestrial and aquatic ecosystems. Biotic factors, predation or competition, show comparable effects on the fish communities in both lake and stream/ river systems. However, the abiotic influences in lakes and streams are quite different in their relative importance in determining the fish community composition.[149,150] In general, the abiotic components of both systems can be divided into physical and chemical factors.

Habitat features affect the species distribution at different spatial scales. In a regional scale fish species distribution can be affected by climate, where as factors like channel gradient and particle size of substrate, affects at local and very small local scales respectively. Temperature limit the range of fish species both in a broad geographic scale and at finer scales within particular streams and low temperatures may also limit the distribution of species and affect community composition. In addition, depth and water velocity are the most important requirements of spawning fish and depth is the most serious limitation fish passage during periods of reduced flow. In addition, stream velocity is necessary for the respiration of many benthic invertebrates and reproduction of some fish species. Streams that provide a variety of velocities usually support a more diverse aquatic community. Current velocity influences water quality and adds more diverse habitat types.[151,152]

The chemical composition of the water in streams varies strongly, depending on season, time of day, place, and depth. Of all the chemical substances in natural waters, oxygen is one of the most significant chemical factor affecting fish community composition. Increases of stream water temperature stress aquatic organisms by reducing the dissolved oxygen concentration of the water. Besides this, removal of riparian vegetation and channelization of streams can disrupt stream water temperature regimes, causing further disruption or mortality to aquatic organisms.

In environments dominated by human activity, such as the agricultural practices, channel morphology is strongly influenced by anthropogenic factors and affects both abiotic and biotic components of a stream. Moreover, stream flow is affected by both forces of nature and by humans (such as urbanization and land use changes). As a result, both the velocity and depth of the streams can be influenced these forces which directly or indirectly affects for those stream dwelling fishes.[153]

Land use, including agriculture, forest harvesting, and urbanization, can have profound impacts on receiving water bodies .The past effects of these activities can have significant long term effects on fish and macro invertebrate communities that can persist long after that land use has ceased or has been replaced by another type of land use. For example agriculture can result in excess nutrient loading that can lead to eutrophication of streams and anoxia of fishes. Moreover, increased sediment loads limit fish habitat and are associated with poor biotic condition due to sediment deposition covering gravel, filling interstitial spaces, and burying logs.

Urban development impacts the environment in a variety of ways, including reduction of fish and wildlife habitats. Besides an increased demand for food, a growing human population accompanied by urbanization and industrialization have led to over exploitation and pollution of freshwater resources and have consequently impacted on aquatic ecosystem health.[154] Streams in urbanizing watersheds differ greatly from natural stream systems. As a result, urban stream ecosystems are subjected to a variety of insults ranging from accelerated rates of sedimentation to bio-magnification of toxic chemicals to flash flooding. Even though urbanization brings severe modification of landscape, its effect on stream fish community may be limited but the main concern is its long term cumulative effects.

Sediment is the most known water quality pollutant worldwide. A stream can be considered to be abnormally or excessively impacted by sediment due to human activities are. Sediments fill the interstices of gravel and cobble stream bottoms, greatly decreasing the spawning areas for many fish species and valuable habitat for macro invertebrates that serve as food for many fish species. Sedimentation in stream channels reduces in-stream cover for fish and depresses their food supply by filling channel interstices and reducing the substrate's potential to produce food.

Conclusion

In conclusion, stream fish communities are influenced by many biotic and abiotic factors either directly or indirectly causing physical damage, habitat destruction which in turn causes food lost. Biotic interactions such as competition, predator avoidance, and prey availability influence fish communities. Generally, fish habitat requirements in fresh water streams are related to a number of factors, including the population dynamics of the fish themselves, geomorphology and climate, and the flow regime. In addition, the quality and quantity of riparian and in-stream habitat is vital to fish, particularly with regard to temperature, dissolved oxygen, sediment and pollutants.

Acknowledgments

Conflicts of interest

None.

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