ecosystem-based management, and public awareness and concern are growing rapidly. In plain language, in order to manage, restore, and conserve lotic ecosystems, we have to understand how they function, we need to assess their condition over time in order to identify status and trends in river health, we need tested and proven management practices, and we need the will and organizational structure to put good intentions into action. The following sections will briefly examine some of these issues, which offer many opportunities for new partnerships among scientists, practitioners, and policy specialists to begin to reverse the many negative trends documented in the preceding section.

## 13.3.1 Bioassessment

Monitoring the status and trends of freshwater biota and ecosystems is essential in order to quantify human impacts and evaluate the effectiveness of management actions. Biological indicators of water quality have been in use for at least 100 years, and initially relied on the use of suites of species that were sensitive to organic enrichment and low oxygen levels. Known as Saprobic Indices, these were in wide use in Europe by the 1950s (Wright 1995). In the United States, water quality measures such as low dissolved oxygen, species diversity metrics such as the Shannon-Weaver Index, and a few indicator species known to be intolerant of pollution were the primary tools for monitoring stream condition into the 1970s. The 1972 amendments to the Clean Water Act called for maintaining and restoring the biological integrity of freshwaters, and that language is now reflected in widely used integrative ecological indices based on the biota and on aspects of habitat (Karr et al. 1986, Plafkin et al. 1989) including Karr's Index of Biological Integrity (IBI). The goal of these indices is to measure river condition, and increasingly this is referred to as "river health," in the very broad sense that a healthy river is one in good condition (Karr and Chu 1999).

The IBI is a multimetric index, meaning that it is the sum of 10-12 individual metrics, including species richness and composition, local indicator species, trophic composition, fish abundance, and fish condition. Because it is based on multiple metrics, which are considered to be sensitive to different levels and types of environmental stress, the IBI should be a useful integrator of multiple stressors affecting biological assemblages (Figure 13.16). Biotic integrity has been shown to vary within a region in relation to land-use measures and other indicators of environmental conditions (Section 13.1.3). The IBI has subsequently been adapted for use with macroinvertebrates (Kearns and Karr 1994) and periphyton (Hill et al. 1999).

Standardization of biological assessment faces a number of methodological challenges. The number of species in a sample increases with sampling effort and stream size, and varies across regions owing to differences in the regional species pool (Section 10.1). These are difficult but resolvable problems, and have led to prescriptions of sampling effort (such as a stream length equal to 25 times its width), different cut-off levels for metrics based on stream size (five darter species may be necessary for the highest score in a third-order stream, versus 1-2 species at a first-order site), and regional IBIs (including different scoring systems for warm water and cold water fish faunas) (Karr and Chu 1999).

Another approach that is gaining favor uses statistical models to predict the expected set of species from environmental site characteristics. Known as Rivpacs (River Invertebrate Prediction and Classification System) when first developed in the United Kingdom (Wright et al. 1984, Moss et al. 1987), and Ausrivas for its application in Australia (Marchant et al. 1997), it uses a multivariate model developed using undisturbed reference sites to predict which species have a high probability of occurring based on environmental measurements that characterize the site. When a test site is to be evaluated, its environmental conditions are used to predict the expected

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FIGURE 13.16 'physical, chemic 2000.)

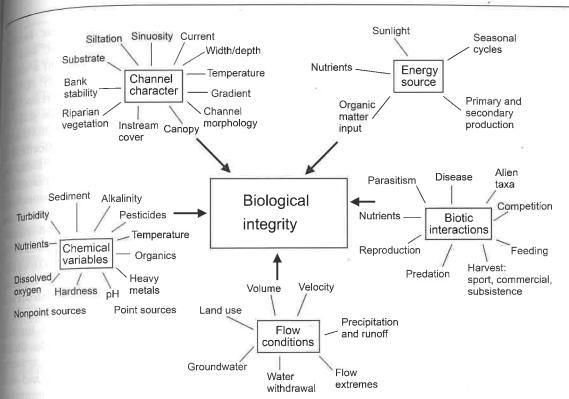
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rigure 13.16 The Index of Biotic Integrity measures changes to stream health in response to human alterations to physical, chemical, and biological components of the five principal factors depicted. (Reproduced from Karr and Chu 2000.)

assemblage if the site is unaltered, and then the observed assemblage is compared to the expected (O/E). Not for the statistically faintofheart, O/E predictive models have proven to provide a sensitive measure of disturbance in southeastern Australia (Marchant et al. 1997) and are under development in other countries, including the United States (Hawkins 2006). In Principle this method requires a substantial number of undisturbed streams to use as reference sites, but in some areas all streams may be moderately or substantially disturbed. This has led to the use of "least-disturbed" and "bestavailable" sites for scoring purposes (Stoddard et al. 2006), which is useful for comparison of sites within a region but makes difficult any comparison of index values across regions.

Analyses that are based on species traits represent yet another approach that holds promise for biological assessment. In one example, Usseglio-Polaterra et al. (2000) assembled data on 22 traits for 472 benthic macroinvertebrate taxa of the Loire River, and then employed multivariate ordination techniques to examine longitudinal changes in the assemblage. Because they were able to detect changes linked to dams, urban zones, and tributary inputs not detected with faunal data alone, they suggest that trait analyses may prove a useful additional method of bioassessment.

Although bioassessment is widely and successfully used to determine impairment of streams and compliance with water quality standards, the ability to combine state assessments into

regional or national assessments of ecological integrity has been hindered by the lack of a common interpretative framework. To address this issue, Davies and Jackson (2006) proposed a model of biological response to a gradient of environmental stress within a framework of six tiers that describe how closely a water body resembles its natural state (Figure 13.17). By associating narrative descriptions of the response of ten ecological attributes to increasing levels of stressors, this model intends to provide more uniform and consistent assessment of the status of aquatic ecosystems.

## 13.3.2 Restoration and recovery of lotic ecosystems

Relatively intact streams and rivers can be managed to maintain a full complement of species and the natural range of ecosystem processes that characterize a healthy system, and degraded systems can be improved and restored. There is general agreement that emphasis should be placed on maintaining and restoring physical

and biological processes that create healthy ecosystems and high-quality habitat, and on designing site-specific activities within a wholecatchment context (Roni et al. 2002). Specific activities are diverse and vary with stream type, the nature of the problems, and the goals of managers (Table 13.4). In the Pacific Northwest and other areas where salmonid enhancement is the primary goal, efforts commonly focus on improvements to habitat through the placement of boulders and wood, on restoring connectivity by replacement of poorly sited road culverts and reconnecting the stream channel to off-channel habitats such as beaver ponds, and on protecting the riparian zone as a source of shade, cover, and allochthonous inputs (Roni et al. 2002). Especially for rivers that now lack a mature riparian as a source of wood, the addition of large wood to streams has become a widely used method to enhance stream habitat worldwide (Reich et al. 2003). In physically unstable systems, bank stabilization to reduce slumping and sediment inputs often is a major goal, accomplished

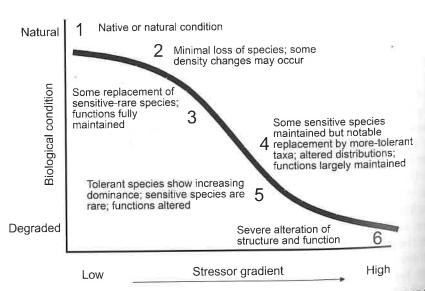


FIGURE 13.17 Conceptual model depicting changes in biological condition of a stream in response to an increasing gradient of anthropogenic stress. Numbers 1 through 6 refer to six tiers of river condition from fully natural and unaltered to that which is highly degraded. (Reproduced from Davies and Jackson 2006.)

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TABLE 13.4 practices, L' restoration.

Goal

Aesthetics/ recreation/ education

Bank stabil

Channel reconfigura Dam remov

Fish passag

retrofit

Floodplain reconnecti

Flow mod

Instream 1 improvem

Instream s managem Land acqu

Riparian managem

Stormwai managen

Water qu managen