Chapter 14
Recreational Fisheries: The Need for Sustainability in Fisheries Management of Alpine Rivers

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14.1 Introduction

Fishing is an ancient practice in the acquisition of natural resources dating back to the Middle Stone Age. The principal reasons why humans visit waters to catch fish underwent a substantial transition in many countries throughout the preceding decades. While fishing to gain food still is an important factor in tropical areas of the world, especially in Africa and Asia, it is mostly for sport in inland waters of economically higher developed countries, as in major parts of Europe and North America (Welcomme 2016). There, the majority of fishermen nowadays fish solely to obtain recreation or to experience the aesthetics of nature.

However, many people still like to fish, and recreational fishing has developed into a notable economic sector in European countries (Arlinghaus 2004). Besides the economic values related to recreational fishing, social and ethical components are of increasing importance. Along with the growing common perception that fishing is a reasonable pastime, animal welfare and nature conservation issues are raised that, in extreme cases, deem fishing morally reprehensible (Arlinghaus et al. 2012).

Aside from social perceptions of fishing, it is significant that anglers represent the most prominent stakeholder group for aquatic ecosystem concerns in many areas of the world. Fishermen represent a very valuable source of experience and knowledge that can be explicitly valuable whenever nature conservationists are in need of support from a larger group of people (see Chap. 16). Often they are the “memory of a river,” recalling fish sizes, catch rates, and ecological conditions. Therefore, many ideas or campaigns to protect or restore freshwater ecosystems are driven by people who enjoy fishing and thus have developed a closer tie to aquatic ecosystems.

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As testament to their reliable support for nature conservation and their serious interest in "fish welfare," recreational fisheries/fishermen have to work on strategies as to how (1) to use fish stocks in a sustainable way, (2) to protect healthy or to restore impaired habitats, and (3) to practice fishing in a morally/ethically defensible way.

In general, management is required wherever human activities negatively impact fish habitats or where commercial and/or recreational fisheries use stocks in an unsustainable way. Next to those impacts the reestablishment of formerly endangered piscivorous predators (e.g., cormorants, otters), the spreading of invasive fish species (some of them introduced by fishermen), or the consequences of global change comprise further interferences that can cause substantial problems for natural fish stocks. The probability that such problems combine or overlap is very likely in Europe, severely complicating the challenge of managing fisheries sustainably. In the end, all potential problems of wild fish stocks are related to human activities. Therefore, the need to manage fish, ultimately, is always associated with human influences, attitudes, behavior, and expectations. Modern fisheries management in waters dedicated primarily to recreational fishing must try to merge nature conservation needs and the satisfaction of a still-growing number of anglers.

The majority of Austrian running water bodies can be assigned to the rhithral and are predominantly colonized by brown trout (*Salmo trutta*) and other salmonid species, like the European grayling (*Thymallus thymallus*) and the Danube salmon (*Hucho hucho*). Similar to other Central European countries, the rainbow trout (*Oncorhynchus mykiss*), which was first brought to Austria in 1886 (MacCrimmon 1971) and successfully established self-sustaining populations, evolved rapidly as a target species for recreational fishing. Additionally, many anglers fish in natural lakes as well as other stagnant water bodies like artificial ponds, reservoirs, and floodplain oxbows, targeting a broader diversity of fish species.

In this chapter we focus on the management of salmonid rivers and streams and present an example of a highly valuable trout fishing beat in a pre-alpine river. On that basis we discuss the cornerstones of our understanding of sustainable fisheries management, the tools fisheries management can use and the restrictions or limits sound management has to address.

14.2 The Ybbs Case Study

One fishing beat that is an example of modern fisheries management is situated in Lower Austria in the upper reaches of the River Ybbs. There, the so-called River Ois drains from the foothills of the Northern Limestone Alps. Its constrained and largely preserved natural riverbed can be characterized as pool-riffle channel type (Frissell et al. 1986; Montgomery and Buffington 1997) with a mean discharge of 4.5 m^3/s. The river stretch features a high variance of structural diversity, water depth, and heterogeneous substrate conditions. This fishing beat comprises a wetted area of about 5.2 ha over a length of 4 km and an average width of about 12 m (Fig. 14.1).

Fig. 14.1 Pool-riffle sequences define the character of the Ois River, a trout stream located in the foothills of the Northern Limestone Alps in Lower Austria (Source: C. Ratschan)

An important prerequisite for the sustainable harvest of fish is the analysis of key parameters related to the population size of the extant, exploited species. As a first step we distinguish two population aspects. The first one estimates stock density, which is typically described as the sum of individuals or the sum of weight for a given area and for the existing size classes. The second one estimates total stock size and then calculates the number of harvestable fish. To gain these data, regular fish censuses are required. In this context, it is critical for fisheries managers to recognize the key relationships that link fish abundance and biomass with density-independent factors, such as the carrying capacity of a river, which, over the long term, can change due to a variety of natural or anthropogenic influences (Fig. 14.2). In other words, changing environmental conditions entail changing population densities. However, historically overexploitation has repeatedly occurred when management practices are tied to habits or routines rather than regular environmental updates (e.g., Sánchez-Hernández et al. 2016). Consequently, exploitation of natural resources such as wild fish stocks requires a constant reconsideration of what an ecosystem under current conditions is able to yield (Fig. 14.2a, see also Chap. 16 regarding *path dependence*).

By means of regular stock assessments deeper insights into the magnitude of short-term population dynamics can be gained, which describe a further parameter to be considered (Fig. 14.2b). Rapidly changing stocks are predominantly regulated by density-dependent factors as well as seasonal environmental influences and could be relevant for determining harvesting quotas.

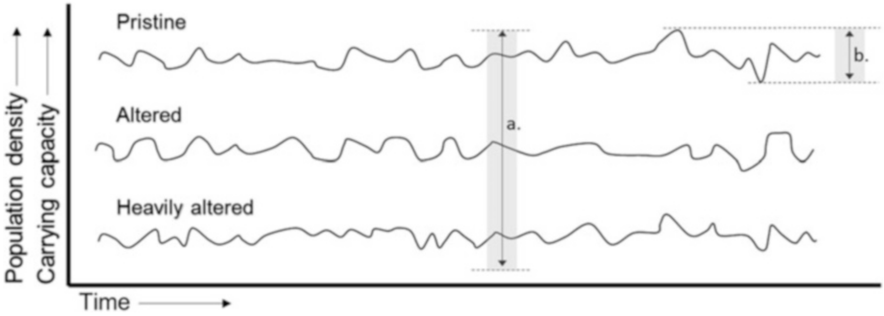

Fig. 14.2 Natural and human-induced levels and variations of the population densities. a: The size of a population is a matter of the carrying capacity of the respective water body. The carrying capacity is related to natural conditions and/or anthropogenic influences. In this example three different levels of population density are illustrated, assuming a heavily altered situation of low density up to a pristine situation of high population density. b: Small-scale dynamics of the population density as a consequence of varying density-dependent and natural environmental factors

In the respective river section of the River Ois, a quantitative fish sampling campaign has been carried out yearly (1997–2016) to assess the named parameters of the salmonid species. In terms of species distribution, brown trout dominates, holding an average share of 66%. It is followed by the nonnative rainbow trout (29%) and European grayling (5%). Further species to be found are bullhead (*Cottus gobio*), occasionally arctic char (*Salvelinus umbla*), and nonnative brook trout (*Salvelinus fontinalis*). To further illustrate the management approach, the as yet unexploited brown trout (catch-and-release management) is taken as example.

The first step to sustainably harvesting brown trout is to capture the demographics of the population. In so doing we can see that recruitment is subject to extensive natural fluctuations (Fig. 14.3). According to data from almost two decades of semiquantitative sampling (cf. Unfer et al. 2011), high reproduction success of brown trout occurs every 2.8 years on average. The observed population dynamics can mostly be attributed to hydrological conditions during the incubation period (Unfer et al. 2011). The latter are seasonally differing, flow conditions and further density-independent factors responsible for short-term fluctuations in fish populations (Fig. 14.2b). Differences in reproductive success are further manifested in the density of the total stock, with fluctuations of up to 200% of the total biomass in any respective time period (see also Table 14.1).

Following the determination of stock densities, the yearly production of brown trout has to be considered in order to identify regions in the recruitment curve where harvest becomes possible. Production is defined as the amount of tissue elaborated per unit time per unit area (Clarke et al. 1946; Waters 1977). Our monitoring data over successive years allows us to illustrate the production balance for single age or size categories. For example, reading cells of the same color on a diagonal from upper left to lower right, the net production (production minus loss) of the 0+ cohort (age class 1 in Table 14.1) from 2010 to 2011 totals 10 kg/ha. The same cohort gains a further increment of 22 kg/ha by the year 2012 before the net production becomes

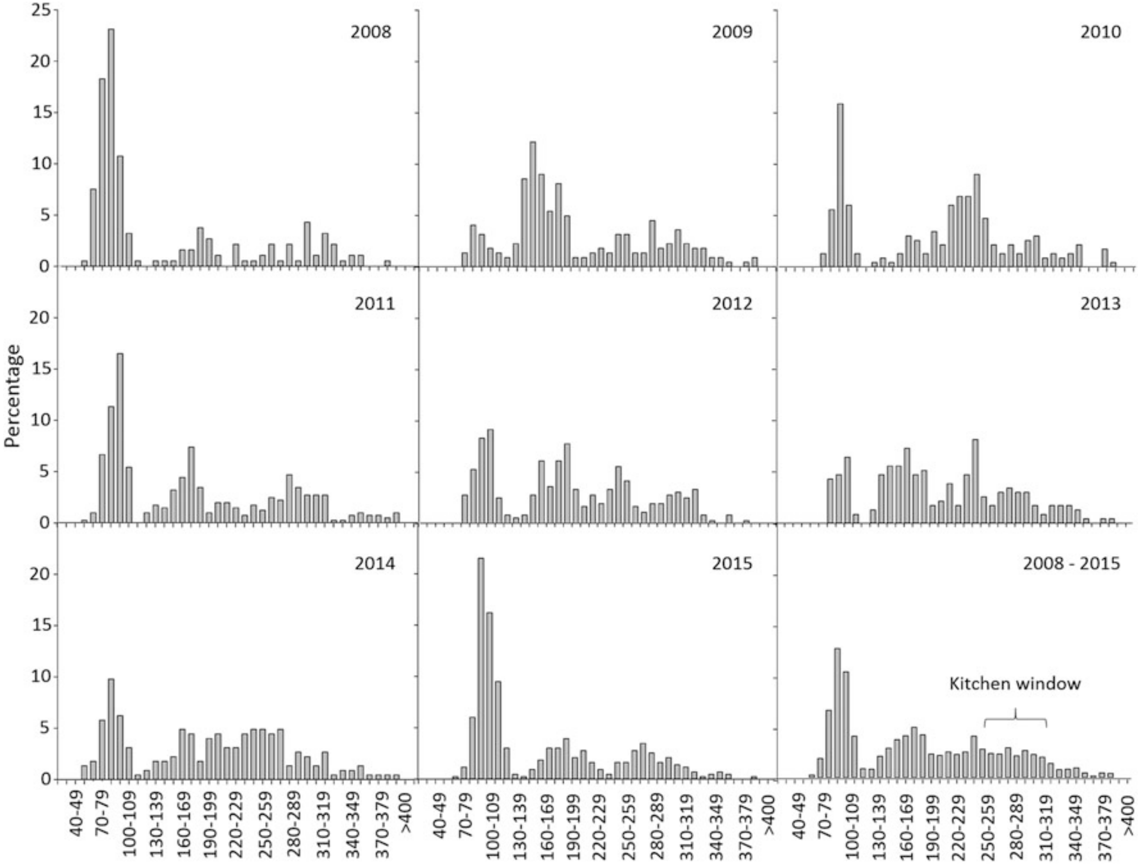

Fig. 14.3 Relative length frequency plots of the brown trout population in the years 2008–2015 and cumulated for the 8-year period 2008–2015 also showing the suggested "kitchen window" in the size class 250–320 mm

Table 14.1 Biomass and net production (kg/ha) of brown trout between 2008 and 2015

Size class	Age class	2008	2009	2010	2011	2012	2013	2014	2015
<120 mm	1	1^{+1}	$0.2^{+0.2}$	1^{+1}	2^{+2}	1^{+1}	$0.5^{+0.5}$	$1.4^{+1.4}$	3^{+3}
120–220 mm	2	2	9^{+8}	6^{+6}	11^{+10}	12^{+10}	8^{+7}	10^{+10}	8^{+7}
220–320 mm	3	12	20^{+18}	27^{+17}	39^{+33}	32^{+22}	23^{+11}	29^{+21}	30^{+20}
>320 mm	4	8	$12^{-0.6}$	15^{-5}	$27^{+0.2}$	17^{-22}	12^{-20}	9^{-14}	11^{-18}
Total biomass$^{\text{Total net production}}$		24	41^{+26}	48^{+19}	78^{+45}	63^{+12}	44^{-2}	50^{+18}	53^{+12}

The production (superscript figures) is calculated on the yearly increment of biomass of the respective cohort. Delimitation of size classes follows the age classes

Table 14.2 Abundance and production (Ind/ha) of brown trout between 2008 and 2015.

Size class	Age class	2008	2009	2010	2011	2012	2013	2014	2015
<120 mm	1	199^{+199}	39^{+39}	114^{+114}	282^{+282}	226^{+226}	85^{+85}	265^{+265}	452^{+452}
120–220 mm	2	48	251^{+52}	109^{+70}	199^{+85}	262^{-20}	203^{-23}	189^{+104}	163^{-102}
220–320 mm	3	69	107^{+59}	190^{-61}	172^{+63}	201^{+3}	146^{-116}	196^{-7}	157^{-32}
>320 mm	4	25	29^{-41}	37^{-70}	59^{-131}	53^{-119}	34^{-167}	25^{-121}	30^{-166}
Total abundance $^{\text{Total net production}}$		341	426^{+110}	450^{+52}	712^{+299}	743^{+90}	468^{-222}	675^{+241}	802^{+153}

The production (superscript figures) is calculated on a yearly increment of individuals for the respective cohort. Delimitation of size classes follows the age classes

negative (−20 kg/ha) in the subsequent year. Over the long run, the described scheme of positive and negative production turns out to be typical, with culminating positive net production in age class 3 and negative net production for older classes.

Along with the increment of biomass, an increase of fish abundance can be documented for the transition from age class 1 to age class 2 (Table 14.2), unless fish densities have already been very high in the first year. In the following year, fish abundance typically stabilizes, apparently by interacting again with the previous year's level, before it decreases again in age class 4 when fish grow older. General life cycle characteristics of brown trout become evident in any respective river stretch when one considers long-term stock developments of both biomass and fish abundance. Especially in case of low reproductive success, it becomes evident that downstream movement of juvenile stages from the headwaters and tributaries increases production (higher abundances of age class 2 and 3 compared to preceding years). Finally, when fish grow older, natural mortality, out-migration, and potentially otter (*Lutra lutra*) predation explain decreasing fish abundance and biomass, hence the negative net production in age class 4.

The natural decrease of fish abundance in size class 4 further supports recommendation that the harvest of fish needs to focus on the most productive, i.e., the third class. Therefore, instead of applying the usually prescribed minimum size of harvestable fish, we recommend a harvest slot (*kitchen window*) with a minimum fish length of 250 mm and a maximum length of 320 mm (Fig. 14.2) that corresponds to an average weight of 200 g per fish. By the application of harvest slots within a realm of high productivity, fishing mortality becomes a sustainable expansion of natural mortality that leaves enough excess for future generations to persist. The harvest slot furthermore leads to benefits such that fish outgrowing the kitchen window remain in the ecosystem, further developing and releasing their high value for the reproductive success of the population. Also, from a genetic point of view advantages arise, as the removal of intermediate-sized fish potentially decreases the risks of reducing fish genetic heterogeneity (Birkeland and Dayton 2005).

Finally, for the determination of harvest quotas, Mertz and Myers (1998) assume that, if fishing mortality is equal to the natural mortality, at least one half of the production of the stock may be harvested. Based on the available data (Table 14.1, total biomass), the average total net annual production ($\tilde{x}_{\mathrm{p}} = 19$ kg/ha) of the whole river Ois fishing beat (5.2 ha) can be calculated as 96 kg per year (2008–2015). Half of the yearly net production divided by an average weight of a harvested fish of 200 g results in an average possible sustainable harvest of almost 250 brown trout per year. In comparison, the current stock of brown trout in a similar size/age class, e.g., between 22 and 32 cm, averages more than 800 available individuals in the total fishing beat. On average the proposed harvest quota would therefore range between one third to one fourth of the respective stock, which means a sufficient amount of fish remaining to continue and grow bigger, even in years of very low abundance. Additionally, the exploitation of fish within the limits of the "kitchen window" would reduce the total biomass below the river's carrying capacity, i.e., below unsustainable mortality levels. That increases the chances of survival for smaller fish, and this extra production again can result in surplus or sustainable production (Wallace and Fletcher 2001). In summary, the example of the River Ois illustrates the necessity to develop fisheries management approaches on the basis of careful consideration of (changing) stock quantities. The analysis of quantitative fish data reveals the size and the dynamics that are inherent in the stock and therefore form the basis for management decisions.

Note that the observed dynamics are specific to habitat characteristics at several scales nested inside of each other, e.g., to the local characteristics of the fishing beat, as well as to the location of a beat within the distribution boundaries of a species and to the characteristics and the quality of the surrounding catchment. In this context, the abovementioned fishing beat is located at the upper distribution boundaries of grayling and rainbow trout. An impassable migration barrier at the lower section of the beat (Fig. 14.4) proves to be responsible for the decreasing numbers of grayling, since adult returners are not able to recolonize their nursery river reaches. Rainbow trout, by comparison, are able to maintain stable stocks within the reach of the beat. However, despite the fact that brown trout abundance and biomass are twice that of rainbow trout, only rainbow trout are currently harvested. The continuing monitoring of the stocks provides information on how rainbow trout are affected by fisheries exploitation and provides valuable knowledge for a future exploitation of brown trout. Grayling, however, are generally not harvested, which is due to the location of the beat in the upper most distribution area of this species, the small size of the stock, and the aforementioned deficits in the life cycle of grayling.

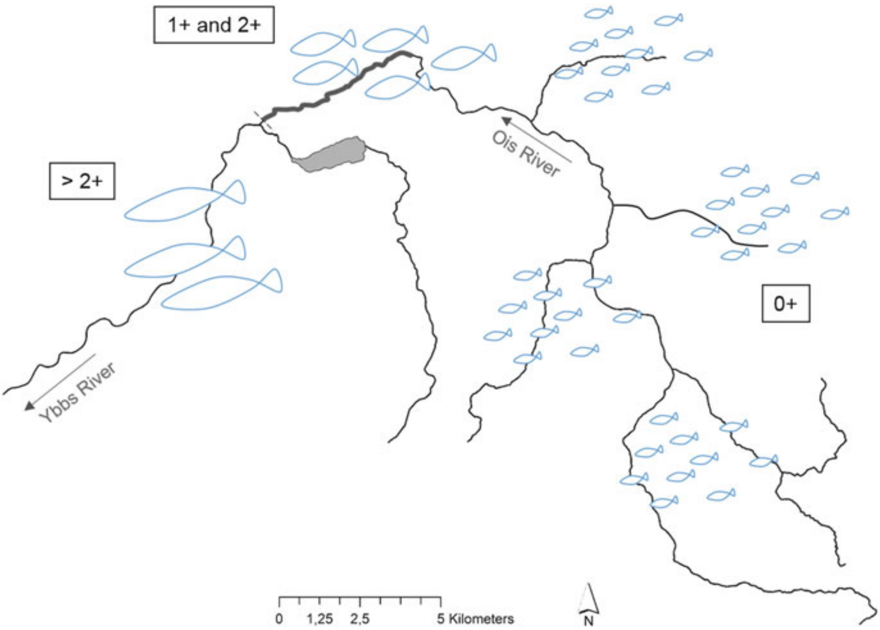

Fig. 14.4 Simplified life cycle scheme of brown trout in the catchment of the River Ybbs (Ois). Juvenile (0+) brown trout out-migrate from nursery headwaters and tributaries to lower river sections. The respective fishing beat (bold line) benefits from immigrating trout. Older fish (>2+) partly out-migrate to lower river sections. Boxes indicate highest abundance of respective age class within the catchment. A migration barrier (dashed line) at the lower end of the fishing beat prevents upstream migration

14.3 Managing Impacted Habitats

The high habitat quality of the fishing beat on the Ois is an exception in the Austrian river landscape. Most of Austria's waters are impacted to a varying extent by river channelization, impoundments, water abstraction, and hydropeaking (see Chaps. 2–13). The degree of deterioration and the interplay and severity of different impact combinations can be manifold. The consequences of impaired habitat quality in any case are the reduction of the habitats' carrying capacity and bottlenecks in the life cycles of affected fish populations. To assess the consequences and to derive proper management measures, a process called "deficit analysis" (Holzer et al. 2004) is carried out in three steps:

1. Analysis of the habitat quality to isolate and specify potential bottlenecks
2. Analysis of the stock (development)
3. Analysis of preceding management activities

14.3.1 Analyzing Habitat Quality

The first step of deficit analysis aims to detect the occurring habitat deficits, which typically are related to hydrological (water abstraction, hydropeaking, thermal alterations, etc.) as well as morphological impacts (bank stabilization measures, longitudinal/lateral barriers, etc.). Both types of interventions, but also the retention of bedload in upper reaches of the catchment, can have further negative consequences for the quality of bed sediments and the availability of food. The analysis of habitat quality is intended to serve fisheries management purposes. The main focus is on the habitat requirements of all different life stages of the river-type-specific fish species, clearly highlighting the species relevant for angling and relevant prey fish. This is in many cases congruent or at least in line with processes of river restoration projects, but the scope of river restoration is generally broader, and fish fauna are just one out of many important aspects related to the ecological integrity of running waters (see Chaps. 15 and 19).

The starting point for the habitat analysis is set by the life cycle of the fish species of interest. A fish life begins at the spawning ground—therefore the quality of spawning habitats is a major issue and has to be thoroughly analyzed. The most prominent fish species of alpine rivers, such as brown trout, grayling, and Danube salmon, rely on loose gravel for spawning and successful recruitment. Potential spawning habitat deficits are typically related to increased accumulation rates of fine sediments, on the one hand, or to an artificial coarsening of bed sediments on the other hand (see Chap. 8). Increased input of fines leads to clogging of the interstitial pores and consequently degraded gravel beds, hindering redd excavation or the successful development of incubated eggs. Retention of sediments through torrent control structures and impoundments as well as flushing out gravel due to reservoir management practices lead to coarsening of bed sediments, impeding redd construction for interstitial spawning salmonid species. Overall, alterations of natural sediment regimes are a severe and widespread problem in alpine rivers, and deficits of suitable spawning habitats are consequently among the major bottlenecks in many rivers and streams (e.g., Hauer et al. 2013; Pulg et al. 2013). For example, trout fry develops inside interstitial pores for a period of up to 6 months. Thus, not only the spawning itself but also the early development after hatching is affected by deteriorated riverbeds. Even though eggs are able to develop, high losses can occur in the alevin or early fry stage when sealed river beds prevent juveniles from successfully emerging.

Further on in the life cycle, early juvenile stages are threatened by a variety of human-induced, hydrological impacts, such as stranding due to hydropeaking surges (see Chap. 5), reservoir flushing (see Chap. 6), thermal changes (see Chap. 11), etc. Morphological alterations due to damming and other river control measures (see Chap. 3) can lower habitat quality for all different life stages. While residual flow stretches mainly reduce the amount of adult fish habitat as the amount of flow and consequently habitats are reduced (see Chap. 4), many regulated channels lose important habitats for juvenile fish, such as shallow gravel banks or adjacent side arms and backwaters. Another major problem is the disruption of migration pathways, both laterally and longitudinally (see Chap. 9). Beside weirs and ramps, riverbed degradation and, consequently, disrupted connections between main stem and tributaries hamper spawning migrations and decrease the original longitudinal range of populations. In addition to hindering upstream migration, specifically hydropower weirs and the associated turbines can cause high mortality of downstream migrating fish. Even this incomplete list of possible habitat perturbations reveals how analyzing habitat quality constitutes a major task of fisheries management. As the life cycle stages of any fish species are related to distinct habitat features, the quality of these features has to be assessed and contrasted with data on fish demographics and distributions. In many cases, fish population structures specifically reflect the habitat situation and help identify potential quality shortcomings.

The most powerful management action to sustainably support healthy fish populations is habitat restoration. Consequently, especially for the conservation of wild fish stocks, the primary task of fisheries managers is to pursue all options to restore habitat conditions to as close to a pristine situation as possible. Small-scaled mitigation measures, such as the maintenance or improvements of spawning grounds (e.g., Pulg et al. 2013), can be carried out and financed relatively easily by associations responsible for fisheries. However, mitigation or restoration at large- or even catchment-scales needs broader efforts (see Chap. 15) that should nonetheless be supported by fisheries managers. To attain objectives on a larger scale, fisheries managers dealing with common issues (e.g., along the same river) have the chance to gain greater influence when they form coalitions and join with local communities to speak with a common voice (see Chap. 16). Combining a critical mass of expert and public opinion is a vital necessity in Austria, where riverine water bodies are characterized by a small-scale segmentation of management units.

However, when the habitat quality analyses are completed, the results have to be contrasted and merged with the results of step 2, the survey of the current fish stocks. Quantitative electrofishing data must first be generated to enable a comprehensive assessment of the actual population status, e.g., abundances, biomass, and population structures. As highlighted in the Ois example, yearly surveys and long-term data series create the most desirable basis for analysis. In many cases fish stock data are missing or collected only sporadically. However, it is an important management task to gather stock data. Although the financial expenditure for fish stock surveys is substantial, it will pay off, since in combination with the habitat quality survey potential bottlenecks become detectable. Furthermore, the elimination of habitat deficits will sustainably improve the stocks, as opposed to stocking as a continuous management measure, which generates costs without solving the underlying problems (see below).

Further, to have sufficient knowledge on the actual fish populations and habitat quality provides the opportunity to reflect and evaluate preceding management actions, specifically success or failure of stocking campaigns (see below). The results of all the three steps of deficit analyses provide the basis for the elaboration of management strategies and to derive management actions.

14.3.2 Stocking Fish: Restrictions and Possibilities

When to Consider Stocking?

If bottlenecks remain after all possibilities to improve the habitat are exhausted, then a fisheries manager has to consider other options to improve the fish stock (cf. Fig. 14.5). Not only in Austria but also in other regions of the world, stocking of artificially propagated fish has been seen as the major (often the only) tool and duty of fisheries management in recreational fisheries. While large amounts of fish of various species and age classes are still stocked, stocking lost its status as panacea and is nowadays more and more questioned. The majority of recent scientific literature dealing with stocking fish in riverine environments stresses potential ecological problems and threats deriving from stocking activities (e.g., Christie et al. 2014). On the one hand, stocked fish suffer from high mortality and emigration rates after release, so economic success is increasingly in doubt. On the other hand, there is clear proof that propagated fish have negative consequences for wild stocks and populations due to genetic admixture or homogenization as well as to increasing competition for habitat and food (e.g., Fraser 2008; Olden et al. 2004).

However, if habitat problems remain and essential environmental prerequisites for different life stages are lacking, stocking might be the only option to sustain recreational fishing. There are different motives to stock (Laikre 1999; Welcomme and Bartley 1998) whereby stocking to mitigate/compensate environmental impacts is the most common reason but stocking for conservation purposes is becoming more and more popular. While compensatory stocking can help to sustain recreational fishing, and can be seen as ecologically reasonable, stocking solely to attract or satisfy anglers can hardly be justified in the context of sound or ecologically orientated fisheries management. Whenever fishes are stocked, one should account for possible negative consequences for the receiving ecosystems and contrast them with potential benefits (mainly socio-ecological). Economic issues or the benefit of

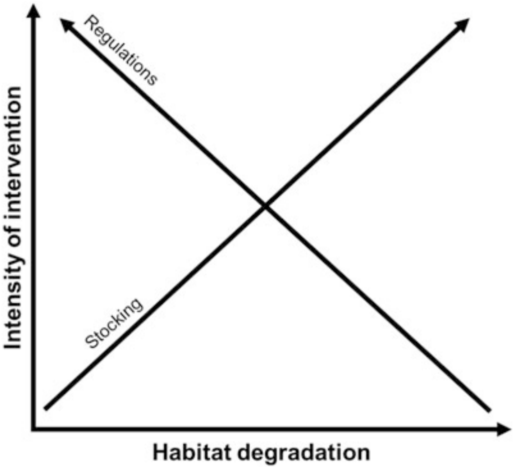

Fig. 14.5 Fisheries management actions have to be adopted according to the ecological status of a river

the owners of fishing rights play an important role in Austria, where the right to fish is a private law and profits are part of the income of the respective fishing right holder. This fact hampers the elaboration and implementation of large-scale, e.g., catchment wide, fisheries management strategies or plans and stands in contrast to countries where the right to fish is public and ecological or nature conservation issues typically have priority over commercial aspects.

Quality of Stocked Fish

Besides the negative impacts that stocked fish might have on wild stocks due to resource competition processes, two further major issues have to be considered: aspects of genetic descent as well as deficits deriving from the artificial propagation in hatchery environments. The latter can result in both behavioral and/or phenotypical deficiencies that, in many cases, are already genetically fixed. Typically, hatchery fish suffer from various abnormalities as they are kept under hatchery conditions for a period of time. As the time spent in the hatchery environment increases, the process of adapting wild animals to human-controlled environments leads to a wide range of behavioral as well as physiological alterations. In general, domestication results in increased fitness under hatchery conditions but decreased fitness under natural conditions (Berejikian et al. 2005) leading to high mortality rates after release (e.g., Weiss and Schmutz 1999). Among the reasons for weak performance of stocked hatchery fish are reduced ability to identify and take natural food, failure to adaptively react to variable food availability, increased boldness in responding to novel objects, reduced flight response, etc. (e.g., Järvi 2002). About 10–15 years ago, researchers postulated that post-release survival has to be enhanced (Maynard et al. 2004). However, if large hatchery fish (catchable sizes) are stocked, it might be more favorable that mid- to long-term survival rates are low, to avoid crossbreeding with wild conspecifics that spreads negative impacts on the genetic integrity of wild populations.

Domestication effects are more likely to be avoided if fish for stocking purposes originate from wild breeders and the duration of their stay in hatcheries is as short as possible. However, as shall be explained below, stocking of juvenile size classes does not guarantee high survival rates. (Unfer et al. 2009; Pinter et al. 2018) nor can undesired genetic consequences be fully prevented (Christie et al. 2016).

Stocking for Conservation

Stocking to achieve conservational aims is the only ecologic reason to release propagated fish. However, fish deriving from artificial propagation will always create repercussions, e.g., reduced reproductive fitness (Araki et al. 2007; Christie et al. 2014). This is so even if the aim of stocking is the reestablishment of reproducing populations in cases where a habitat bottleneck has been restored or a viable river (reach) should be recolonized (e.g., after a fish kill). As stated above, effort to (re) establish a population or stock is only meaningful and promising if the habitat prerequisites for self-sustainability are given or habitat quality has been restored. The foremost aim of any conservational stocking campaign should be the initiation of primary (re)colonization, which implies stocking over a restricted period of time, not continuously. Although the aims of conservational stocking are respectable, the task is far from being simple. The most important precondition is to select or identify a donor population of suitable genetic origin. In Austria, decades of stocking fish of foreign origin and trans-basin spreading of populations of both brown trout and European grayling substantially altered the genetic integrity of wild fish populations, particularly those of salmonid species (Duftner et al. 2005; Pinter 2008; Meraner et al. 2013b; Schenekar et al. 2014). Nowadays, fish species, predominantly cyprinids, e.g., nase (*Chondrostoma nasus*) and barbel (*Barbus barbus*), are stocked with increasing regularity and in increasing quantities. This is so, not least because of increasing problems related to successful protection and subsequent recolonization of riverine habitats by fish-eating predators (cormorant, otter, merganser). The distribution of further species across different river basins increases the risk of modifying the up-to-now widely unimpaired genetic integrity of riverine fish species, which were of minor importance for recreational fishing. Exemplarily, in the Po River catchment (Italy), the native barbel (*Barbus plebejus*) already got virtually replaced by the non-native European barbel (Meraner et al. 2013a).

Which Size/Age Classes Can Be Stocked?

In case a suitable donor population (of local origin and adequate size) is available, the next question is how to carry out the restocking? As it is mandatory to avoid domestication effects as far as possible, the first choice will be to stock fertilized eggs. Eggs can be stocked in “artificial nests” and/or breeding boxes. There are different types of boxes, while the application of eggs using breeding boxes in Austria is known by the term “Cocooning” (Holzer et al. 2011). A major advantage of stocking eggs to avoid domestication is that hatchlings can adapt to the natural environment from the earliest stage on. If potential spawning sites for egg deposition are selected, fish emerging from the nests can home back to the site after they are themselves ready to spawn, and a regularly used spawning ground/site can be established.

While the optimum life stage for conservational stocking is evident, various problems remain. As already mentioned the first task is to spot a suitable donor population, which has to be large enough and genetically appropriate. Furthermore, the number of eggs needed to be successful is unclear but in any case high. The European grayling provides a good example: A female grayling spawns about 5000 eggs over a period of 4 years, corresponding to a lifetime amount of 20,000 spawned eggs. For a population to remain stable, each couple has to produce two adult fish during their life spans. This means that, out of 20,000 eggs on an average, two adult fish will develop. The minimum number of adults for self-sustaining populations is 50, following the 50/500 rule (Franklin 1980). Consequently, to receive these 50 adult fish a few years later the planting of half a million eggs would be required; in other words, the eggs of 100 females (5000 eggs each).

Populations where it is ecologically acceptable to take such a high amount of spawners are scarce. Admittedly, fertilization rates of artificial spawning will be higher compared to natural redds as well as to survival rates to the eye-point stage. On the other hand, large egg numbers are needed so as to establish a founder population and to compensate for losses of reproductive fitness and further imperfections due to, e.g., the inhibition of natural partner selection and modification of other processes of natural selection. We suggest continuing yearly plantings for the duration of a full life cycle to stabilize the initial stock by more than just one cohort. Survival rates among the cohorts can, of course, vary markedly, as the juveniles are exposed to natural hazards (see the Ois example).

A study of the success of stocking juvenile age classes of brown trout carried out in different Austrian streams between 2005 and 2008 clearly demonstrated that stocking of 0+ and 1+ trout had very low success. For this study, juveniles of a hatchery strain as well as fish derived from wild spawners of local origin were used, and the performance (survival) was contrasted with the resident population (Pinter et al. 2018). In all streams native wild trout outcompeted the stocked 0+ strains. Similar results were obtained for 1+ trout, which were stocked into further natural streams after being reared for 1 year under three different rearing conditions (a natural stream, a structured flow channel, conventional hatchery round tank). Also in these experiments, independent of their rearing history, survival rates of stocked trout after one and a half years were below 10%. Survival was far below that of the resident fish, which again outcompeted the stocked 1+ trout (Unfer et al. 2009).

Monitoring the Success of Stocking

Whenever fisheries managers release fish, they watch them swimming away, convinced that they did a good deed, following the agricultural maxim “who will reap must sow.” But as already noted, managing fish stocks in riverine environments is a complex challenge. Following a stocking campaign that releases catchable sizes, subsequent fishing often satisfies anglers. This is because hatchery fish entering natural waters are easy to catch since they soon begin to starve and are therefore prone to take all kinds of bait. Inside the hatchery they received artificial food in great quantities, but in the wilderness they are in many cases neither adept at recognizing natural food items nor able to react to varying food availability (Järvi 2002). As high rates of these fish will die or move away soon after release, they are economically helpful only for a limited time period after stocking. If it is the overall management aim to satisfy anglers, who like to easily catch naive hatchery fish, the aim might be reached best by regularly releasing hatchery fish, e.g., every second week. If stocking is aimed to support the natural populations, then the targeted purpose would definitely not be achieved. But failure or success can easily be monitored. Nowadays, different tagging methods for all size classes of fish are established. Even eyed eggs, e.g., of brown trout, can be marked using chemical dyes (e.g., Unfer and Pinter 2013), or their origin can be classified through molecular-biological methods (e.g., Meraner et al. 2013b). It is surprising that the majority of fisheries managers spend huge amount of money for stocking but monitoring studies on the success are scarce and often judged as too expensive. Recent studies on fish stocking in rivers show either failure (e.g., Persat et al. 2016; Vonlanthen and Schlunke 2015; Mielach et al. 2015) or at least limited success (e.g., Caudron et al. 2011).

How to Regulate Fishing

All management perspectives, conservational, economic, or fish-ecological, hold that fishing regulations should primarily aim to preserve viable populations. Waters supporting healthy stocks need to be managed without stocking interventions but nevertheless can be harvested in a sustainable way following the necessary regulations (cf. Fig. 14.5): Fisheries regulations can protect the long-term productivity of river ecosystems and fish populations by taking fish following guidelines and catch limits set by natural production and, likewise, by releasing fish in size and age classes of limited availability. This follows investment principles of withdrawing only the interest while leaving the fund intact. However, if fish shall be released, it would be counterproductive to harm these fish. Therefore, it is mandatory to restrict the fishing gear if management strategies aim to release certain species or size classes. The closer to a pristine habitat situation, i.e., a very good status according to the WFD, the stricter must be the formulation and implementation of regulations regarding gear restrictions and angling pressure (see below). Examples of good practices to minimize hooking mortality include the use of barbless hooks, bait that can't be swallowed, or the minimization of handling procedures of fishes dedicated to release. Regarding fish handling ethical sound practices have to be mandatory in any case.

The example of sustainable harvest in the river Ois represents more than a concept or slogan. It is a realistic management option. On the other hand, at least from an ethical point of view, pure "catch-and-release" (releasing all caught individuals) is questionable. While it can make sense to release all individuals of a threatened species or to preserve a small stock or population, pure "catch-and-release" regulations are hard to explain to people who generally conceive of angling as cruel. If people go fishing with the intention to release their entire catch, they are indeed playing with creatures, which is hardly acceptable for animal welfare proponents, irrespective of the debate as to whether fish feel pain or not (Braithwaite 2010; Rose et al. 2014).

Our view is that fishing can and should be a reasonable pastime as long as we aim at finessing, catching, and taking home healthy and tasty food, as the human race has done for millennia, provided that modesty finds its way into the understanding of the way natural resources are used. In this context, a further regulatory lever comes into play: *angling pressure*. Angling pressure can be expressed by days or hours of angling per river length or water surface area. As it can be quantified, so can it be restricted. Limiting angling pressure means that fish are caught less frequently. This helps to avoid learning effects and reduces timidity, which supports angler satisfaction as it will be easier to hook a fish compared to intensively fished beats. Furthermore, limited angling pressure reduces insurance rates and, consequently, hooking mortality. According to Fig. 14.5, specifically near-natural habitats have to be protected from overfishing to meet conservational requirements, while altered or artificial water bodies, where in many cases stocking will be a frequently used management tool, can also be burdened with higher pressure. The general scheme of adjusting fishing regulations to fit the ecological status of water bodies can be used to guide anglers and therefore also angling pressure (Fig. 14.5). Near-natural streams have to be managed and fished appropriate to conservational requirements, while heavily altered or artificial water bodies require a broader range of management opportunities. One cannot forget however that flowing waters remain open ecological systems. Therefore, management actions should always be considered thoroughly in advance, as their effects may reach far beyond the boundaries of a management unit. Finally, as people, specifically children or urban societies, should get the chance to experience angling and to develop a closer relationship to fish and aquatic systems, proper strategies as how to guide as well as foster recreational fishing must be developed, safeguarding the future of this leisure activity and of aquatic ecosystems.

14.4 Conclusions

Contemporary management of recreational fisheries needs to balance between the poles of anglers' desire and the sociopolitical and moral obligation to conserve nature. Therefore, management goals should be defined by involving all relevant parties, i.e., authorities, legislators, fishing right owners, or fishing associations. If we subscribe to adaptive management, then the authorities would work with local practitioners and scientists to establish a vision, define what is known and not known, set goals, develop and implement policies, monitor results, and periodically repeat the entire process. Otherwise, we are stuck in the rut of conventional, top-down management (see Chaps. 15 and 16). As soon as the goals for a water body are defined, the different tools a fisheries manager has can be used. It is our conviction that recreational fishing and environmental conservation can and should be merged, whereby the fisheries have to accept their subordinate role to nature conservation in near-natural waters. Subordination, however, does not mean a loss of rights or benefit, but can resemble a successful strategy provided that modest and sustainable harvest schemes are elaborated and angling is carried out in an ethical acceptable way. The example of the River Ois illustrates that if the management of fishing beats is done thoughtfully, sustainable harvest and maintenance of vital stocks can be guaranteed.

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