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Full Length Research Paper

The principal negative environmental impacts of small hydropower plants in Turkey

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There has been a substantial increase in recent years in the number of small hydropower plants (SHP) as an alternative renewable energy source. SHPs are plants which have a capacity of 0.5 to 25 MW and are subject to the environmental impact assessment procedures different from those of other plants in Turkey. There are 903 small hydropower plants in the country including those with a license application under evaluation, those in the process of construction or production. The number of the plants is ever increasing with the newly developed projects. While offering ecological advantages from a global perspective, SHPs may cause some environmental impacts at the local and regional level. In the present study, 40 SHPs (4 in the process of production, 22 under construction, 14 with an application under evaluation) were investigated and evaluated on site and some recommendations made.

Key words: Small hydropower plants, environmental impacts, habitat deterioration, environmental flow, fish and wildlife passages, Turkey.

INTRODUCTION

Today, energy consumed all over the world comprises 34.5% liquids, 26% coal, 23.5% natural gas, 5.5% nuclear and 10.5% renewables (EIA, 2010). In order to meet the increasing energy demand, many countries, especially the developing ones such as Turkey have concentrated on renewable energy sources instead of fossil fuels which are in danger of depletion and may contribute to global warming (Ren21, 2010). Turkey meets 75% of its energy need from imported natural gas, petrol and coal. The rest is accounted for by the internal resources. Overall, the country meets 32% of its energy need from natural gas, 29.9% from petrol, 29.5% from coal, and 8.6% from renewable energy resources like hydropower (ETBK, 2010). In order to decrease the energy dependancy on external sources, the use of hydropower has been heavily emphasized and promoted in the last decade in Turkey, which is separated into 29 large drainage basins (DSI, 2010). Today, 18.5% of electric power is produced in hydroelectric power plants. This production only accounts for 38% of the hydrolic potential of the country (ETBK, 2010). Until recently the majority of the rivers flew freely in Turkey, which ranks as the eighth among the countries with the largest dams in size following China, USA and India (WCD, 2000). In 2003, a regulation about Water Usage Agreement was launched, and the private sector was granted the permission to produce energy in Turkey, with a purpose to make use of the country's hydrolic potential in a better way (Anonymous, 2003a). In addition, in 2005, "the law related to the use of renewable energy resources for electrical energy production purposes" was enacted to support and encourage the private sector to invest in this area (Anonymous, 2005). Following this, hundreds of hydroelectric power plant projects were implemented most of which were small-scaled (Küçükali and Barış, 2009) and located in the northeastern Turkey.

The definition of "small hydropower" is usually defined based on its capacity. It is accepted to be less than 50 MW in China, less than 30 MW in the United States, up to

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25 MW in India and 2 to 10 MW in EU countries (Ren21, 2010). As for Turkey, the hydroelectric power plants are divided into three categories according to their capacity as required by the environmental impact assessment regulations: those below 0.5 MW, between 0.5 to 25 MW and above 25 MW. SHPs are plants which have a capacity of 0.5 to 25 MW and are subject to environmental impact assessment procedures specifically devised for this category of plants different from those of other plants in Turkey (Anonymous, 2008). The number of small-scale hydroelectric power plants in Turkey is 903. However, only approximately 10% of these is in the operational production phase (EPDK, 2010), and the rest is either in the process of initial evaluation or in the construction phase. This low rate of success in the investments can be ascribed to bureucratic and administrational setbacks, and the public opposition to expropriation of the land and to the potential damage of the plant construction on the natural environment. Ecosystem destruction, physical habitat alteration, water chemistry alteration and direct species additions and removals (Malmqvist and Rundle, 2002), damage on freshwater habitats and organisms (Palmer et al., 1997), depletion of floodplain wetlands, decrease in sediment transport, (Kingsford, 2000), decrease and extinction in fish populations due to preventing fish migration and moves, a significant change in natural flow regimes (SHERPA, 2010) are among the most well-known environmental threats of SHPs. Some of the negative environmental impacts of SHPs have led the public to develop a negative attitude towards SHPs while they are usually preferred in regards to renewability, emergency management and reduction in flood risk. As a result of the lawsuits filed by the citizens and non-governmental organizations who have observed the damage on the environment, some plant constructions were stopped by court decision.

Environmental Impact Assessment studies have recently been conducted in accordance with the regulations of the Turkish Ministry of Environment and Forestry in order the decrease the environmental problems brought about by hydroelectric plants (Anonymous, 2003b, 2008). Although environmental impact assessments were obligatory for the hydroelectric plants with a capacity of 50 MW and above, this became obligatory in 2008 for only those with a capacity above 25 MW. As for the projects below 25 MW capacity, Provincial Directorate of Environment and Forestry was given the right to assess the environmental impact (Anonymous, 2003b, 2008). Today, environmental impact assessments are required for all hydroelectric plants due mainly to the pressure from the public, yet the most effective environmental impact assesments are applied in plants located in protected areas, which form approximately 6% of the country's total land area (Anonymous, 2007a).

In this study, 40 SHPs which have undergone environmental impact assessmentand are located mostly in the northeastern Turkey were evaluated. As a result, some major environmental problems due to the planning, constraction and production of SHPs were identified, and some recommendations made.

MATERIALS AND METHODS

Selection of the SHPs was based on the location of the plants with a special attention given to obtaining SHPs in the process of production, under construction and in the process of license application. As a result, forty SHPs were selected from among small-scale (0.5-25 MW capacity) hydroelectric plants located mostly in the northeastern Turkey (Figure 1). Of these, 4 were in the process of production, 22 under construction and 14 awaiting approval for license application. Upon the request of the Ministry of Environment and Forestry and some firms, 16 of these plants (1 in the process of production, 11 under construction, and 4 in the process of license application)- prepared and presented reports about the impact on target species, wildlife, and natural environments (Table 1). Of the 40 plants evaluated, 25 are located in ecosystems under protection (1 in the process of production, 10 under construction, and 14 in the process of license application).

Scientific and technical project documentationof these plants were obtained from the respective governmental institutions, namely the Ministry of Environment and Forestry, Energy Market Regulatory Authority and General Directorate of State Hydraulic Works (DSI). The compatibility of the initial project documentation data to the application on the ground was determined through on site investigations. In all these plants, globally recognized major negative environmental effects of SHPs were evaluated such as harm to fish populations, loss of aquatic habitat, a significant change in natural flow regimes and deterioration of the landscape (SHERPA, 2010).

Any environmental problem faced was classified as one of the negative environmental effects of SHPs mentioned above and discussed under a convenient title in the "disscussion" section. For example, factors like tree cut, digging, fill areas, road construction, blasting, construction of water storage systems such as regulator, pool or lake construction, construction of supply canals, hauling and dumping the excavated earth in the area, loss of riparian zone and destruction of wetlands, waste water coming from the construction of tunnels, and cumulative impacts like habitat degradation, fragmentation, loss or alteration were collected under the section "habitat deterioriation". The fact that the citizens whose land was expropriated had psychological difficulties in leaving the areas they had been using for centuries to start a new life was considered a "social problem" caused by the expropriation, and thus was not included in the assessments. In order to determine which of the problems had more impact, each problem was graded for practical purposes from 1 to 5 depending on their impact degree. Here 1 stands for no impact, and 5 severe impact. In addition, a "?" was used for situations in which the effect of an environmental problem could not be determined. Initial reports prepared upon the request of the Ministry of Environment and Forestry and companies for the 16 plants to determine the impacts on target species, wildlife and natural environment were heavily consulted to come up with some of the recommendations made.

RESULTS AND DISCUSSION

As a result of the analysis of 40 SHPs; 4 in the process of production, 22 under construction, 14 awaiting approval of license application, the principal negative impacts were classified under nine main headings (Table 1).

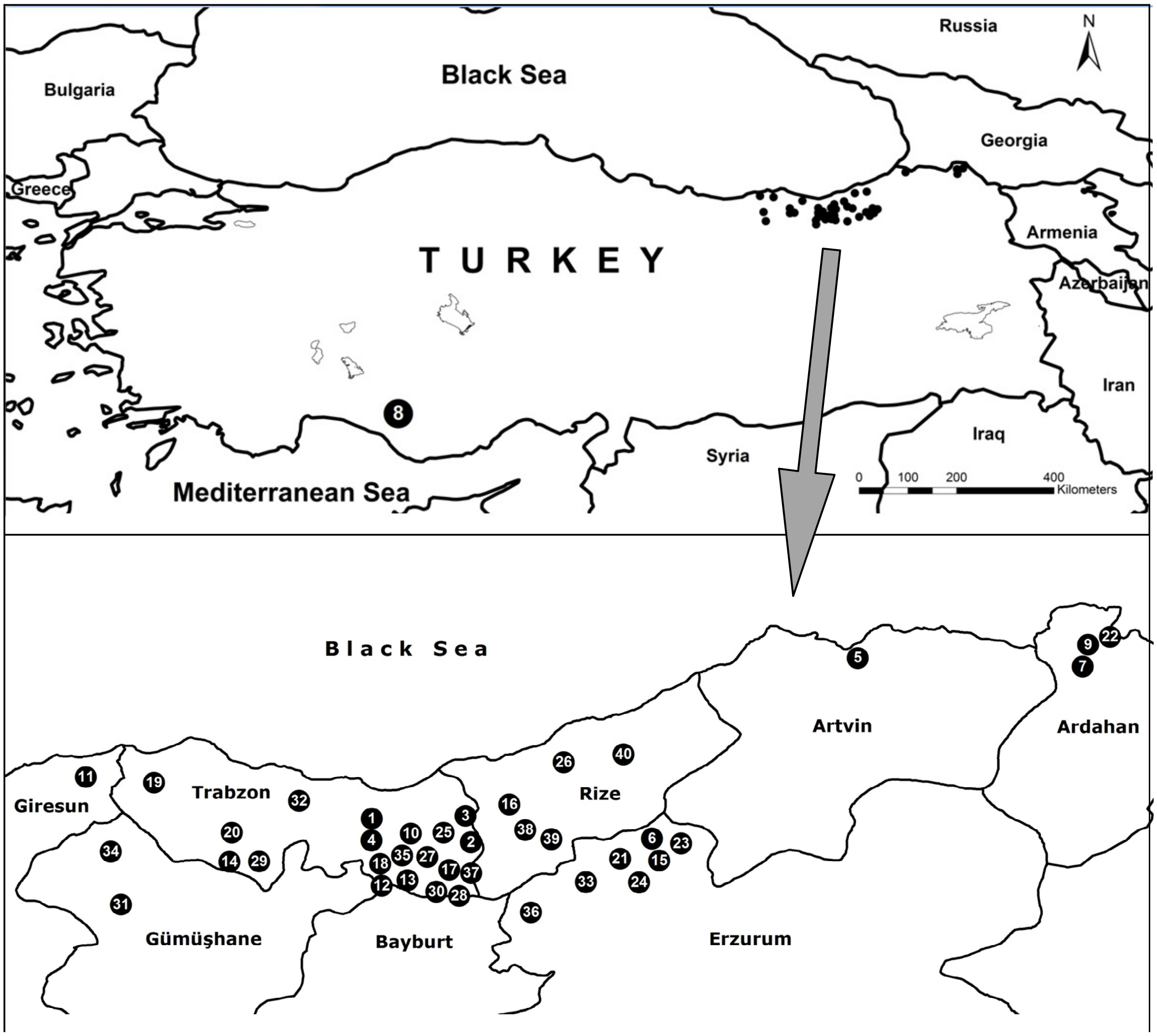

Figure 1. Location of 40 small hydropower plants in Turkey (One of them in the south, the others in the northeastern parts of Turkey).

Habitat deterioration

Habitat deterioration is the main environmental problem in plants under construction while it is the second most important problem in plants in the process of production and in the application evaluation. Habitat deterioration observed in the form of habitat degradation, fragmentation, loss or alteration is mainly caused by such factors as tree cut, excavation, fill areas, road construction, blasting, construction of water storage systems like regulator, pool or lakes, construction of supply canals, excavations, loss of riparian zone and destruction of wetlands. Water was used to be carried through pipe lines for 1 to 6 km in highly steepmountaneous areas in the beginning of the 2000s. As a result, many problems had to be dealt with including tree cut, erosion and excavated material and associated dumping. However, today these problems are experienced less frequently since water is generally carried via tunnels. Instead, other problems like waste water in the tunnel site and excavations have become a major concern.

The effect of more than one plant over a river is much greater than that of a single plant due to the cumulative impacts resulting from consecutive construction (Odom, 2010). It has been observed that the majority of the habitat deterioration problems stems from the improper planning and handling of the cumulative impacts. They are not accounted for on the basis of a river's reservoir, nor are the plants constructed over the main river and its tributaries in such a way as to cause as little damage to the environment as possible. In almost all river basins, the hydroelectric plants are constructed immeddiately one after another starting nearly from the very source of the river to where it empties into the sea. The projects are so close to each other that only a 50 to 300 m obligatory tailwater discharge distance is maintained between the

Table 1. The 40 SHPs analyzed and the main negative impacts on the environment.

S/n	Hydroelectric Plant	Capacity (MW)	Condition	Environmental Problems** Degree of gravity (1 = no impact, 5 = severe impact, ? = uncertain)								
				a	b	c	d	e	f	g	h	j
1	Günayşe, Köprübaşı, Trabzon*	8.45	In the process of production	5	4	5	3	2	2	4	3	3
2	Sarmaşık I, Hayrat, Trabzon	20.00		4	4	5	3	2	2	4	3	2
3	Sarmaşık II, Hayrat, Trabzon	21.74		4	4	5	3	2	2	4	3	2
4	Yukarı Manahoz, Trabzon	22.86		5	4	5	3	2	2	4	3	3
5	Camili, Artvin	2.81	In the process of under construction	3	4	4	?	3	3	3	4	1
6	Başyurt, Çamlıkaya, Erzurum	3.23		3	4	4	?	4	4	3	4	2
7	Çakırkoç (Posof I), Ardahan*	4.10		3	3	3	?	3	3	3	3	1
8	Alacami – Bucakköy, Antalya*	4.12		3	4	3	?	3	3	3	4	1
9	Söğütlükaya (Posof III), Ardahan*	4.94		3	3	3	?	3	3	3	3	1
10	Ataköy, Trabzon	5.00		3	4	4	?	4	4	3	3	2
11	Çanakçı I, Görele, Giresun	6.00		4	4	4	?	4	4	4	3	1
12	Balkodu II, Trabzon	6.43		5	4	4	?	4	4	4	3	5
13	Çamlıkaya, Karaçam, Trabzon	7.00		5	4	4	?	4	4	4	3	5
14	Cevher II, Maçka, Trabzon*	7.38		5	4	5	?	4	4	4	4	2
15	Çamlıkaya, Erzurum	8.41		4	4	4	?	4	4	4	4	2
16	Ambarlık I-II, Rize*	9.00		4	4	4	?	4	4	3	3	2
17	Uzungöl I, Trabzon	9.00		4	4	4	?	4	4	3	5	1
18	Balkodu I, Trabzon	9.10		5	4	4	?	4	4	4	3	5
19	Çanakçı, Vakfıkebir, Trabzon	9.46		4	4	4	?	4	4	4	3	1
20	Cevher I, Maçka, Trabzon*	9.68		5	4	5	?	4	4	4	4	1
21	Yedigöl, Erzurum *	11.42		3	3	3	?	3	3	3	5	1
22	Merekler – Algölü, Ardahan*	12.53		3	3	3	?	3	3	3	3	1
23	Sırakonaklar, Erzurum*	13.42		3	3	3	?	3	3	3	4	1
24	Aksu, Erzurum*	14.39		3	3	3	?	3	3	3	3	1
25	Üçharmanlar, Of, Trabzon	16.64		4	4	4	?	4	4	3	3	2
26	Uzundere II, Rize*	20.00		5	4	4	?	4	4	3	3	2
27	Volkan, Çaykara, Trabzon*	1.84	License application assessment	4	4	?	?	?	?	?	3	?
28	Güven, Demirkapı, Trabzon	3.75		5	4	?	?	?	?	?	5	?
29	Meryemana, Trabzon	4.01		5	4	?	?	?	?	?	5	?
30	Demirkapı, Trabzon	5.60		5	4	?	?	?	?	?	5	?
31	Gelincik, Torul, Gümüşhane	6.30		4	4	?	?	?	?	?	3	?
32	Yanbolu, Trabzon	6.90		4	4	?	?	?	?	?	3	?
33	Çayırözü, Ovit, Erzurum*	7.99		5	4	?	?	?	?	?	5	?
34	Fındık, Kürtün, Gümüşhane*	9.00		4	4	?	?	?	?	?	3	?
35	Çınar, Balkodu, Trabzon	9.40		4	4	?	?	?	?	?	4	?
36	Cevizli, Pazaryolu, Erzurum*	11.65		5	4	?	?	?	?	?	4	?
37	Kısacık, Demirkapı, Trabzon	14.14		5	4	?	?	?	?	?	5	?
38	Selin I, Cimil, Rize	17.85		4	4	?	?	?	?	?	4	?
39	Selin II, Cimil, Rize	23.00		4	4	?	?	?	?	?	4	?
40	Dikkaya, Fırtına, Rize	25.00		4	4	?	?	?	?	?	4	?

(*): The plants over which a report was prepared upon the request of Ministry of Environment and Forestry or firms; (**): Environmental Problems: a) Habitat deterioration, b) Fish and wildlife passage, c) Environmental flow d) High-voltage power lines, e) Wastes, f) Dust and noise, g) Rehabilitation and restoration, h) Visual pollution, j) Illegal hunting.

projects. The plants over highlands with highly sensitive ecosystems receive the same treatments with little or no regards given to the idiosyncratic properties of the area. But, a scientific report presented to General Directorate of Nature Conservation and National Parks in the Verçenik Mount Wildlife Development Site (Başkaya, 2009a) indicated that the construction of plants above 1300 m would be more harmfull on the environment than its expected benefits Although environmental impact assessment is required for the plants above 0.5 MW capacity at present, as a result of public pressure to decrease the environmental problems, the assesments are not made as effectively and efficiently as required. Even this insensitive assessment in Turkey has the same barrier effect as the “Water Framework Directive” has had on the development of SHPs in many EU countries (EC Directive, 2000).

Fish and wildlife passages

According to laws of the country, considering the changing habitat conditions, it is essential that ease be maintained in wild animals’ movement including fish. To this end, construction of fishways or fish ladders for fish migration and movement, and constructions like overpass, underpass, culvert or bridge for other wildlife species is necessary. Today, only fish ladders are constructed in plants as a wild animal passage. Fish ladders were present in only certain projects at the beginning of the 2000s. Today, releasing inadequate water to these ladders, most of which are not technically appropriate, is another problem. It has been reported that even the most appropriate fish passages in France create at least some delay in migration and the plant turbines cause fish deaths (Larinier, 2008). Apart from the delays in migrations, appropriate filter systems and new technology “fish-friendly” turbines should be used in order to prevent fish and other water organisms from being harmed by getting into the water to be used in small hydropower plants. In addition, methods like fish locks, borland lock, by-pass channels, lift, fish elevators and transportation of fish upstream via truck should also be considered (Trussart et al., 2002).

Wildlife passages for other wild animals apart from fish can be incorporated into all projects, most of which are in the process of construction at the moment. In many plants awaiting application evaluation, the reports prepared upon the request of firms and presented to the Ministry of Environment and Forestry emphasize that the construction of passages for large mammals like Brown bear (Ursus arctos), Roe deer (Capreolus capreolus), Anatolian chamois (Rupicapra rupicapra asiatica) and Wild goat (Capra aegagrus) and small terrestrial mammals like Eurasian badger (Meles meles), European otter (Lutra lutra), Weasel (Mustela nivalis) and Pine marten (Martes martes) are required (Başkaya, 2009a,b,c,d). Furthermore, it is noted in the same reports that wildlife passages without banisters be constructed in certain distances in order to ease the animal passages along the way on the basis of high priority species and ecosystem features (Başkaya, 2009a,b,c,d). Last but not least, signs about the high priority species should be placed in and around the project sites for increasing the public awareness to the environment. Such an activity has never been observed in any plant.

Quantity of environmental flow (reserved flow) and monthly distribution

The amount of environmental flow to be released into the river basin for the continuity of natural life and its monthly distribution are among the mostly discussed topics in the country. The calculation of the quantity of the environmental flow and the distribution per month requires lengthy scientific studies. Nowadays, there is no universally valid solution to calculate environmental flow (SHERPA, 2010). The Tennant (Montana) Method, which is used more extensively than other methods with a rate of 30% worldwide (Tharme, 2003), is also the most widely used method in Turkey. It is stated that Tennant Method should be used in rivers with a slope of less than 1% (Mann, 2006) and there should be differences concerning the use in every area or country (Orth and Maughan, 1981; Acreman and Dunbar, 2004). Although it is stated that it could be used in only carstic areas and dry or low flow rivers in Turkey (Özdemir et al, 2007), today it is used in every kind of rivers without any adjustments in the method.

Today, there are different practices for calculating the amount of reserved flow in every country. For example, in Germany this is between 1/3 and 1/6 of the mean minimum flow, in Greece >1/3 of the mean summer flow, and in France generally more than 1/10 of inter-annual mean flow, and more than 1/20 of inter-annual mean flow in high flow rivers larger than $80m^3/s$ (SHERPA, 2010). In the beginning of the 2000s, the environmental flow was 1% of mean annual flow in Turkey; it was later raised to 2.5% and then to 5%, and at present it is 10%. In an environmental flow of 10% which is regarded as “too low” by Tennant, living things can only live for a short time (Tennant, 1976). In Turkey this rate which has been accepted by the governmental institutions for all rivers except protected areas, should be raised to at least 20%. The environmental flow in protected areas was 5 to 10% in the beginning of the 2000s. Today, this rate is 15 to 25%. However, given the characteristics of the protected areas, this should be at least 20% in the dry season and 40% in the wet season. Moreover, the amount of water required for the needs of the people living in the river reservoir should also be added to the calculated reserved flow.

The lack of control over environmental flow

It has been observed that this is a highly serious problem in plants already in the production phase. Today, there is no strict control over the amount of environmental flow.

Even the required 10% environmental flow, which is considered insufficient by the majority of public, sometimes is not released into river beds for several days. In this respect, though some fines are adequate as legal enforcement, the control efforts are not carried out continuously. Although a repeated fine received may require the closure of the organization completely. The law has never been put to practice for mainly political concerns and, to a certain extent, the lack of control personnel and equipment.

High-voltage power lines

The damage to bird and human health as well as visual pollution is also a topic of discussion in the country. The underground transmission which is safer in this respect is not used in the country due to the cost and time involved in construction. The negative effects of high-voltagepower lines on birds are reported to beare heavier than those of wind turbines (Kuvlesky, 2007) But, no or little attention is paid in the determination of the powerline routes, creating a danger for birds, jeopardizing public health and causing aesthetic deformations in the natural ecosystems. As a solution, high-voltagepower lines should be designed to pass at least 300 m away from the residential areas with a concern about the integrity of the landscape and aesthetic view.

Wastes

Nearly in all the plants under construction, hardly any precautions are taken to prevent the negative environmental effects of solid and liquid wastes such as glass, nylon, tin, paper, waste water from toilet,and kitchen sink and oil and fuel used in machines and other equipment. In addition, polluted water during the tunnel constructions is usually discharged to rivers without any treatment. In this respect, it is recommended that solid wastes be stocked in solid waste depots, liquid wastes in septic tanks and oil and fuel waste in containers (Başkaya, 2009a,b,c,d).

Dust and noise

Limited precautions have been taken with regards to the increased traffic, the dust and noise resulting from the construction works such as excavation, filling, cutting and blastings. Precautions taken only involved the wetting of graveled road and the covering of the trucks carrying excavated material to reduce the amount of dust release. As for the noise, the construction machines should be of high standards and be under regular maintenance, and the blastings should be carried out employing environmentally friendly techniques. In addition, there is almost no arrangements in the work hours with respect to the wildlife requirements. In the plants in protected areas and ecosystems, the work hours should be reorganized especially on the basis of the biology of the priority species. For example, in the breeding season of Wild goat and Anatolian chamois, construction works should cease between 06:00 to 09:00 in the morning and 16:00 to 19:00 in the evening, and theconstruction work should be carried out so carefully that no disturbance is given to the animals (Başkaya, 2009b).

Inadequate rehabilitation and restoration of habitat

During construction, the environment is ignored; however, after the construction stage, partial rehabilitation and restoration works are undertaken through grass seeding and planting trees. In the reports presented to the Ministry of Environment and Forestry, it is recommended that a habitat at least as large as the areas damaged should be planted with trees, bushes, shrubs and herbaceous species that are compatible with the natural flora. (Başkaya, 2009a,b,c,d).

Illegal hunting

In recent years, illegal hunting by the project personnel has been added to the existing illegal hunting types. Especially the personnel working in some of the plants in construction and production stages illegally hunt some wildlife species. These species include Wild goat, Anatolian chamois, Roe deer, Brown bear, Wolf *(Canis lupus*), Fox (*Vulpes vulpes*), Wild boar (*Sus scrofa*), Wild hare (*Lepus europaeus*), Caucasian black grouse (*Tetrao mlokosiewiczi*), Caspian snowcock (*Tetraogallus caspius*), Wild goose species (*Anser* sp.), Wild ducks species (*Anas* sp.) and Brown trout (*Salmo trutta*). In hunting,some machinaries and intelligence devices used in the plants are heavily utilized either individually or in cooperation with the local people. In this respect, the personnel should especially be informed of the sensitivity of the target and high priority species and environment, and they should be prevented from illegal hunting (Başkaya, 2009a,b,c,d).

Conclusion

As can be seen from the disscussion above, habitat deterioriation ranked first among the negative factors, followed by environmental flow, fish and wildlife passages, rehabilitation and restoration, visual pollution, wastes, dust and noise, illegal hunting, and high-voltage power lines. Considering the plants in the process of production, construction and license application assessment individually, there may be differences in the rank order of the problems. The major problems in plants in the process of production are environmental flow, habitat deterioration, fish and wildlife passages, rehabilitation and restoration, power lines, visual pollution, illegal hunting, wastes, dust and noise. On the other hand, the order in plants in the process of appli-cation assessment is as follows: habitat deterioration, environmental flow, fish and wildlife passages, wastes, dust and noise, visual pollution, rehabilitation and restoration, illegal hunting and power lines. All of the 14 plants that are in the process of license application assessment are located in protected areas and ecotourism regions. Although the construction of these plants have yet to start, field observations and the study of the project documents made it clear that there would be serious problems with respect to the implementation of fish and wildlife passages as well as visual pollution due to the improper location and the design of the proposed plants.

Turkish governments have taken precautions for environmental issues resulted from renewable energy utilization but these are obviously not adequate (Küçükali and Barış 2009). However, most impacts can be avoided or reasonably mitigated if the projects are correctly planned, designed and controlled. And also, more attention must be paid on especially cumulative impacts and monitoring studies on every process of plants.

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