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# Ecological Impact of Economic Development on Sardinian Herpetofauna

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**Abstract:** *The link between ecology and economies is manifest over the world as a result of long-term processes. But because these processes are long term, it is hard to prove the link. On Sardinia serious economic development was late to arrive, having occurred only over the last few decades. As a case study, research was carried out for 10 years on the state of nature as well as the economic growth in one of the least developed areas abutting the Gulf of Orosei on the east coast. Based on research and lasting attention to political affairs concerning the project, we formulate general recommendations for the area. In 1995, the Italian Government will be asked by the European Government to undertake serious steps to save endemics (especially herpetofauna) of Europe's last pristine areas.*

Impacto ecológico del desarrollo económico sobre la herpetofauna de Cerdeña

**Resumen:** *La relación entre ecología y economía se manifiesta en todo el mundo como resultado de procesos a largo plazo. Sin embargo, debido a que los procesos son a largo plazo, es difícil probar esta relación. En Cerdeña, el desarrollo económico serio arribó tardíamente, habiendo ocurrido sólo en las últimas décadas. La investigación de un estudio de caso ha sido llevada a cabo a lo largo de 10 años, dirigida tanto hacia el estado del medio natural como hacia los cambios económicos en una de las áreas menos desarrolladas que rodean al Golfo de Orosei en la costa este Sardinia. Se formulan recomendaciones generales para el área basadas en esta investigación y en la persistente atención a las cuestiones políticas relativas al proyecto. En relación con Cerdeña, el Gobierno Europeo pedirá al Gobierno Italiano que tome serias medidas para salvar a las especies endémicas (especialmente en lo relacionado con herpetofauna) de los últimos entornos vírgenes de Europa.*

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## Introduction

The total surface area of Sardinia exceeds 24,000 km<sup>2</sup>, making it one of the largest islands in the Mediterranean. In administrative terms it is under the jurisdiction of Italian Government. At a regional level, however, it is self-governing. The island is divided into four provinces: Sassari (north), Cagliari (south), Oristano (west), and Nuoro (east). The average population density ranges between 40 inhabitants per square kilometer in Nuoro

to 110 per kilometer in Cagliari. The population density is low by European standards (<10 per km<sup>2</sup>), outside residential areas in particular. This is one reason why there are a relatively large number of areas that are not heavily affected by humans. Another explanation is that serious economic development was late in arriving. Until the 1970s, the Sardinian economy was based mainly on agricultural and crafts products (Colomo & Ticca 1984).

The areas used either extensively or not at all are characterized by a great diversity in vegetation structure and landscape form. The Sardinian landscape is shaped by sandy beaches, mountains, upland plains,

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river beds, and extensive marshes, all of which play host to a rich flora and fauna. For example, there are no fewer than seven Sardinian and six Tyrrhenian endemic taxa among the amphibians and reptiles, such as rare birds as the Black Vulture (*Aegyptus monachus*) and Eleonora's Falcon (*Falco eleonora*) breed there, and there are indications that the extremely rare monk seal (*Monachus monachus*) can still be found (Voeselek & van Rooy 1984). The pronounced increase in economic growth as well as the rise in tourism are placing both the landscape and the flora and fauna under pressure. With encouragement from the European Community and other sources, areas are being opened up and developed (Kommission der Europaeischen Gemeinschaften 1992). The pace of development is so rapid that it has all the signs of an economic recovery program.

On the basis of the rich herpetofauna, the Societas Europaea Herpetologica (SEH) commissioned a study in 1984 of the status of nature in one of the least developed areas of Sardinia still in its original state. This area abuts the Gulf of Orosei (Fig. 1). The study focused on the herpetofauna, partly due to its value as an indicator of ecosystem health in general (Voeselek & van Rooy 1984). On the basis of this study and the resultant recommendations, the Standing Committee of the Berne Convention (Council of Europe) recommended in 1988 a number of measures to protect nature in this area. The Italian Government failed to implement the measures, and the ecosystem deteriorated. In 1989 the SEH again reported on the situation on the basis of new field observations (van Rooy 1989). The report described a negative trend in the preservation of the herpetofauna. An on-the-spot appraisal was therefore carried out in 1992 under the provisions of the Berne Convention. The resultant report underlined the need to implement measures to safeguard the various Sardinian habitats (Stumpel 1992). The preparations being made to designate the Gennargentu Mountains (Fig. 1), adjacent to the study area, as a nature park may allow for action. The current thinking is to merge the study area with the mountains to create a single nature park.

We intend to show the link between ecology and economies through the use of Sardinia only as a case study because the relationship between the two forces is at play around the globe, not just in Sardinia.

## The Economy

Sardinia had almost 1.7 million inhabitants in 1990. Between 1980 and 1990 the average annual growth in the population was 0.5%, more than twice the Italian average over the same period (Croene 1992). Along with population growth, per capita consumption is also rising. Annual growth between 1980 and 1988 was 4.2%,

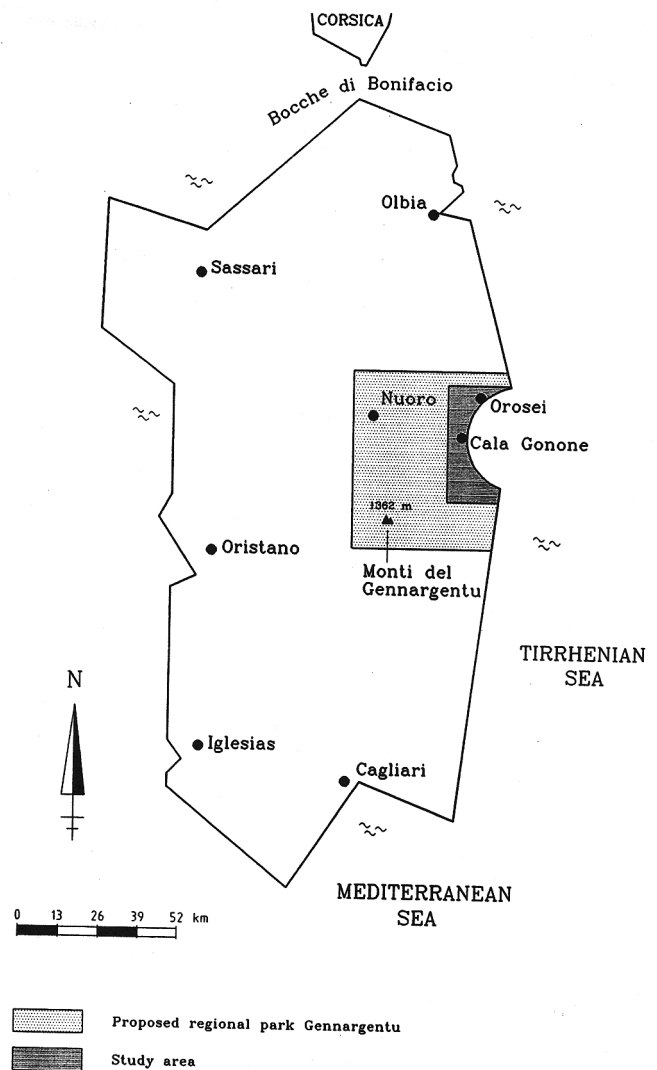


Figure 1. Map of Sardinia.

reaching 4.5% in 1988 and 1989. This growth figure also exceeds that for Italy as a whole (Banco di Sardegna 1991). As a result of the sharp increase in consumption, there was a significant decline in exports between 1985 and 1989. The fall was experienced in agricultural products (-29%), chemicals (-42%), industrial products (-29%), and wood (-22%). The fall in exports contrasts with a rise in the import of foodstuffs (+43%)—in particular, tobacco (+40%), wood (+25%), and printed paper (+59%) (Croene 1992). Apart from the aforementioned link between population growth and economic growth, a proportion of these developments can be explained by a growth in tourism. The annual number of nights spent by tourists between 1973 and 1988 was 2,356,251 and 7,428,478, respectively, an increase of 315% in 15 years (Istituto Nazionale di Statistica 1991; Croene 1992). The tourists are usually affluent and stay in three-star-or-higher hotels, tourist resorts, or villages of holiday homes (Banco di Sardegna

1992). These facilities are generally in the hands of non-Sardinians. The tourist season is mainly confined to the summer months (Banco di Sardegna 1992).

For an island experiencing such growth, a good infrastructure is vital, including a good ports infrastructure. Olbia appears to be becoming the main port of Sardinia. Access channels making the harbor navigable to vessels with a larger tonnage are being created there (Croene 1992).

The European Community's Regional Development Programme 1977–1980—being realized in the 1990s—focused on areas such as physical planning, infrastructure, and the environment. The physical planning proposed was improvement in the spatial distribution of functions and key focal points. The infrastructure allegedly required improvements and expansions in several areas, ranging from the road and rail network to waterworks. The environment was interpreted in particularly narrow terms and linked directly to human economic function. Reference is made only to the quality of water, soil, and air if it was considered important for human functions, such as extraction of drinking water and flood control (Kommission der Europaischen Gemeinschaften 1992). The Programme advocated economic growth in almost all areas, completely ignoring nature and saying virtually nothing about the environment. Both, however, are practical conditions governing human activity and of direct importance for an economic endeavor such as tourism. Ecotourism is virtually unknown in Sardinia while it is the means of making nature conservation affordable.

## The Landscape

Developed areas are growing in Sardinia as a result of population growth, economic growth, and the increase in tourists. New areas of industry and resorts are also growing. The expansion of the existing urban area and the construction of industrial estates are making inroads into areas where agriculture has been the business for generations, the ring around towns and villages. To offset this loss of agricultural land, areas previously inaccessible are being opened by the construction of roads. Centuries-old trees, notably Holm oaks (*Quercus ilex*), are being felled with two aims in mind: to meet the growing demand for timber and to create space for agricultural crops. Following the felling, cattle grazing takes care of the final clearing. Over the last few decades in particular, numerous agricultural settlements have been created in this manner, which in their turn represent the first step toward further exploitation of the area. Large cattle from these settlements penetrate the surrounding areas, previously little-touched. Goats and pigs in particular cause great damage in these areas. Their method of foraging prevents young trees from

growing. Large areas are already characterized by the absence of adult trees, the presence of forms of bonsai, and monocultures of a few nonedible plants such as asphodel (*Asphodelus* spp.). In order to meet the demand for wood, quick-growing pines (*Pinus nigra*) have been planted on some cleared areas, creating monocultures.

The main impact of rapidly growing tourism is felt on landscapes along the coast. For example, hotels and other facilities have appeared near sandy beaches previously cut off entirely by rocks, or *calas*. Their sheltered location and the surrounding natural beauty make such *calas* very popular with tourists. Boat trips are organized from such places as Cala Gonone—a rapidly growing village at the edge of a *cala*—to bring the *calas* that are not yet accessible by land within reach of the public. Moorings for boats, snackbars, and kiosks form part of the “new” landscape for such *calas*. Apart from the development of the beaches, many agricultural and natural areas located near the coast are also being developed for hotels and tourist villages.

The development is making its mark on the environment. Fresh water is the element most seriously affected; saline water also exhibits increasing algal blooms in sheltered spots in the summer. Freshwater systems are coming under pressure in qualitative as well as quantitative terms (van Rooy et al. 1993). They are affected quantitatively by the expansion of urban and agricultural area, causing water to run off rather than infiltrate; by the felling of original, deciduous trees and the planting of nonnative conifers; by the storage of water in reservoirs that are sensitive to evaporation; by the increasing use of drinking and process water; and by very limited water-treatment facilities that allow water to be used only once. The direct consequences are drying-up of land, characterized by streams running dry, changes in the vegetation structure, and the need to move more and more water. Some areas are even affected by desertification (De Jong et al. 1995). In qualitative terms, both the ground and surface water have been affected by the largely untreated discharges of domestic and industrial effluent. Only recently has water treatment begun to receive attention, and sewage treatment plants have been built on a modest scale. Agriculture has also played its part in the decreasing water quality. Fertilizers in the water have created algal blooms, and pesticides have disrupted the ecological functioning of water systems (De Jong et al. 1995). The agricultural lands in the study area have been “enriched” each year by the addition of 3–10 kg of pesticides per hectare (Netherlands Institute of Public Health and Environmental Protection 1992). Water quality has also been adversely affected by the leaching of chemicals and domestic waste from largely uncontrolled rubbish dumps. These problems will almost certainly continue until scarcity of good water becomes apparent on a broad scale (Brundtland 1987).

Deterioration of soil and air quality also witness to the environmental effects of the changes on Sardinia. Several locations have experienced soil erosion caused by the clearing of the vegetation (Netherlands Institute of Public Health and Environmental Protection 1992). Pollution of water and air also pollute the soil. The source of air pollution lies mainly outside the study area.

## Ecological Impact

An ecosystem consists of abiotic and biotic components between which interactions occur. Any impact on one implies an impact on the other, albeit this relationship is most strongly manifest in changes in the abiotic component, which we have discussed for Sardinia (Liddle 1975). Below we provide an outline of the impact of developments in Sardinia on the biotic component, with an emphasis on the herpetofauna studied as an indicator.

In general, excessive human intervention leads to impoverishment of the structure and diversity of vegetation (Liddle & Scorgie 1980). This is abundantly true in the study area. Adult oaks were uprooted and young trees were given no chance because of excessive grazing by cattle. At (over)grazed locations, herbal vegetation consists of ground-covering a few centimeters in height and well-developed submersed aquatic vegetation has given way to algae and reeds. This change in the vegetation structure has also changed the habitat of several animal species, causing specialized animal species to disappear in favour of less specialized species. To form a picture of changes in the biotic component, the herpetofauna in the Gulf of Orosei were studied over a number of years (Voeselek & van Rooy 1984; Corbett 1989; van Rooy 1989; Stumpel 1992). The decision to choose herpetofauna as an indicator was prompted in part by the quick responses of most amphibians and reptiles to changes in their living environment.

The Gulf of Orosei region consists of a wide variety of habitats within a relatively small area, ranging from pristine sections to those intensively used by humans. The major part of the area is undisturbed, or only slightly so. It harbors a rich herpetofauna (18 species), including three rare and seriously endangered Sardinian and six Tyrrhenian endemics (Table 1). Table 2 presents the characteristic species of reptiles and amphibians for the main habitats in the area (Voeselek & van Rooy 1984).

The most-sensitive species are encountered at a limited number of sites. Further research will investigate whether this is natural and, if so, on what scale. Nevertheless, this situation emphasizes the vulnerability of the species involved. For example, a study of one of the Sardinian cave salamanders (*Speleomantes supramontis*) identified it in a single cave near an agricultural area

undergoing development. The cave is frequently visited by speleologists who disturb the microclimate at the entrance, where most of the salamanders reside, by removing vegetation. Nevertheless, in the summer of 1984 the average relative humidity was 86%. In four similar caves it was less than 80%, and none of these caves contained cave salamanders. These results fit with former research on cave salamanders *Speleomantes supramontis* showing the dependence of salamanders on high relative humidity (Bruno 1980; Kühnel et al. 1983). There have also been strikingly few observations of the Sardinian brook salamander (*Euproctus platycephalus*), which initially was found widely on the island (Alcher 1975). The species was found exclusively in a number of hydrological interconnected mountain pools by means of temporary brooks (Voeselek & van Rooy 1984; Stumpel 1992). Serious pollution of the highest pool, because of its use as a washing place for cattle and utensils, could have had some impact on the system as a whole and could have caused the species to disappear from the system. The species is also extremely rare elsewhere on the island. The study area probably plays host to the most important world population of what in all probability is Europe's rarest amphibian.

Sporadic observations are reported of loggerhead turtles (*Caretta caretta*). It is not clear whether this comes from the secrecy of (illegal) catches by fishermen or whether there are actually few animals that occur along the coast. No observations of nesting activities have been reported despite the physical suitability of the sandy beaches and the good-to-moderate surrounding marine environments (Whitmore et al. 1991). The Sardinian grass snake (*Natrix natrix cetti*), which in the near future may be elevated to a full species, is extremely rare. It occurs in the same brook system as the Sardinian brook salamander. Bedriaga's rock lizard (*Lacerta bedriagae*) has never been found in the study area, even though potential habitat for this very rare endemic seem to occur. Within 10 years the number of observations of the Tyrrhenian wall lizard (*Podarcis tiliguerta*) has fallen both in and near inhabited or frequently visited areas, in favor of the less specialized Sardinian wall lizard (*Podarcis sicula cetti*) (Voeselek & van Rooy 1984; Stumpel 1992).

The highly localized occurrence of sensitive species is closely related to human intervention in various landscape types, pollution of the environment, and disturbance by tourists. Sensitive plants and animals survive only where human influence is limited. Frequently, these are the areas that are not yet easily accessible. If sensitive species are scattered throughout the landscape, the risk of genetic isolation and their eventual disappearance is great. If there is further manifestation of human intervention in the last suitable areas, the encroachment will proceed more rapidly and the disap-

Table 1. Sardinian herpetofauna taxa, their presence in the Gulf of Orosei area, and their endemism.

Sardinian Taxon	Gulf of Orosei	Sardinian Endemic	Tyrrhenian Endemic
<b>Salamanders</b>			
Sardinian cave salamander ( <i>Speleomantes genei</i> )	—	x	
Supramonte cave salamander ( <i>Speleomantes supramontis</i> )	x	x	
Monte Albo cave salamander ( <i>Speleomantes flavus</i> )	—	x	
Imperial cave salamander ( <i>Speleomantes imperialis</i> )	—	x	
Sardinian brook salamander ( <i>Euproctus platycephalus</i> )	x	x	
<b>Frogs and Toads</b>			
Tyrrhenian painted frog ( <i>Discoglossus sardus</i> )	x		x
Green toad ( <i>Bufo viridis viridis</i> )	x		
Sardinian tree frog ( <i>Hyla sarda</i> )	x		x
<b>Turtles, Tortoises, and Terrapins</b>			
Leatherback ( <i>Dermochelys coriacea</i> )	—		
Loggerhead turtle ( <i>Caretta caretta</i> )	x		
Green turtle ( <i>Chelonia mydas</i> )	—		
Hermann's tortoise ( <i>Testudo hermanni hermanni</i> )	—		
Mediterranean spur-thighed tortoise ( <i>Testudo graeca graeca</i> )	—		
Marginated tortoise ( <i>Testudo marginata</i> )	—		
European pond terrapin ( <i>Emys orbicularis</i> )	x		
<b>Lizards</b>			
Common gecko ( <i>Tarentola mauritanica mauritanica</i> )	x		
Turkish gecko ( <i>Hemidactylus turcicus turcicus</i> )	x		
European leaf-toed gecko ( <i>Phyllodactylus europaeus</i> )	x		x
Pygmy algyroides ( <i>Algyroides fitzingeri</i> )	x		x
Bedriaga's rock lizard ( <i>Lacerta bedriagae</i> )	?	x	
Tyrrhenian wall lizard ( <i>Podarcis tiliguerta tiliguerta</i> )	x		x
Sardinian wall lizard ( <i>Podarcis sicula cetti</i> )	x		x
Three-toed skink ( <i>Chalcides chalcides vittatus</i> )	x		
Eyed skink ( <i>Chalcides ocellatus tiligugu</i> )	x		
<b>Snakes</b>			
European whip snake ( <i>Coluber viridiflavus viridiflavus</i> )	x		
Horseshoe whip snake ( <i>Coluber bippocrepis</i> )	—		
Sardinian grass snake ( <i>Natrix natrix cetti</i> )	x	x	
Viperine snake ( <i>Natrix maura</i> )	x		

pearance of the populations will be a matter of a few decades at most.

## Conclusions and Recommendations

The current demographic and economic development of Sardinia is totally at odds with the ecological functioning of the island. The traditional synergy between culture and nature has given way in just a few decades to exploitation of nature. In view of its dependence on nature, it is therefore very likely that the current economic growth is a finite phenomenon. In particular, mass tourism is responsible for the erosion of nature on Sardinia—directly in the form of pollution, disturbance of peace and quiet, and the use of space, and indirectly by the use of drinking and processed water and natural materials for the construction of resorts and the associated opening-up of natural areas.

The Berne Convention, which was ratified by Italy in 1982 and which sets forth clearly defined measures for Sardinia in a recommendation of the Standing Committee (no. 13, 1988), has so far failed to meet its aims. Not

a single measure to protect highly valuable ecological areas has been implemented up to 1994. In this case area protection is nothing but a condition for the protection of sensitive species, with the areas required to be of sufficient size to maintain metapopulations.

Immediate action needs to be taken regarding the use of the study area. If current trends continue, the result will be short-term economic blossoming at the expense of the area's natural qualities. The possible loss of these qualities also implies a sharp decline in the economy. With a view to the sustainable development of the area, it is advisable for human disturbance of the area to be curbed. The legal framework for this could be found by designating the area a regional park.

The current relationship between tourism and nature—as a tourist attraction—is to the benefit of the former and to the detriment of the latter. This one-sided relationship is therefore destined to have a short life. For example, by switching to ecotourism (nature pricing) some synergy could be achieved within the relationship. The tourist pays, for example, for the purchase and maintenance of a nature area or the imagined regional park, and nature retains its attraction value. Various pro-

**Table 2. Habitats in Gulf of Orosei area and their characteristic reptiles and amphibians.**

Habitat	Characteristic Species
Coastal Dunes (beaches, sand dunes, dune lakes, calas)	Loggerhead turtle ( <i>Caretta caretta</i> )
	European pond terrapin ( <i>Emys orbicularis</i> )
	Eyed skink ( <i>Chalcides ocellatus tiligugu</i> )
Rivers and Streams	Sardinian brook salamander ( <i>Euproctus platycephalus</i> )
Mountain Lakes	Sardinian brook salamander ( <i>Euproctus platycephalus</i> )
	Sardinian grass snake ( <i>Natrix natrix cetti</i> )
Maquis	Tyrrhenian wall lizard ( <i>Podarcis tiliguerta tiliguerta</i> )
Forests	Supramonte cave salamander ( <i>Speleomantes supramontis</i> )
Rocks and Cliffs	European leaf-toed gecko ( <i>Phyllodactylus europaeus</i> )
	Supramonte cave salamander ( <i>Speleomantes supramontis</i> )
Limestone Caves	Pygmy algyroides ( <i>Algyroides fitzingeri</i> )
	European whip snake ( <i>Coluber viridiflavus viridiflavus</i> )
Agricultural Regions	Common gecko ( <i>Tarentola mauritanica mauritanica</i> )

jects in preparation in Europe are evidence of the fact that ecotourism has sound prospects of success (Bech et al. 1993).

It is important for Sardinia to draw up an integrated plan that covers all the uses of land (nature, agriculture, tourism, etc.). Each function should be given such a place in the plan as to allow for the broadest and most sustainable use. It also makes sense to draw up concrete and binding management plans to guarantee that the strategic plan is implemented. Means of finance should also be part of the plan. The possibilities include European Community subsidies, ecotourism, and changes in agriculture towards internationally appreciated, naturally grown crops.

The lack of hard data other than that mentioned in the two basic reports (Voeselek & van Rooy 1984; van Rooy 1989) in combination with the research results shows the need for further basic research and a monitoring program. An integrated monitoring program should be developed to track the effects of measures. The program should ideally focus on the abiotic, the biotic, and the human function components of the areas.

To carry out the plans successfully, it is vital that the local population be involved. Without its cooperation large spatial projects cannot be effectively implemented. Effective education of the population will clarify the consequences of the current developments, not least for the native people themselves. A small part of the population is already aware of the value of nature

conservation. Economic value is by no means last on its agenda.

The problems outlined in this article focus on Sardinia and the herpetofauna found there. It is not intended, however, to be anything other than a case study illustrating a global problem. Wherever relatively short-term economic prosperity is seen as the highest benefit, sensitive forms of life give way, in some cases forever; thereafter, reconsideration is no longer possible. We advocate that nature be given a more prominent position in environmental impact assessments. In addition, nature should be regarded as the guest of honor in large-scale spatial interventions, as the party with primary rights. We must allow nature to participate in our decisions as a full partner. This is particularly true of areas located within the main ecological structure of Europe (De Ruiter 1992) or any other continent.

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