Comparative Ecosystem Study Between Two Coastal MAB Biosphere Reserves, France and United States

Biosphere Reserve Comparison

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ABSTRACT

To understand the ecological processes that influence biological diversity, and to refine management recommendations on a global scale, we compared coastal plant and animal communities at two study sites, Ile d'Ouessant, France, and the Marin Peninsula, United States, which are located in Biosphere Reserves, mer d'Iroise and the Central California Coast. We studied the patterns and factors influencing the recovery of native species after cessation of livestock production and traditional human use by sampling 300 United States and 145 French randomly selected plots at each site. In France we accumulated 422 detections of twelve species in 6,009 trap nights during 1992 through 1994. In the United States we accumulated 2,414 detections of 24 species in 14,965 trap nights during 1990 through 1994.

We examined the establishment of new uses and their potential effect on biodiversity. Mechanisms resulting in changes in species diversity were sought. This is a preliminary report of work that we hope will lead to long term ecological monitoring and a step toward achieving the goals which make biosphere reserves a functional reality through sharing experience in ecosystem analysis, remote sensing, and geographic information system modeling.

Introduction

Not all reserves or protected areas began as pristine functional ecosystems. In many cases they experienced moderate to extreme ecological disturbance from a variety of land use practices (Cairns 1988). With the watchwords, protect and manage for biological diversity (Wilson 1988), the yardstick of global health in the future will be how successful humanity completes that task. Since MacArthur (1965) began examining species relationships, the question remains, "How do we manage for biological diversity?" The dynamics between exotic and native species is not always well understood. We conducted research to examine the relationship of biological diversity to patterns of historic and present land uses with an emphasis on post-agricultural secondary succession. This succession was often accompanied by exotic species invasions, such as broom, thistle, and hemlock (Howell 1982) or bracken fern (Brigand et al. 1992). The purpose of this paper is to introduce our research project and some preliminary results.

Our goal was to quantify biological diversity, the number and abundance of species, by comparison of two coastal areas which exhibited similar habitat structure, grassland and heathland. Each area was protected in a larger regional, Parc d'Armorique, or national, Golden Gate National Recreation

Area, park and designated as part of an International Biosphere Reserve (BR) in 1988 (UNESCO 1989). Each area experienced grazing by cattle or sheep, some cultivation, and is making the transition from agricultural to park use.

UNESCO's direction for the Man and the Biosphere (MAB) Program had three main objectives: 1) long term ecological monitoring and research, 2) sustainable development, and 3) education (Batisse 1980, 1982, 1986). These objectives were realized through the formation of biosphere reserves that contain important biological resources representative of major biomes of the earth (Udvardy 1975). In this context UNESCO and the International Union for the Conservation of Nature (IUCN) held a workshop in 1989 about coastal and marine biosphere reserves. The workshop's primary recommendation, which was adopted by UNESCO, was the formation of networks among biosphere reserves for long term comparative ecological studies (Bioret et al. 1989, di Castri et al. 1992). The International MAB Coordinating Council recommended the implementation of four objectives: 1) conservation and sustainable use of biodiversity, 2) exploration of approaches to sustainable development in regional units, 3) communication of information on environment and development, and 4) contribution to the Global Terrestrial Observing System developed by the United Nations Environmental Program (UNEP) through international networks of biosphere reserves (U.S. State Dept. 1993).

In 1990, we formed a team to determine the feasibility of conducting comparative biodiversity research between the mer d'Iroise BR, France, and the Central California Coast BR, United States, both in temperate coastal ecosystems. The goal of this research project was to: 1) develop long term ecological monitoring within two coastal biosphere reserves, 2) examine the ecological consequences in changes of human use from traditional agriculture to new uses within parks or protected areas, and perhaps ultimately, 3) examine the relationship of succession to changes in global climate. Knowledge of the dynamic processes and the consequences of human activities to biodiversity provide the basis for management recommendations for protected areas with similar ecosystems and impacts. In addition to the general objectives, we had specific objectives for improvement and integration of approaches in sampling, mapping, remote sensing (SPOT, LANDSAT), and geographic information systems (GIS) (GRASS 4.1, ARC/Info 6.0).

Study Sites

Both study areas were included within coastal-marine biosphere reserves created in 1988, the mer d'Iroise BR and the Central California Coast BR. The mer d'Iroise BR study area, Ile d'Ouessant, is characterized by maritime grassland, heathland, willow riparian, and meadows. Ile d'Ouessant is a 1,558 ha island situated off the most western tip of France 27 km northwest of Brest. The Central California Coast BR study area, the Marin Peninsula, is characterized by grassland, coastal-scrub, willow riparian, and meadows. In the Marin Peninsula is a 3,315 ha headlands forming the northern limit of the Golden Gate, California, 2 km north of San Francisco. The study in Marin encompassed the three principal watersheds of the district, Rodeo, Gerbode and Tennessee Valleys, comprising 1,427 ha.

Both areas meet the sea at rocky cliffs that are subjected to strong winds and salt spray. Topographically the Marin watersheds rose from sea level to about 305 m. Ile d'Ouessant rose from sea level to 60 m. The uplands consisted of a mosaic of grassland and shrub communities that are bisected by valleys and draws with willow lining the streams. The meadows of each area were used as pasture or cropland associated with past agricultural practices. On Ile d'Ouessant sheep minimally grazes many of the meadows. In the Marin Peninsula cattle do not graze the meadows, but deer browse for forbs. Each area is exposed to an oceanic climate with relatively high humidity and coastal fog (Table 1). The summer drought in the Marin Peninsula was softened by additional precipitation, 50 mm, from coastal fog drip typical of forested north-coastal California (SWA Group 1975).

Atlantic grassland and heathland communities characterize the flora on Ile d'Ouessant. The dominant grassland species are red fescue (Festuca rubra ssp. pruinosa), thrift (Armeria maritima), and maritime carrot (Daucus carota ssp. gummifer). The dominant heathland species are Atlantic gorse (Ulex gallii), heather (Erica cinerea), and (Calluna vulgaris). Meadows are composed primarily of (Dactylis glomerata), (Anthoxanthum odoratum), and (Holcus lanatus). The willow riparian is composed of small trees (Salix atrocinerea and S. viminalis) under which several hydrophilous plants are found, yellow flag (Iris pseudacorus) and (Oenanthe orocata).

Annual and perennial grassland and California coastal scrub communities characterize the fauna of the Marin Peninsula. Soils were derived from a complex of radiolarian chert, basalt, and sandstones of the Franciscan Formation (SWA Group 1975). Vegetation is a mosaic of coastal scrub, coyote brush (Baccharis pilularis Ssp. consanguinea), coastal sage (Artemisia californica), bush lupine (Lupinus arboreus), bush monkeyflower (Mimulus aurantiacus), and poison oak (Toxicodendron diversiloba), and a mixture of annual and perennial grasslands (Barbour and Major 1988). Small patches of oak (Quercus spp.) and chaparral (Ceanothus spp. and Adenostoma fasciculatum) were found at a few sites. The riparian areas were characterized by willow (Salix spp.) and introduced eucalyptus (Eucalyptus globulus).

Ile d'Ouessant had a long period of human habitation from the Mesolithic, Neolithic, Gallo-Roman through agriculture dating to Celtic culture around 500 AD. Agricultural abandonment began on Ile d'Ouessant in the 1930's preceded by a population decline that began in 1910 (Brigand et al. 1992). Tourism steadily increased since the 1980's. Succession after agricultural abandonment lead to native heath and maritime grassland, but also to thick patches of bracken fern (Pteridium aquilinum), black berry (Rubus sp.), and other exotic species. Native habitats formed only the fringe around the island.

European culture colonized the Marin Peninsula in the late 1700's and early 1800's. Agricultural abandonment began in the 1970's with the formation of the Golden Gate National Recreation Area, and tourism steadily increased since that time. Succession after agricultural abandonment native coastal scrub and grassland, but also patches of thistle, broom, hemlock (Tsuga sp.), and western bracken fern. Native habitats formed a mosaic interspersed among the agricultural lands.

Ile d'Ouessant is an inhabited island with population of 1,000 residents. The Marin Peninsula is inhabited by 200 members of park staff and partnership organizations. Both areas are within the buffer zones of their respective biosphere reserves forming the transition from developed to fully protected areas. Because of their inclusion into parks, the areas face increased use from tourism and recreation. Visitation to Ile d'Ouessant was nearly 200,000 visitors per year and to the Marin Peninsula was nearly 900,000 visitors per year. The density of use varies throughout the areas with very high visitation along the coastal edge and around scenic locations.

Methods

In the Marin Peninsula we established 300 randomly selected study plots in four primary vegetation types, coastal prairie, meadow, coastal scrub, and willow riparian as part of other ongoing research (Howell 1993). On Ile d'Ouessant we established 145 randomly selected study plots in four similar vegetation types, maritime grassland, meadow, heathland, and willow riparian. The Universal Transverse Mercator (UTM) coordinates were plotted on an enlarged U.S. Geological Survey topographic map, scale approximated 1:20,000 and French Institut Géographique National topographic map, scale 1:25,000. Each point was located in the field by two to four people using meter tapes or calibrated range finders, and hand held compasses. Starting points were located by identifying corresponding features on the topographic map, such as road and trail junctures. The location of the center stake corresponded to the computer generated or grid overlay of the UTM coordinate for that point. At each randomly selected point a steel stake was driven into the ground to form the center of the 10 m radius plot. The dimensions of the plot were designed to fit within a single Landsat TM pixel (30 m x 30 m). Each plot was permanently identified with a serially numbered aluminum tag.

In July-August, 1990 and 1991, a total of 136 U.S. plots were sampled for vegetation, and in June 1992 65 French plots were sampled for vegetation. Initially plots were characterized as grassland, meadow, heath/coastal scrub, or willow by inspection during the first visit to the site. Plots were sampled using 4 parallel, 25-m transects spaced at 5-m intervals centered on the plot stake (Canfield 1941). In coastal scrub, individual overlap foliar cover (Westman 1981a, 1981b) was measured for each plant species intercepted by the transect. Species present in the plot but not intercepting the transect were recorded (Westman 1981a, 1981b). Grassland plots were sampled using the point intercept method at 2-m intervals for a total of 50 sample points per plot. Annual and perennial grass heights were classed as greater than or less than 30 cm. Plants that comprised at least 10% cover or frequency on one plot were used in the following analyses.

In the U.S., 300 randomly selected study plots were sampled in grassland, meadow, coastal scrub, and willow for amphibians, reptiles, and mammals during spring and summer 1990 to 1994. In France 145 randomly selected study plots were sampled in grassland, meadow, heath, and willow for amphibians, reptiles, and mammals during spring and summer 1992 to 1994. Terrestrial vertebrates were detected by four techniques as described below. Wildlife abundance was determined using a variety of methods. At the end of each sampling day, data were entered into a computer database by volunteers and reviewed by a biological technician. Earthwatch volunteers provided much of the labor for study plot establishment and field sampling. Based in Watertown, Massachusetts, Earthwatch is a non-profit organization which provides grants to and recruits lay volunteers for field research projects.

Small Mammal Trapping--Trapping was accomplished using 20-cm Sherman live traps (H.J. Spencer & Sons, P.O. Box 131, Gainesville, FL 32602) baited with peanut butter and rolled oats (Barrett 1982, Davis 1982, Dedon and Barrett 1982, Cooperrider et al. 1986). Three types of small mammal live trap were used in France, shrew trap, Sherman type trap, and rat trap (Michel Pascal, I.N.R.A., Laboratoire de la faune sauvege et cynégétique, 78350 Jouy-en-Josas, France, pers. comm.). Small mammals were marked with metal ear tags (size 1005-1, National Band and Tag Co., P.O. Box 430, Newport, KY 41072) for later identification.

Reptile and Amphibian Trapping--Sampling for reptiles and amphibians followed Barrett (1982), Davis (1982), Dedon and Barrett (1982), and Bury and Raphael (1983). Trapping was accomplished using one 5-gal bucket placed in the ground as a pitfall covered by a 30 x 30 x 0.7 cm plywood lid raised 5 cm above the rim. The location of the pitfall at each plot was 5 m from the center stake of a 10-m radius plot on the same contour as the stake. Pitfalls were lined with leaf litter to prevent desiccation of amphibians and cotton to prevent hypothermia in small mammals. Buckets not in use were covered with lids, covered with soil and a large rock. Reptiles and amphibians were not marked.

Sooted Track Plates--Larger mammals were sampled using sooted track plates (Barrett 1983, Taylor and Raphael 1988) baited with canned cat food. Cat food cans were punctured and left for the 9 or 10-day sampling period. When cans disappeared they were replaced with new cans. Track stations (2-40 x 80 cm aluminum sheets placed to form an 80 x 80 cm square) were laid out for the 10-day inventory period, checked daily and recovered at the end of the period. Tracks were circled with a line scratched in the soot to prevent confusion with new tracks.

Incidental Observations--Species seen while field observers walked into and out of study plots locations were recorded.

Species were identified by using standard field guides (Schilling et al. 1983, Stebbins 1985, Jameson and Peeters 1988) and reference specimens obtained from the California Academy of Sciences. Michel Pascal (I.N.R.A., Laboratoire de la faune sauvege et cynégétique, 78350 Jouy-en-Josas, France) provided preliminary identification of all mammals, and reference specimens were sent to his laboratory for verification. Unique specimens will be sent to the national museum in Paris.

Traps, trackplates, and artificial covers were checked daily, except in 1991 when artificial covers were checked at the end of the 10-day period. Absolute abundance was determined by calculating only captures of newly tagged individuals rather than including recaptures. In the case of tracks, the prints identified each day were considered as a new individual.

Statistical analyses followed guidelines in Steele and Torrie (1960), Zar (1974), Norusis (1988), and Wilkinson (1990). Cluster analysis was performed to explore relationships between plant associations (Manly 1986). Sixteen of the original 45 plant species selected for analysis had sufficient sample size for the clustering algorithm to work. The clustering algorithm used a single linkage euclidean distance to measure dissimilarities among 136 sample plots in the United States and 65 sample plots in France. This procedure, called nearest neighbor, reflected the minimum distances between the closest members of respective clusters (Norusis 1988: B-72, Wilkinson 1990: 25). Upon visual inspection of several clustering trials with SPSS ten clusters emerged after 20 iterations. Ten clusters were specified using the K-means command (Wilkinson 1990: 35).

Results

A similar level of effort per plot was expended to sample coastal habitat types in the Marin Peninsula and on Ile d'Ouessant (Table 2). Terrestrial vertebrate capture rates were lower on Ile d'Ouessant.

The principal habitats of the study were structurally similar between the two study areas. The nearest neighbor cluster analysis of percent cover derived plant associations in four similar broad categories for the two study areas (Table 3).

Twelve terrestrial vertebrate species were detected on Ile d'Ouessant while 24 species were detected on the Marin Peninsula (Table 4). Ile d'Ouessant had one reptile while the Marin Peninsula had four, exclusive of snakes. Domestic cats and dogs were evident at both study areas near human habitation, but tracks were not detected in the native brushland or native grassland habitats. Lagomorpha distribution was nearly ubiquitous in both study areas. No native carnivores were detected on Ile d'Ouessant while five carnivore species were in the Marin Peninsula (Table 5).

Three mammal species had statistically significant correlations with native habitats. On Ile d'Ouessant the common rat was restricted exclusively to riparian-willow (Chi-square = 51.15, df = 9, $p = 0.0001$), and the long-tailed field mouse was found almost equally in native heathland and maritime grassland (Chi-square = 33.36, df = 21, $p = 0.042$). On the Marin Peninsula the deer mouse was more abundant and encountered more frequently in the coastal shrub versus grassland habitat ($x = 2.106$, freq. = 0.682, $p < 0.05$ versus $x = 1.241$, freq. = 0.444, $p < 0.05$). Although the deer mouse (Pema) was found throughout coastal scrub, except in areas inhabited by woodrats

(Nefu) (Pema = 4.0 - 1.165*Ln(Nefu), R^2 = 0.882), the deer mouse had a moderate correlation with native purple needlegrass (Table 6).

Discussion

The Marin Peninsula had 14 native mammal species, that is species not commensal with humans nor introduced. This order of magnitude is similar to the value reported for an island in the Thousand Islands, New York, with 10 mammals on a 5.9 Km^2 island 0.9 Km from shore (Lomolino 1986). Ile d'Ouessant had two native mammal species which is a similar number to smaller islands in the British and California Channel Islands (Lawlor 1986). In the transition from a peninsula to an island of similar size, species diversity diminishes. An extreme case such as 9.1 ha island Alcatraz in Golden Gate National Recreation Area has two terrestrial vertebrates, a salamander and a mouse (Howell and Pollak 1992). Ile d'Ouessant has lost 80% of its native habitat. The most noticeable absences on the island were among the reptiles and carnivores. We do not know the species composition of the island before habitation, but lack of dispersal to the island may well account for the absence of reptiles. The absence of carnivores may be explained by a multiplicity of factors such as failure to colonize, persecution by local inhabitants, or loss of sufficient habitat to support viable populations leaving a remanent subset of the former fauna (Patterson and Atmar 1986).

One could say that we spent a great deal of time catching mice, but what does it mean? Terrestrial vertebrates, other than birds and bats, are relatively poor dispersers, especially across salt water barriers (Lawlor 1986). The Marin Peninsula is in transition from one state of use to another and may have a higher diversity, currently, because of intermediate levels of disturbance (Connell 1978, Huston 1979). The Marin Peninsula could become more like an island with lower diversity in the long term if increased development eliminates routes of dispersal. Robinson et al. (1992) reported increased individual persistence of larger bodied species with increased patch size and recommended detailed population analyses to understand the effects of fragmented habitats. By studying population declines or extinctions we may be able to develop predictive models for biodiversity loss (Shafer 1990).

In addition to the question of how we manage for biodiversty, an even more important question is emerging about the effect of biodiversity loss on ecosystem function (Baskin 1994). In this study the deer mouse exhibited a relationship with a native grass species. Do deer mice distribute seed and accelerate reestablishment of native habitats, or does their feeding on purple needle grass seed slow the rate of recolonization of native habitats? Howell (1993) observed higher diversity of native species in native habitats. Through our work we see that native populations persist in native habitats, but habitat loss or isolation may push these populations below the threshold of viability. Even if native habitats can recover, in the case of islands or isolated reserves, sources of recolonizing species may not be readily available and may require proactive management to restore or maintain biodiversity (Cairns 1988). Quality, amount, and diversity of habitat will determine the number and kind of species that will persist. In the systems we study, we see the lower limits of that persistence. Ecological preserves of all types must guard against isolation from the larger ecological context and must guard against internal loss of habitat. We think that through comparative studies of a series from simple to more complex systems like this one, we can come to understand these relationships. Additional research is required to compare mainland France near Ouessant and north of the Marin Peninsula. It is clear that 3 to 5 years of data is not enough to see these patterns emerge as with the transition of the Marin Peninsula. We think that networks among biosphere reserves provide an excellent framework for this kind of research.

Acknowledgements

We want to thank Earthwatch and the Earthcorps volunteers for their belief in our work, their hard labor, and generous support of this research project. This project was partially funded by the National Park Service, Golden Gate National Recreation Area. This project would never have begun without the park's support for long term ecological research. We also want to thank Dr. Sarah Allen and Dr. Richard T. Golightly for reviewing an early draft of this paper and for providing thoughtful comments.

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Figure 1. Study Site, Marin Peninsula, California Coast Biosphere Reserve, United States.

Figure 2. Study Site, Ile d'Ouessant, mer d'Iroise Biosphere Reserve, France.

Table 1. Comparative climatic characteristics of the study areas, Central California Coast and mer d'Iroise Biosphere Reserves, United States and France.

	Ile d'Ouessant	Marin Peninsula
Temperature (^oC)		
Annual Mean	11.9	11.6
Summer Mean	16.4	13.3
Winter Mean	7.7	10.0
Insolation (h)	1692	1778
Precipitation (mm)	699	711
Days of Rain (p>0.1 mm)	183	62
Days of Fog (Apr.-Sep.)	34	37

Table 2. Level of effort for sampling similar habitats between Central California Coast and mer d'Iroise Biosphere Reserves, United States and France.

	Ile d'Ouessant	Marin Peninsula
Year	1992-1994	1990-1994
Duration (yr)	3	5
Field Days	50	215
Earthwatch Teams	5	23
Volunteers	31	182
Plots Sampled	145	300
Trap Nights (TN)	6,009	14,965
Captures	422	2,414
Captures/TN	0.070	0.161

Table 3. Summary of vegetation genera based on cluster analysis for Central California Coast and mer d'Iroise Biosphere Reserves, United States and France (n=number of plots in each cluster).

Association Type	Marin Peninsula(n)	Ile d'Ouessant(n)
Native Brushland	Baccharis(24)	Ulex,Erica(30)
Native Grassland	Stipa(11)	Festuca,Armeria(18)
Meadow	Phalaris,Festuca(3)	Dactylus,Holcus(12)
Exotic Grassland	Bromus,Avena(34)	-----
Mixed Grassland	Baccharis,Avena(72)	-----
Willow	Salix(10)	Salix(5)

Table 4. Terrestrial vertebrate species observed during an inventory of coastal grass and brushland habitats at Central California Coast and mer d'Iroise Biosphere Reserves, United States and France. (Exclusive of bats and snakes).

	Number of Species	
CLASS	Ile d'Ouessant	Marin Peninsula
AMPHIBIANS	1	1
REPTILES[+]	1	4
MAMMALS		
Marsupialia	0	1
Insectivora	2	2
Rodentia	4 (1)[*]	6 (1)
Lagomorpha	1	2
Carnivora	2 (2)	7 (2)
Artiodactyla	1	1
SUM	12 (3)	24 (3)

[+] Exclusive of snakes.

[*] Number of species in common between two biosphere reserves.

Table 5. Terrestrial vertebrate species observed during inventory of coastal grass and brushland habitats at Central California Coast and mer d'Iroise Biosphere Reserves, United States (US) and France (FR). (Excludes bats and snakes).

Common Name (Species name)	FR	US
AMPHIBIANS		
California newt (Taricha torosa)		+
Common toad (Bufo)	+	
REPTILES		
Western fence lizard (Sceloporus occidentalis)		+
Western skink (Eumeces skiltonianus)		+
Southern alligator lizard (Elgaria multicarinatus)		+
Northern alligator lizard (Elgaria coeruleus)		+
Stone wall lizard (Podarcis muralis)	+	
MAMMALS		
Opossum (Didelphis virginiana)		+
Vagrant shrew (Sorex vagrans)		+
Shrew-mole (Neurotrichus gibbsii)		+
Lesser white-toothed shrew (Crocidura suaveolens)	+	
Hedgehog (Erinaceus europaeus)	+	
Southern pocket gopher (Thomomys bottae)		+
Western harvest mouse (Reithrdontomys megalotis)		+
Deer mouse (Peromyscus maniculatus)		+
Dusky-footed wood rat (Neotoma fuscipes)		+
Meadow vole (Microtus californicus)		+
Long-tailed field mouse (Apodemus sylvaticus)	+	
House mouse (Mus musculus)	+	+
Common rat (Rattus norvegicus)	+	
House rat (Rattus)	+	
Brush rabbit (Sylvilagus bachmani)		+
Black-tailed hare (Lepus californicus)		+
Rabbit (Oryctolagus cuniculus)	+	
Domestic dog (Canis familiaris)	+	+
Gray fox (Urocyon cinereoargenteus)		+
Raccoon (Procyon lotor)		+
Striped skunk(Mephitis)		+
Spotted skunk (Spilogale gracilis)		+
Domestic cat (Felis catus)	+	+
Bobcat (Felis rufus)		+
Black-tailed deer (Odocoileus heminous)		+
Domestic sheep (Ovis aries)	+	