18 Coastal Vegetation as Indicators for Conservation

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18.1 Introduction

18.1.1 Environmental Indicators

According to Dale and English (1999), "environmental indicators are tools for different environmental decision-making situations. There are three types of tools aiding environmental decision-making: bits of information, or data; tools to gather data; and tools to organize and analyze data, including models to describe relationships among units of information. They may be quantitative or qualitative". According to the above, environmental indicators are direct and indirect forms to measure the environmental quality. They define the present state and the tendencies of the environmental capacity to sustain ecological and human health (EPA and SEMARNAP 1997). They are designed to quickly and easily inform decision makers about environmental information dealing with natural conditions. If used for monitoring, over time they may communicate information about ecosystem changes and trends. As management tools, they may provide awareness over developing problems and actions needed. There have been various efforts to design environmental indicators trying to make them analogous and comparable to economic or social indicators. For instance, an exotic species can be a variable to measure vegetation quality that is an environmental health indicator; income is a variable to measure poverty, a socio-economic indicator related to social health.

In the 1980s, environmental economists in developed countries (Canada and Europe) designed indicators of the pollution agents in air, water, and soils (Hammond et al. 1995). In the 1990s, several international organizations started to develop indicators to measure sustainability in other countries. Therefore, along with pollution as an environmental indicator, others were added, such as erosion, deforestation, and biodiversity. The main efforts refer to national scale indicators because they are used to evaluate a country's environmental performance (NRC 2000; SEMARNAP 2000).

Ecological Studies, Vol. 171
M.L. Martínez, N.P. Psuty (Eds.)
Coastal Dunes, Ecology and Conservation

In the USA, the National Research Council (2000) worked on ecological indicators for the national scale. They selected these based on general importance, conceptual basis, reliability, temporal and spatial scales, statistical properties, data requirements, skills required, data quality, data archiving, robustness, international compatibility, costs, benefits, and cost-effectiveness. The recommended indicators for the USA are indicators of the extent and status of the nation's ecosystems – land cover and land use. Indicators of the nation's ecological capital are total species diversity (measures the ecological capital actually present), native species diversity, nutrient runoff, and organic soil matter. Indicators of ecological functioning or performance are carbon storage, production capacity, net primary production, trophic status of lakes, stream oxygen, and for agricultural ecosystems, nutrient-use efficiency and nutrient balance.

In Mexico, the environmental ministry (SEMARNAP 2000) has developed an Environmental and Nature Resources Information System where 24 environmental indicators consist of 11 issues; water pollution in towns, biodiversity loss, global climatic change, county rubbish, erosion, forestry resources, fishery resources, air pollution, desertification, watershed pollution, and destruction of the ozone layer.

Until today, most of the biodiversity indicators measured the state of the ecosystem and the response to this state; endangered species lists, statistics of deforested land and abandoned fields, and statistics of land under any protection policy. Nevertheless, none of these clearly measures the pressure of human activities over natural ecosystems (Hammond et al. 1995). These indicators are useful for federal policies to evaluate the recovery of the national environment but cannot be compared at the regional or local level because local indicators need to be more specific.

Nevertheless, beginning efforts to select environmental indicators in smaller regions and sites, rather than countries, are developing. For example, in regional ordinances there are environmental impact assessments or risk and vulnerability studies (Villa and McLeod 2002).

18.1.2 Ecological Indicators

Ecological indicators can be used to assess the condition of the environment, to provide an early warning signal of changes in the environment, or to diagnose the cause of an environmental problem. Ideally, the suite of indicators should represent key information about structure, function, and composition of the ecological system (Dale and Beyeler 2001). These represent ecosystem characteristics related to or derived from a biotic or abiotic measurement. They can provide qualitative or quantitative information about the ecosystem composition, structure, and function (Noss 1997). The complexity of biotic systems suggests that the evaluation of the ecosystem can be by multiple organization levels and spatial and temporal scales (Table 18.1). In practice, the

Table 18.1. Ecological indicators for plant species in three complexity levels proposed by the authors

Authors	Ecological indicators		
	Landscape	Community-ecosystem	Population-species
Noss (1990, 1997)	**Composition:** To identify, distribution, richness, proportion of patch types, collective patterns of species distribution. **Structure:** Heterogeneity, connectivity, fragmentation, patch size frequency distribution. **Function:** Disturbance processes, energy flow rates, human land-use trends.	**Composition:** Life-form proportions, C_4:C_3 plants species ratios, proportion of endemics and exotics, threatened and endangered species, to identify relative abundance, frequency, richness, evenness, diversity of species, dominance-diversity curves. **Structure:** Physiognomy, foliage density and layering, horizontal patchiness, abundance, density. **Function:** Herbivory, parasitism and depredation rates, patch dynamics, human intrusion rates and intensities.	**Composition:** Absolute or relative abundance, frequency, importance or cover value, density. **Structure:** Dispersion, population structure. **Function:** Physiology, life history, phenology, demographic process, metapopulation dynamics, growth rate, adaptation.
Keddy et al. (1993)		Diversity, guild, plant biomass.	Exotics and rare species.
Argemeier and Karr (1994)	Fragmentation, number of communities, persistence.	Number of species, species evenness, number of trophic links.	Age or size structure, dispersal behavior.
Jone and Riddle (1996)	Clustering of habitat, habitat connectivity, status and trends data on vertical structure and species composition, configuration of habitats and ecosystems.	Representative species of each guild.	Number of species, species diversity indexes, number or percentage of federally-threatened or endangered species.
Cendrero (1997)	Fragmentation Spatial distribution of communities Persistence of habitats	Ecosystem diversity, productivity, percentage of natural cover, species diversity index.	Rare, threatened and endemic species
Dale & Beyeler (2001)		Species richness Species evenness Number of trophic levels	Age or size structure Dispersal behavior

elements are more frequently used as indicators than the processes, because elements are more sensitive to degradation and less expensively monitored (Angermeier and Karr 1994).

Every plant species is an indicator of environmental conditions. The traditional use of indicator species for evaluating and monitoring the environmental conditions is discussed. As Noss (1990, 1997) mentions, the use of these indicator species may present conceptual and procedure problems. For instance, scale errors occur if there is the usual supposition that an indicator species has the same response in a higher level of the biological organization. As well, (Landres 1992) mentions that communities, habitats, and landscapes may also indicate environmental qualities, but not by single species indicators but by a specific plant community or by a particular landscape.

The selection of indicators is a process that depends on the databases available (Fig. 18.1). These databases are broad and heterogeneous because they are products from divergent objectives driven by the needs of the decision-makers and public. These primary data contain all ecological variables. In this first phase of the indicator-generating process, the primary data are large (Hammond et al. 1995; Bergquist and Bergquist 1999) but only used by a small scientific population.

The second phase corresponds to the decision-maker sectors, which, in contact with scientific experts, select those variables that summarize landscape, ecosystem, community, or population performance. These variables need to represent standard situations or "universal" features to be used for comparisons around the world. For example, the composition indicator may

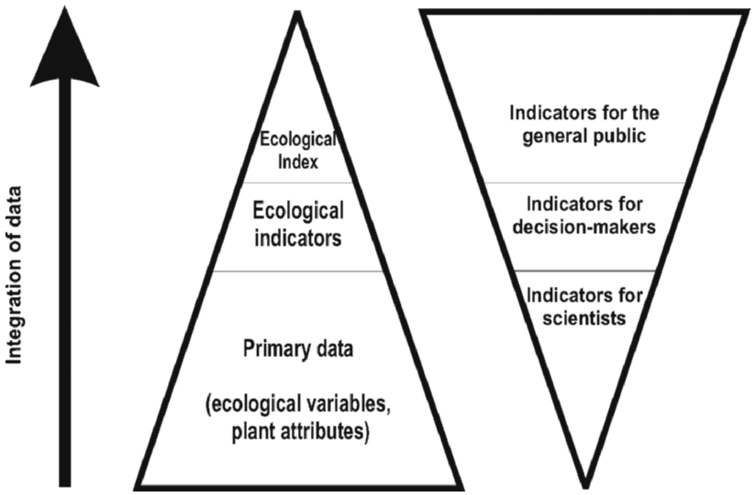

Fig. 18.1. Generation of the environmental index and the audience to whom they are focused

aggregate ecological variables such as species number and origin to explain human impact on plant communities. Structural indicators can combine species life forms and species life span to express natural impacts such as fire or hurricanes on a vegetation type. Functional indicators may join species physiological adaptations and productivity to select carbon-storage ecosystems (NRC 2000). The combined use of ecological variables, turn the variables themselves into ecological indicators (Table 18.1). For instance, they are useful to communicate information about environmental policy application, monitoring results, and environmental education successes.

The third phase corresponds to the integration of ecological indicators into ecological indices. For example, using compositional indicators together with structural indicators may evaluate the environment quality of an ecosystem. The number of species may mean a certain quality but if life form proportions are added, the description of the ecosystem to be evaluated is more accurate. Finally, the ecological index is a mathematical expression, which can be "translated" to be understandable by the public.

Our work builds on groundwork of the coastal plant community's ecology to propose the combinations of vegetation variables as ecological indicators to measure coastal ecosystem suitability for purposes of conservation and restoration. These indicators might be powerful tools for monitoring sand dunes of protected areas. Our work deals with more complex indices for conservation programs (SEMARNAP-INE 1995; Ahumada 2000; Espejel 2001; Espejel et al. 2002), but in this paper we refer to the ecological indicators of the sand dune vegetation that have been analyzed and incorporated to the coastal management indices and used in the northern coastal zone of Baja California, Mexico.

18.2 Methods

18.2.1 Ecological Indicator Selection

Higher-level scale indicators (landscape level) were generated by analyzing the coastal zone of northern Baja California with the Organization for Development and Economic Cooperation (ODEC) method suggested by Lourens et al. (1997) and used in Mexico (SEMARNAP 2000).

For the community-level scale indicators, we used our database which resulted from 212 "releves" (plots) collected between 1989 and 2001 along the Pacific coast of Baja California (Moreno-Casasola and Espejel 1986; Moreno-Casasola et al. 1998). Physically modified sites were sampled to add measures of the presence of invasive species, modifications of vegetation structure, and to detect functional changes.

The floristic list (Appendix) consists of 125 plant species. It shows the family and the species, to which we assigned the presence or absence of the 10 ecological variables or attributes used to build the ecological indicator. The list was classified to obtain the total number of species (region) and total per site (El Socorro, Punta Banda, Tijuana Estuary).

El Socorro and Punta Banda are part of our own generated data, but we used a species list from the literature of the Tijuana estuary to test the usefulness of literature data. We selected these three sites to test the indicators. Therefore, the three sites are different from one another. El Socorro is the more complex sand dune systems (sandy beaches, embryonic sand dunes, high mobile and fixed dunes, wet and dry slacks, slashed areas), more isolated and less modified by agriculture and urban areas than the other two sites. Punta Banda and the Tijuana estuary are sand spits with embryonic sand dunes and small mobile and fixed dunes (Fig. 18.2).

The criteria used to select ecological indicators were the importance of the plant species in these coastal sand dune communities (Table 18.2). We had in

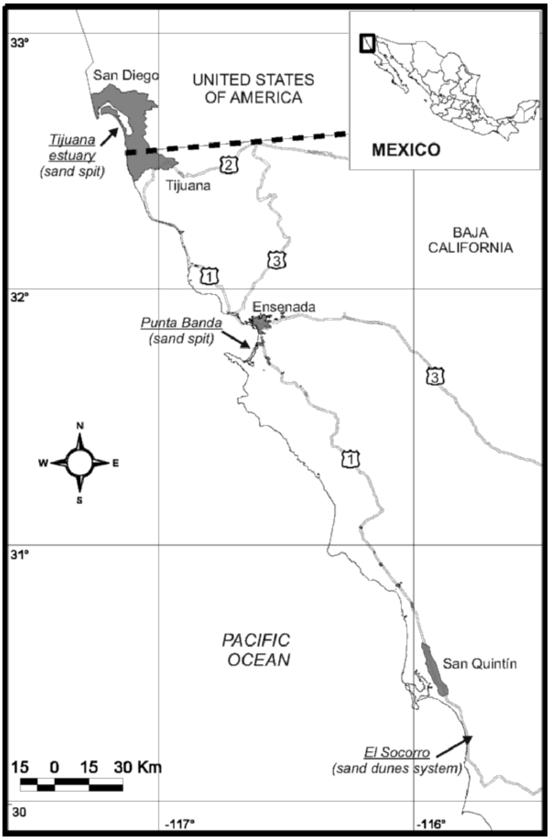

Fig. 18.2. Study area in which the ecological indicators for sand dune systems were analyzed

Table 18.2. Plant species variables or attributes. In ***bold*** are those selected for the ecological indicators (compositional, structural, and functional indicators)

Variables (attributes)	Ecological indicator types	Organization level
Species distribution		
Native species	Compositional	Species
Exotic species	Compositional	Species
Species abundance		
Absolute or relative abundance	Compositional	Population-species
Frequency	Compositional	Population-species
Species morphology		
Life forms	Structural	Species
Tree		
Shrub		
Sub shrub		
Desert forms (Cactaceae, Agavaceae, Crassulaceae and other succulent species of Aizoaceae, Chenopodiaceae, and Solanaceae)		
Perennial herb		
Annual herb		
Prostrate herb		
Erect herb		
Vines		
Vegetation associations	Structural and compositional	Community
Coastal succulent sage scrub		
Coastal chaparral		
Coastal dune		
Salt-marshes		
Riparian		
Introduced grassland		
Species functional features		
Pubescence	Functional	Species
Succulence		
Keystone species	Functional	Species
Soils fixer		
Nitrogen fixer		

mind the users of the ecological-indicator decision makers, who in this case are nonbiologists (Dale and Beyeler 2001). Therefore, we refused nonevident attributes such as physiological features (CAM, C_3, or C_4 strategies), which might be ecologically significant but difficult to visualize in the field. We consulted the literature on plant functional types of similar environments to contribute to our own selection (Barbour et al. 1985; Barbour 1992; Espejel 2001; Infante 2001; Garcia-Novo, this book). Native and exotic species are easily recognized using botanical catalogues; in this region Horn (1993), Whitson (1996), and Grennan (1999) are useful. The presence of exotics explains human impacts (roads, urban development); the presence of natives and desert forms indicate sand dune quality. Life forms may relate to continuous impacts, for example, grasses appear after fires or grazing. Shrubs and prostrated species stabilize sand, thus meaning more mature sand dunes. Vines (and lichens) may indicate microenvironmental humidity (Spjut 1996). Pubescence is an environmental adaptation to high temperatures and aridity. It improves water retention for plants in late successional stages. It can be considered an indicator of protection. Succulence is a plastic trait, induced by soil or air-borne salinity (Rozema et al. 1982) indicating early successional stages. It can be considered a stress tolerance indicator. Nitrogen fixers imply relations with richer soils and more stabilized older dunes. They can be consider an indicator of adaptation.

18.2.2 Calculation of Ecological Indicators

The ecological indicators were divided in compositional indicators based on the proportion of native species and the proportion of exotic species. It is expressed as

$$Ic = \frac{n_i / Nn}{e_i / Ne}$$

where
Ic =compositional indicator
n_i =native species in site or plot i,
e_i =exotic species in site or plot i,
Nn =total number of native species (of the region or of the site to be compared)
Ne =total number of exotic species (of the region or of the site to be compared)

The structural indicator is based on the proportion of life forms and is expressed by

$$Is = (s_i/Ns) + (d_i/Nd) + (p_i/Np) + (h_i/Nh) + (v_i/Nv)$$

where
Is =structural indicator
s_i =number of shrubs in the site or plot i.

Ns = total number of shrubs (of the region or of the site to be compared)
d_i = number of desert forms in the site or plot i
Nd = total number of desert forms (of the region or of the site to be compared)
p_i = number of prostrated herbs in the site or plot i
Np = total number of prostrated herbs (of the region or of the site to be compared)
h_i = number of erect herbs in the site or plot i
Nh = total number of erect herbs (of the region or of the site to be compared)
v_i = number of vines in the site or plot i
Nv = total number of vines (of the region or of the site to be compared)

The functional indicator is related to the proportion of legumes or nitrogen fixers, pubescence representing aridity resistance, and succulents meaning salinity adaptation. The indicator is calculated as

$$\mathrm{If} = (\mathrm{pu_i}/\mathrm{Npu}) + (\mathrm{su_i}/\mathrm{Nsu}) + (\mathrm{nf_i}/\mathrm{Nnf})$$

where
If = functional indicator
pu_i = number of pubescent species in the site or plot i
Npu = total number of pubescent species (of the region or of the site to be compared)
su_i = number of succulent species in the site or plot i
Nsu = total number of succulent species (of the region or of the site to be compared)
nf_i = number of nitrogen fixers in the site or plot i
Nnf = total number of nitrogen fixers (of the region or of the site to be compared)

The ecological index was calculated adding all three ecological indicators. These values were normalized obtaining five classes; Very high (0.8–1.00), high (0.79–0.60), medium (0.59–0.40), low (0.39–0.20), and very low (0.19–0). For instance, a very high value of the compositional indicator means that the sample or site has more natives, thus it has a better value for conservation purposes. On the contrary, a very low indicator value means that the sample or site has more exotics, thus it has the lowest value for conservation purposes. If compared, in a decision-making process we can select the samples or sites with higher values for conservation and those with lower values can be used for other purposes.

18.3 Results

18.3.1 Environmental Indicators for the Region (Landscape-Scale Indicators)

At the higher level scale (landscape), environmental indicators were identified (Fig. 18.3), and ecological indicators, at the community level, were selected (bold). The columns of this figure show the potential threats, early warning and threat indicators in the northern Baja California coastal region where the sand dunes occur. This analysis allowed us to identify the pressure that causes impacts on the vegetation and helped us to select the elements, which could be the framework to search for ecological indicators. The state-response analysis allowed us to identify some environmental indicators but cannot measure them. Therefore, we selected community-scale indicators to be able to measure them quantitatively.

18.3.2 Ecological Indicators for Coastal Dunes (Plant–Community Scale)

The compositional indicator shows clear differences among sites, and for the site richness this indicator shows the quality of the site if compared to the region (Table 18.3). The Tijuana estuary and Punta Banda sand spits are rather poor sites, surrounded by urban and agriculture areas. Both showed very low and low compositional indicators. This means that for the five exotics, the proportion with native plants offers a site with less quality than El Socorro, which has a medium compositional indicator.

The structural indicator (Table 18.3) reflects the sand dune systems complexity, despite the compositional quality. This is shown in the El Socorro site where the structural indicator is high and the other two sites have a low and very low value. The proportion of life forms is more similar between El Socorro and the "region" than the other two sites, which have no desert forms or vines.

The functional indicator (Table 18.3) is clear in the nitrogen fixers when they disappear in the simpler sites. As with the structural indicator, the functional indicator reflects the functional complexity of the El Socorro sand dune system.

The sum of these three indicators forms the ecological index. If the value is closer to 1 it means that is similar to the "region" sand dune systems. In this case, El Socorro site reflects a high quality in terms of its composition, structure, and function. This site represents the better richness quality, the most structural complexity, and holds the highest key functional traits of the sand dunes of the Pacific coast of northern Baja California.

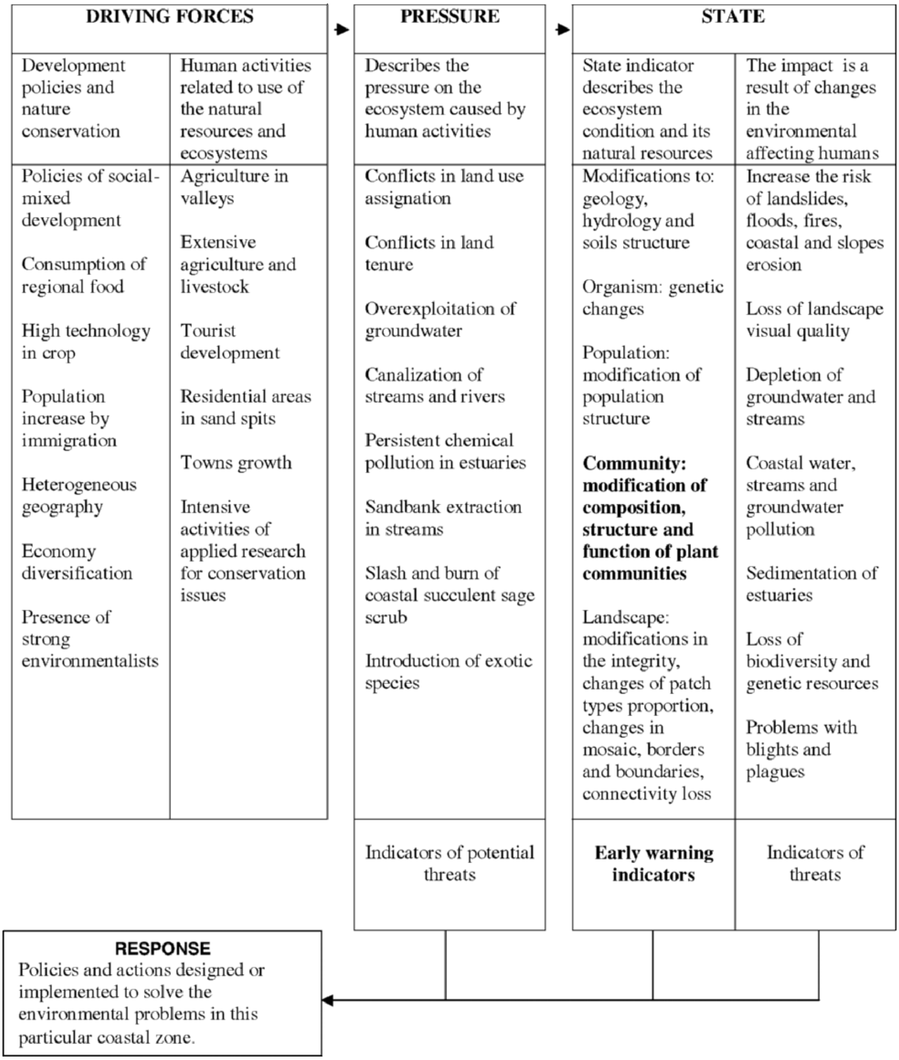

Fig. 18.3. Pressure-state-response scheme to identify environmental indicators in the Baja California coastal succulent sage scrub, sand dune, coastal chaparral, riparian wetland, agriculture, and urban field region. In *bold* are the early warning ecological indicators that we selected for this chapter. (After Laurens et al. 1997)

Table 18.3. Ecological index reflecting the sand dune plant species composition, structure, and function in a region (Pacific coast of northern Baja California) and three sites (El Socorro and Punta Banda (our own data) and the Tijuana Estuary. (Data from Delgadillo 1995)

Trait	Regional	El Socorro			Punta Banda			Tijuana Estuary		
	Number of species 125	Number of species 85	Indicator	Normalized	Number of species 32	Indicator	Normalized	Number of species 21	Indicator	Normalized
Native	109	78			27			16		
Exotic	16	7			5			5		
Compositional			1.64	0.56 Medium		0.79	0.27 Low		0.47	0.16 Very low
Scrub	42	33	0.79		12	0.29		8	0.19	
Desert form	6	4	0.67		0	0.00		0	0.00	
Prostrate herb	36	22	0.61		12	0.33		11	0.31	
Erect herb	36	22	0.61		10	0.28		2	0.06	
Vine	5	4	0.80		1	0.20		0	0.00	
Structural			3.47	0.68 High		1.10	0.21 Low		0.55	0.11 Very low
Pubescent	85	59	0.69		20	0.24		12	0.14	
Succulent	26	16	0.62		13	0.50		7	0.27	
Nitrogen fixer	10	6	0.60		0	0.00		0	0.00	
Functional			1.91	0.63 High		0.74	0.24 Low		0.41	0.13 Very low
Ecological index				1.87			0.73			0.40
Normalized				0.62 High			0.24 Low			0.13 Very low

18.4 Discussion and Conclusion

Most ecological indicators have been developed for aquatic ecosystems (Karr 1994, 1997a, b, 1998; Karr and Chu 1997; Done and Reichelt 1998), and in large-scale areas such as countries (NRC 2000; SEMARNAP 2000). We are searching for ecological indicators at the ecosystem and community level. We chose the sand dune vegetation to integrate ecological indicators "easy to see" to facilitate the daily work of the decision-makers and nonbiologists. Special concern was put into composition, structure, and function as suggested by Noss (1990, 1997). Dale and Beyeler (2001) suggest eight criteria to develop ecological indicators.

Our proposed ecological indicators meet several of these criteria, because they

1. are easily measured with a floristic list and little training in sand dune flora,
2. are sensitive to stress on sand dune systems such as the nitrogen fixers of the functional indicator,
3. respond to stress in a predictable manner. This is shown in the compositional indicator because perturbation allows predicting exotics invasion,
4. are anticipatory (signify an impeding change in the ecological system),
5. predict changes that can be averted by management actions,
6. are integrative (the full suite of indicators provides a measure of coverage of the key gradients across the ecological system). The ecological index is integrative itself,
7. All the ecological indicators selected have a known response to natural disturbances, anthropogenic stresses, and change over time.
8. All the indicators proposed reflect a specific floristic richness that shows the low variability in response to the particular stresses of most of the sand dunes in the world.

The examples that we present in this chapter show the present state of a beginning monitoring program for the sand dunes of northern Baja California. For a conservation or restoration monitoring aim, this is a useful tool to compare different sites or regions worldwide. With these 'present state' figures (Table 18.3), we can start monitoring as many sand dunes as possible as suggested for various ecosystems and communities (Noss 1990; Costanza et al. 1992; Keddy et al. 1993; Angermeier and Karr 1994; Jones and Riddle 1996; Cendrero 1997; Noss 1997). The compositional and the structural indicators are most effective to measure early changes of the landscape. Therefore, we suggest the variables of these ecological indicators be incorporated into the National Environmental Indicators System (SEMARNAP 2000). If changes are shown in one, five, or ten years, we can have a national response to the early warning indicators (Fig. 18.3) suggested to measure changes in the state of the coastal ecosystems (Lourens et al. 1997).

The ecological indicators applied to sand dune communities are useful for restoration and conservation issues. For ecological monitoring in the local context, the indicators provide essential information for the selection of the minimum number of variables to measure (Spellerberg 1991; Woodley et al. 1993; Dale and English 1999; Schulze 1999). The index also proved to be useful to choose representative areas in a regional context (El Socorro in this case).

If the index is calculated in several plots, quadrats or releves, it can also be useful in the selection of the most representative permanent plots to study continuously in long-term studies.

These types of studies are a priority to assess natural-area performance (Dale and English 1999; Schulze 1999). In addition, the indicators can help evaluate changes and trends caused by disturbance, especially if they are placed on protected or managed areas (Schmitt and Osenberg 1996; Wright 1996; Nelson and Serafin 1997). Applied research is mainly done using natural experiments (Connell 1975; Eberhardt and Thomas 1991) that often need to select the minimum data and the smallest area to minimize research efforts for time and budget (Spellerberg 1991; NRC 2000).

Because of the vulnerability of sand dunes to exotic species invasion (Brown and McLachlan 1990; Nordstrom 2000), the compositional indicator provides information for timing control maneuvers to stop or minimize the invasion and establishment of exotic species (Hiebert 1997).

The exercise presented in Table 18.3 seems to be useful to select representative sites on the regional scale. The ecological index, simultaneously analyzing ecological indicators, identifies the complexity of a dune system and provides a tool to select sites for conservation, restoration, and for monitoring programs. Furthermore, this analysis is useful for decision makers in the incorporation of literature data as shown by the Tijuana Estuary site. Managers often have low budget programs. Therefore, they rely on published data, which they then can compare with their own scarce field data.

Primary data (measured or literature-based) generated for scientific purposes other than management, conservation, or restoration can be used to select ecological indicators for decision makers in their local or regional programs. The ecological indicators of sand dunes seem to be a useful tool for monitoring conservation and restoration, impact and plant invasion assessment, and selecting protected natural areas. The public, from NGOs and local communities, can use these indicators for similar purposes. We propose these sand dunes variables as ecological indicators to be adapted and used in future monitoring conservation and restoration programs worldwide.

Appendix: Floristic List of Northern Baja California Coastal Sand Dune Systems

Family	Species	Life form	Distribution
Acanthaceae	*Justicia californica* (Benth.) Gibson	Shrub	
Aizoaceae	*Carpobrotus aequilaterus* (Haw.) N.E. Brown	Desert form	Introduced
Aizoaceae	*Mesembryanthemum crystallinum* L.	Desert form	Introduced
Aizoaceae	*Mesembryanthemum edulis* L.	Herb	Introduced
Aizoaceae	*Mesembryanthemum nodiflorum* L.	Desert form	Introduced
Anacardiaceae	*Rhus integrifolia* (Nutt.) Benth. & Hook. var *integrifolia*	Shrub	
Asclepiadaceae	*Asclepias subulata* Decne.	Herb	
Asclepidaceae	*Cynanchum peninsulare* S.F. Blake	Vine	Endemic
Asclepidaceae	*Sarcostemma arenarium* Decne.	Vine	Endemic
Asteraceae	*Ambrosia chamissonis* (Less.) Greene	Shrub	
Asteraceae	*Amblyopappus pusillus* Hook.& Arn.	Shrub	
Asteraceae	*Artemisia californica* Less.	Shrub	
Asteraceae	*Bebbia juncea* (Benth.) Greene var. *juncea*	Shrub	
Asteraceae	*Chaenactis glabriuscula* D.C. var. *glabriuscula*	Herb	
Asteraceae	*Chrysanthemum coronarium* L.	Herb	Introduced
Asteraceae	*Encelia californica* Nutt.	Shrub	
Asteraceae	*Encelia farinosa* A. Gray var. *farinosa*	Shrub	
Asteraceae	*Haplopappus berberidis* A.Gray	Shrub	Endemic
Asteraceae	*Haplopappus venetus* (H.B.K.) S.F. Blake ssp. *furfuraceus* (Greene) Hall	Shrub	
Asteraceae	*Haplopappus venetus* (H.B.K.) S.F. Blake ssp. *tridentatus* (Greene) Hall	Shrub	Endemic
Asteraceae	*Haploppapus squarrosus* H. & A. ssp. *grindelioides* (DC.) Keck.	Shrub	
Asteraceae	*Helianthus niveus* (Benth.) Brandegee ssp. *niveus*	Herb	
Asteraceae	*Heterotheca sessiliflora* (Nutt.) Shinn ssp. *sessiliflora*	Shrub	
Asteraceae	*Jaumea carnosa* (Less.) A. Gray	Herb	
Asteraceae	*Perityle emoryi* Torr.	Herb	
Asteraceae	*Pluchea serica* (Nutt.) Cov.	Shrub	
Asteraceae	*Porophyllum gracile* Benth.	Shrub	

Appendix: (*Continued*)

Family	Species	Life form	Distribution
Asteraceae	*Senecio californicus* DC.	Herb	
Asteraceae	*Senecio douglasii* DC. var. *monoensis* (Greene) Jepson	Shrub	
Asteraceae	*Stephanomeria virgata* Benth.	Herb	
Asteraceae	*Viguiera laciniata* A. Gray	Shrub	
Boraginaceae	*Cryptantha intermedia* (A. Gray) Greene	Herb	
Boraginaceae	*Heliotropium curassavicum* var. *oculatum* (Heller) I.M. Johnst.	Herb	
Boraginaceae	*Pectocarya linearis* DC var. *ferocula* I.M. Johnst.	Herb	
Cactaceae	*Echinocereus maritimus* (M.E. Jones) K. Schum.	Desert form	Endemic
Cactaceae	*Mammillaria dioica* K. Brandegeei	Desert form	
Cactaceae	*Opuntia cholla* Weber	Desert form	
Cactaceae	*Pachycereus pringlei* (S. Wats.) Britt. & Rose	Desert form	
Capparidaceae	*Isomeris arborea* Nutt. en Torr. & Gray	Tree	
Caryophyllaceae	*Cardionema ramosissima* (Weinm.) Nels. & Macbr.	Herb	
Caryophyllaceae	*Silene gallica* L.	Herb	Introduced
Chenopodiaceae	*Atriplex barclayana* (Benth.) D. Dietr. ssp. *palmeri* (S. Wats.) Hall & Clements	Shrub	
Chenopodiaceae	*Atriplex californica* Moq. in DC.	Herb	
Chenopodiaceae	*Atriplex canescens* (Pursh.) Nutt. ssp. *canescens*	Shrub	
Chenopodiaceae	*Atriplex canescens* (Pursh.) Nutt. ssp. *linearis* (S. Wats.) Hall & Clements.	Shrub	
Chenopodiaceae	*Atriplex coulteri* (Moq.) D. Dietr.	Shrub	
Chenopodiaceae	*Atriplex hastata* (L.) Hall & Clem.	Herb	Introduced
Chenopodiaceae	*Atriplex julaceae* S. Wats	Herb	Endemic
Chenopodiaceae	*Atriplex lindleyi* Moq.	Herb	Introduced
Chenopodiaceae	*Atriplex pacifica* Nels.	Herb	
Chenopodiaceae	*Atriplex semibaccata* R. Br.	Herb	Introduced
Chenopodiaceae	*Chenopodium murale* L.	Herb	Introduced
Chenopodiaceae	*Salsola kali* L. var. *tenuifolia* Tausch.	Shrub	Introduced
Chenopodiaceae	*Suaeda californica* S. Wats.	Desert form	

Appendix: (*Continued*)

Family	Species	Life form	Distribution
Convolvulaceae	*Calystegia macrostegia* (Greene) Brummit ssp. *tenuifolia* (Abrams) Brummitt	Vine	
Convolvulaceae	*Cuscuta salina* Engelm.	Vine	
Convolvulaceae	*Cuscuta veatchii* Brandegee	Vine	Endemic
Crassulaceae	*Dudleya attenuata* (S. Wats.) Moran ssp. *orcuttii* (Rose) Moran	Desert form	Endemic
Crassulaceae	*Dudleya lanceolata* (Nutt.) Britt. & Rose	Desert form	
Cruciferae	*Cakile maritima* Scop.	Herb	Introduced
Cruciferae	*Draba cuneifolia* Nutt. ex T. & G. var. *integrifolia* S. Wats	Herb	
Cruciferae	*Erysimum capitatum* (Dougl.) Greene	Herb	
Cruciferae	*Sisymbrium irio* L.	Herb	Introduced
Ephedraceae	*Ephedra californica* S.Wats.	Shrub	
Euphorbiaceae	*Croton californicus* Muell.-Arg.	Herb	
Euphorbiaceae	*Euphorbia micromera* Engelm.	Herb	
Euphorbiaceae	*Euphorbia misera* Benth.	Shrub	
Euphorbiaceae	*Euphorbia polycarpa* Benth.	Herb	
Euphorbiaceae	*Stillingia linearifolia* Wats.	Shrub	
Frankeniaceae	*Frankenia palmeri* Wats.	Shrub	Endemic
Frankeniaceae	*Frankenia salina* Jtn.	Shrub	
Hippocastanaceae	*Aesculus parryi* A. Gray	Shrub	Endemic
Hydrophyllaceae	*Phacelia distans* Benth.	Herb	
Hydrophyllaceae	*Phacelia hirtuosa* A. Gray	Herb	Endemic
Juncaceae	*Juncus acutus* L.	Herb	
Labiatae	*Hyptis emoryi* Torr.	Shrub	
Leguminosae	*Astragalus anemophilus* Greene	Herb	Endemic
Leguminosae	*Astragalus didymocarpus* Hook & Arn.	Herb	
Leguminosae	*Astragalus insularis* Kell var. *quintinensis* M. E. Jones	Shrub	Endemic
Leguminosae	*Astragalus sanctorum* Barneby	Herb	
Leguminosae	*Astragalus trichopodus* (Nutt.) A. Gray ssp. *leucopsis* (T & G) Thorne	Herb	

Appendix: (*Continued*)

Family	Species	Life form	Distribution
Leguminosae	*Lotus bryantii* (Brandegee) Ottley	Herb	Endemic
Leguminosae	*Lotus distichus* Greene	Shrub	Endemic
Leguminosae	*Lotus scoparius* (Nutt. ex T. & G.) var. *scoparius* Nutt.	Herb	
Leguminosae	*Trifolium gracilentum* Torr. & Gray	Shrub	
Malvaceae	*Sphaeralcea ambigua* A. Gray var. *ambigua*	Shrub	
Nyctaginaceae	*Abronia maritima* Nutt. ex Wats. ssp. *maritima*	Herb	
Nyctaginaceae	*Abronia umbellata* Lam.	Herb	
Nyctaginaceae	*Mirabilis californica* Gray	Shrub	
Onagraceae	*Camissonia bistorta* (Nutt. ex T. & G.) Raven	Herb	
Onagraceae	*Camissonia californica* (Nutt. ex T. & G.) Raven	Herb	
Onagraceae	*Camissonia cheiranthifolia* (Hornem es Spreng) Raimann ssp. *suffruticosa* (S. Wats) Raven	Herb	
Onagraceae	*Camissonia cheiranthifolia* (Sprengel) Raimann ssp. *cheiranthifolia*	Herb	
Onagraceae	*Camissonia crassifolia* (Greene) Raven	Herb	Endemic
Onagraceae	*Camissonia hirtella* (Greene) Raven	Herb	
Onagraceae	*Oenothera californica* (S. Watson) S. Watson	Herb	
Papaveraceae	*Eschscholzia californica* Cham.	Herb	
Plumbaginaceae	*Limonium californicum* (Boiss) Heller	Herb	
Plumbaginaceae	*Limonium californicum* (Boiss.) Heller var. *mexicanum* (Blake) Munz	Herb	
Poaceae	*Bromus rubens* L.	Herb	Introduced
Poaceae	*Distichlis spicata* (L.) Greene	Herb	
Poaceae	*Melica imperfecta* Trin.	Herb	
Poaceae	*Monanthochloe littoralis* Engelm.	Herb	
Poaceae	*Polypogon monspeliensis* (L.) Desf.	Herb	Introduced
Polygonaceae	*Eriogonum fasciculatum* Benth. var. *fasciculatum*	Shrub	Endemic
Polygonaceae	*Nemacaulis denudata* Nutt.	Herb	
Polypodiaceae	*Cheilanthes newberryi* (D. Eaton) Domin	Herb	

Appendix: (*Continued*)

Family	Species	Life form	Distribution
Polypodiaceae	*Polypodium californicum* Kaulf.	Herb	
Portulacaceae	*Calandrinia ciliata* (R. & P.) DC. var. *menziesii* (Hook) Macbr.	Herb	
Portulacaceae	*Calandrinia maritima* Nutt.	Herb	
Primulaceae	*Anagallis arvensis* (L.) Krause	Herb	Introduced
Resedaceae	*Oligomeris linifolia* (Vahl.) Macbr.	Herb	
Saururaceae	*Anemopsis californica* (Nutt.) Hook. & Arn.	Herb	
Scrophulariaceae	*Cordylanthus maritimus* A. Gray spp. *maritimus*	Herb	
Scrophulariaceae	*Cordylanthus orcuttianus* A. Gray	Herb	Endemic
Scrophulariaceae	*Galvezia juncea* (Benth.) Ball. var. *juncea*	Shrub	Endemic
Simmondsiaceeae	*Simmondsia chinensis* (Link.) C.K. Schneid.	Shrub	
Solanaceae	*Lycium andersonii* A. Gray	Shrub	
Solanaceae	*Lycium brevipes* Benth.	Shrub	
Solanaceae	*Lycium californicum* Nutt. ex Gray spp. *californicum*	Shrub	
Solanaceae	*Physalis crassifolia* Benth. var. *crassifolia*	Desert form	
Solanaceae	*Solanum hindsianum* Benth.	Shrub	

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