Chapter 2
Thermal Pollution Caused by Hydropower Plants

Alaeddin Bobat

Abstract Thermal pollution is the change in the water temperatures of lakes, rivers, and oceans caused by man-made structures. These temperature changes may adversely affect aquatic ecosystems especially by contributing to the decline of wildlife populations and habitat destruction. Any practice that affects the equilibrium of an aquatic environment may alter the temperature of that environment and subsequently cause thermal pollution. There may be some positive effects, though, to thermal pollution, including the extension of fishing seasons and rebounding of some wildlife populations. Thermal pollution may come in the form of warm or cold water being dumped into a lake, river, or ocean. Increased sediment build-up in a body of water affects its turbidity or cloudiness and may decrease its depth, both of which may cause a rise in water temperature. Increased sun exposure may also raise water temperature. Dams may change a river habitat into a lake habitat by creating a reservoir (man-made lake) behind the dam. The reservoir water temperature is often colder than the original stream or river. The sources and causes of thermal pollution are varied, which makes it difficult to calculate the extent of the problem. Because the thermal pollution caused by Hydropower Plants (HPPs) may not directly affect human health, it is neglected in general. Therefore, sources and results of thermal pollution in HPPs are ignored in general. This paper aimed to reveal the causes and results of thermal pollution and measures to be taken in HPPs.

2.1 Introduction

Manufacturing is the activity of "**utility creation**" according to economists. Economic output is divided into physical (tangible) goods and intangible services. Consumption of goods and services is assumed to produce utility. Goods are items that can be seen

A. Bobat (✉)
University of Kocaeli, Kocaeli, Turkey
e-mail: bobatus@gmail.com

A.N. Bilge et al. (eds.), *Energy Systems and Management*,
Springer Proceedings in Energy, DOI 10.1007/978-3-319-16024-5_2

and touched, such as a book, a pen, and a folder. Services are provided for consumers by other people, such as doctor, dentist, haircut, and eating out at a restaurant (Zwikael and Smyrk 2011). Services are something completely different from goods. Services are intangible commodities that cannot be touch, felt, tasted, etc. They are the opposite of goods, where goods are something that can be traded for money; services are when you hire a person or someone to do something for you in exchange of money. Services are usually hired or rented; they cannot be owned like goods can. Since it requires people and one cannot legally own a person in today's world, services can only be for hire (Humphreys et al. 2001). In this regard, electric production can be acknowledged as a service output.

All the manufacturing systems that produce utility (goods and services) perform in accordance with inputs-transformation-outputs (ITO) model (Fig. 2.1). The factors of production such as capital, manpower (labour), raw material (land or natural resources), and management (or entrepreneur) constitute the main inputs of this model. These factors are processed in a certain time, and goods and services are obtained as outputs at the end of process. However, efficiency of this production process is less than 100 % because of waste or deficiency (Ely and Wicker 2007). On the other hand, the waste or deficiency may involve significant social, economic, and environmental costs. For instance, the existing wastes can cause the environmental problems in ecosystem.

According to the first law of thermodynamics, energy and matter available in a system or an environment can be transformed (changed from one form to another), and they can disperse around but they can neither be created nor destroyed. The clean-up costs of hazardous waste, for example, may outweigh the benefits of a product that creates it. The same law is acceptable for energy production. Moreover, the hazardous waste, it can be waste heat or thermal pollution/alteration in the energy production, can cause the environmental problems in aquatic ecosystem. Therefore, natural resources or natural systems have been deteriorated or consumed/used ex parte by human in a way.

According to the second law of thermodynamics, every process emits some heat or waste to the environment at the end of process (Toossie 2008). One of the biggest sources of the thermal pollution in water comes from electric power plants where water passes through the condenser and returned to the environment as an altered

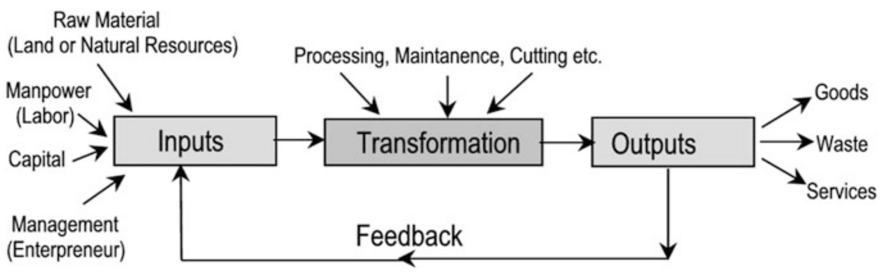

Fig. 2.1 General manufacturing model

temperature. The production of energy in hydropower plants (HPPs) also resembles general manufacturing model—ITO—and complies with the first and second laws of thermodynamics. The water changing physical, chemical, biological properties, and flowing regime during energy production process causes the problems in aquatic environment as well. As to ITO model, main inputs are running water as a natural resource, equipment, capital, manpower, etc. in HPPs. The water changing physical, chemical, and biological features in reservoir, penstock, turbine, pipelines, and cooling system reveals thermal pollution/alteration in aquatic environment more or less while electrical energy is obtained as an output in ITO model (Fig. 2.2).

In fact, healthy water bodies exhibit ecological integrity, representing a natural or undisturbed state. Ecological integrity is a combination of three components: chemical integrity, physical integrity, and biological integrity. Chemical integrity includes the chemical components such as dissolved oxygen, organic matter inputs, nutrients, groundwater and sediment quality, hardness, alkalinity, turbidity, metals, and pH; physical integrity includes the physical features such as sunlight, flow, habitat, temperature, gradient, soils, precipitation runoff, channel morphology, local geology, groundwater input, in-stream cover, and bank stability; and biological integrity includes the function and structures of biological communities (EPA 2002). When one or more of these components is degraded by any man-made structures, the health of the water body will be negatively affected and, in most cases, the aquatic life living there will reflect the degradation (Fig. 2.3).

Thermal pollution is the change in the water temperatures of lakes, rivers, and oceans caused by man-made structures or industries. It is also called as "waste heat" in a sense. Waste heat is an inevitable by-product of the power plants. In a fossil-fuel power plant, the amount of heat energy rejected is approximately 60 %. The amount rejected by a nuclear power plant is even larger—close to 70 % (Haider 2013).

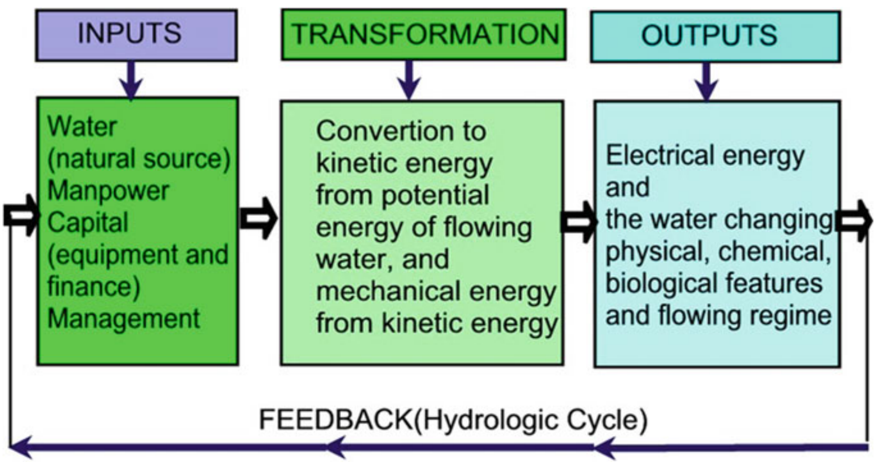

Fig. 2.2 ITO system in HPPs

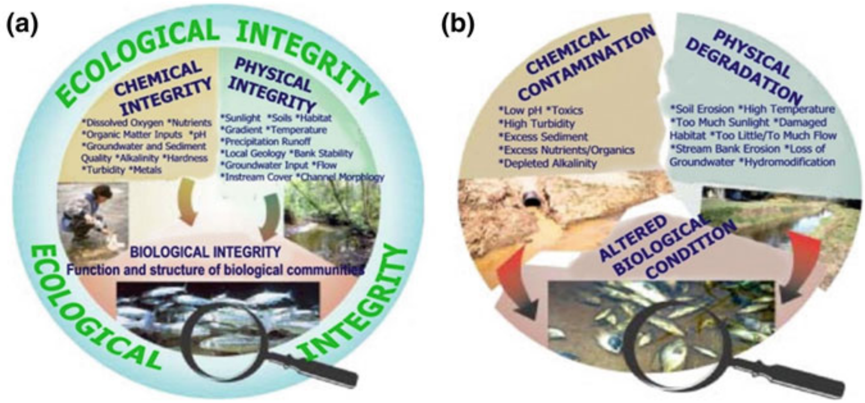

Fig. 2.3 **a** Healthy water bodies and **b** unhealthy water bodies (from EPA 2002)

The medium that receives this no longer-needed heat is the coolant from where water was drawn to keep the equipment cool. That is why power plants are almost always built near rivers, lakes, or seashores for a ready supply of cooling water. This practice of dumping the waste heat in the form of modified water into its natural source is called thermal pollution, and the sources and causes of thermal pollution are varied, which makes it difficult to calculate the extent of the problem. Also, because the negative effects of thermal pollution may not directly affect human health, it is not as well known as other types of pollution. The nuclear power industry is tightly regulated; therefore, the impact of nuclear power plants on the environment, including its production of thermal pollution, usually in the form of warm water, is better documented. But, the thermal pollution caused by HPPs has not been well known and documented, and therefore, sources and results of thermal pollution in HPPs are ignored in general. In this chapter, thermal pollution coming from HPPs is studied, and the causes and results of thermal pollution, and measures are to be taken into account and discussed.

2.2 Hydropower as an Energy Source

By taking advantage of the water cycle, it has been tapped into one of the nature's engines to create a useful form of energy. In fact, human being has been using the energy in moving water for thousands of years. Today, exploiting the movement of water to generate electricity, known as hydroelectric power, is regarded as the largest source of renewable power in worldwide.

The most common method of generating hydroelectric power is by damming rivers to store water in reservoirs. Building-up behind a high dam, water accumulates potential energy. The water in the reservoir is considered stored energy. When the gates open, the water flowing through the penstock becomes kinetic energy because it is in motion. Hydroelectric energy is produced by the force of falling water. Upon its release, the flow turns turbines, which then generate electricity. The capacity to produce this energy is dependent on both the available flow and the height from which it falls. In order to generate electricity from the kinetic energy in moving water, the water has to be moving with sufficient speed and volume to turn a generator. To increase the force of moving water, **impoundments or dams** are used to raise the water level, creating a "**hydraulic head**", or height differential. When water behind a dam is released, it runs through a pipe called a penstock and is delivered to the turbine. When the water reaches the end of the penstock, it turns a water wheel or "**turbine**" at enormous speeds. The turbine rotates, via a connected shaft to an electrical generator, and this generator creates electricity. It is the turbine and generator working in combination that converts "**mechanical energy**" into "**electric energy**". The current is then passed onto the transformer, converting it to a small current at a high voltage, and through the transmission lines to substations where the voltage will be reduced and the electricity distributed to customers. High voltage is needed because a large amount of energy is needed to transport electricity over long distances (Fig. 2.4) (HowStuffWorks 2001). Moreover, to avoid the excess warming of the turbine, cooling water coming from adjacent reservoir or ground is used (USDI 2005; Kumar et al. 2011).

Hydroelectric generation can also work without dams, in a process known as **diversion**, or **run-of-river** (RoR). Portions of water from fast-flowing rivers, often at or near waterfalls, can be diverted through a penstock to a turbine set in the river or off to the side. Another RoR design uses a traditional water wheel on a floating platform to capture the kinetic force of the moving river. While this approach is inexpensive and easy to implement, it does not produce much power.

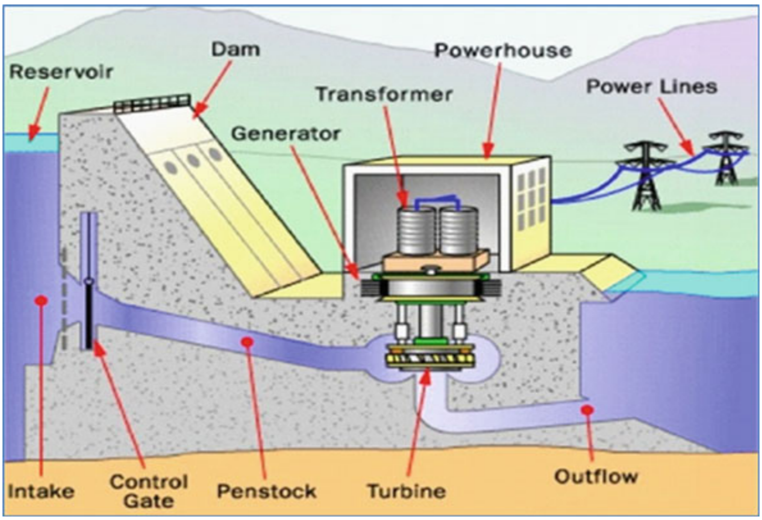

Fig. 2.4 A view from *inside* part of reservoir hydropower plant (from HowStuffWorks 2001)

Another type of hydropower, though not a true energy source, is pumped storage. In a pumped storage plant, water is pumped from a lower reservoir to a higher reservoir during off-peak times, using electricity generated from other types of energy sources. When the power is needed, it is released back into the lower reservoir through turbines. Inevitably, some power is lost, but pumped storage systems can be up to 80 % efficient. Future increases in pumped storage capacity could result from the integration of hydropower and wind power technologies. Researchers believe that hydropower may be able to act as a battery for wind power by storing water during high-wind periods (DoE 2004; EERE 2006).

Compared to other power plants working on fossil fuels, HPPs have the lowest operational cost (only the initial cost is high and construction takes a long time), the longest operational life, the highest efficiency rates, and the cheapest electricity generated (Davis 2006). The ability to meet power demand fluctuations is an advantage of HPPs with reservoirs. In this regard, HPPs are one of the most responsive factors (easy to start and stop) of any electric power generating source. Furthermore, HPPs are preferred because of their environment-friendly (they do not emit any direct pollutant), clean, (partly) renewable, and reliable technologies. HPPs stop the flooding and harmful effects of the rivers, store irrigation, and drinking water and give chance to fish farming and produce revenue (Yüksek and Kaygusuz 2006). Reservoir lakes can be used for recreation, water-based activities such as boating, skiing, fishing, and hunting. HPPs can set up in many sizes and have relatively low maintenance costs. Moreover, they are the domestic source of energy and can become tourist attractions in their own right. However, they have some disadvantages, such as disappearing habitats and species, melting deltas, decreasing ground water, changing water quality, drying natural lakes, influencing physical and biological environment, economical unproductiveness, landscape destruction, deforestation, microclimate changes as well as socio-economic degeneracy during the construction and operation (Spilsbury and Spilsbury 2008; Bobat 2010; Bobat 2013; Aksungur et al. 2011; UoCS 2014).

2.3 The Sources and Results of Thermal Pollution in HPPs

Any practice that affects the equilibrium of an aquatic environment may alter the temperature of that environment and subsequently cause thermal pollution. There may be some positive effects, though, to thermal pollution, including the extension of fishing seasons and rebounding of some wildlife populations. But, temperature changes may adversely affect ecosystems by contributing to the decline of wildlife populations and habitat destruction. Besides power plants, thermal pollution is caused by deforestation, drought, global warming, evaporation, and soil erosion exposes water bodies to more sunlight, thereby raising the temperature. Whatever may be the cause, thermal pollution degrades water quality of the source by a process that changes its ambient temperature.

Water temperature has a direct or indirect influence on aquatic water ecosystems, and it regulates fish distribution in freshwaters. Thus, there is limited potential for transfer of fish between various water environments. Water temperature, quantity, and quality play a critical role and determine the distribution of fish species, stock catch, and diversification of aquaculture, i.e. presence of frogs, crabs, shrimps, and molluscs in the water body. This species cannot survive beyond 19 °C temperature of water (Miller and Stillman 2012).

In fact that the decrease in water amount and the change in water temperature reduce the amount of dissolved oxygen and nutrients negatively denature fish and other macroscopic/microscopic organisms, and their quantitative and qualitative nature. As a result of this, these alterations in stream negatively affect all the food chain from freshwater to marine environment (Poff et al. 1997).

Freshwater streams are complex ecosystems that sustain a range of thermally sensitive organisms, but are at risk due to encroachment and degradation by increasing power generation, industrialization, and urbanization. A freshwater stream is defined as a stream that supports trout and other cold water fish species (Eaton et al. 1995). Trout are native to cold water streams and very sensitive to temperature changes. Trout species prefer to avoid water temperatures exceeding 21 °C (Coutant 1977). Once temperatures rise above that level, mortality rates begin to increase (Lee and Rinne 1980). Feeding, spawning, overall health, and growth of cold water fish are also adversely affected (Edwards et al. 1979). For example, the survival of the endemic trout species (*Salmo trutta labrax*) of Eastern Black Sea Region (Fig. 2.5a) is closely related to water amount in the downstream since it has liking for gravity, cold, and oxygen-rich aquatic environment. And this species cannot spawn in the water of which temperature exceeds 12 °C (Aksungur et al. 2007). Water temperature also influences the early development of aquatic organisms. Furthermore, it affects the larvae and eggs of fish in freshwaters. For instance, trout eggs may not hatch if the water is too warm. Even if they hatch, they would not survive for a long time because aquatic juveniles are the least tolerant to abrupt

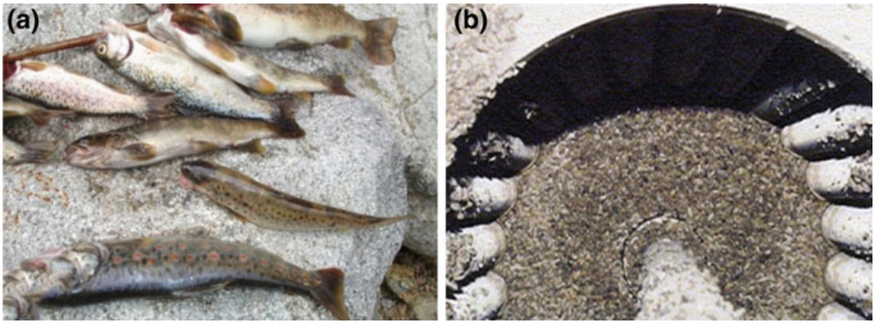

Fig. 2.5 **a** Endemic *brown* trout and **b** bioaccumulation of Zebra Mussel in screens

temperature changes. It was observed that trout will actually select cool water even if it is low in oxygen (Matthews et al. 1994; Matthews and Berg 1997). These findings suggest that mitigating thermal pollution in developing freshwater stream watersheds is essential for protecting sustainable trout fisheries. Water temperature affects the overall biological and chemical composition of a stream (Pluhowski 1970; Paul and Meyer 2001; Poole and Berman 2001). It influences nutrient cycles and productivity within fluvial systems (Allan and Castillo, 2007). The anthropogenic thermal degradation associated with land development has been found to permanently alter water temperature regimes (Nelson and Palmer 2007). Water temperature was cited as one of the most important environmental factors that affect assemblages of cold water macro-invertebrates (Wang and Kanehl 2003). These unique systems are often drastically altered, or even destroyed, when traditional development occurs within a cold water stream watershed.

HPPs with dams may change a running water habitat into a lake system by creating a reservoir (man-made lake) behind the dam. The water temperature in reservoir is occasionally colder than the original stream or river. On the contrary, downstream of dams and HPPs has generally warm water than upstream because of passing of water from pipelines, penstock, turbine, and cooling system. Despite the change in water temperature emerging from construction and operation of HPPs is not occurred as high as that in fossil-fuel and nuclear power plants, it is too important to affect lifecycle and survival of aquatic organisms. For instance, on the Euphrates River of Turkey, due to cascade of HPPs with reservoirs, Zebra Mussel (*Dreissena polymorpha* Pallas) has extremely reproduced under changing ecological conditions. The alteration in water temperature of reservoir especially has supported the lifecycle and spawning of Zebra Mussel. So, it has caused the significant technical, economic, and ecological damages reducing and/or blocking water flow (Fig. 2.5b) in HPPs (Bobat et al. 2002; Bobat 2003; Bobat et al. 2004). Also, the mitigations taken against populations of Zebra Mussel, such as hypo-plants at the entrance of the drinking water systems, cause TOC risk during the water treatment plant process.

The construction of dams and reservoirs for water storage, power generation, and diversion for other usage can affect flow and depth of the water. Furthermore, the speed and depth of flow can play the important role in transfer and dispersion of nutrients and dissolved gases such as CO_2 and O_2 in aquatic environment and it can influence the respiration and reproduction activities of some aquatic species (Allan and Flecker 1993). The changes in the speed, depth, outflow, and timing of stream generally damage aquatic organisms (Power et al. 1995). Together with other factors cited above, the friction of water through penstock and pipelines, the crashing of water to turbine blades, and use of water for cooling increase water temperature in both reservoir and tailrace to some extent. Since water can absorb thermal energy while experiencing only small changes in temperature, most aquatic organisms have developed enzyme systems that operate in a narrow temperature range. In some cases, this change can devastate even heat-tolerant species that are inured to warmer waters. The temperature change of even one to two degree Celsius can cause significant change in organism metabolism and other adverse cellular biology effect. Principal adverse changes can include rendering cell walls less permeable to necessary osmosis, coagulation of cell protein, and alteration of enzyme metabolism. These cellular level effects can adversely affect reproduction and also cause mortality.

Menon et al. (2000) opined that the species that are intolerant to warm water conditions may disappear, while others preferring this condition may thrive so that the structure of the community changes. Respiration and growth rates may be changed. An increase of temperature may result in the loss of sensitive species. They have also stressed on the influence of certain parameters, which exert profound influence on the distribution and availability, in which temperature is stated to be first. HPPs have been adversely affected the natural stocks of cold water fish. The activities pertaining to the projects under construction are responsible for increase in the silt load and destruction of fish food organisms in streams. The increased silt load along with changed temperature regime of channel adversely affected the feeding and spawning of fish (Qureshi et al. 2010).

The presence of dissolved oxygen is probably the single most important factor in the biology of aquatic systems, and a great variety of physical and biological interactions stem from it. But, as the temperature of water increases, dissolved oxygen content in water decreases. Since metabolism requires oxygen, some species may be eliminated entirely if the water temperature rises by 1–2 °C. Additionally dissolved oxygen is the key to assimilation of organic wastes by microorganisms. Warming a water body will impair this assimilation (Resh et al. 1988).

Thermal pollution not only kills heat-intolerant fish, but also plants, thereby disrupting the web of life dependent on the aquatic food chain. Also, the elimination of heat-intolerant species may allow less desirable heat-tolerant species to take over.

Fish are often disturbed, migrate, and spawn in response to temperature cues. When water temperature is artificially changed, the disruption of aquatic organisms' normal activities and patterns can be catastrophic. There may be large-scale migration to an environment more favourable to their survival. The addition of new species of fish will change the eco-balance of the migrated area.

Thermal pollution can also increase the susceptibility of aquatic organisms to parasites, toxins, and pathogens, making them vulnerable to various diseases. If thermal pollution continues for a long time, it can cause huge bacteria and plant growth leading to algae bloom that will subsequently result in even less oxygen in the water. Algae have unfavourable effects on aquatic life.

2.4 Discussion, Conclusion, and Recommendations

Thermal pollution occurs as a natural process required by first and second laws of thermodynamics for any thermodynamic cycle to operate. The first-law efficiency is defined based on the first-law principle of conversion of one form of energy to another, without any consideration to the quality of the energy resource. First-law efficiency is input/output efficiency, i.e. the ratio of energy delivered in a desired form and the energy that must be expended to achieve the desired effect. It does not differentiate between the qualities of the energy sources. The second-law efficiency compares the efficiency of an actual device (first-law efficiency) to that of the same or a similar device operated under ideal conditions. The second-law efficiency of all ideal devices is equal to one, and for all real devices is smaller than one. The Kelvin-Plank statement of the second law says no power plant can be 100 % efficient. They will always reject some heat to the environment. The Clausius statement of the second law implies that heat transfer by itself will always be from a high temperature to a lower temperature. This means that the waste heat rejected from the power plant will always be at a higher temperature than the environment (Toossie 2008).

The same process also performs in HPPs. Water is often used as a cooling medium and a main source of kinetic energy in HPPs and returned to the environment warmer than when it started in accordance with first and second laws of thermodynamics. Therefore, the changes in water temperature of reservoir and tailrace cause thermal alterations.

The release of water changing temperature into the environment is a controversial issue. In some cases, it is said that heat addition causes no harm and even improves conditions, whereas in others, the whole ecosystem is changed. Some say the best fishing is near a thermal outfall while others claim the hot water is killing the fry and larva. Whatever the stand, it is generally agreed that some species prefer warmer water while others prefer colder water. It is also known that some species, especially juveniles, can only stand elevated temperatures for a given period of time, the higher the temperature, the shorter of the lethal exposure time. In general, discharging warm water into a cooler body of water will result in the change of biolife in the neighbourhood of the discharged from cold water species to warm water species. The size of the effected region can be from a few centimetres to several thousand metres from the discharge. As a result, the problem becomes how to reduce the amount of heat rejected to the environment and the impact it has on it.

All hydroelectric structures affect a freshwater's ecology mainly by inducing a change in its hydrologic characteristics (flow regime, temperature, pH, DO, and so on) and by disrupting the ecological continuity of sediment transport and fish migration through the building of dams, dikes, and weirs. However, the extent to which a stream's physical, chemical, and biological characteristics are modified depends largely on the type of HPPs, whereas RoR HPPs do not alter a stream's flow regime extremely the creation of a reservoir for storage hydropower entails a major environmental change by transforming a fast-running fluvial ecosystem into a still-standing lacustrine one. The extent to which a HPP has adverse impacts on the riverbed morphology, on water quality, and on fauna and flora is highly site-specific and to a certain degree dependent on what resources can be invested into mitigation measures.

Water quality issues related to reservoirs depend on several factors: climate, reservoir morphology and depth, water retention time in the reservoir, water quality of tributaries, quantity and composition of the inundated soil and vegetation, and rapidity of impounding, which affects the quantity of biomass available over time. Also, the operation of the HPP and thus the reservoir can significantly affect water quality, both negatively and positively. Water quality issues can often be managed by site selection and appropriate design, taking the future reservoir morphology and hydraulic characteristics into consideration. The primary goals are to reduce the submerged area and to minimize water retention in the reservoir. The release of poor-quality water (due to thermal stratification, turbidity, and temperature changes both within and downstream of the reservoir) may be reduced by the use of selective or multi-level water intakes. This may also help to reduce oxygen depletion and the volume of anoxic waters. Since the absence of oxygen may contribute to the formation of methane during the first few years after impoundment, especially in warm climates, measures to prevent the formation of anoxic reservoir zones will also help mitigate potential methane emissions.

The choice of location is playing an important role in HPPs, especially to the relation of water course and the habitat in surrounding. The careful environmental feasibility studies are needed to prevent the negative impacts to the environment. The deep studies need to take to decide the best location to minimize the negative effects of changing the water course and also the effect to the immigration of the fish and other water inhabitants. The place will not require flooding large areas also need to be chosen, and the environmentally sensitive places, such as the natural conservation, also need to be avoided.

The developing countries and Turkey especially have the richest biodiversity, and the richness of freshwater in many regions has not been discovered yet. For these reasons, HPPs under construction and in operation have the potential to cause major environmental problems. Whereas many natural habitats are successfully transformed for human purposes, the natural value of certain other areas is such that they must be used with great care or left untouched. The choice can be made to preserve natural environments that are deemed sensitive or exceptional. To maintain biological diversity, the following measures have proven to be effective: establishing protected areas; choosing a reservoir site that minimizes loss of ecosystems; managing invasive species through proper identification, education, and eradication; and conducting specific inventories to learn more about the fauna, flora, and specific habitats within the studied area. Moreover, the efficiency of HPPs can be improved by replacing obsolete or worn turbine or generator parts with new equipment, fine-tuning performance, reducing friction losses of energy, and automating operations. These efficiency improvements are expected to have only very minor and short-term environmental impacts. Replacement of turbine gates and runners (the surfaces against which water is impinged) can be environmentally beneficial because more efficient turbines generally kill fewer fish, and because new turbine parts can be designed to facilitate aeration at dams that release water with low dissolved oxygen (DO) concentrations.

Since investors are usually interested in construction costs and incomes to be obtained, the physical, chemical, and biological features are ignored in general. In fact, the alterations in freshwater are vital for both sustainability of aquatic ecosystem and return of investment. For this reason, it is also important to compare the environmental effects of HPPs with alternatives.

Water availability is crucial for many energy technologies, including hydropower, and energy is needed to secure water supply for agriculture, industries, and households, particularly in water-scarce areas in developing countries. This mutual dependence has leaded to the understanding that the water-energy nexus must be addressed in a holistic way, especially regarding climate change and sustainable development. Providing energy and water for sustainable development will require improved regional and global water governance, and since hydroelectric facilities are often associated with the creation of water storage facilities, hydropower is at the crossroads of these issues and can play an important role in enhancing both energy and water security. Therefore, hydropower development is part of water management systems as much as energy management systems, both of which are increasingly becoming climate driven.

References

Aksungur, M., Alkan, A., Zengin, B., Tabak, İ., & Yılmaz, C. (2007). Karadeniz Alabalığının Tatlısu Ortamındaki Göçü Üzerine Bazı Çevresel Parametrelerin Etkisi. *Ekoloji, 17*(65), 28–35.

Aksungur, M., Ak, O., & Özdemir, A. (2011). Nehir tipi hidroelektrik santrallerinin sucul ekosisteme etkisi: Trabzon Örneği. *Journal of Fisheries Sciences, 5*(1), 79–92.

Allan, J. D., & Castillo, M. M. (2007). *Stream ecology: Structure and function of running waters* (2nd ed.). Dordrecht: Springer.

Allan, J. D., & Flecker, A. S. (1993). Biodiversity conservation in running waters. *BioScience, 43*, 32–43.

Bobat, A., Hengirmen, M., & Zapletal, W. (2002). Problems of zebra mussel at dams and hydro projects on the Euphrates River, *Hydro 2002: Development*, *Management and Performance, Antalya, Proceedings Book*, 475–484.

Bobat, A. (2003). Hidroelektrik Santrallarda Ekolojik Bir Sorun: Zebra Midye, *Türkiye 9. Enerji Kongresi*, Bildiriler Kitabı, Cilt I, 327–349.

Bobat, A., Hengirmen, M., & Zapletal, W. (2004). Zebra mussel and fouling problems in the Euphrates basin. *Turkish Journal of Zoology, 28*, 161–177.

Bobat, A. (2010). Yavaş ve Sessiz Olur Akarsuların Ölümü-III: Baraj ve HES'lerin Etkileri (The streams die slowly and quietly—III: The Positive and Negative Effects of Dams and HPPs), December 15, 2010. www.enerjienergy.com

Bobat, A. (2013). The triple conflicts in hydro projects: Energy, *economy and environment, Fresenius Environmental Bulletin, 22*(7a), 2093–2097.

Coutant, C. C. (1977). Compilation of temperature preference data. *Journal of the Fisheries Research Board of Canada, 34*, 740–745.

Davis, J. (2006). *Advances in hydropower technology can protect the environment, alternative energy sources* (pp. 82–87). Detroit: Greenhaven.

DOE (U.S. Department of Energy). (2004). Hydropower: Setting a course for our energy future, DOE/GO-102004-1981. http://www.nrel.gov/docs/fy04osti/34916.pdf

Eaton, J. G., McCormick, J. H., Goodno, B. E., O'Brien, D. G., Stefany, H. G., Hondzo, M., & Sheller, R. M. (1995). A field information-based system for estimating fish temperature tolerances. *Fisheries*, *20*(4), 10–18.

Edwards, R. W., Densem, J. W., & Russell, P. A. (1979). An assessment of the importance of temperature as a factor controlling the growth rate of brown trout in streams. *Journal of Animal Ecology, 48*(2), 501–507.

EERE (Office of Energy Efficiency and Renewable Energy). (2006). Wind energy systems integration. Washington, DC: U.S. Department of Energy. http://www1.eere.energy.gov/windandhydro/wind_sys_integration.html

Ely, R. T., & Wicker, G. R. (2007). *Elementary principles of economics: Together with a short sketch of economic history, chapter II: The factors of production*. Whitefish: Kessinger Publishing, LLC.

EPA. (2002). Biological assessments and criteria: Crucial components of water quality programs. USA-EPA, Office of Water, 822-F-02-006.

Haider, Q. (2013). Thermal pollution of water by power plants. The Daily Star, September 14, 2013.

HowStuffWorks. (2001). How hydropower plants work. http://science.howstuffworks.com/environmental/energy/hydropower-plant1.htm. Access: September 11, 2014.

Humphreys, B. R., Maccini, L. J., & Schuh, S. (2001). Input and output inventories. *Journal of Monetary Economics, 47*, 347–375.

Kumar, A., Schei, T., Ahenkorah, A., Caceres Rodriguez, R., Devernay, J. M. Freitas, M., Hall, D., Killingtveit, A., & Liu, Z. (2011). Hydropower. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer & C. von Stechow (Eds.), *IPCC special report on renewable energy sources and climate change mitigation*. Cambridge: Cambridge University Press.

Lee, R. M., & Rinne, J. N. (1980). Critical thermal maxima of five trout species in the Southwestern United States. *Transactions of the American Fisheries Society, 109*, 632–635.

Matthews, K. R., Berg, N. H., Azuma, D. L., & Lambert, T. R. (1994). Cool water formation and trout habitat use in a deep pool in the sierra Nevada, California. *Transactions of the American Fisheries Society, 123*(4), 549–564.

Matthews, K. R., & Berg, N. H. (1997). Rainbow trout responses to water temperature and dissolved oxygen stress in two Southern California stream pools. *Journal of Fish Biology, 50* (1), 50–67.

Menon, A. G. K., Singh, H. R., Kumar, N. (2000). Present eco-status of cold water fish and fisheries. In H. R. Singh & W. S. Lakra (Eds.), *Coldwater fish and fisheries* (pp. 1–36). New Delhi: Narendra Publishing House.

Miller, N. A., & Stillman, J. H. (2012). Physiological optima and critical limits. *Nature Education Knowledge, 3*(10), 1.

Nelson, K. C., & Palmer, M. A. (2007). Stream temperature surges under urbanization and climate change: Data and responses. *Journal of the American Water Resources Association, 43*(2), 440–452.

Paul, M. J., & Meyer, J. L. (2001). Streams in the urban landscape. *Annual Review of Ecology Systematics, 32*, 333–365.

Pluhowski, E. J. (1970). Urbanization and its effect on the temperature of streams on Long Island, New York. U.S. Geological Survey, Professional Paper 627-D, New York City, NY.

Poff, L. N., Allan, D., Bain, M. B., Karr, J. R., Prestaggard, K. L., Richter, B. D., et al. (1997). The natural flow regime: a paradigm for river conservation and restoration. *BioScience, 47*, 769–784.

Poole, G. C., & Berman, C. H. (2001). An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms of human-caused thermal degradation. *Environmental Management, 27*(6), 787–802.

Power, M. E., Sun, A., Parker, M., Dietrich., W. E., Wotton J. T. (1995). Hydraulic food-chain models: An approach to the study of web dynamics in large rivers. *BioScience 45*, 159–167.

Qureshi, T. A., Qureshi, T. A., Chalkoo, S. R., Borana, K., & Manohar, S. (2010). Effect of thermal pollution on the hydrological parameters of river Jhelum (J & K). *Current World Environment, 5*(2), 292–2827.

Resh, V. H., Brown, A. V., Covich, A. P., Gurtz, M. E., Li, H. W., Minshall, G. W., et al. (1988). The role of disturbance in stream ecology. *Journal of the North American Benthological Society, 7*, 433–455.

Spilsbury, R., & Spilsbury, L. (2008). *The pros and cons of water power*. New York: Rosen Central Publication.

Toossie, R. (2008). *Energy and the environment: Sources, technologies, and impacts*. Irvine: VerVe Publishers. ISBN 978-1-4276-1867-2.

UoCS (Union of Concerned Scientists). (2014). How hydroelectric energy works, environmental concerns. Access: May 06, 2014. http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/how-hydroelectricenergy.html

US Department of Interior, Bureau of Reclamation, Power Resources Office. (2005). Hydroelectric power. http://www.usbr.gov/power/edu/pamphlet.pdf

Wang, L., & Kanehl, P. (2003). Influences of watershed urbanization and instream habitat on macroinvertebrates in cold water stream. *Journal of the American Water Resources Association, 39*(5), 1181–1196.

Yüksek, O., & Kaygusuz, K. (2006). Small hydropower plants as a new and renewable energy source. *Energy Sources, Part B: Economics, Planning, and Policy, 1*(3), 279–290.

Zwikael, O., & Smyrk, J. (2011). The input-transform-outcome (ITO) model of a project. In O. Zwikael & J. Smyrk (Eds.), *Project management for the creation of organisational value* (pp. 11–35). London: Springer.

Springer

http://www.springer.com/978-3-319-16023-8

Energy Systems and Management
Bilge, A.N.; Toy, O.; Günay, M.E. (Eds.)
2015, X, 324 p. 135 illus., 108 illus. in color., Hardcover
ISBN: 978-3-319-16023-8