Approche intégrative des enjeux de conservation de la biodiversité méditerranéenne pour la priorisation de la désignation des aires protégées. Application au cas du Liban

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À ceux que j'aime,
dont l'amour et le soutien me sont si indispensables

À mes parents,
pour l'affection et le support qu'ils m'ont donné

À Antonio,
le plus grand bonheur de ma vie

À Angelo,
mon cadeau du ciel

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LISTE DES ACRONYMES

A.D. : Anno Domini

AMAP : botAnique et Modélisation de l'Architecture des Plantes et des végétations

AZE : Alliance Zéro Extinction

BioDivMeX: BioDiversity of the Mediterranean Experiment

CBD : Convention pour la BioDiversité

CDR : Conseil de Développement et de Reconstruction

CEDRE : Coopération pour l'Évaluation et le Développement de la Recherche

CEPF : Critical Ecosystem Partnership Fund

CNRS-L : Conseil National de la Recherche Scientifique - Liban

EcoMed : Écologie et Médiation

ELARD : Earth Link & Advanced Resources Development

EU : European Union

FSD : Formulaire Standard de Données

GEF : Global Environmental Fund

GIS : Geographic Information System

GRP: Grant Research Programme

HDR : Habilitation à Diriger la Recherche

HENR : Horsh Ehden Nature Reserve

IBA : Important Bird Area

IMBE : Institut Méditerranéen de Biodiversité et d'Ecologie marine et continentale

INFFER : Investment Framework for Environmental Resources

IPA : Important Plant Area

IUCN : International Union for Conservation of Nature

J.C. : Jésus Christ

KBA : Key Biodiversity Area

LIA : Laboratoire International Associé

LUC : Land Use Cover

MoA : Ministry of Agriculture

MoE : Ministry of Environment

MSc : Master of Science

NAPPA : National Action Plan for Protected Areas

NBSAP : National Biosafety Strategy and Action Plan

NGO : Non-Governmental Organization

O-LiFE : Observatoire Libano-Français de L’Environnement

PA : Protected Area

PhD : Philosophiae Doctor (Doctor of Philosophy)

PMR : Plant Micro-Reserves

PNUE : Programme des Nations Unies pour l'Environnement

SA : Scientific Article

SDATL : Schéma Directeur D’aménagement du Territoire Libanais

S.E.S. : Socio Ecological Systems

SIG : Système d’Informations Géographiques

SPNL: Society for the Protection of Nature in Lebanon

UNDP : United Nations Development Programme

UNEP : United Nations Environment Programme

UNESCO : United Nations Educational, Scientific and Cultural Organization

USD : United States Dollar

WCMC : World Conservation Monitoring Center

WCPA : World Commission on Protected Areas

WDPA : World Database on Protected Areas

ZICO : Zones Importantes pour la Conservation des Oiseaux

ZNIEFF : Zones Naturelles d'Intérêt Ecologique, Faunistique et Floristique

CHAPITRE 1
Introduction générale et problématique

« Lorsque le dernier arbre aura été abattu, le dernier fleuve pollué, le dernier poisson capturé, vous vous rendrez compte que l'argent ne se mange pas. » (Chef Seattle, 1854)

L'histoire de conservation de la nature et des ressources naturelles remonte à la nuit des temps, lorsque l'homme protégeait les forêts et les espaces naturels pour son propre bien.
Au Liban, au 2ème siècle après J.C., l'Empereur Hadrien délimita des réserves forestières de cèdres, de sapins, de genévriers et de chênes pour son usage personnel, et interdit à tout autochtone d'y prélever. Environ 180 inscriptions gravées sur les rochers (stèles d'Hadrien) témoignent aujourd'hui de cet héritage (Abdul-Nour, 2001).
En France, au moyen-âge, la chasse était un privilège de la noblesse et des dignitaires de l'État ou du clergé. Les Seigneurs protégeaient leurs privilèges de chasse (les forêts) et certaines zones étaient réservées à la chasse royale (Garner et Moriceau, 2004).
Dans la péninsule arabe, les sociétés nomades interdisaient jadis la coupe des arbres en désert pour assurer l'ombre à leurs troupeaux (Bagader *et al.*, 1994).

Très rapidement cet élan relatif de protection se transforma en besoin réel de conservation, un besoin émanant d'une conscience de l'homme que sa subsistance était étroitement liée à celle de la nature (Chanvallon, 2009). C'est ainsi que les initiatives de conservation écologique au vrai sens du terme se succédèrent au fil du temps. Depuis la réserve naturelle de Fontainebleau[1] en 1861 (Lazzarotti, 2011), jusqu'aux sites « Alliance Zéro Extinction » (AZE) (Ricketts *et al.*, 2005), la démarche de conservation se positionna au cœur des priorités scientifiques et témoigna d'une avancée remarquable. Adressant non seulement la question de protection écologique en soi, mais aussi les aspects socioéconomiques liés aux biens et aux services fournis par les écosystèmes naturels aux sociétés et à l'économie, la problématique de conservation s'installa au carrefour de l'interdisciplinarité (Legay, 2006).

Des espèces protégées aux espaces protégés, des zones d'inventaires scientifiques à intérêt de conservation aux « Hotspots » de biodiversité, la conservation de la biodiversité et la préservation des écosystèmes naturels demeure la finalité. Outre les aires protégées proprement

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[1] Première réserve naturelle créée au monde, avant même la création du Parc national de Yellowstone aux États-Unis en 1872.

dites, un large éventail de systèmes d'identification et de classification existe pour cette fin, dont :

- Le programme d'inventaires naturalistes ZNIEFF (Zones Naturelles d'Intérêt Ecologique, Faunistique et Floristique) (Maurin *et al.*, 1997)
- Les « Hotspots » de biodiversité (Mittermeier *et al.*, 1998; Myers *et al.*, 2000)
- Les Zones Importantes pour la Conservation des Oiseaux (ZICO ou IBA - Important Bird Areas) (Bibby *et al.*, 1992; Balmford & Long, 1994; Stattersfield *et al.*, 1998)
- Les Zones Humides de la Convention Ramsar (1971)
- Les Centres de Diversité Végétale (Davis *et al.*, 1994-95)
- Les Zones Importantes pour les Plantes (IPA - Important Plant Areas) (Anderson, 2002)
- Les Zones Clés pour la Biodiversité (KBA - Key Biodiversity Areas) (Eken *et al.*, 2004)
- Les Sites Alliance Zéro Extinction (AZE) (Ricketts *et al.*, 2005).

Néanmoins, les aires protégées demeurent les piliers fondamentaux des stratégies nationales et internationales de conservation de la biodiversité (Gaines *et al.* 2010 ; Pimm *et al.*, 2001). Elles agissent comme refuges pour les espèces et fournissent un espace propice pour l'évolution naturelle (Naughton-Treves *et al.*, 2005). Zones géographiquement définies, désignées, ou règlementées et gérées pour atteindre des objectifs spécifiques de conservation (CDB, 1992), les aires protégées sont considérées comme l'un des meilleurs outils pour la conservation des écosystèmes et de la biodiversité dans le monde (Chape *et al.*, 2005 ; Gaines *et al.*, 2010 ; Game *et al.*, 2009 ; Gray, 2010 ; Lester *et al.*, 2009 ; Lubchenco *et al.*, 2003, 2007; Pimm *et al.*, 2001).

L'argument principal qui sous-tend l'établissement de nouvelles aires protégées dérive de résultats d'analyses montrant une plus grande richesse et/ou abondance spécifique au sein qu'à l'extérieur de celles-ci (Halpern & Warner, 2002 ; Lester *et al.*, 2009 ; Lubchenco *et al.*, 2003, 2007 ; Micheli *et al.*, 2004). Toutefois, l'importance de conserver la biodiversité « commune », siège des processus évolutifs et support des dynamiques écosystémiques (grands espaces de milieux ouverts, espaces de continuité écologique associés aux pratiques agricoles à faible empreinte, corridors à petite échelle en zones fortement anthropisées, etc.), en dehors des zones protégées, demeure également prioritaire (Cox & Underwood, 2011).

La conservation de la biodiversité en milieu méditerranéen terrestre présente un défi majeur dans un contexte global naturel et socioéconomique complexe, où l'importance écologique de protection des richesses biologiques se confronte avec les besoins économiques d'exploitation et d'usage des ressources naturelles (Lovejoy, 2008 ; Quézel, 1999 ; Thompson *et al.*, 2009).

Point chaud de la biodiversité, le bassin méditerranéen est un des principaux centres de la diversité végétale avec plus de 25.000 espèces dont la moitié est endémique (Quézel, 1995). Situé au confluent de 3 continents, bordé de 40.000 km de côtes et siège de 22 pays, il constitue l'un des 34 points chauds de biodiversité mondiale, caractérisé à la fois par des niveaux élevés d'endémisme et des niveaux critiques de pertes d'habitats (Médail & Myers, 2004 ; Médail & Quézel, 1999 ; Mittermier *et al.*, 2005). Marqué par la présence humaine depuis le néolithique, berceau d'une population qui était de 276 millions en 1970 et est projetée à plus de 500 millions en 2020 (Abis, 2006), destination touristique accueillant plusieurs millions de touristes chaque année, ce bassin est d'autant plus fragilisé par les pressions anthropiques diverses (urbanisation, infrastructures touristiques, exploitation des ressources naturelles, commerce maritime, etc.) et la fragmentation. Si les problèmes ne sont pas comparables entre les rives Nord, Sud et Est de la Méditerranée, les besoins en termes de gestion de la biodiversité et des espaces naturels sont similaires même s'ils sont exprimés de façons différentes selon les pays. La Méditerranée représente ainsi, d'ores et déjà, l'objet principal des efforts de conservation (Khater, 2015).

Quelles priorités pour sa conservation face à une fragmentation croissante des milieux naturels ? Quel rôle pour la science dans l'orientation des politiques publiques de conservation ?

Dans une région particulièrement soumise aux enjeux croissants d'anthropisation, les initiatives de conservation se multiplient et se hâtent. Plusieurs alternatives de protection existent pour répondre aux différents enjeux écologiques de conservation. Toutefois, les types et les modes de protection diffèrent d'un pays à l'autre et ne sont pas nécessairement comparables (Dudley, 2008). Cette différence émane de la diversité des régimes législatifs, des besoins de conservation spécifiques à chaque pays et des contextes socioéconomiques relatifs à chacun. Selon le rapport des Nations Unies sur les aires protégées (Chape *et al.*, 2003), plus de 1.000 termes différents sont connus pour être utilisés lors de la désignation de zones protégées. Cependant, bien que le nombre d'aires protégées ait connu une croissance rapide au cours des 20 dernières années en région Méditerranéenne, la mesure dans laquelle celles-ci représentent, maintiennent et conservent les ressources biologiques et les processus écologiques est encore mal appréhendée (Gaston *et al.*, 2008 ; Le Saout *et al.*, 2013 ; Rodrigues *et al.*, 2004).

En contexte méditerranéen, la complexité de mise en place de nouvelles aires protégées découle non seulement des enjeux écologiques très particuliers à chaque zone naturelle tels que la taille (Cote *et al.*, 2001) et le recouvrement spatial (Mora & Sale, 2011), mais aussi de la diversité des régimes règlementaires en vigueur (Lester & Halpern, 2008), de la qualité d'application de la loi (Kritzer, 2004) et, surtout, de l'absence d'indicateurs et de critères écologiques et socioéconomiques normalisés et objectifs, permettant une priorisation pertinente des choix de conservation (Olivier *et al.*, 1995).

Reconnaissant le fait que les aires protégées ne sont pas des « îles », mais des composantes d'un système socioéconomique dynamique environnant (Brandon *et al.*, 1998), et que leur création demeure essentielle pour maintenir la biodiversité et éviter les importantes pertes d'espèces (Brandon *et al.*, 2005), la conciliation des priorités écologiques de conservation aux besoins socioéconomiques de développement est une nécessité incontournable pour aboutir à une planification stratégique et ciblée, permettant de maintenir les services écosystémiques et la biodiversité, sans imposer de sérieuses restrictions sur les moyens de subsistance humaine (Brandon *et al.*, 2005). Le concept de systèmes socio-écologiques répond parfaitement à cette logique. Il reconnait la complexité des interactions entre l'homme et la nature, et prend en compte les aspects écologiques ainsi que la dimension humaine dans la planification de la conservation (Folke, 2007 ; Lagadeuc & Chenorkian, 2009 ; Liu *et al.*, 2007 ; Redman *et al.*, 2004). La conception idéale d'une aire protégée doit ainsi suivre une approche intégrative de conservation qui prend en compte une multitude de facteurs, y compris la diversité des espèces et des habitats, l'état de conservation, l'adéquation de la zone, et le contexte socioéconomique prévalent (Brandon, 2002 ; Cowling & Pressey 2003 ; Devictor *et al.*, 2010 ; Johnson *et al.*, 2003 ; Pressey, 1998 ; Sallafsky & Wollenberg, 2000).

Dans ce cadre, la définition de descripteurs écologiques et socioéconomiques visant la priorisation des enjeux de conservation, la valorisation des espaces naturels, et la désignation d'aires protégées a fait l'objet de nombreuses recherches scientifiques (Angermeier & Karr, 1994 ; Bode *et al.*, 2008 ; Derous *et al.*, 2007 ; Gauthier *et al.*, 2010 ; Gehlbach, 1975 ; Goldsmith, 1975 ; Gubbay, 1995 ; El-Hajj *et al.*, 2015[2] ; Haughton & Siar, 2006 ; Jacot, 2009 ; Karr, 1991 ; Kier *et al.*, 2009 ; Laguna *et al.*, 2004 ; Lepareur, 2011 ; Lindenmayer *et al.*, 2000 ; Margules & Usher, 1981 ; Noss, 1995 ; Noss *et al.*, 2002 ; Olivier *et al.*, 1995 ; Pressey *et al.*,

[2] **Annexe 9:** El-Hajj, R., Varese, P., Nemer, N., Tatoni, T. and Khater, C. 2015. Mediterranean ecosystems challenged by global changes and anthropogenic pressures: vulnerability and adaptive capacity of forests in North Lebanon. *Revue Écologique (La Terre et la Vie)*, 70(1):3-15.

1994 ; Pressey & Taffs, 2001 ; Rabinowitz, 1981 ; Radford *et al.*, 2011 ; Ratcliffe, 1977 ; Roberts *et al.*, 2003 ; Schmeller *et al.*, 2008 ; Smith & Theberge, 1986 : Tans, 1974, Tubbs & Blackwood, 1971 ; Usher, 1986 ; Van der Ploeg & Vlijm, 1978 ; Viry, 2013 ; Wright, 1977). Une multitude de descripteurs a été identifiée pour adresser les divers enjeux de conservation des habitats et des espèces, tout en en alliant les priorités socioécologiques. Néanmoins, ces descripteurs demeurent non standardisés, ils appartiennent à des catégories différentes (quantitatifs, qualitatifs, espèces, habitats, écologiques, socioéconomiques), ils répondent à des besoins différents (protection, gestion, aménagement) et se trouvent dans la plupart des cas dupliqués et parfois non appliqués.

Comment surmonter ce défi en contexte Méditerranéen ?
Comment contrer l'opportunisme des initiatives de conservation et créer des réseaux d'aires protégées qui correspondent à de vraies priorités écologiques et socioéconomiques ?
Comment simplifier les complexités naturelles et socioéconomiques pour monter des stratégies de conservations pertinentes ?
Comment influencer, voire orienter, les processus de prises de décision dans les politiques de conservation ?

Dans le contexte Méditerranéen pluri-complexe, tant au niveau écologique que sociopolitique, la problématique de conservation des espaces naturels est de plus en plus prépondérante et problématique (Underwood *et al.*, 2009). La mise en place de zones protégées mobilise une grande diversité d'outils et, selon le contexte, se traduit par des mesures d'acquisition foncière, des mesures règlementaires ou, encore, des mesures contractuelles entre les acteurs des territoires (Lefebvre & Moncorps, 2010). Bien que le bassin méditerranéen fasse l'objet d'investissements importants pour la protection des espaces naturels, la variabilité des contraintes foncières, financières et législatives, dans les différents pays, rend ces efforts inégalement distribués, et plutôt centralisés dans les pays les plus développés (CEPF, 2011).

Face à ces défis, la mise en place rapide d'un système intégré de conservation de la biodiversité et l'accompagnement des décideurs dans la conception et la mise en place de réseaux d'aires protégées s'impose (Ferrier & Wintle, 2009).

Conserver la biodiversité et les écosystèmes naturels revient à les classer par ordre prioritaire d'intervention, où tout doit être pris en compte dans les politiques d'aménagement et de conservation (Ball *et al.*, 2009 ; Das *et al.*, 2006 ; Kukkala & Moilanen, 2013 ; Reyers, 2004). Il s'agit donc de proposer une démarche objective permettant d'orienter les choix de protection pour les rendre plus efficaces. Cette démarche, basée sur une combinaison de descripteurs écologiques et socio-économiques qui, parfois, sont quasiment absents ou subjectifs, permettrait d'orienter les initiatives de conservation (surtout au Liban) et de prioriser la conservation de la biodiversité ainsi que la désignation des aires protégées, qui jusqu'à ce jour, semblent répondre à un « pattern » sociopolitique « opportuniste » plutôt qu'écologique.

Situé sur les rives Est de la Méditerranée, le Liban est reconnu comme un « Hotspot » de biodiversité tant à l'échelle spécifique (plus de 9.119 espèces répertoriées dont 4,486 espèces de faune et 4,633 espèces de flore, avec des taux élevés d'endémisme atteignant 12% chez la flore), qu'à celle des écosystèmes (plus de 10 étages de végétation avec les variantes des séries de végétation) (Abi-Saleh, 1978 ; Abi-Saleh et Safi, 1988 ; MOE/GEF/UNDP, 2009).

Les initiatives de protection au Liban remontent aux années 1930 et concernent à ce jour une centaine de sites, protégés soit officiellement par le biais de lois, de décrets, de décisions ministérielles ou de décisions municipales locales, soit à travers des conventions internationales signées ou ratifiées par le Liban (El-Hajj *et al.*, *Accepted*). Toutefois, les initiatives de conservation des écosystèmes demeurent jusqu'à ce jour des réponses à des demandes particulières, notamment pour la protection des cédraies (loi 558/1996 du Ministère de l'Agriculture) ou des espèces protégées comme les tortues marines (décision ministérielle numéro 125/1, 1999). L'absence d'un cadre juridique et de critères propres aux différentes catégories d'aires protégées freine les initiatives de conservation. Seules les réserves naturelles et les sites naturels disposent de règlementations officielles.

Une tentative de stratégisation des politiques de conservation, publiée en 2004 sous la forme d'un schéma directeur d'aménagement du territoire libanais (SDATL, 2004) recommande la valorisation des richesses naturelles du pays dans un principe de continuité des espaces naturels, et ce, par l'établissement de parcs naturels tout le long du territoire Libanais ainsi que la protection de sites naturels « ponctuels » remarquables (telles que les zones fossiles, les ponts naturels, les grottes, les gouffres, etc.), de la zone des sommets au-delà de 1,900 mètres d'altitude, de l'étage du cèdre et du genévrier entre 1,500 et 1,900 mètres d'altitude, de l'aire du sapin de Cilicie, espèce rare et endémique du moyen-orient, des grandes vallées, des coupures vertes le long du littoral, etc.

Malgré son adoption par décision du conseil des ministres en 2009, la mise en application de ce schéma directeur est encore en cours de pré-réalisation, principalement dans le but de développer des schémas de cohérence territoriale à l'échelle des régions, qui permettraient une meilleure définition des espaces en vue de leur protection / conservation.

Les contraintes à la mise en œuvre d'une telle stratégie sont multiples et passent principalement par la prise en compte de la propriété foncière des terrains (article 15 de la constitution libanaise) surtout dans un contexte de plus en plus urbanisé où les problématiques de développement démographique prennent une ampleur considérable (Faour *et al.*, 2013), et de faiblesse du cadre législatif règlementant la gestion de la biodiversité et des écosystèmes naturels (Khater, 2015).

En réponse à ce besoin inéluctable et notamment face aux risques de fragmentation des paysages et des écosystèmes inhérents au contexte du Liban et à une échelle plus large au contexte méditerranéen, ce travail de thèse vise à :

1. Identifier les principaux descripteurs écologiques qui permettent de proposer une priorisation des enjeux de conservation des écosystèmes méditerranéens
2. Relever les contraintes socioéconomiques principales, incontournables dans une tentative de protection / conservation / développement durable des écosystèmes
3. Proposer une combinaison de descripteurs socioécologiques permettant une orientation réfléchie et adaptée pour la future désignation des aires protégées au Liban (en particulier) et autour du bassin méditerranéen (en général), et monter, sur base des descripteurs identifiés, un outil de support à la décision permettant de systématiser et de structurer les priorités de conservation de la biodiversité en utilisant les meilleures connaissances disponibles, et de proposer plusieurs alternatives de protection priorisées, parmi lesquelles l'utilisateur (ministère, municipalité, région, etc.) serait en mesure de choisir la plus appropriée en fonction du contexte sociopolitique prévalent.

Afin de répondre à ces objectifs, cette thèse présente, à la suite de l'introduction, une partie méthodologique qui exposera l'approche adoptée pour l'identification des descripteurs écologiques et socioéconomiques, la priorisation de ceux-ci et leur structuration en un outil d'aide à la décision ; 3 chapitres qui porteront respectivement sur : i) la justification de la problématique de la thèse en évaluant la cohérence ou la pertinence du réseau existant d'aires protégées au Liban avec les principaux besoins écologiques de conservation et l'analyse des carences, ii) l'identification des descripteurs écologiques et socioéconomiques, et iii) le développement de l'outil d'aide à la décision. Ces 3 chapitres sont illustrés par des articles en cours de révision dans des revues internationales, ou prêts à être soumis à l'issue de la soutenance. La thèse se termine par une synthèse générale et une conclusion qui permettent de discuter la validité des descripteurs et de l'outil d'aide à la décision pour la priorisation des choix de conservation de la biodiversité au Liban et en contexte Méditerranéen, et d'appréhender les liens entre l'existant et les paramètres définis pour comprendre le fonctionnement des écosystèmes naturels Méditerranéens continentaux et viser leur conservation optimale.

CHAPITRE 2
Méthodologie générale

« On ne peut se passer d'une méthode pour se mettre en quête de la vérité des choses. » (René Descartes, 1637)

Se donnant pour objectif de proposer une combinaison de descripteurs socioécologiques permettant une orientation réfléchie et adaptée pour la désignation des aires protégées au Liban et en Méditerranée, et de structurer sur ce un outil d'aide à la décision permettant de systématiser et de prioriser les choix de conservation de la biodiversité, ce travail de thèse adopte l'approche méthodologique suivante :

Afin d'intégrer le sujet dans son contexte et de justifier le besoin réel d'orienter les initiatives de conservation en contexte Méditerranéen sur des bases scientifiques pertinentes, une analyse de la cohérence du réseau actuel d'aires protégées au Liban avec les besoins réels de conservation écologique est effectuée en un premier temps. Cette analyse permet d'évaluer la pertinence de ce réseau dans la conservation de la biodiversité et des écosystèmes en adressant la question suivante : est-ce que le réseau existant d'aires protégées au Liban couvre vraiment l'essentiel des richesses écologiques du territoire ? Sinon, que faire et comment récupérer les carences ?

Pour ce faire, une analyse spatiale de la distribution des aires protégées à travers le logiciel SIG (Système d'Information Géographique) est réalisée :

- Un bilan (carte) exhaustif des aires protégées au Liban est dressé
- Cette carte est ensuite superposée sur les carte des zones d'inventaires scientifiques au Liban, notamment celles des IBA (A-Rocha/SPNL, 2008) et des IPA (Radford *et al.*, 2011), afin d'analyser la distribution des aires protégées existantes et de la comparer à celle des zones à intérêt écologique de conservation
- La carte superposée des aires protégées et des zones à intérêt écologique de conservation (IPA et IBA) est ensuite superposée sur :
    - La carte d'occupation des sols (SDATL, 2004)
    - La carte des sols (SDATL, 2004)
    - La carte superposée des étages bioclimatiques et des étages de végétation, élaborée sur base des cartes produites par Abi-Saleh et Safi (1988)

- Une analyse détaillée des résultats est effectuée
- Le besoin de mettre en place un système intégré et pertinent basé sur des descripteurs écologiques et socioéconomiques adaptés est identifié (*cf.* Chapitre 3)

Répondant au besoin levé par l'analyse de la cohérence du réseau existant d'aires protégées avec les priorités écologiques de conservation, une vaste revue bibliographique sur les descripteurs écologiques et socioéconomiques utilisés autour du monde dans l'orientation des stratégies de conservation et la désignation d'aires protégées est effectuée. Ceci inclut les descripteurs et les critères quantitatifs et qualitatifs renseignant des données visant la protection, gestion, ou aménagement des milieux naturels terrestres en vue de leur préservation.

Sur base de cette revue, et en s'inspirant du corpus des descripteurs collectés, une série de descripteurs écologiques et socioéconomiques pertinents, complémentaires, non redondants, et adaptés au contexte méditerranéen, est définie. Un minimum de descripteurs, renseignant un maximum de données écologiques et socioéconomiques au niveau d'un site donné en vue de son éventuelle protection, est ainsi identifié. L'adéquation de chaque descripteur au contexte méditerranéen est également justifiée sur base bibliographique (*cf.* Chapitre 4).

Chaque descripteur est ensuite décliné en modalités (ou sous-descripteurs), chaque modalité en variantes, et chaque variante en valeurs, justifiées par la bibliographie.

Sur base des descripteurs écologiques et socioéconomiques identifiés, un outil d'aide à la décision informatisé est conçu et développé. Cet outil oriente les alternatives de conservation de la biodiversité en priorisant les choix de désignation des aires protégées en contexte méditerranéen terrestre.

La structure sous-jacente à l'outil repose sur une matrice numérique composée d'un algorithme spécifique. Cette matrice consiste en un tableau à double entrée, ou sont présentées :

- En colonnes : 6 « catégories » de zones de protection, allant du niveau de protection le plus strict au niveau le plus flexible, et déclinant chacune un à plusieurs « types spécifiques » d'aires protégées, appliqués en contexte méditerranéen. La définition de ces catégories est inspirée des différents systèmes de catégorisation d'aires protégées adoptés au niveau mondial en général, et en Méditerranée en particulier.
- En lignes : les descripteurs avec leurs modalités, variantes et valeurs respectives.

L'algorithme numérique, composé de 3 chiffres (0 ; 0.5 et 1), est ensuite utilisé pour remplir cette matrice tout en accordant à chaque combinaison « Catégorie - Valeur de descripteur » un chiffre approprié :

- « 0 » signifie que pour une valeur donnée d'un descripteur donné, cette catégorie d'aire protégée n'est pas pertinente (idéalement elle ne devrait pas être applicable).
- « 0.5 » signifie que pour une valeur donnée d'un descripteur donné, cette catégorie d'aire protégée n'est ni recommandée, ni déconseillée (elle peut être considérée comme neutre). Même si elle est retenue, elle ne constitue pas forcément l'option optimale pour la conservation.
- « 1 » signifie que pour une valeur donnée d'un descripteur donné, cette catégorie d'aire protégée est très pertinente, elle est donc a priori parfaitement adaptée et peut être considérée comme recommandée.

Cette approche reflète comment la variation d'un aspect écologique ou socioéconomique spécifique peut affecter les priorités de conservation.

Le renseignement de la matrice par les algorithmes appropriés est basé sur une analyse inspirée de la bibliographie et d'exemples réels d'application des différentes catégories d'aires protégées au Liban et en Méditerranée.

Cette matrice a fait ensuite l'objet de discussions et de validation par un collège d'experts pour évaluer et confirmer la pertinence des concepts scientifiques sous-jacents et donner une dimension scientifique plus crédible à celle-ci (*cf.* Annexe 4).

Pour un site donné dédié à la conservation, l'utilisateur devrait dans un premier temps renseigner le maximum possible de descripteurs écologiques et socioéconomiques en choisissant les valeurs adéquates en fonction des informations dont il dispose. Sur base de cet apport, l'outil d'aide à la décision octroie un score pour chacune des catégories d'aires protégées (le mode de fonctionnement de l'outil est détaillé dans le chapitre 5). Ce score est converti en pourcentage de pertinence relatif à chaque catégorie.
Sur ce, l'outil fourni à l'utilisateur des choix de conservation priorisés, et ceci, en fonction des particularités écologiques et socioéconomiques préalablement renseignées par ce dernier.

Enfin, afin de valider le bon fonctionnement de l'outil, la matrice est testée sur 4 sites au Liban représentant respectivement :

- Un site protégé, isolé en milieu urbain, et à faible étendue géographique (110 hectares) : la réserve naturelle de Bentael (Mont Liban)

- Un site protégé, reconnu pour sa très grande diversité animale et végétale et les taux élevés d'endémisme et de rareté inhérents, et à plus grande étendue géographique (1000 hectares) : la réserve naturelle de Horsh Ehden (Nord Liban)
- Un site en cours de mise en réserve par le ministère de l'Environnement : les falaises de Ras Chekka (Nord Liban)
- Un site non protégé, mais présentant selon les écologistes un intérêt ultime de conservation : la forêt de Baabda (Beyrouth)

Suite à cette étape, la matrice est convertie en un outil informatisé, accessible en ligne, en partenariat avec un développeur web.

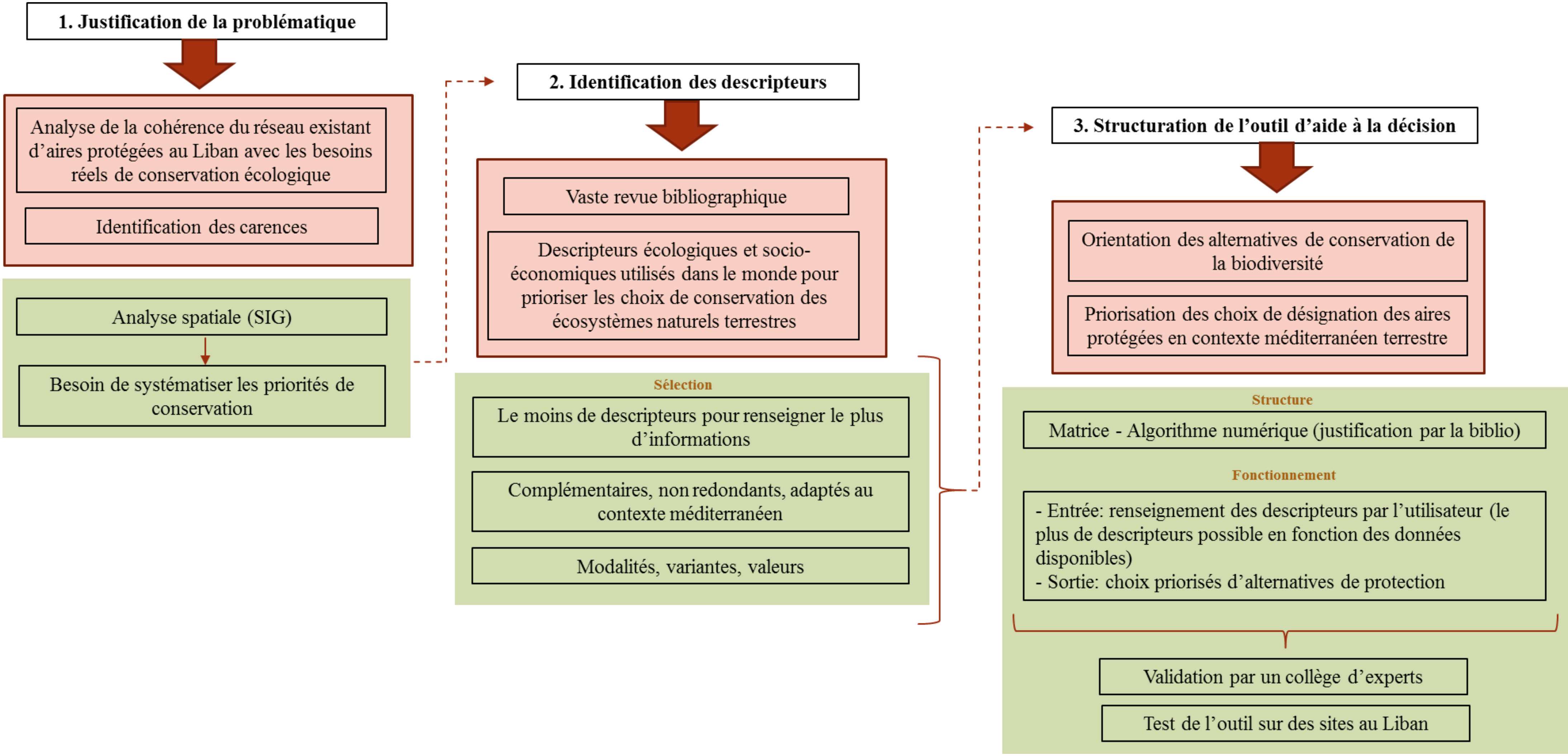

Figure 1. Approche méthodologique générale adoptée

CHAPITRE 3

Les réseaux d'aires protégées dans la conservation de la biodiversité Méditerranéenne : quels rôles, quels défis ?

Les écosystèmes méditerranéens sont défiés par la présence et les activités humaines. Des milieux dégradés qui reçoivent de plus en plus l'attention des aménageurs, aux aires protégées cible de la préoccupation des gestionnaires, la restauration et la conservation de la biodiversité demeurent la finalité.

Marginalisée des considérations nationales, surtout en termes de prise de décisions et lors de l'élaboration de politiques territoriales, la biodiversité représente le maillon faible de la chaîne des considérations environnementales, notamment en Méditerranée (un des hotspots de biodiversité mondiale) et au Liban (un des 10 mini-hotspots de la Méditerranée). L'importance de la prise en compte des aspects de conservation de la biodiversité et des écosystèmes naturels dans les politiques territoriales demeure ainsi prioritaire afin de maintenir les processus écologiques naturels qu'ils supportent et de préserver les valeurs et les atouts qu'ils apportent aux hommes.

Les aires protégées constituent les piliers fondamentaux des stratégies nationales et internationales de conservation de la biodiversité. Elles sont à la fois au cœur de la résilience des écosystèmes et de l'équilibre des systèmes écologiques, et agissent comme des refuges pour les espèces en fournissant un espace propice pour l'évolution naturelle. Elles sont ainsi considérées comme l'un des meilleurs outils pour la conservation des écosystèmes et de la biodiversité dans le monde. Néanmoins, bien que le nombre d'aires protégées ait connu une croissance rapide au cours des 20 dernières années, la mesure dans laquelle celles-ci représentent, maintiennent et préservent les principales richesses écologiques est encore mal appréhendée, et d'importantes lacunes demeurent dans leur couverture de la biodiversité mondiale (en général) et méditerranéenne (en particulier).

Répondant aux exigences de la convention pour la biodiversité et dans le but de conserver *in situ* ses écosystèmes naturels hautement reconnus pour leur richesse spécifique, le Liban a entamé la désignation d'aires protégées depuis 1930 afin de concrétiser la protection de sa biodiversité. Jusqu'à ce jour, plus qu'une centaine d'aires protégées réparties entre protections légales (réserves naturelles, forêts protégées, sites et monuments naturels), désignations internationales (réserves de biosphères, sites RAMSAR, sites du patrimoine mondial de l'UNESCO) et désignations locales (Hima) sont établies le long du territoire. Toutefois, les enjeux clés de la biodiversité restent encore dispatchés dans des écosystèmes fortement soumis à une pression anthropique peu ou pas contrôlée. Si le réseau actuel regroupe 15 réserves naturelles, 32 sites et monuments naturels, 27 forêts protégées, 15 Himas, 3 réserves de biosphère, 4 sites RAMSAR et 5 sites du patrimoine mondial de l'UNESCO, seules les réserves naturelles et les sites naturels disposent d'un cadre juridique bien qu'incomplet. Il n'existe ni de critères propres aux différentes catégories d'aires protégées ni de mécanismes de désignation bien définis.

Une analyse spatiale de la distribution des aires protégées au Liban basée sur la superposition de la carte du réseau actuel d'aires protégées sur les cartes des zones à importance écologique de conservation (IPA et IBA), la carte des sols, la carte du mode d'occupation des sols, la carte des étages de végétation et la carte des étages bioclimatiques, montre que ce réseau ne couvre pas les principales richesses écologiques que l'on retrouve sur le territoire, notamment les zones importantes pour les plantes, les zones importantes pour les oiseaux, les phryganes d'altitudes, les milieux naturels ouverts, les matorrals, les formations rupestres, les sols basaltiques, les étages de végétation pré-steppiques, etc. La désignation actuelle des aires protégées semble répondre à une configuration sociopolitique opportuniste plutôt qu'écologique et ces aires seraient principalement vouées à la conservation de quelques espèces phares (*Cedrus libani* principalement), ou d'habitats d'espèces protégées ou vulnérables (*Caretta caretta*, *Chelonya midas*, etc.). Au-delà de cette considération écologique de base, les critères orientant le choix de conservation semblent totalement absents ou subjectifs.

Dans un contexte où conserver la biodiversité et les écosystèmes naturels revient à les classer par ordre prioritaire d'intervention, où tout doit être pris en compte dans les politiques d'aménagement et de conservation, il s'agit surtout de proposer une démarche objective permettant d'orienter les mesures de protection pour les rendre plus efficaces. Cette démarche, basée sur une combinaison de descripteurs écologiques et socio-économiques, permettrait surtout d'orienter les initiatives de conservation (au Liban en particulier) et de prioriser la conservation de la biodiversité ainsi que la désignation des aires protégées qui jusqu'à ce jour se fait au cas par cas.

Article 1

Pertinence of protected areas networks in biodiversity conservation strategies: Insights from an eastern Mediterranean context

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Abstract

Biodiversity conservation has become one of today's major challenges in a complex socio-ecological context, where common socioeconomic needs for resources exploitation are confronted to striking ecological conservation priorities. Protected areas constitute the key foundation for national and international strategies of effective biodiversity and ecosystems conservation. This paper assesses the effectiveness of protected areas networks in representing key ecological assemblages in Mediterranean environments. Based on a spatial interpretation of the distribution of existing and "preset" protected areas in Lebanon, and the analysis of their coherence with key ecological conservation needs, the pertinence of protected areas designation with respect to biodiversity conservation priorities is assessed. Analysis is performed through the overlay of the protected areas map of Lebanon with that of the areas of high ecological conservation value, the land cover/land use map, the soil map, and the overlaid map of bioclimatic and vegetation levels. A chi-square statistic is also used to significantly compare and assess the distribution of existing protected areas according to land cover, soil and bioclimatic/vegetation aspects. Results exhibit that the existing network of protected areas does not represent the country's main ecological assets in terms of species richness, soil specificities, important areas for biodiversity, and key eco-complexes. Current protected areas designation seems to answer very particular needs and to follow socio-political opportunities in Lebanon (in particular) and the Mediterranean (in general), while it should be based on pertinent ecological and socioeconomic criteria that would highlight the relevance and priority for conservation measures. Rethinking/widening the government efforts towards biodiversity protection is thus identified as a major need.

Keywords: Biodiversity; protected areas; criteria; indicators; GIS; Lebanon

Introduction

Biodiversity conservation in today's world has become a challenging task in a complex natural and socioeconomic context, where the economic need for resources exploitation outweigh ecological conservation priorities, in an overall setting of global changes triggering further profound implications on living systems (Lovejoy, 2008; Quézel, 1999; Thompson *et al.,* 2009). In such a fluctuating environment, maintaining biodiversity is much simpler than restoring it (Scheffer & Carpenter, 2003). A strategy at the forefront of biodiversity conservation is the reliance on protected areas (Gaines *et al.* 2010; Pimm *et al.*, 2001). *In situ* conservation maintains existing biodiversity and preserves ecological processes, where protection spearheads the response to the rapidly accelerating biodiversity crisis (Abuzinada, 2003). Opportunities exist indeed to develop reserve networks which conserve biodiversity without adversely affecting existing human settlements and land use, while supporting rural livelihoods (Brandon *et al.,* 2005).

Protected areas are recognized as geographically defined areas designated or regulated and managed to achieve specific conservation objectives (CBD, 1992). They constitute the key foundation for national and international strategies of effective biodiversity and ecosystems conservation, while acting like refuges for species and providing natural platforms for evolution (Naughton-Treves *et al.,* 2005). This can be seen through the 1994 IUCN classification system for protected areas, which considers biodiversity conservation as its main pillar, although it also recognizes the importance of other protected area objectives such as recreation and tourism. A spark interest and strong advocacy in creating protected areas to specifically conserve biodiversity was strongly endorsed by several studies (Chape *et al.*, 2005; Gaines *et al.*, 2010; Game *et al.*, 2009; Gray, 2010; Lester *et al.*, 2009; Lubchenco *et al.*, 2003, 2007; Pimm *et al.*, 2001). Most of the enthusiasm for establishing new protected areas actually derived from results of analyses showing greater richness and/or abundance (or biomass) of species within than outside individual protected areas (Halpern & Warner, 2002; Lester *et al.* 2009; Lubchenco *et al.*, 2003, 2007; Micheli *et al.*, 2004). Yet, other numerous studies confirmed that this fact is not universal (Bagella *et al*., 2013; Guidetti & Sala, 2007; Mora *et al.*, 2011; Newmark, 1987; Parks & Harcourt, 2002; Rakitin & Kramer, 1996; Rivard *et al,*. 2000; Rogers & Beets, 2001; Thouless, 1998; Western *et al.*, 2009) and stressed on the importance of also conserving biodiversity outside of protected areas (Cox & Underwood, 2011). Hence, while the number of protected areas has been growing rapidly over the past 20 years, the extent to which these are effectively representing, maintaining and conserving key ecological features is still poorly understood (Gaston *et al.*, 2008; Rodrigues *et al.*, 2004), and substantial gaps remain in their coverage of global biodiversity (Le Saout *et al.*, 2013). Brennan (2009) confirms in that respect that marine protected areas are considered as major tools for biodiversity conservation, while Khan *et al.* (1997) argue that protected area networks do not always effectively conserve unique ecological values. Mora and Sale (2011) discuss significant shortcomings in the usual process of implementation of protected areas that preclude relying on them as a global solution for biodiversity conservation, and confirm that the effectiveness of existing protected areas will not be able to overcome current trends of biodiversity loss. The shortcomings include technical problems associated with large gaps in the coverage of critical ecological processes and the overall failure of such areas to protect against the broad range of threats affecting ecosystems.

This contrast in the outcomes of protected areas might be related to the differences in their characteristics such as size (Cote et al. 2001), position and spatial coverage with regards to conservation targets (Mora & Sale 2011), types of implemented regulations (Lester & Halpern 2008), quality of law enforcement (Kritzer 2004), possibility that available information is biased by the tendency to publish significant results (Gaston et al. 2008), and most of all, the lack of systematic and informative ecological and socioeconomic criteria and/or indicators that would be as much objective as possible to prioritize conservation initiatives and biodiversity offset schemes (Bowker et al. 2008; Olivier et al. 1995; Quétier & Lavorel, 2011). This information remains though essential for assessing the overall role of protected areas in biodiversity conservation and identifying where protected areas need to be further integrated with other conservation efforts to achieve effective species and ecosystems conservation and reach optimal protection.

Arising from this complex understanding of protected areas' role in achieving biodiversity conservation, this paper assesses the effectiveness of these areas in Lebanon (Eastern Mediterranean) in conserving the country's key ecological features, through a spatial analysis of their distribution and coherence with key ecological conservation needs. It will accordingly highlight the main gaps and needs to reach optimal conservation in a Mediterranean context, and answer the following question: does the current network of protected areas in Lebanon comply with key ecological conservation needs or does protected areas' designation still remain a bargaining chip between socioeconomic and political priorities/opportunities??

Lebanon: a quick snapshot

Lebanon occupies only 0.007% of the world's land surface area and is home to 1.11% of the world's plant species and 2.63% of the reptile, bird and mammal species (Tohmé & Tohmé, 2007; MoE/UNDP/ECODIT, 2011). The floristic richness estimates 2,670 plant species with a high percentage of endemics (17.8%) among which 13.7% are regional endemics and 4% are narrow endemics (Mouterde, 1966, 1970, 1983; Tohmé & Tohmé, 2007, 2014).

As a result of its biogeography, geology, topography and historic human settlements particular to the Mediterranean basin, Lebanon falls within a recognized center of plant diversity that is considered a global hotspot (Blondel & Aronson, 1999; Médail & Quézel, 1999; Myers *et al.*, 2000) and presents a wide variety of habitats ranging from islands, coastal lands, rivers and high mountains culminating at 3,088 meters. Adding this complexity to the prevailing topoclimatic conditions has resulted in an altitudinal organization of vegetation levels with respect to bioclimatic zones (Abi-Saleh, 1978; Abi-Saleh & Safi, 1988).

However, biodiversity in Lebanon is under severe threat of decline and extinction and the major pressures include habitat loss and degradation, unsustainable species harvesting, climate change, pollution, and to a lesser extent, the threat related to genetic pollution and hybridization between cultivated and wild relatives (Sattout & Abboud, 2007).

Recognizing both the value of biodiversity, ecosystems and landscapes as well as the various threats related to human development, the Lebanese Government initiated as early as the 1930's a conservation policy based on prevention through the establishment of a network of protected areas over the territory.

Materials and Methods

In an attempt to address the questions raised by the working hypothesis, the suggested methodological approach underlines the fittingness of the existing protected areas network in Lebanon (legally protected areas, local and international designations) in representing key land cover, soil, vegetation and bioclimatic features, while comparing this distribution to that of identified areas of ecological conservation values across the country, and diagnosing gaps.

Aiming to assess the protected areas network pertinence in representing key ecological and biodiversity features in Lebanon, a spatial analysis of their distribution was performed through GIS mapping. In addition, a chi-square statistic (performed through the SPSS 21 software) was used as a non-parametric test to investigate if there are statistical significant differences between the distribution of the existing protected areas and areas of ecological conservation value along different land cover types, soil types and bioclimatic/vegetation levels. This goodness-of-fit test highlights some determinant conclusions regarding the significance of protected areas coverage.

First, an exhaustive map of protected areas was produced. This map includes first legal protections (protected areas designated by law, decree or ministerial decision from the Lebanese government upon the suggestion of the Ministries of Environment or Agriculture, including Nature Reserves, Natural Sites and Monuments, and Protected Forests). It displays on a second hand local designations (Hima conservation system). The Hima is an approach for natural resources conservation (sites, species and habitats) through a community based management. It originated from more than 1,500 years ago where it was spread along the Arab Peninsula as a tribal system of sustainable management of natural resources. In Lebanon, a Hima is a decentralized protected area, declared through municipal decision, where management and decisions are made by the local communities themselves). On a third level, the map exhibits areas under international designations (Biosphere Reserves, RAMSAR sites and UNESCO World Heritage Sites). Finally, the map displays the seven National Parks that were conceived along the Lebanese territory by Lebanon's 2006 Master Plan (Schéma Directeur d'Aménagement du Territoire Libanais) produced by the Council for Development and Reconstruction and voted by parliament decree in 1999. Still, these parks are not yet established in Lebanon).

This map was then overlaid with the map of areas with ecological conservation value, where scientific inventories were performed, highlighting the importance of their potential conservation. Particularly, this map includes key biodiversity areas for birds (Important Bird Areas- IBAs, A-Rocha/SPNL 2008) and plants (Important Plant Areas- IPAs, Radford et al. 2011) in order to compare and analyze the distribution of existing protected areas to that of identified areas of high ecological interest.

In a following step, the overlaid map of protected areas and areas of ecological conservation values was overlaid with:

- The land cover / land use map of Lebanon (LUC) (SDATL, 2004), in order to analyze the spatial distribution of existing protected areas and areas of ecological conservation value with regards to the country's vegetation cover, water bodies, barren lands and other types of land use.
- The soil map of Lebanon (SDATL, 2004), in order to highlight the spatial coverage of main soil types by these areas in Lebanon and identify gaps.
- The overlaid map of bioclimatic levels and vegetation levels of Lebanon, which was produced in the frame of this study, based on the maps of Abi-Saleh & Safi (1988), in order to assess: the altitudinal distribution of protected areas and other areas of ecological conservation value in Lebanon with respect to vegetation levels; and their spatial coverage of the different bioclimatic levels inducing dissimilar microclimatic conditions.

The selection of these criteria was mainly based on:

- Their key significance in impacting the establishment of diverse eco-complexes recognized for their variability in structures, functions and ecological attributes.
- The availability of exhaustive geospatial data for Lebanon related to them

Results are subsequently summarized and thoroughly analyzed via GIS analytical tools.

Results

Spatial distribution of protected areas in Lebanon

The protected areas network in Lebanon features as per Figure 1: 15 nature reserves, 32 natural sites and monuments, 27 protected forests, 15 Himas, 3 biosphere reserves, 4 RAMSAR sites, 5 UNESCO world heritage sites and 7 potential natural parks. Other areas of ecological conservation value include 15 IBAs and 20 IPAs.

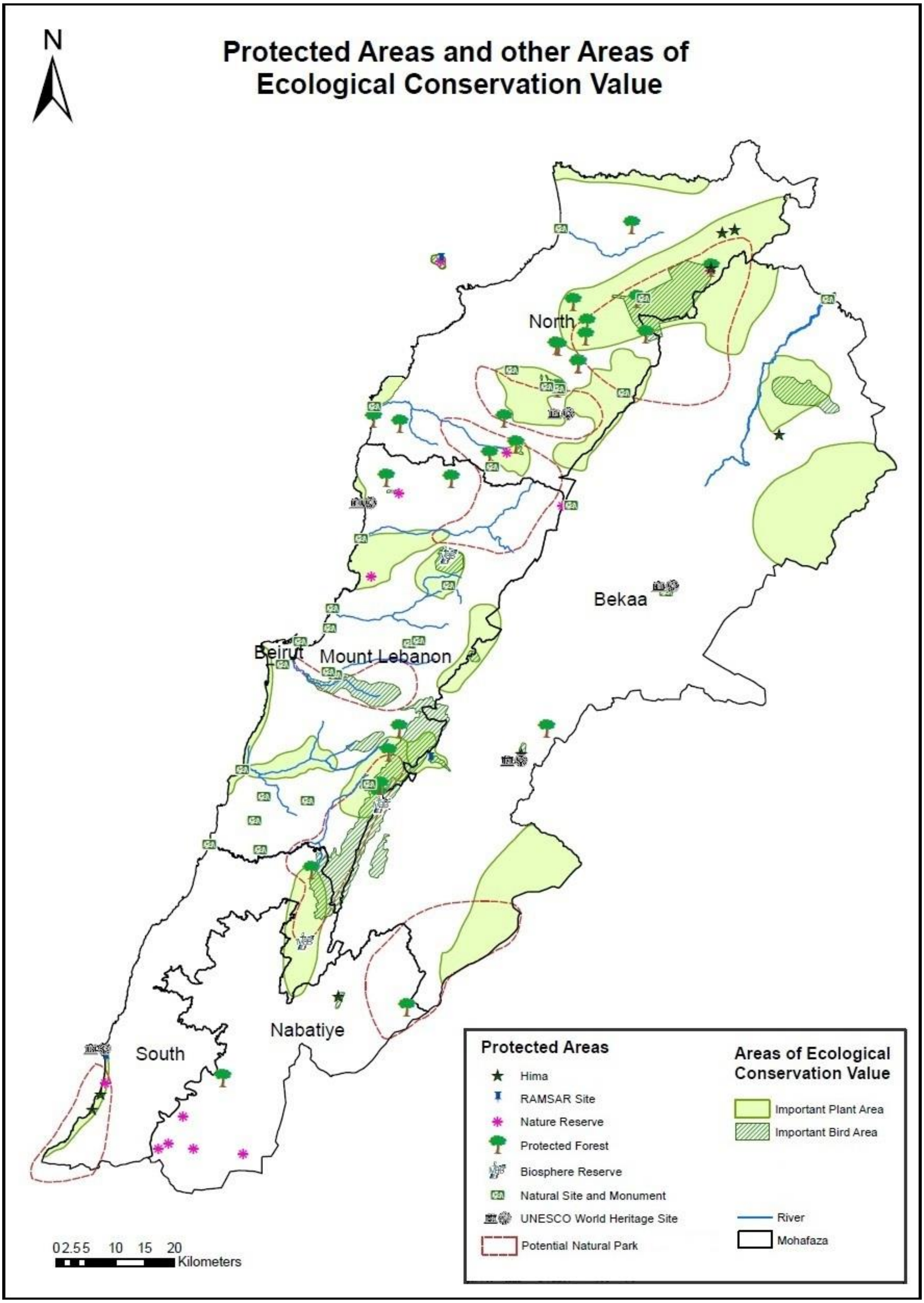

Figure 1- Overlaid map of existing protected areas in Lebanon and other areas of ecological conservation value

The existing network of legally protected areas expands over the whole Lebanese territory, with a yet more emphasized distribution on the western flank of the country, delineated by the western chain of mountains which outlines the eastern limits of the Northern and Mount Lebanon governorates (Mohafaza) (Fig. 1).

Protected areas distribution with respect to land cover

Overlaying the map of protected areas and other areas of ecological conservation value with the land cover map of Lebanon (Figure 2) exhibits that 54% of "legally" protected areas fall on clear to dense forests, from which 56% cover coniferous stands (cedars, firs, pines and juniper). Another 11% are distributed on grasslands and scrublands, whereas only 2 protected areas partially cover barren lands. Inland wetlands are represented by 4% of protected areas, while protected rivers and coastal ecosystems account for 18%; the rest of protected areas being scattered on medium to large field crops and low-density urban fabrics. The last cases reflect those of Himas, UNESCO world heritage sites and biosphere reserves, which encompass socio-ecological systems (Table 1).

IPAs distribution analysis reveals that more than 37% of the IPAs include large tracts of bare rocks, bare soils, clear to dense grasslands and scrublands (mainly in the far North and Anti-Lebanon), whereas more than 20% encompass coastal ecosystems and inland wetlands, and only 20% represent forest ecosystems.

Results of the chi-square statistic test reveal that the percentage of coverage of each land cover type by the existing network of protected areas (including legal, local and international designations) does not fit significantly (is not associated) with that represented by IPAs ($\chi^2 = 83.7$, df = 3, $p < 0.01$), which further confirms the significant shortcomings in the coverage of some land cover types by the existing network of protected areas (Table 2).

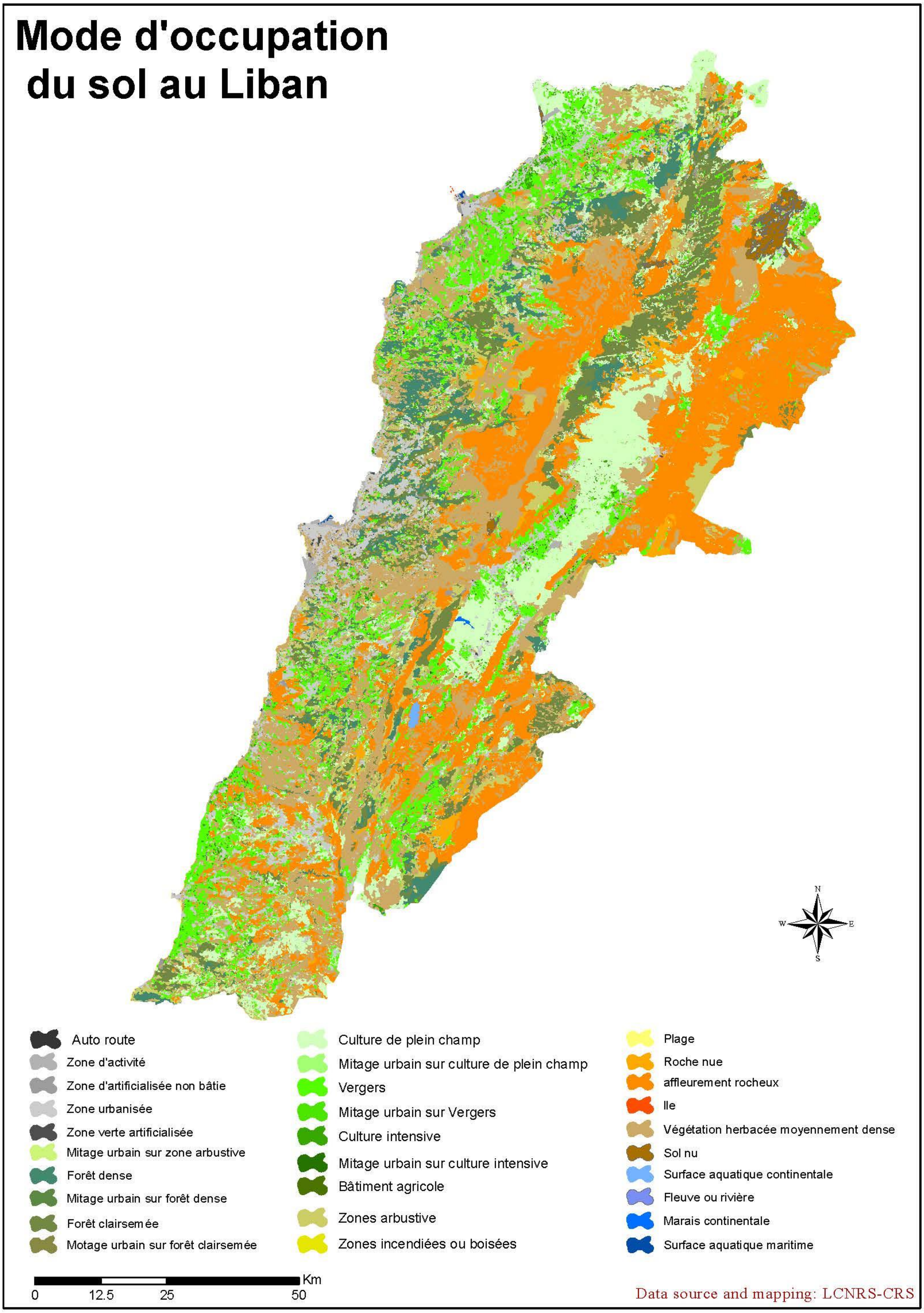

Figure 2- Land cover/Land use map of Lebanon

Table 1- Percentage of coverage of each land cover type by the existing network of protected areas

Land cover type	Percentage (%) over Lebanon	Percentage (%) of coverage by the existing network of protected areas	Percentage (%) represented by IPAs
Forests and woodlands	25.2	54	21
Herbaceous areas (grasslands and scrublands) and barren lands	31	11	37
Swamps, wetlands and water bodies	0.3	22	24
Urban areas, cultivated areas and unproductive areas	43.5	13	18

Table 2- Results of the chi-square statistic on the comparison between the percentages of land cover types represented by the network of existing protected areas in Lebanon and that represented by IPAs

Land cover type	Residuals
Forests and woodlands	20.1
Herbaceous areas (grasslands and scrublands)	61.4
Swamps, wetlands and water bodies	0.181
Urban areas, cultivated areas and unproductive areas	1.92

Df	χ^2	Sig.
3	**83.7**	0.00

Protected areas distribution with respect to soil types

Soil types have strong ties with biodiversity. Henceforth, the nature of the substrate, as usually determined by the nature of the underlying rock, is a key factor in determining the distribution of habitats and species.

Overlaying the protected areas and other areas of ecological conservation value map with the soil map confirms that barren lands (karst formations, cliffs, exposed rocks, gravel pits, etc.) are hardly represented by the existing network of protected areas (2%), while being of more significance in the suggested network of important plant areas (13%) considered to host high rates of flora richness and endemism (Table 3). Similarly, black and grey soils are poorly represented in the existing network of protected areas in Lebanon (5%) compared to that of IPAs (10%).

Table 3- Percentage of soil types represented by the network of existing protected areas in Lebanon compared to that represented by important plant areas

Soil type (SDATL, 2004)	**Percentage (%) represented by the existing network of protected areas**	**Percentage (%) represented by IPAs**
Red soil (*Terra Rossa*) - passes sometimes to forest brown soil	38	18
Mixed soil (mainly on mountains) on alterning marl, limestone and sandstone or on marl with bedded limestone	17	19
Yellowish mountain soil	14	11
Coastal sand	9	4
Black or grey soil (sometimes rubified, on basalt)	5	10
Recent fluvial alluvium	5	6
Sandy soil	4	6
Gravel pits, stones and bare rocks	2	13
Consolidated dunes	0	2
Other (poudingues, brown soils, chestnut soils, artificial hills, etc.)	6	11

Results of the chi-square statistic test affirm that the percentage of soil types represented by the existing network of protected areas does not fit significantly (is not associated) with the percentage represented by IPAs ($\chi^2 = 87.05$, df = 9, $p < 0.01$), which further confirms the significant shortcomings in the coverage of some soil types by the existing network of protected areas (Table 4).

Table 4- Results of the chi-square statistic on the comparison between the percentage of soil types represented by the network of existing protected areas in Lebanon and that represented by IPAs

Soil type (SDATL, 2004)	**Residuals**
Red soil (*Terra Rossa*) - passes sometimes to forest brown soil	20
Mixed soil (mainly on mountains) on alterning marl, limestone and sandstone or on marl with bedded limestone	2
Yellowish mountain soil	3
Coastal sand	5
Black or grey soil (sometimes rubified, on basalt)	5
Recent fluvial alluvium	1
Sandy soil	2
Gravel pits, stones and bare rocks	11
Consolidated dunes	2
Other (poudingues, brown soils, chestnut soils, artificial hills, etc.)	5

Df (Degree of freedom)	χ^2	**Sig.**
9	**87.05**	0.00

Protected areas distribution with respect to vegetation and bioclimatic levels

Vegetation in Lebanon is typically represented by clear altitudinal leveling where 10 vegetation levels, each characterized by specific plant associations, can clearly be distinguished with respect to altitude. This leveling is firmly correlated to bioclimatic conditions which have contributed to the establishment of 5 bioclimatic levels in Lebanon according to the Emberger Quotient (Abi-Saleh et al. 1996). Figure 3 displays the resulting overlaid distribution of bioclimatic and vegetation levels in Lebanon. Micro and macroclimatic conditions, as well as changes in vegetation levels and series (from humid valleys to steppic and pre-steppic areas) have indeed a considerable impact on biodiversity distribution patterns, as they contribute in the delineation of different types of habitats and micro-habitats, each recognaized for specific ecological features.

Results of overlaying the map of protected areas and other areas of ecological conservation value with the overlaid map of bioclimatic and vegetation levels are presented in Table 5 which exhibits the percentages of existing protected areas, IPAs and IBAs falling over the different vegetation and bioclimatic levels in Lebanon.

Remarkably, existing protected areas are mainly distributed in the typical Mediterranean vegetation series (between 0 and 2,000m of altitude) with a yet almost insignificant extent over the typical Oro-Mediterranean vegetation level (>2,000m) and the presteppic Mediterranean vegetation series (northern Bekaa, anti-Lebanon chain and the eastern side of the western mountain chain) characterized by the predominance of arid to per-humid environments prevailed by open shrublands, scrublands and rocky stations, where the Lebanese government did not yet initiate the establishment of protected areas.

In contrast, 52% of the IPAs are identified in areas representing the presteppic Mediterranean vegetation series and the typical Oro-Mediterranean vegetation level. This disparity clearly highlights the importance of these areas in terms of flora specific richness. Besides, whereas most of the existing protected areas are designated in the sub-humid, humid and per-humid bioclimatic levels, IPAs show a roughly equal distribution over all the bioclimatic levels even in the arid and semi-arid levels.

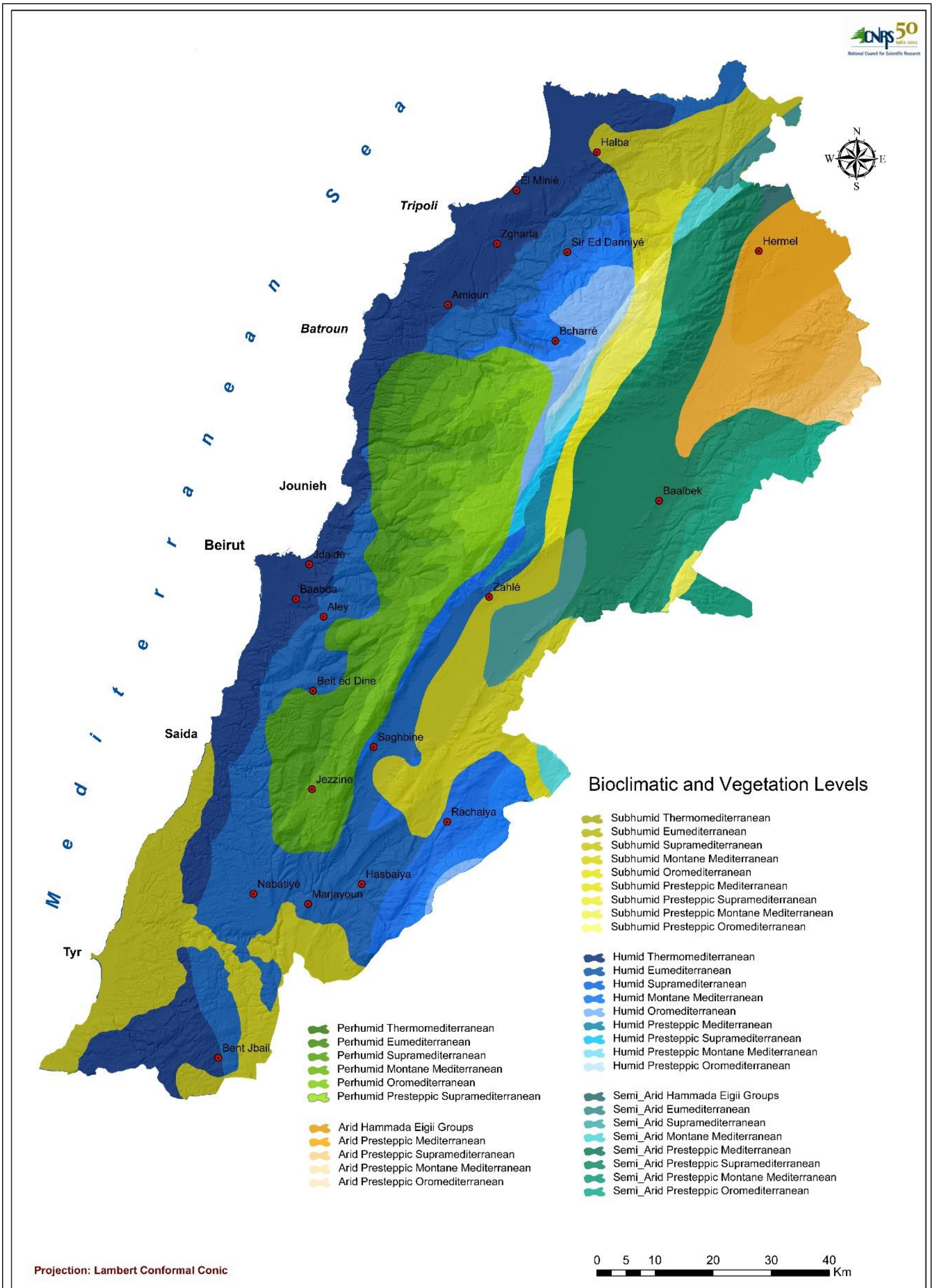

Figure 3- Overlaid map of bioclimatic and vegetation levels in Lebanon

Table 5- Distrbution (%) of existing protected areas, IPAs and IBAs with respect to the different vegetation and bioclimatic levels in Lebanon.

Vegetation and bioclimatic levels		Existing protected areas (%)	IPAs (%)	IBAs (%)
Typical Mediterranean vegetation series	Thermo-Mediterranean (0-500 m)	25	10	19
	Eu-Mediterranean (500-1000 m)	27	14	25
	Supra-Mediterranean (1000-1500 m)	16	10	19
	Montane Mediterranean (1500-2000 m)	18	14	25
	Oro-Mediterranean (>2000 m)	4	17	6
Presteppic Mediterranean vegetation series	Thermo and Eu-Mediterranean presteppic (1000m-1500m)	6	7	6
	Presteppic Supra-Mediterranean (1400m-1800m)	0	7	0
	Presteppic Montane Mediterranean (1800-2400m)	4	7	0
	Presteppic Oro-Mediterranean (>2400 m)	0	14	0
Bioclimatic levels	Arid	4	17	12
	Semi-Arid	10	24	19
	Sub-Humid	39	21	25
	Humid	22	21	19
	Per-Humid	25	17	25

Results of the chi-square statistic test reveal that the percentage of bioclimatic/vegetation levels represented by the existing network of protected areas does not fit significantly (is not associated) neither with the percentage represented by IPAs ($\chi^2 = 156.8$, df = 13, $p < 0.01$), nor by that represented by IBAs ($\chi^2 = 39.4$, df = 13, $p < 0.01$) which further highlights the substantial gaps in the coverage of some bioclimatic/vegetation levels by the current network, and underlines the priority for conservation of perimeters represented by IPAs and IBAs (Table 6).

Table 6- Results of the chi-square statistic on the comparison between the percentages of bioclimatic /vegetation levels represented by the network of existing protected areas in Lebanon and those represented by IPAs and IBAs

Vegetation and bioclimatic levels		**Residuals** (between distributions (%) of existing protected areas and IPAs with respect to the different vegetation and bioclimatic levels)	**Residuals** (between distributions (%) of existing protected areas and IBAs with respect to the different vegetation and bioclimatic levels)
Typical Mediterranean vegetation series	Thermo-Mediterranean (0-500 m)	15	6
	Eu-Mediterranean (500-1000 m)	13	2
	Supra-Mediterranean (1000-1500 m)	6	3
	Montane Mediterranean (1500-2000 m)	4	7
	Oro-Mediterranean (>2000 m)	13	2
Presteppic Mediterranean vegetation series	Thermo and Eu-Mediterranean presteppic (1000m-1500m)	1	0
	Presteppic Supra-Mediterranean (1400m-1800m)	7	0
	Presteppic Montane Mediterranean (1800-2400m)	3	4
	Presteppic Oro-Mediterranean (>2400 m)	14	0
Bioclimatic levels	Arid	13	8
	Semi-Arid	14	9
	Sub-Humid	18	14
	Humid	1	3
	Per-Humid	8	0

Df	χ^2	**Sig.**
13	**156.8 (IPAs)**	0.00

Df	**χ2**	**Sig.**
13	**39.4 (IBAs)**	0.00

Discussion

Protected areas distribution in Lebanon: an echo from the past

The particular distribution of protected areas in Lebanon, especially in the Northern and Mount Lebanon governorates, can be attributed to several drivers primarily related to the fact that these two governorates are the most biologically diverse regions of Lebanon (MOA 2003; Sattout & Abboud 2007). Forests in the North cover 21% of its area, an extent considered being the largest forest continuum in Lebanon harboring the key elements of the Lebanese flora (Sattout 2007), whereas Mount Lebanon encompasses high levels of biodiversity rates along with critical high altitude ecosystems recognized for their key ecological value (Demopoulos 2008). Although large areas of great ecological importance (IBAs and IPAs) are identified in the vicinity of the Bekaa valley (the largest agricultural plain in Lebanon) and the eastern mountain chain, these areas remain nearly exempt from protected areas (Figure 1). Few reasons back front this disparity in the spatial coverage of protected areas between the North and Mount Lebanon *versus* the Bekaa and Anti-Lebanon mountain range. This goes back in history to the Roman era in Lebanon (2^{nd} century A.D.), when Emperor Hadrian delimited and claimed cedar, fir and juniper forests as "imperial domains" and halted their exploitation. Since then, conifer forests were given an ultimate priority in conservation (Shackley 2005). In the 20^{th} century, the Lebanese government initiated national conservation strategies favoring the protection of these stands. The forestry law No. 558 of 1996 stipulates that all cedar, fir, juniper and "other coniferous forests" in Lebanon are protected *de facto*.

Yet, given the fact that these forests were (and are still) mostly confined in North and Mount Lebanon, the Lebanese government through its ministries of environment and agriculture initiated the appropriate legal processes for their conservation. The arid environment of the Anti-Lebanon mountain chain (Abi-Saleh & Safi 1988) along with the large deforestation campaigns that took place between 1963 and 1998 in the inner Bekaa and Hermel valleys and Anti-Lebanon (Asmar 2011) hindered the establishment of such forests while privileging open shrubby structures, still currently excluded from the existing protected areas network, although recognized for their high specific fauna and flora richness, along with high rates of endemism (Bischoff & Schmidtler 1999; Günter et al. 2012; Hraoui et al. 2001, 2002; Mouterde 1966, 1970, 1983; MoE/GEF/UNDP 2009; MoE/UNDP/ECODIT 2011; Sattout 2007; Tohmé & Tohmé 2009, 2011). Conversely, forest cover increased in Mount Lebanon region as forests naturally expanded. The quasi-absence of national strategies for habitat/ecosystems conservation (except for the RAMSAR convention), have had a profound impact on the negligence of these semi-arid open areas of the Bekaa and Anti-Lebanon, falling in considerable part under strict tribal governance systems which further hampered governmental interventions for resources protection.

The Lebanese Master plan suggested in 2006 a network of seven natural parks that have not yet been neither established, nor even legally recognized as an official category of protected areas (although highly aspired for by local communities). Expanding over the whole Lebanese territory, this network covers an approximate area of 1,800Km^2 (around 17% of the country's overall surface) and extends over large tracts of IPAs and IBAs, being thus able to potentially bridge a great gap in the existing network of protected areas if implemented. However, given that this category is still not formally legalized and created, natural parks remain an ultimate objective to meet.

Although on a first broad level of analysis the current distribution of protected areas in Lebanon does not seem to cover yet all key areas of ecological interest, one cannot deny the fact that existing conservation initiatives constitute a first step towards the creation of an integrated network of protected areas. The presence of these areas *per se* highlights the positive will of the government, local communities, and national and international organizations, to establish local protection initiatives, and contributes already to the conservation of about 7% of Lebanon's terrestrial and marine ecosystems (Jaradi & Khater 2009).

Protected areas distribution with respect to land cover types: unveiling subtle gaps

The variability in land cover types and land use patterns has a great impact on biological diversity, and is thus considered as a key element in orienting conservation priorities. Besides, land use changes are a major driver of the distribution and functioning of ecosystems. Protected areas distribution in Lebanon is hence assessed with regards to land cover types to assess the extent to which each type is represented by the existing network and identify potential gaps.

The disparity in the spatial coverage of the different types of land cover by the existing protected areas and the areas of ecological conservation value (Tables 1 and 2), highlights the importance of scrublands, grasslands and bare land ecosystems in sheltering high rates of specific flora biodiversity, and underlines their subsequent ecological conservation value. Remarkably, these areas are not fairly represented by the existing network of protected areas in Lebanon, although rare in the country (namely in northern Bekaa, Anti-Lebanon and above the tree line - 2,000m) (Asmar 2011), with a specific fauna richness generally known to outdo that of forest ecosystems (Nangendo et al. 2002; Sala et al. 2001; Xiaoxu et al. 2011).

Another particular land cover feature in Lebanon is the high mountainous spring snow spots recognized as areas of extreme ecological, aesthetic, and economic value for the country. They constitute a national treasure and a repository for biodiversity and water resources. However, the Anti-Lebanon chain remains highly vulnerable to overgrazing patterns, where this practice has nearly destroyed most of the landscape by degrading the vegetation cover and consequently affecting the spring snow spots feeding underground water reservoirs (Asmar 2011). The current myriad of laws and regulations related to urban planning, water, forests and protected areas does not recognize the intrinsic value of mountains as a system, and tends to approach development piecemeal (MoE/UNDP/ECODIT 2011). In France on the contrary, mountains are protected by Law No. 85-30 dated 9/1/1985 called "Loi Montagne". This latter delimits mountain zones, provides guidelines for construction, recognizes specific institutions dedicated to the management of mountain areas, approaches sustainable economic development of rural areas, and regulates tourism projects in mountains. In Lebanon, only the Makmel Mountain in north Lebanon is classified as a natural site. Unless the site is proclaimed a national park consistent with the recommendations of the national land use master plan (SDATL), the mountain will come under increasing pressure from urbanization including logging, hunting, and quarrying. Other mountains and plateaus such as Sannine, Kneisseh, Aaqoura, Tannourine and Akkar are not protected by any regulation and are therefore vulnerable to large-scale urban developments that will inevitably disturb their natural features including karst, springs, caves, sinkholes and thalwegs.

Protected areas distribution with respect to soil types: a "bare" reality

Soil types and characteristics have a great impact on flora diversity (Janssens et al. 1998; Roem & Berendse 2000; Sylvain & Wall, 2011). Calcareous *Terra Rossa* (red soils) and Rendzinas are the most common types of soils in Lebanon and the Mediterranean region (Darwish 2006; Durn 2003; Lamouroux 1971). The majority of nature reserves and protected forests in Lebanon fall on red soils, which explains their high representation in the existing network of protected areas.

Rare in Lebanon yet known for their importance as fertile substrates for specific flora development (Bell et al. 1998; Boland et al. 2006; Darwish 2006; Roem & Berendse 2000), black and grey soils are on the contrary poorly represented in the existing network of protected areas in Lebanon compared to that of IPAs (Tables 3 and 4). This disparity highlights the fact that uncommon soils support indeed the establishment of rare plant communities adapted to such particular soil features.

These gaps underline the importance of further considering areas expanding over stones, bare rocks and black or grey soils for conservation, as these substrates are rarely spread in the country and thus harbor rare plants and animals communities. Examples of such areas include the high altitude open shrubby ecosystems in North and Mount Lebanon sheltering high rates of flora and reptiles diversity and endemism (EcoMed, unpublished data; Hraoui et al. 2002), rocky slabs, and rocky stations in South and Mount Lebanon harboring high rates of rare and endemic plants, reptiles and amphibians species (EcoMed, unpublished data; Hraoui et al. 2001; Tohmé & Tohmé 2007; Tohmé & Tohmé 2014).

Protected areas distribution with respect to bioclimatic and vegetation levels: an ultimate confirmation

The results of overlaying the map of protected areas and areas of ecological conservation value with the overlaid map of bioclimatic and vegetation levels, fall in perfect compliance with those achieved when overlaying the map of protected areas with those of the land cover and soils, and globally confirm the gap in protecting areas falling on arid to semi-arid Oro-Mediterranean zones, characterized by presteppic vegetation series mainly prevailed by barren lands and scrublands, and largely located in the far north of Lebanon, the Bekaa and Anti-Lebanon (Tables 5 and 6). In fact, the combination of presteppic and arid to semi-arid environments creates privileged habitats for a wide number of flora and reptiles species (Bischoff & Schmidtler 1999; Günter et al. 2012; Hraoui et al. 2001, 2002; Mouterde 1966, 1970, 1983; Sattout 2007; Tohmé & Tohmé 2009, 2011) and preferred repositories and/or flyways for some migratory birds (A-Rocha/SPNL 2008), which explains the importance of these areas on the ecological level and stresses therefore the need to protect their structural (physical) and functional attributes.

Synthesis

A comparative analysis of the achieved results confirms that the existing network of protected areas in Lebanon does not fairly cover the country's key ecological features and is thus not completely coherent with the main ecological conservation needs. Several gaps remain in the coverage of important plant areas, fauna habitats, key soil types, major vegetation series and bioclimatic levels, mountain spring spots, inland wetlands, etc., while current conservation interests still strictly target coniferous forests (especially cedars), and to a lesser extent, coastal ecosystems. This can be clearly explained by the existing lack of mechanisms for protected areas design and designation in Lebanon, where these latter are randomly created upon the availability of funds and the socio-political opportunities to establish protected areas in particular villages, and is thus not based on pertinent scientific criteria able to spot and appropriately orient and prioritize conservation initiatives. After all, conservation is about prioritization, and prioritization is all about answering questions about when, where, and how we can efficiently achieve conservation goals. It is usually achieved within a wider decision-making context in which the needs of many land users and stakeholders are acknowledged, and in which fundamental criteria for understanding the issues associated with protected areas as global biodiversity indicators, protected area location and design, and the effectiveness of protected areas in achieving conservation objectives (Rodrigues *et al.* 2004) are taken into account. Still, in a prevailing unstable political and socioeconomic context where national security issues have overshadowed nature conservation priorities, even though the gaps in protected areas coverage remain numerous and of ultimate importance to address, these areas have succeeded to conserve at least few spots of ecological importance before they even disappear or get exploited. Anyhow, while the number of protected areas is progressively growing over the country, the extent to which these areas correlate with identified conservation priorities and effectively represent, maintain and conserve key ecological features is still poorly satisfying. Besides, the current absence of a legal framework for protected areas designation and management in Lebanon hinders somehow effective conservation initiatives. In this context, the Lebanese government is currently drafting a law for protected areas that will hopefully "systematically" orient protected areas creation and categorization.

Conclusion

The spatial analysis of protected areas distribution in Lebanon reveals that the current designation of protected areas is not entirely based on systematic ecological criteria and indicators, as the existing network discloses several gaps in the coverage of the main eco-complexes over the territory. For instance, two specific areas worth of conservation include the plain of Nahr El Assi in northern Bekaa recognized as both IPA and IBA, and the northern mountain of Anti-Lebanon also renowned as an IPA. Besides, it remains of key importance to effectively enforce the official (legal) creation of natural parks in Lebanon.

Adding to that, socioeconomic aspects in protected areas designation are not fully taken into account when attempting to establish a new conservation initiative. Therefore, it is of utmost importance to identify pertinent criteria and descriptors and develop an efficient system of protected areas designation that would objectively orient conservation priorities based on relevant ecological and socioeconomic criteria encompassing all aspects related to biodiversity (flora and fauna), physical environments (soil, topography, geology, etc.) and livelihoods.

Biodiversity conservation does not require at all absolute protection, but can be achieved through simple and easy approaches integrating socio-ecological systems. This is the role of protected areas. The goal is to achieve desired conservation of key ecological features while respecting the whole system embedding them.

Conflict of Interest

The authors declare no conflict of interest.

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References

Abi-Saleh B., 1978. Etude Phytosociologique, Phytodynamique et Ecologique des Peuplements Sylvatiques du Liban : Signification Bioclimatique et Essai de Cartographie Dynamique. Dissertation. Université d'Aix-Marseille III, Marseille, France.

Abi-Saleh B. & Safi S., 1988. Carte de la Végétation du Liban au 1/500 000 + Notice explicative. Ecol. Mediterr. 14(1/2): 123-142.

Abi-Saleh B., Nasser N., Rami H., Safi N., Safi S. & Tohmé H., 1996. La Flore Terrestre: Habitats Forestiers et Ecosystèmes Naturels. In: UNDP - Ministère de l'Agriculture (Liban), Étude de la Diversité Biologique du Liban, T. III, Projet PNUE / GF / 6105-92-72, Liban.

Abuzinada A. H., 2003. The role of protected areas in conserving biological diversity in the kingdom of Saudi Arabia. J. Arid. Environ. 54(1): 39-45.

A-Rocha & SPNL (Society for the Protection of Nature in Lebanon), 2008. The Identification and Conservation of New Important Bird Areas in Lebanon. IBA's map. Project funded by MAVA foundation.

Asmar F., 2011. Country Pasture/Forage Resource Profiles. Lebanon. FAO, 43p.

Bagella S., Caria M.C. & Filigheddu R., 2013. Gap analysis revealed a low efficiency of Natura 2000 network for the conservation of endemic species in Mediterranean temporary freshwater habitats. Plant Biosyst. 147(4): 1092-1094.

Bell M. J., Moody P. W., Connolly R. D. & Bridge B. J., 1998. The role of active fractions of soil organic matter in physical and chemical fertility of Ferrosols. Aust. J. Soil Res. 36(5): 809-819.

Bischoff W. & Schmidtler J. F., 1999. New data on the distribution, morphology and habitat choice of the Lacerta laevis-kulzeri complex. Nat. Croat. 8(3): 211-222.

Blondel J. & Aronson J., 1999. Biology and wildlife of the Mediterranean region. Oxford University Press, New York.

Bowker M. A., Miller M. E., Belnap J., Sisk T. D. & Johnson N. C., 2008. Prioritizing conservation effort through the use of biological soil crusts as ecosystem function indicators in an arid region. Conserv. Biol. 22(6), 1533-1543.

Brandon K., Gorenflo L. G., Rodrigues A. S. L. & Waller R. W., 2005. Reconciling Biodiversity Conservation, People, Protected Areas, and Agricultural Suitability in Mexico. World Dev. 33(9) : 1403-1418.

Brennan M. J., 2009. Les aires marines protégées comme outils de conservation de la biodiversité marine : application de critères de sélection et considération de la pertinence des critères adoptés dans le cadre de la convention sur la diversité biologique (Dissertation). Université de Sherbrooke, Québec, Canada.

Boland D.J., Brooker M.I.H., Chippendale G.M., Hall N., Hyland B.P.M., Johnston R.D., Kleinig D.A., McDonald M.W. & Turner J.D., 2006. Forest Trees of Australia, 5th edition. Csiro Publishing, 2006, Nature, 736p.

CBD (Convention on Biological Diversity)., 1992. http://www.cbd.int/doc/legal/cbd-en.pdf [accessed on 3.04.2014]

Chape S., Harrison J., Spalding M. & Lysenko I., 2005. Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philos. T. Roy. Soc. A. 360: 443-455.

Cote I. M., Mosqueira I. & Reynolds J. D., 2001. Effects of marine reserve characteristics on the protection of fish populations: a meta-analysis. J. Fish. Biol. 59: 178-189.

Cox R.L. & Underwood E.C., 2011. The Importance of Conserving Biodiversity Outside of Protected Areas in Mediterranean Ecosystems. Plos One. 6(1): e14508.

Darwish T., 2006. Soil map of Lebanon, 1:50000. Monograph series no.4. National Council for Scientific Research. Beirut, Lebanon, 367p.

Demopoulos H., 2008. A study into the importance of Jabal Moussa for birds in Lebanon. Jabal Moussa bird research 2007-2008. A Rocha, Lebanon, 42p.

Durn G., 2003. Terra Rossa in the Mediterranean Region: Parent Materials, Composition and Origin. Geol. Croat. 56(1): 83-100.

Gaines S. D., Lester S. E., Grorud-Colvert K., Costello C. & Pollnac R., 2010. Evolving science of marine reserves: new developments and emerging research frontiers. Proc. Natl. Acad. Sci. U.S.A. 107: 18251-18255.

Game E. T., Grantham H. S., Hobday A. J., Pressey R. L., *et al*., 2009. Pelagic protected areas: the missing dimension in ocean conservation. Trends Ecol. Evol. 24: 360-369.

Gaston K. J., Jackson S. F., Cantú-Salazar L. & Cruz-Piñón G., 2008. The Ecological Performance of Protected Areas. Annu. Rev. Ecol. Evol. Syst. 39: 93-113.

Gray N. J., 2010. Sea change: exploring the international effort to promote marine protected areas. Conservat. Soc. 8: 331-338.

Guidetti P. & Sala E., 2007. Community-wide effects of marine reserves in the Mediterranean Sea. Mar. Ecol. Prog. Ser. 335: 43-56.

Günter C. M., Zeegers T., Hogsette J. A., Revay E. E., Kravchenko V. D., Leshvanov A. & Schlein Y., 2012. An annotated checklist of the horse flies (Diptera: Tabanidae) of Lebanon with remarks on ecology and zoogeography: Pangoniinae and Chrysopsinae. J. Vector Ecol. 37(1): 216-220.

Halpern B. S. & Warner R. R., 2002. Marine reserves have rapid and lasting effects. Ecol. Lett. 5: 361-366.

Hraoui-Bloquet S., Sadek R. & Geze R., 2001. Amphibians of Lebanon: Inventory, geographical and altitudinal distribution. Bull. Soc. Herpet. Fr. 99(3): 19-28.

Hraoui-Bloquet S., Sadek R. A., Sindaco R. & Venchi A., 2002. The herpetofauna of Lebanon: new data on distribution. Zool. Middle East. 27: 35-46.

Janssens F., Peeters A., Tallowin J. R. B., Bakker J. P., Bekker R. M., Fillat F. & Oomes M. J. M., 1998. Relationship between soil chemical factors and grassland diversity. Plant Soil. 202: 69-78.

Jaradi G. & Khater C., 2009. Third national report for Lebanon to the Convention on Biological Diversity. Lebanon: United Nations Development Program. 256p.

Khan M. L., Menon S. & Bawa K. S., 1997. Effectiveness of the protected area network in biodiversity conservation: a case-study of Meghalaya state. Biodivers. Conserv. 6(6): 853-868.

Kritzer J. P., 2004. Effects of noncompliance on the success of alternative designs of marine protected-area networks for conservation and fisheries management. Conserv. Biol. 18 : 1021-1031.

Lamouroux M., 1971. Etude de sols formés sur roches carbonatées : pédogenèse fersiallitique au Liban. PHD thesis, ORSTOM Paris, 314p.

Le Saout S., Hoffmann M., Shi Y., Hughes A., Bernard C., Brooks T.M., Bertzky B., Butchart S.H.M., Stuart S.N., Badman T. & Rodrigues A.S.L., 2013. Protected Areas and Effective Biodiversity Conservation. Science. 342(6160): 803-805.

Lester S. E., Halpern B. S., Grorud-Colvert K., Lubchenco J., Ruttenberg B. I., Gaines S. D., Airamé S. & Warner R. R., 2009. Biological effects within no-take marine reserves: a global synthesis. Mar. Ecol. Prog. Ser. 384: 33-46.

Lester S. E. & Halpern B. S., 2008. Biological responses in marine no-take reserves versus partially protected areas. Mar. Ecol. Prog. Ser. 367: 49-56.

Lovejoy T., 2008. Climate change and biodiversity. REV. SCI. TECH. O.I.E, 27(2).

Lubchenco J., Palumbi S. R., Gaines S. D. & Andelman S., 2003. Plugging a hole in the ocean: the emerging science of marine reserves. Ecol. Appl. 13: 3-7.

Lubchenco J., Gaines S., Warner R., Palumbi S., *et al*., 2007. The science of marine reserves, 2nd edition, international version. Available at: www.piscoweb.org [accessed on 25 March 2014].

Médail F. & Quézel P., 1999. Biodiversity Hotspots in the Mediterranean Basin: Setting Global Conservation Priorities. Conserv. Biol. 13:1510-1513.

Micheli F., Halpern B.S., Botsford L.W. & Warner R.R., 2004. Trajectories and correlates of community change in no-take marine reserves. Ecol. Appl. 14: 1709-1723.

MoA (Ministry of Agriculture), 2003. National Action Program to Combat Desertification. Beirut, Lebanon. 71p.

MoE (Ministry of Environment) / GEF (Global Environmental Fund) / UNDP (United Nations Development Program), 2009. Fourth National Report of Lebanon to the Convention on Biological Diversity. Towards 2010 Biodiversity Target, Beirut, Lebanon. 243p.

MoE (Ministry of Environment) / UNDP (United Nations Development Program) / ECODIT, 2011. State and trends of the Lebanese environment. 355p. URL: http://www.MOE.gov.lb/Pages/SOER2010.aspx

Mora C. & Sale P.F., 2011. Ongoing global biodiversity loss and the need to move beyond protected areas: a review of the technical and practical shortcomings of protected areas on land and sea. Mar. Ecol. Prog. Ser., 434: 251-266.

Mora C., Aburto-Oropeza O., Ayala A., Ayotte P.M., *et al.*, 2011. Global human footprint on the linkage between biodiversity and ecosystem functioning in reef fishes. Plos Biol. 9: e1000606

Mouterde P., 1966. Nouvelle Flore du Liban et de la Syrie. Tome premier. Edition de l'Imprimerie Catholique de Beyrouth, 563p.

Mouterde P., 1970. Nouvelle Flore du Liban et de la Syrie. Tome deuxième. Edition de l'Imprimerie Catholique de Beyrouth, 720p.

Mouterde P., 1983. Nouvelle Flore du Liban et de la Syrie. Tome troisième. Edition de l'Imprimerie Catholique de Beyrouth, 578p.

Myers N., Mittermeier R.A., Mittermeier C.G., Da Fonseca G.A.B. & Kent J., 2000. Biodiversity hotspots for conservation priorities. Nature. 403: 853-858.

Nangendo G., Stein A., Gelens M., De Gier A. & Albricht R., 2002. Quantifying differences in biodiversity between a tropical forest area and a grassland area subject to traditional burning. Forest Ecol. Manag. 164: 109-120.

Naughton-Treves L., Buck Holland M. & Brandon K., 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods. Annu. Rev. Env. Resour. 30: 219-252.

Newmark W.D., 1987. A land-bridge island perspective on mammalian extinctions in western North American parks. Nature. 325 : 430-432.

Olivier L., Galland J.P., Maurin H. & Roux J.P., 1995. Livre Rouge de la flore menacée de France. Tome I : Espèces prioritaires. Muséum National d'Histoire Naturelle, Conservatoire Botanique National de Porquerolles, Ministère de l'Environnement, Paris. 621p.

Parks S.A. & Harcourt A.H., 2002. Reserve size, local human density, and mammalian extinctions in US protected areas. Conserv. Biol. 16: 800-808.

Pimm S.L., Ayres M., Balmford A., Branch G., *et al*., 2001. Can we defy nature's end? Science. 293 : 2207-2208.

Quétier F., & Lavorel S., 2011. Assessing ecological equivalence in biodiversity offset schemes: key issues and solutions. Biol. Cons. *144*(12) : 2991-2999.

Quézel P., 1999. Biodiversité végétale des forêts méditerranéennes, son évolution éventuelle d'ici à trente ans. For. méditerr. 20(1): 3-8.

Radford E.A., Catullo G. & Montmollin B. (eds.), 2011. Important Plant Areas of the south and east Mediterranean region: priority sites for conservation. IUCN, Gland, Switzerland and Malaga, Spain. Gland, Switzerland and Malaga, Spain: IUCN. VIII + 108p.

Rakitin A. & Kramer D.L., 1996. Effect of a marine reserve on the distribution of coral reef fishes in Barbados. Mar. Ecol. Prog. Ser. 131: 97-113.

Rivard D.H., Poitevin J., Plasse D., Carleton M. & Currie D.J., 2000. Changing species richness and composition in Canadian national parks. Conserv. Biol. 14: 1099-1109.

Rodrigues A., Andelman S.J., Bakarr M.I., Boitani L., Brooks T.M., Cowling R.M., Fishpool L.D.C., Da Fonseca G.A.B. *et al*., 2004. Effectiveness of the global protected area network in representing species diversity. Nature. 428.

Roem W.J. & Berendse F., 2000. Soil acidity and nutrient supply ratio as possible factors determining changes in plant species diversity in grassland and heathland communities. Biol. Conserv. 92(2): 151-161.

Rogers C.S. & Beets J., 2001. Degradation of marine ecosystems and decline of fishery resources in marine protected areas in the US Virgin Islands. Environ. Conserv. 28 : 312-322.

Sala O.E., Austin A.I. & Vivanco L., 2001. Temperate grassland and shrubland ecosystems. Enc. Biodiv. 5: 627-635.

Sattout E., 2007. Assessment of flora biodiversity and forest composition and structure in Akkar-Donnieh area. Final report. Setting the Path towards the establishment of a National Natural Park in the region of Akkar - Donnieh project. Mada/RSCN/SDC, Beirut, Lebanon, 69p.

Sattout E., & Abboud M., 2007. National Capacity Self-Assessment for Global Environmental Management. Thematic Biodiversity Profile. National Self-Assessment for Global Management, GEF/UNDP/MoE, Beirut, Lebanon, 108p.

SDATL., 2004. Schéma directeur d'aménagement du territoire libanais. Rapport final, Dar El Handassah (Liban) et IAURIF (France), 239p.

Scheffer M. & Carpenter S.R., 2003. Catastrophic regime shifts in ecosystems: linking theory to observation. Trends Ecol. Evol. 18: 648-656.

Shackley M., 2005. Managing the cedars of Lebanon. In: The politics of world heritage: negotiating tourism and conservation (current themes in tourism) by David Harrison (Editor), Michael Hitchcock (Editor), Channel View Publications, 192p.

Sylvain Z. A. & Wall D. H., 2011. Linking soil biodiversity and vegetation: implications for a changing planet. Am. J. Bot. 98(3): 517-527.

Thompson I., Mackey B., McNulty S. & Mosseler A., 2009. Forest Resilience, Biodiversity, and Climate Change. A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43, 67p.

Thouless C.R., 1998. Large mammals inside and outside protected areas in the Kalahari. T. Roy. Soc. S. Afr. 53: 245-255.

Tohmé G. & Tohmé H., 2007. Illustrated flora of Lebanon. CNRS publication, 608p.

Tohmé G. & Tohmé H., 2009. Espèces nouvelles du Liban et redescription d'espèces endémiques. Lebanese Science Journal. 10(2).

Tohmé G. & Tohmé H., 2011. Nouvelles recherches sur la flore endémique et naturalisée du Liban. Lebanese Science Journal. 12(2).

Tohmé, G. & Tohmé H. (2014). Illustrated flora of Lebanon. CNRS publication, 610p.

Western D., Russell S. & Cuthill I., 2009. The status of wildlife in protected areas compared to non-protected areas of Kenya. Plos One. 4:e6140.

Xiaoxu J., Mingan S., & Xiaorong W., 2011. Richness and composition of herbaceous species in restored shrubland and grassland ecosystems in the northern Loess Plateau of China. Biodivers. Conserv. 20(14): 3435-3452.

CHAPITRE 4

La conservation de la biodiversité Méditerranéenne continentale : au carrefour entre descripteurs écologiques et socioéconomiques

Les types et les modes de classification des aires protégées diffèrent d'un pays à l'autre et ne sont nécessairement pas comparables. Cette différence émane de la diversité des régimes législatifs, des besoins de conservation spécifiques à chaque pays et des contextes socio-économiques relatifs à chacun. Plus de 1,000 termes différents sont connus pour être utilisés dans le monde entier pour la désignation de zones protégées.

Depuis le début des années 1900, la recherche de descripteurs visant la priorisation des enjeux de conservation a fait l'objet de recherches scientifiques interdisciplinaires portées par des écologistes, des gestionnaires, des aménageurs, des économistes et des sociologues. Reconnaissant l'importance d'un écosystème naturel tant au niveau écologique qu'au niveau socioéconomique, plus d'une centaine de descripteurs écologiques et socioéconomiques ont été ainsi définis par les spécialistes pour orienter les modalités de désignation des aires protégées et les choix de protection d'un site donné. La rareté (des espèces et des habitats), l'endémisme (des espèces et des habitats), la connectivité spatiale, la surface du site, la représentativité de l'habitat, la typicalité de l'écosystème, l'intégrité fonctionnelle, les menaces anthropiques, la valeur économique d'usage du site, et la valeur esthétique du site, sont quelques indicateurs parmi l'ensemble des critères identifiés au fil du temps par les communautés scientifiques.

Néanmoins, tous ces descripteurs demeurent non standardisés, ils appartiennent à des catégories différentes (quantitatifs, qualitatifs, espèces, habitats, écologiques, socioéconomiques), ils répondent à des besoins différents (protection, gestion, aménagement), et se trouvent dans la plupart des cas dupliqués et parfois non appliqués, bien que l'objectif soit commun : la conservation de la biodiversité.

Dans un souci de systématisation des initiatives de conservation, et en réponse au besoin critique de définition d'une méthode scientifique fiable et pertinente permettant une orientation réfléchie et adaptée de la désignation des aires protégées au Liban (en particulier) et autour du bassin méditerranéen (en général), une combinaison de descripteurs écologiques et socioéconomiques est identifiée, inspirée du corpus de critères et d'indicateurs utilisés au niveau mondial pour la priorisation des enjeux de conservation et permettant de proposer une priorisation des enjeux de conservation des écosystèmes méditerranéens continentaux.

Ces descripteurs sont complémentaires, non redondants, facilement renseignables, et adaptés au contexte méditerranéen. Un minimum de descripteurs sont définis, renseignant un maximum de données écologiques et socioéconomiques au niveau d'un site donné en vue de son éventuelle protection. Chaque descripteur est décliné en modalités (ou sous-descripteurs), chaque modalité en variantes, et chaque variante en valeurs, le tout sur base bibliographique.

Ces descripteurs comptent :
Au niveau écologique :

- La rareté ou l'irremplaçabilité (des espèces / des habitats)
- L'extension de l'habitat (au sein du territoire, et la superficie relative de l'habitat dans l'aire à protéger par rapport à la superficie totale de l'habitat dans le territoire)
- La connectivité spatiale (naturalité de l'environnement et perméabilité maximale)
- L'intégrité fonctionnelle (dynamique locale des espèces et écosystèmes cibles et structure des écosystèmes cibles)
- La dynamique régionale ou tendance évolutive (des espèces et écosystèmes cibles)

Au niveau socioéconomique :

- Les menaces exogènes anthropiques (anciennes, actuelles ou probables / planifiées)
- La valeur économique d'usage ou de non-usage du site (espace d'usage direct, ou espace à valeur emblématique et/ou spirituelle)
- Les contraintes foncières et financières (maîtrise foncière et moyens financiers de mise en œuvre de l'initiative de protection)
- La règlementation et le niveau d'engagement légal du pays (présence de règlementation relative à la conservation et/ou aux aires protégées, présence d'autres règlementations spécifiques au site en question, et degré d'application / respect de la règlementation)

Ces descripteurs permettent d'identifier les principaux enjeux écologiques d'un site et de relever les contraintes socioéconomiques principales incontournables dans une tentative de conservation. Cette combinaison de descripteurs socioécologiques permet de systématiser et de structurer les priorités de conservation d'un site donné en utilisant les meilleures connaissances disponibles.

Article 2

What indicators for ecosystems conservation?

Orienting conservation priorities and protected areas designation in Mediterranean continental environments

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Abstract

Protected areas constitute a key foundation for national and international strategies of effective biodiversity and ecosystems conservation. Yet, they are not islands; they are components of their surrounding social and ecological contexts. Reconciling biodiversity conservation, people, protected areas and sustainable livelihoods requires a focused strategic planning for conservation and development. The designation of new reserves must be thus based on sound indicators within ecological, socioeconomic, institutional, and financial contexts. Many of ecological and socioeconomic indicators have been designed for this purpose by practitioners

and conservation planners around the world. Although these indicators are crucial to orient conservation priorities and protected areas designation patterns, their identification remains a big challenge, largely due to the fact that an indicator is a simplification of a system (whether natural or social) which is characterized by high structural complexity, considerable spatial heterogeneity and temporal fluctuations.
This paper presents a review of ecological and socioeconomic indicators globally used to orient conservation planning on the global and national levels. It also suggests a set of suitable, relevant, and practical set of indicators, adapted to Mediterranean-type continental environments that can serve to pertinently orient conservation priorities and protected areas designation.

Keywords: Socio-ecological systems; Descriptors; Decision-support tool; Biodiversity; Mediterranean; Protected areas.

1. Introduction

IUCN's World Database on Protected Areas (WDPA, 2014) records over 100,000 protected areas worldwide, covering over 12% of the Earth's land surface. Protected areas are recognized as the most important core units for *in situ* conservation (Gaines *et al.* 2010; Game *et al.*, 2009; Gray, 2010; Lester *et al.,* 2009; Lubchenco *et al.,* 2003, 2007; Pimm *et al.,* 2001). Conservationists and protected area managers around the world spend millions of dollars each year to conserve biodiversity and create new protected zones (Castro & Locker, 2000). However, measuring the number and extent of protected areas only provides a unidimensional indicator of political and national commitments to biodiversity conservation (Chape *et al.,* 2005).

Protected areas play a vital role in biodiversity conservation. Yet they are not islands, they are components of their surrounding social and ecological contexts (Brandon *et al.*, 1998). The most significant challenge facing both conservation and development is the need to support rural livelihoods by adequately assessing and capturing the value of environmental services (Kremen *et al.*, 2000). Reconciling biodiversity conservation, people, protected areas and sustainable livelihoods requires thus a focused strategic planning for conservation and development, which maintains biodiversity and ecosystem services without imposing serious restrictions on livelihoods (Brandon *et al.*, 2005, Ferraro & Pressey, 2015). Still, the creation of new protected areas remains essential to maintain biodiversity and avoid major species losses (Brandon *et al.*, 2005, Geldmann *et al.*, 2013). The designation of new reserves that halt habitat degradation and species extinction must be based on sound information from the ecological, socioeconomic, institutional, and financial contexts (Cowling & Pressey, 2003). Building on such information, it is possible to design protected areas that are integrated into the landscape and that support, rather than detract from, local livelihoods. Understanding such complex systems requires simplification, and essential to this understanding is the construction of a simple picture with a limited set of relevant factors: indicators (Turnhout *et al.*, 2007).

What indicators to orient conservation priorities and prioritize protected areas designation patterns in complex socioecological contexts? Conservation efforts usually emphasize on the preservation of individual species, landscapes, indicator species, and endemic or rare species, rather than socio-ecological processes (Margules & Pressey, 2000). This is partially due to a lack of informative indicators on ecosystem function and socioecological dynamics (Bowker *et al.*, 2008; El-Hajj *et al.*, *Accepted*). Unfortunately, many reserve systems throughout the world are highly biased toward particular subsets of natural features, usually small habitats with less economic value and fewer species, while larger and biologically richer areas are inadequately protected (Pressey, 1994). Therefore, although individual reserves may be valuable, existing reserve networks often fail to represent adequately the biodiversity within a particular region (Brandon *et al.*, 2005; El-Hajj *et al.*, *Accepted*; Gaston *et al.*, 2008; Le Saout *et al.*, 2013; Rodrigues *et al.*, 2004). The ideal design of a protected area has to be based on numerous factors, including habitat assets, species diversity, conservation status, suitability of the area, and the socioeconomic context in and around the proposed reserve (Brandon, 2002; Cowling & Pressey, 2003; Pressey, 1998).

Arising from this complex understanding of protected areas and their socioecological importance, this paper presents a review of key ecological and socioeconomic indicators used by practitioners and conservation planners around the world to establish new protected areas. Consequently, it suggests a justified set of suitable, practical and adapted descriptors, to pertinently orient protected areas designation in Mediterranean-type continental environments.

2. Methodology

A systematic synthesis based on peer reviewed and grey literature is applied to investigate ecological and socioeconomic indicators and the criteria used for setting conservation priorities and designing protected areas worldwide. This comprehensive review brings forward the diversity of criteria tailored to orient conservation initiatives and highlights major conservation schemes and processes. Based on this bibliographic review, a specific set of descriptors is identified to orient protected areas designation in Mediterranean environments. This minimum number of pertinent descriptors is defined as those able to describe maximum ecological and socioeconomic features of a specific site in view of its potential designation as a protected area. These indicators cover key ecological and socioeconomic variables that reflect the major processes and aspects that orient protection patterns. They do not overlap with each other (no redundancy) but are instead complementary, and are specifically adapted to Mediterranean environments. They are also integrative, easy to measure, practical, customized for continental environments (at least), and above all, address both the ecological and socioeconomic aspects of conservation. Justification of the choice and its adaptation to Mediterranean environments is provided for each identified descriptor.

3. Ecological indicators: simplifying complexity

In connection with the upsurging focus on conservation, ecologists must develop sound methods for monitoring, assessing, and managing ecological integrity through the use of indicators. Ecological indicators represent key information and provide a simple and efficient method to examine the ecological structure, function, and composition of an ecological system while capturing the complexities of the ecosystem (Karr, 1981). Yet, these indicators should remain simple enough to be easily and routinely monitored and modeled (Dale & Beyeler, 2001). However, this is not an easy task. This has to do with the fact that an ecological indicator is a simplification of nature, which is perceived to be a system characterized by high structural complexity, considerable spatial heterogeneity, and temporal fluctuations. Ecological indicators attempt to measure the ecological quality of ecosystems and can be used as instruments to evaluate the effects of policies on nature (Turnhout *et al.*, 2007). Many different levels exist for ecological indicators, making it a complex and potentially confusing concept.

The concept of biological or ecological indication has long historical roots. Kolkwitz and Marsson (1902) were among the first to describe aquatic systems in terms of indicator species. For terrestrial systems, Ellenberg (1974) made an important contribution by systematically linking abiotic soil factors with existing vegetation. Margules and Usher (1981) examined nine published schemes concerned with the assessment of conservation potential and ecological value. In each case, they listed the criteria used to judge the suitability of a habitat for conservation. These include diversity (including species richness and habitat diversity), rarity, naturalness, numbers of biological interactions (e.g. predatory, competition), area, threat of human interference, typicality, representativeness, educational value, amenity value, recorded history, scientific value, uniqueness, wildlife reservoir potential, ecological fragility, position in ecological/geographical unit (spatial position), potential value, availability, replaceability, ease of acquisition, and management considerations.

Up till now, the use of ecological indicators to assess biodiversity status and prioritize conservation needs has been growing worldwide and new conservation systems and protected areas based on a set of specific indicators are emerging despite the presence of a wide set of criteria used for ranking the relative ecological and conservation values of potential reserves.

The design of conservation reserves has been widely debated for decades. At the global scale, several schemes have been employed to identify areas that may be particularly important for the long-term maintenance of biodiversity. As decision criteria, these schemes have variously used data on patterns of species richness, endemism, phylogenetic age of species, vulnerability, irreplaceability, as well as other habitat features. They have led to the recognition of, for example, biodiversity hotspots (Mittermeier *et al.*, 1998; Myers *et al.*, 2000); centers of plant diversity (Davis *et al.*, 1994, 1995); endemic bird areas (Bibby *et al.*, 1992; Balmford & Long, 1994; Stattersfield *et al.*, 1998); key biodiversity areas (Eken *et al.*, 2004); alliance for zero extinction sites (Ricketts *et al.*, 2005); ecoregions (Olson & Dinerstein, 1998) and many other priority areas for conservation. To varying degrees, such schemes have influenced both thoughts and actions.

In prioritizing areas for conservation at the national (administrative) scale, conservationists around the world have used various criteria for evaluating natural areas for the intent of land-use planning and protected areas designation. These include, among other, rarity (on the specific and habitat levels), site uniqueness, species richness (diversity), size, site naturalness, fragility, representativeness, spatial connectivity, typicality, vegetation structure, fragility, number of plant alliances, number of plant structural formations, vulnerability, irreplaceability and endemism (Derous *et al.*, 2007; Gauthier *et al.*, 2010; Gehlbach, 1975; Goldsmith, 1975; Gubbay, 1995; Kier *et al.*, 2009; Laguna *et al.*, 2004; Noss *et al.*, 2002; Pressey *et al.*, 1994; Pressey & Taffs, 2001; Rabinowitz, 1981; Smith & Theberge, 1986; Tans, 1974; Tubbs & Blackwood, 1971; Van der Ploeg & Vlijm, 1978; Wright, 1977). The use of these descriptors led to the recognition of numerous types of protected areas worldwide - varying from one country to another according to each nation's legislations and conservation needs - such as micro-reserves, nature reserves, protected forests, sanctuaries, protected seascapes, and so on (Chape *et al.*, 2003).

While the focus on rare, threatened and endemic species has commonly been retained (Abbitt *et al.*, 2000; Bode *et al.*, 2008; Bonn *et al.*, 2002; Daniels *et al.*, 1991; Dobson *et al.*, 1997; Drinkrow & Cherry, 1995; Troumbis & Panayotis, 1998), studies revealed that reserve networks focusing solely on threatened and endemic species may not be sufficient to preserve the overall species diversity present in a country (Bonn *et al.*, 2002).
In terms of size, several debates argued whether a Single Large Or Several Small (cf. the SLOSS debate, 1970-1980) reserves were a superior means of conserving biodiversity. While numerous studies confirmed that larger protected areas are more desirable for long-term species conservation and maintain of ecological and evolutionary processes (Bierregaard *et al.*, 2001; Cowling *et al.*, 1999), other researches argued that small reserves are adequate for some species and are almost always better than no reserve or management over an area at all (Turner & Corlett, 1996).

Karr (1991), Angermeier and Karr (1994) and Noss (1995) used ecological integrity as a key criteria for ecosystems assessment. Ecological integrity refers to system wholeness, including the presence of appropriate species, populations, and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa. Measuring ecological integrity can rely on a set of indicators including number of populations, species richness, spatial distribution of communities, stands age, etc., and is currently increasingly being used to guide monitoring efforts across protected areas (Wurtzebach & Schultz, 2016).

In Europe, the Natura 2000 network is a network of protected sites scattered along the European Union, made up of Special Areas of Conservation and Special Protection Areas designated respectively under the Habitats Directive and the Birds Directive, and including both terrestrial and marine sites (Ostermann, 1998). It uses species and habitat features such as representativeness, conservation status, functionalities (resting, breeding, feeding, wintering or summering area), habitat size, population density of target species, spatial connectivity and species vulnerability as main descriptors to orient the designation of the protected sites (Lepareur, 2011; Viry, 2013).

The international union for conservation of nature (IUCN) also invested significant efforts in defining protected areas categories and ecological selection criteria such as naturality, representativeness, size and conservation status (Dudley, 2008).

Other ecological indicators tailored to orient conservation priorities and protected areas designation also include site heterogeneity (Lindenmayer *et al.*, 2000), site unicity and natural character (Gubbay, 1995).

Even though the use of ecological indicators and criteria is gaining further interest in conservation planning, all these descriptors remain unstandardized, as they belong to different categories (quantitative / qualitative, species / habitat) and are frequently found duplicated and sometimes not applicable, although the goal remains still: ecological conservation.

4. Socioeconomic indicators: a key dimension to conservation

Throughout the world, established protected areas are under severe natural and human threats such as land use change, urbanization, excavation, harvesting, hunting, pollution and climate change, which are leading to their progressive fragmentation and isolation (Brandon *et al.* 1998; Bruner *et al.*, 2001; Carey *et al.*, 2000; Oates 1999; Sala *et al.*, 2000). With continued economic growth, it is likely that the pressure on biodiversity will further increase.

Socioeconomic data enable the evaluation of the human context of protected areas - that is, the number of people present, their geographic distribution, and socioeconomic and sociocultural characteristics - in order to provide key insights into the effectiveness of potential new reserves (Brandon *et al.,* 2005). Biodiversity can be well managed or heavily impacted by the actions of relatively few people (Gorenflo, 2002). Reserve categories such as man and biosphere reserves or other sites with human residents, can only be successful if there is participation and management of zoning and use designations. Therefore, successful conservation planning requires socioeconomic data (Polasky, 2008).

Socioeconomic indicators mainly communicate aspects related to external threats on protected areas, economic value of the protected site, educational suitability, management appraisal, potential amenity use, accessibility, as well as financial and legislative contexts for conservation (Gehlbach, 1975; Haughton & Siar, 2006; Roberts *et al.*, 2003; Smith & Theberge, 1986; Wright, 1977). Bode *et al.* (2008) use data on the cost of establishing new biological reserves as indicators to address conservation allocation patterns. Furthermore, socioeconomic indicators provide sound information on the socioeconomic dependence of the surrounding communities on the potential protected area (hunting, recreation, tourism, harvesting, etc.), and the cultural value of the latter (educational, historical or archeological importance) (Jacot, 2009).

Unfortunately, these indicators are not sufficiently taken into consideration during conservation planning. For instance, the designation of Natura 2000 sites in Europe is only founded on ecological indicators. Socioeconomic aspects are only considered in the management phases of these sites (Smith & Theberge, 1986).

However, the concepts of ecosystems services and the economic value of biodiversity are gaining more interest among conservation planners who are further mainstreaming the economic values of ecosystems and biodiversity into conservation initiatives (Naidoo *et al.*, 2008). This upsurging interest draws attention to global economic benefits of biodiversity and highlights the growing cost of biodiversity loss and ecosystem degradation (Sukhdev *et al.*, 2010). Ecosystems services constitute the key foundation of this relatively new concept, where humankind benefits in a multitude of ways from supporting, provisioning, regulating and cultural services provided by ecosystems by virtue of their very existence, a value estimated at US$33 trillion per year (Costanza *et al.*, 1998). In this context, assessing the economic value of biodiversity provides pertinent socioeconomic indicators related to the direct use value, indirect use value, option value and existence value of a given ecosystem (MA, 2005).

5. Integrating ecological priorities with socioeconomic goals

Throughout the last decades, conflicts between the socioeconomic and the ecological spheres in densely populated areas such as the Mediterranean region has brought more burdens to protected areas. Changes in the traditional relationship between men and their environments created new challenges to protected areas, where emerging technologies, globalization, industrial growth, changes in land use, urbanization, excessive exploitation of natural resources, and population growth, all have had a severe impact on terrestrial ecosystems (Huwart & Verdier, 2013; Lampic *et al.*, 2012). This co-evolution (and not just competition) of men and ecosystems underlines a strong need for understanding and aligning ecological and socioeconomic priorities for an integrated conservation of natural resources (Sodhi & Ehrlich, 2010).

Striking a proper balance in conservation planning requires good communication between economists and ecologists (Eppink & van den Bergh, 2007). The need to communicate the scientific concepts of ecological indicators to non-scientists is increasingly being tackled by teams of environmental scientists working with social scientists (Schiller *et al.,* 2001; Redman *et al.*, 2004). Yet, integrating ecological indicators with social and economic goals for resource management remains a big challenge (Dale & Beyeler, 2001).

Due to the complexity of ecosystems and the normative aspects involved in assessing ecosystem quality, indicators used to orient conservation priorities cannot be solely science-based but rather situated in a fuzzy area between science and policy (Turnhout *et al.*, 2007).

Recognizing the fact that man and nature are two inseparable elements which mutually depend on each other for a sustainable persistence, integrating both ecological and socioeconomic aspects in prioritizing conservation patterns is a key first step to achieving such optimal conservation. The concept of socio-ecological systems (S.E.S) is currently gaining further interest among conservationists as it acknowledges the complexity of interactions between man and nature, where both traditional ecological aspects along with the human dimension in nature protection are both taken into consideration during conservation planning (Cioffi-Revilla, 2016; Folke, 2007; Lagadeuc & Chenorkian, 2009; Liu *et al.*, 2007; Redman *et al.,* 2004).

Integration of the social sciences into long-term ecological research is an urgent priority, and what is often divided into “natural” and “human” systems has to be considered a single complex social-ecological system when approaching conservation targets (Redman *et al.,* 2004).

6. Suggesting a set of ecological and socioeconomic indicators for protected areas designation in Mediterranean continental environments

The Mediterranean basin, one of the most biologically diverse regions in the world (Médail & Quézel, 1999; Mittermeier *et al.*, 1998; Myers *et al.*, 2000), owes its high diversity and spectacular scenery to its location at the intersection of two major landmasses, Eurasia and Africa. This basin has experienced intensive human development and impact on its ecosystems for thousands of years, significantly longer than any other biological or cultural hotspot. Important human settlements have existed in the area for at least 10,000 years, shaping its landscapes and drowning its resources. From habitat fragmentation to the mass development of road networks and tourism hubs on coastal areas, today, a mere 5% of the original extent of the hotspot contains relatively intact vegetation, placing the Mediterranean basin among the 4 most significantly altered biodiversity hotspots on Earth (Cuttelod *et al.*, 2008; Underwood *et al.*, 2009). This basin constitutes thus a particularly interesting case study due to the long history of human impact and the complex social-ecological embedded dynamics.

Orienting conservation priorities and protection patterns in the Mediterranean region remains thus a challenging job in this complex socio-ecological context where the extent to which existing protected areas are effectively representing, maintaining and conserving key ecological features is still poorly understood, and where protected areas designation seems to follow political priorities and opportunities (such as in Lebanon) rather than being founded on pertinent ecological and socioeconomic criteria that would highlight the relevance and priority for conservation measures (El-Hajj *et al.*, *Accepted*). Hence, to achieve optimal ecological conservation, there is a need to:

i) Identify pertinent criteria and descriptors that would objectively orient conservation priorities based on relevant ecological and socioeconomic indicators encompassing all aspects related to biodiversity (flora and fauna), physical environments (soil, topography, geology, etc.) and livelihoods (El-Hajj *et al.*, *Accepted*).
ii) Achieve efficient environmental governance, including effective local initiatives (Agrawal & Lemos, 2007) and targeting an improved application of policies and indicators related to conservation planning (Smith *et al.*, 2003)

At this stage, we chose to select a minimum number of pertinent descriptors able to describe maximum ecological and socioeconomic features of a specific site in view of its potential designation as a protected area. These indicators cover key ecological and socioeconomic variables that reflect major processes and aspects orienting protection patterns in one direction or another. They do not overlap with each other (no redundancy) but are complementary, and they are adapted to Mediterranean environments by considering some specific socioeconomic aspects particular to the Mediterranean countries (such as Lebanon), aspects that might affect and challenge conservation initiatives on the national level. Suggested descriptors are inspired from the corpus of indicators globally used to orient conservation priorities and protected areas designation. They are integrative, easy to measure, practical, adapted to Mediterranean-type continental environments (at least), and above all, tackle both ecological and socioeconomic aspects of conservation (Tables 1, 2 and 3). These descriptors can be indeed used to orient conservation planning (protected areas designation) in different regions than Mediterranean-type continental ecosystems (Mediterranean marine ecosystems, polar ecosystems, tropical ecosystems, etc.). However, their originality lies in the fact that they reflect distinguished socio-ecological aspects known to be very particular to the Mediterranean (such as property constraints and species rarity). In other types of ecosystems, such as mangrove ecosystems, other types of descriptors can be of additional value (such as water characteristics, PH, etc.).

Each indicator may contain one or more separate measures, each of which can be assessed separately to identify whether it is changing, and if so, whether this change will affect or not the conservation priority.

Table 1. List of suggested descriptors

Descriptors collected from literature	**Suggested descriptors** (inspired and adapted from the corpus of descriptors collected from literature)	**Justification** (of choice and of adaptation to Mediterranean environments)
ECOLOGICAL DESCRIPTORS		
- Diversity (species and habitats) - Rarity (species and habitats) - Replaceability/ irreplaceability - Endemism	**Rarity or irreplaceability (species and/or habitat level)**	The criterion related to **diversity** or **specific richness** has not been taken into account among the ecological descriptors selected above as its use is hampered by both the absence of objective thresholds and the difficulty of its assessment on-field. However, it is indirectly used in this selected descriptor. In fact, the only method that suggests the use of this criterion is that of Important Plant Areas criterion "B" (Anderson, 2002; Foster *et al.*, 2012), but its application in concrete cases is difficult and rarely possible (*cf.* Vela & Pavon, 2012). Practically, only criterion "A" (presence of globally, regionally and/or nationally threatened species) and to a lesser extent criterion "C" (presence of threatened habitats / vegetation) are usually used (Yahi *et al.*, 2012). **Endemism** degree *per se* provides information on the biogeography of a site, but neither recommends nor discourages its protection or management unless it is rare. Thereby, if a given species is a common endemic at a regional level (e.g. *Teucrium marum* in Corsica-Sardinia), its protection on the national level would not be of great relevance compared to a rare endemic species on the same territory (e.g. *Seseli praecox)*. Therefore, endemism is not considered as such as a descriptor, but is rather included as one of the "rarity or irreplaceability" indicator's modalities, particularly considering the cases of more or less severe restriction of the distribution range (Smith & Theberge, 1986). Compared with other regions of the world (Europe, Australia, California, etc.), the Mediterranean basin hosts more than twice as any in terms of rare species (Cody, 1986; Cowling *et al.*, 1996; Dallman, 1998). Therefore, **rarity** is retained as a descriptor. However, in order not to miss species which presence might go beyond a rarity threshold

		- which itself is subjective and arbitrary - while only very partial data is available, it is preferred to measure the **irreplaceability** value (1divided bythe number of stations in the study area) of each species onsite, regardless of the number of individuals per species. Thus, the cumulative value or sum (for all species present onsite) will serve as a definition of the indicator value (Vanderpert 2007).
- Size (area) - Typicality - Representativeness - Uniqueness	**Habitat extension (representativeness)**	**Habitat extension** reflects the "significance" of habitat "**representation**" within a protected area or at the national level, and thereby, the landscape's structure and the importance of the ecosystem's functions. Habitat mapping is crucial to get reliable estimates of the total area occupied by each habitat (i.e. surface of every habitat occurring in the area under consideration), so as to reach the required conservation targets (Costello, 2009). Areas selected to be representative necessarily include typical or common species, habitats, geophysical characteristic, and so on. Therefore, the concept of representativeness, subsumes **typicality** (Margules & Usher, 1981). The idea of representation is better thought of as an approach to conservation rather than simply a criterion. **Representativeness** and **uniqueness** can be the extremes of a spectrum. A unique area is one that is rare, whereas areas which are representative are typical of a biome or habitat types, typical being defined as "containing all (or most) of the commoner and more widespread species" (Usher, 1980). Habitat extension provides a key dimension for the conservation of typical Mediterranean-type continental ecosystems, adapted to distinctive Mediterranean climatic regimes, and characterized by restricted ranges of specific conifers and broadleaved species (Di Castri & Harold, 2012).
- Naturalness - Position in ecological/geographical unit (spatial position) - Spatial connectivity	**Spatial connectivity**	The knowledge of the extent and **spatial scale** of **connectivity** between natural habitats/ecosystems is of vital importance for the effective design and implementation of protected areas. The connectivity depends on the spatial structure of the landscape and on the permeability of the different components that make it up. It also infers the **naturalness** of the environment (percentage of natural or semi-natural areas in contact with the

		perimeter of the area to be protected) (Mugica *et al.*, 2002). Spatial connectivity plays a vital role in in the design of a coherent conservation network, especially in Mediterranean environments subject to progressive fragmentation challenges (Dudley, 2012).
- Number of biological interactions - Wildlife reservoir potential - Vegetation structure - Number of plant alliances - Number of plant structural formations - Ecological integrity - Conservation status - Ecological functionalities - Population density of target species - Site heterogeneity	**Functional integrity** **Regional dynamic or evolutionary trend**	**Ecological integrity** or **functional integrity** is a complex concept which pulls together many underlying notions. It is a key indicator of ecosystem's health, biodiversity, stability, **conservation status**, sustainability, structure and wildness, but is however particularly challenging to measure as ecosystems are not static entities (Noss 1995). The concept of functional integrity has been discussed by many authors from many perspectives (Cairns 1977; Edwards and Regier 1990; Gauthier 1992; Karr and Dudley 1981; Munn 1993; Pimentel et al. 2000; Woodley et al. 1993; Wurtzebach and Schultz, 2016) and refers to a system's wholeness, where ecosystem's **structure** and **functions** are appropriately operating and where the ecosystem's core (structuring) species are present at viable **population levels.** In conservation strategies, ecological integrity is a key criterion for maintaining sustainable reserve networks in Mediterranean environments (Noss, 1995). On another level, the knowledge of species/ecosystems **regional dynamics** is a key element for orienting conservation strategies (Flournoy, 2003). This type of information set up the foundation for conservation biology (Soulé, 2005) and is of utmost importance in Mediterranean ecosystems, characterized by high spatial and temporal heterogeneities, where environmental stress and human disturbances have a major impact on biological systems dynamics (Médail & Diadema, 2006).
SOCIOECONOMIC DESCRIPTORS		
- Threat of human interference - Recorded history - Ecological fragility - Vulnerability	**External human threats**	From habitat fragmentation to species overexploitation and climate change, global conservation assessments recognized the Mediterranean basin as one of the more fragile and threatened biomes on earth, and a priority for the conservation of the world's biodiversity (Underwood *et al.*, 2009). Designing efficient protected areas networks in

		Mediterranean environments requires a thorough understanding of these threats on and is critical in prioritizing conservation strategies (Kiringe & Okello, 2007). The nature and degree of a threat is likely to change over time. For this reason, consideration of past, present, and foreseeable future influence of human activities on a candidate site for conservation is important (Roberts *et al.*, 2003). To be effectively employed as a criterion for prioritizing conservation initiatives and establishing new protected areas, mitigatable and non-mitigatable human threats should be identified and quantified where possible (Roberts *et al.*, 2003). In many cases, a site may be exposed to more than one threat.
- Economic value - Educational value - Amenity value - Scientific value	**Site economic value (use or non-use value)**	A site's total economic value is classically split only in two sub-criterion: its use and non-use value (Freeman, 1993; Pearce & Warford, 1993). Use value is not split here into direct and indirect values (respectively obtained through removable and non-removable products in nature), as the main objective is to spot whether the site provides or not an economic or economic-like benefit (ecosystem services: provisioning services, regulating services, cultural services, supporting services). The non-use value also includes the existence value and the option value (that could later become a use value). The economic value of a given site have a major impact on conservation priorities. The greater the economic value of a site is, the lesser the priority for strict conservation should be. Mediterranean continental ecosystems are recognized for their high economic value. From carbon sequestration, to watershed protection, recreation and hunting, grazing, timber and fuelwood extraction, etc. the total economic value of a Mediterranean terrestrial ecosystem is estimated up to 350 USD per hectare (Pagiola *et al.*, 2004).
- Availability - Ease of acquisition - Cost of establishment of a new reserve - Accessibility - Management considerations	**Financial and land-use / property constraints**	In prioritizing new areas for conservation, the **availability of financial means** for establishing the conservation initiative (**cost of establishment** of a new reserve) as well as the **ease of acquisition** of the land (land use **property status**), are crucial elements to account in order to assess the feasibility of the conservation project (Worboys *et al.*, 2015). The absence of financial means and/or the complexity of land control can affect protected areas establishment. This is the case of few Mediterranean countries such as Lebanon,

		where the private property is protected by the Lebanese constitution (article 15), which consequently imposes restrictions on the establishment of protected areas on private lands and therefore hampers any official conservation initiative without the consent of the landowner. In France in contrast, the governmental control on private land ownership for the establishment of protected zones remains easier.
- Legislative context for conservation	**Legislation / level of national legal engagement**	No conservation initiative can be established on any natural site unless the local, national or regional **legislative framework** is favorable (Worboys *et al.*, 2015). Legal instruments are crucial tools for the creation of effective protected areas networks, which makes this criterion of utmost importance in prioritizing conservation actions, as greater conservation laws are enforced, more are protection initiatives efficient. In Lebanon, despite all the efforts invested by ministries, municipalities and local communities to establish new categories of protected areas such as natural parks, the legal framework for protected areas designation and management is still missing. Besides, environmental infractions on existing protected zones are rarely and partially penalized by existing laws. This calls for a serious law enforcement. In France, on the contrary, the legal framework for protected areas is comprehensive and satisfactory, laws are respected and infringements are somehow totally penalized.

Table 2. Detailed description of suggested ecological indicators/descriptors

Indicator / descriptor	Definition	Suggested variables to be measured
1. Rarity or irreplaceability (species and/or habitat level)	A rare or irreplaceable area is an area containing: - Rare or unique species or populations; and/or - Habitats (in the broad sense): complete ecosystem (biotope + biocenosis), biocenosis (communities, phyto-sociological associations, etc.), or biotopes	- **Ratio of rare species** if species inventories are comprehensive (number of rare species divided by the total number of species).

	(geomorphological or geological and bioclimatic features) that are unique, rare or unusual. Five different types of species' rarity are discerned in the literature: "widespread rare species" that occur over a wide geographical area but are scarce wherever they do occur and may have a patchy or continuous distribution; "endemic species with restricted geographical ranges"; "disjoint populations that are geographically separated from the main range of the species"; "peripheral populations that are at the edge of their species' geographical range"; and "declining species that were once more abundant and/or widespread but are now depleted." (Smith and Theberge 1986), which makes rarity assessment processes often complex. A rare area is an area where species, populations and geomorphological features are irreplaceable. The irreplaceability of some ecosystems implies the absence of ecological equivalents elsewhere on the structural and functional levels (nature of stands, geomorphological features, and functional integrity). Their loss would mean the probable permanent loss of a certain feature, or the loss of diversity at a given level. The irreplaceability (or uniqueness) of a site is the degree to which spatial options for conservation are lost if the site and its biodiversity are lost (Pressey *et al.*, 1994). Irreplaceability is based on a site's biological composition in relation to the biological composition of other sites. A site has extreme irreplaceability if one or more of its species or habitats are totally confined to it and thus the site is the only option for protecting this species/habitat. The more options that exist for conserving a species, the lower the irreplaceability of the sites at which it occurs. All else being equal, a site with high irreplaceability is a higher priority for conservation action than one with lower irreplaceability (Langhammer, 2007).	- **Presence/number of rare species** if species inventories are not comprehensive (only partial). - **Habitat rarity or unicity** (ecosystem, biotope or biocenosis) if habitat or bioclimatic or geologic inventories or maps are available in the study area (regardless the availability or not of species inventories). - **Presence/number of endemic species (restricted range and/or site restricted species)** with species inventories comprehensive or not.
2. Habitat representativeness / extension	Representativeness refers to the degree to which an area represents a habitat type, an ecological process, a biological community, a geographic or physical characteristic, or any other natural features on a given territory; an area that is an	- **Habitat extension on the territory scale** (administrative level): Relative surface of the habitat in the administrative area (e.g.

	illustrative and exceptional example of specific biodiversity, ecosystems, ecological or physiographic processes, habitat types, communities or other natural characteristics.	national/county level) compared to the total surface of the administrative area (e.g. county). - **Habitat extension within the site of interest** (relative area of the habitat in the potential protected area compared to the total area of the habitat at the administrative level.
3. Spatial connectivity	Ecological connectivity refers to the functional connectivity that links all the elements of an eco-landscape (natural or semi-natural habitats, buffer zones, biological corridors) between them (excluding buildings and human infrastructure) from a species or a population (or a combination of these entities) point of view, for all or part of their development stages, at a given time or for a given period. By extension, connectivity decreases when fragmentation increases.	- **Naturalness of the environmen**t (percentage of natural or semi-natural areas in contact with the perimeter of the area to be protected) - **Maximal permeability** (of the neighboring ecosystem having the highest permeability with the main ecosystem of the area to be protected)
4. Functional integrity	Functional integrity (or ecological integrity) is the degree to which an area is a functional unit; a self-sustaining ecological entity (Wurtzebach and Schultz, 2016). More an area is ecologically autonomous; greater it is effective in protection strategies.	- **Local dynamic / autonomy of the target ecosystem(s)** (regressive, progressive or stable dynamic) within the area to be protected - **Local dynamic / autonomy of the target specie(s)** (source, recipient or balanced population) within the area to be protected - **Structure of the target ecosystem(s)** (complete, nearly complete, incomplete vertical structure)

5. Regional dynamic or evolutionary trend	The regional dynamic refers to the evolutionary trend of an ecosystem or a species on the territory level (e.g. national / country level). It reflects the general tendency of an ecosystem / specie to progress, slowly regress, strongly regress, or remain stable on the territory level. An ecosystem / specie (of major ecological interest / value) can have a local progressive dynamic on a given site (*cf. indicator number 4*), versus a global regressive tendency on the studied national / territory scale.	- **Of target ecosystem(s)** (stable dynamic, progression or regression of the ecosystem) - **Of target specie(s)** when species inventories are available along with the levels of their regression / progression on the territory scale

Table 3. Detailed description of suggested socioeconomic indicators/descriptors

Indicator / descriptor	Definition	Suggested measures
1. External human threats	External threats are threats directly or indirectly caused by man. The impact of a threat mainly depends on the intensity of the latter as well as the vulnerability / resilience of the exposed ecosystem. A threat can be partial and reversible, partial and irreversible or total and reversible, or finally total and irreversible. An area prone to natural or human stress factors may need special protection, especially if it hosts a relatively high proportion of habitats, biotopes or sensitive species that are functionally fragile (highly susceptible to degradation or depletion by human activities or natural events) or with slow recovery rates.	- **Former (past) threat having ended on the site** (the main threat in case there are many) - **Actual threat taking place on the site** (the main threat in case there are many) - **Probable, predicted or planned threat** (climate change; land-use planning: urbanization, road, construction, dam, quarry; area prone fire, erosion, floods, volcanoes…)
2. Site economic value (use or non-use value)	The economic valuation of ecosystem services is a tool for quantifying "benefits" provided by an ecosystem in monetary units most of the time. It is an important tool for the economic evaluation of biodiversity. It responds primarily to the wish and need to use the "economic language" for nature conservation and biodiversity to better	- **Area of direct use value:** supply and/or cultural interest (food, timber, grazing, water, recreation, etc. regardless of

	integrate the environment into economic dynamics. Direct use values are the values of tangible benefits of effective use (hunting, grazing, timber, etc.). These direct use values reflect the direct consumption of resources and the direct interactions with the ecosystem. Non-use values represent the satisfaction of knowing that there is an ecosystem or species (patrimonial, emblematic, spiritual value, etc.).	whether the service is commercial or non-commercial) - **Area of emblematic and/or spiritual value** (non-use value)
3. Financial and land-use / property constraints	No conservation initiative can be established unless financial means are made available for the implementation of this initiative, and land-use / property aspects are favorable to this implementation especially in Mediterranean countries. The property value of the land, the possibility of implementing a conservation project on the land, and the type of land (public, private, military), are key elements determining the potentiality of initiating a conservation action on a given site. Similarly, the availability and easiness of retrieving financial means to ensure the implementation of the protected area are crucial components for the success of the initiative.	- **Land use status or control pattern** (possible, negotiable control on the property; high/low property value; impossible control over the property…) - **Financial means for the implementation of the protection initiative** (probability of getting international, national, local, or individual funds)
4. Legislation / level of national legal engagement	The presence and application of laws and regulations related to environmental protection and biodiversity conservation are key elements to the success of conservation initiatives. Legal enforcement enhances the establishment of new protected areas and sets a specific framework for their creation and management. The presence of legislations is crucial on the national level to improve conservation planning. However, the challenge remains in the application / respect level of these regulations. The more strict and penalized they are, the more conservation is efficient, and vice versa. The assessment of this aspect is essential to orient the type of conservation towards a strict or more or less flexible pattern.	- **Presence of national regulation related to the conservation of biodiversity and/or protected areas** - **Presence of other specific regulations** (water, rivers, coastline, forests, etc.) that can be applied to protect the site - **Level of application / compliance with existing regulations** (strict and complete, partial, level of penalization…)

6. Conclusion

Based on a comprehensive global gap analysis undertaken by Conservation International in 2003, Rodrigues *et al.* (2004) concluded that the degree to which biodiversity is represented within the existing network of protected areas is unknown. Although a number of countries have designed and implemented protected area system plans, studies have confirmed that protected area establishment does not frequently correlate with identified conservation priorities (El-Hajj *et al.*, *Accepted*; Margules & Pressey 2000; Pressey *et al.*, 2002; Rodrigues *et al.*, 2003).

Protected area data, in combination with habitat, species and socioeconomic information, can provide a basis for determining gaps in the extent of biodiversity protection, and thereby inform decision-makers and stakeholders about priorities for conservation action.

However, it is important to choose indicators that are useful at the national/regional levels to provide the baseline framework in which protected areas designation can be framed. By doing so, we can provide meaningful assessments of whether or not biodiversity targets are met.

The set of suggested indicators in this paper can be further used to develop a decision support tool that can serve practitioners and decision-makers in Mediterranean environments to objectively orient protected areas designation. In this context, El-Hajj *et al.* (*In preparation*) developed a decision support tool ("MedConserve") addressed to conservation planners around the Mediterranean basin, aiming to support decision-making processes related to protected areas designation based on a pertinent and scientific approach. This tool prioritizes and reflects the impact of each and every socio-ecological aspect, to different degrees, on the design of a protected area.

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References

Abbitt, R.J.F., Scott, J.M. & Wilcove, D.S. (2000). The geography of vulnerability: incorporating species geography and human development patterns into conservation planning. *Biological Conservation*, 96, 169-175.

Agrawal, A. & Lemos, M. C. (2007). A greener revolution in the making?: environmental governance in the 21st century. *Environment: Science and Policy for Sustainable Developmen*t, 49(5), 36-45.

Anderson, S. (2002). Identifying Important Plant Areas. Plantlife International, London.

Angermeier, P.L. & Karr, J.R. (1994). Biological integrity versus biological diversity as policy directives: protecting biotic resources. *BioScience*, 44, 690-697.

Balmford, A. & Long, A. (1994). Avian endemism and forest loss. *Nature*, 372, 623-624.

Bibby, C.J., Crosby, M.J., Heath, M.F., Johnson, T.H., Long, A.J., Stattersfield, A.J. *et al.* (1992). Putting Biodiversity on the Map: Global Priorities for Conservation. ICPB, Cambridge.

Bierregaard, R.O., Jr., Laurance, W.F., Gascon, C., Benitez-Malvido, J., Fearnside, P.M., Fonseca, C.R., *et al.* (2001). Principles of forest fragmentation and conservation in the Amazon. In: R. O. Bierregaard, Jr., C. Gascon, T. E. Lovejoy, & R. C. G. Mesquita (Eds.), Lessons from Amazonia: The ecology and conservation of a fragmented forest (pp. 371–386). Yale University Press.

Bode, M. Wilson, K., Brooks, T. Turner, W., Mittermeier, R., McBride, M., Underwood, E. & Possingham, H. (2008). Cost-effective global conservation spending is robust to taxonomic group. *Proceedings of the National Academy of Sciences of the United States of America*, 105, 6498-6501.

Bonn, A., Rodrigues, A. & Gaston, K. (2002). Threatened and endemic species: are they good indicators of patterns of biodiversity on a national scale? *Ecology Letters*, 5, 733-741.

Bowker, M., Miller, M., Belnap, J., Sisk, T. & Johnson, N. (2008). Prioritizing Conservation Effort through the Use of Biological Soil Crusts as Ecosystem Function Indicators in an Arid Region. *Conservation Biology*, 22(6), 1533-1543.

Brandon, K. (2002). Getting the basics right: key actions in designing effective parks. In J. Terborgh, L. C. Davenport, & C. Van Schaik (Eds.), Making parks work: Identifying key factors to implementing parks in the tropics (pp. 443–466). Covelo, CA, Washington, DC: Island Press.

Brandon, K., Gorenflo, L., Rodrigues, A. & Waller, R. (2005). Reconciling Biodiversity Conservation, People, Protected Areas, and Agricultural Suitability in Mexico. *World Development*, 33(9), 1403-1418.

Brandon, K., Redford, K., & Sanderson, S. (Eds.) (1998). Parks in Peril: People, politics, and protected areas (pp. 415-440). Covelo, CA, Washington, DC: Island Press.

Bruner, A. G., Gullison, R. E., Rice, R. E. & Fonseca, G. A. B. (2001). Effectiveness of parks in protecting tropical biodiversity. *Science*, 291, 125-128.

Cairns, J. (1977). Quantification of biological integrity. Pages 171-187 in R.K. Ballentine and L.J. Guarraia, eds. The integrity of water. U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Washington, DC.

Carey, C., Dudley, N. & Stolton, S. (2000). Squandering paradise? Gland, Switzerland: WWF International.

Castro, G. & Locker, I. (2000). Mapping Conservation Investments: An Assessment of Biodiversity Funding in Latin America and the Caribbean. Washington (DC): Biodiversity Support Program.

Chape, S., Blyth, S., Fish, L., Fox, P. & Spalding, M. (2003). United Nations List of Protected Areas. IUCN, Gland, Switzerland and Cambridge, UK and UNEP-WCMC, Cambridge, UK. ix + 44pp.

Chape, S., Harrison, J., Spalding, M., & Lysenko, I. (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Philosophical Transactions of the Royal Society of London*, 360, 443-455.

Cioffi-Revilla, C. (2016). Socio-Ecological Systems. Handbook of Science and Technology Convergence. 669pp.

Cody, M.L. (1986). Diversity, rarity and conservation in Mediterranean-climate regions. In: Conservation Biology. The Science of Scarcity and Diversity. Souke M.E., (ed.) Sinauer, Sunderland, M.A., Cody, M.L., Mooney H.A. (1978).

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskin, R., Sutton, P. & van den Belt, M. (1998). The value of the world's ecosystem services and natural capital. *Nature*, 387, 253-260.

Costello MJ. (2009). Distinguishing marine habitat classification concepts for ecological data management. *Marine Ecology Progress Series,* 397, 253-268.

Cowling, R. M., Pressey, R. L., Lombard, A. T., Desmet, P. G., & Ellis, A. G. (1999). From representation to persistence: requirements for a sustainable system of conservation areas in the species-rich Mediterranean-climate desert of southern Africa. *Diversity and Distributions*, 5, 51-71.

Cowling, R. M. & Pressey, R. L. (2003). Introduction to systematic conservation planning in the Cape Floristic Region. *Biological Conservation*, 112, 1-13.

Cowling, R. M., Rundel, P. W., Lamont, B. B., Arroyo, M. K. & Arianoutsou, M. (1996). Plant diversity in Mediterranean-climate regions. *Trends in Ecology and Evolution*, 11(9), 362-366.

Cuttelod, A., García, N., Abdul Malak, D., Temple, H. & Katariya, V. (2008). The Mediterranean: a biodiversity hotspot under threat. In: J.-C. Vié, C. Hilton-Taylor and S.N.

Stuart (eds). The 2008 Review of The IUCN Red List of Threatened Species. IUCN Gland, Switzerland.

Daniels, R.J.R., Hedge, M., Joshi, N.V. & Gadgil, M. (1991). Assigning conservation value: a case study from India. *Conservation Biology*, 5, 464-475.

Dale, V. and Beyeler, S. (2001). Challenges in the development and use of ecological indicators. *Ecological Indicators*, 1, 3-10.

Dallman, P. (1998). Plant life in the world's Mediterranean climates: California, Chile, South Africa, Australia, and the Mediterranean basin. University of California Press. 257pp.

Davis, S., Heywood, V. & Hamilton, A. (1994-95). Centers of Plant Diversity. A Guide and Strategy for their Conservation. IUCN/WWF, Cambridge, 3 volumes.

Derous, S., Agardy, T., Hillewaert, H., Hostens, K., Jamieson, G., Mees, J., Moulaert, I., Olenin, S., Paelinckx, D., Rabaut, M., *et al.* (2007). A concept for biological valuation in the marine environment. *Oceonologia*, 49, 99-128.

Di Castri, F. & Harold, M. 2012. Mediterranean type ecosystems: origin and structure. Vol. 7. Springer Science & Business Media. 408pp.

Dobson, A.P., Rodriguez, J.P., Roberts, W.M. & Wilcove, D.S. (1997). Geographic distribution of endangered species in the United States. *Science*, 275, 550-553.

Drinkrow, D.R. & Cherry, M.I. (1995). Anuran distribution, diversity and conservation in South Africa, Lesotho and Swaziland. *South African Journal of Zoology*, 30, 82-90.

Dudley, N. (Ed.). (2012). Protected landscapes and wild biodiversity (Vol. 3). IUCN. 105pp.

Dudley, N. (Ed.). (2008). Guidelines for Applying Protected Area Management Categories. Gland, Switzerland: IUCN. x + 86pp.

Edwards, C. J. & Regier, H. A. (eds). (1990). An Ecosystem Approach to the Integrity of the Great Lakes in Turbulent Times, Special Publication 90-4, Great Lakes Fishery Commission, Ann Arbor, MI.

Eken, G., Bennun L., Brooks, T., Darwall, W., Fishpool, L., Foster, M., Knox, D., Langhammer, P., Matiku, P., Radford, E., Salaman, P., Sechrest, W., Smith, M., Spector, S. & Tordoff A. (2004). Key Biodiversity Areas as Site Conservation Targets. *BioScience*, 54(12), 1110-1118.

El-Hajj, R., Khater, C., Vela, E. & Tatoni, T. (*Accepted*). Pertinence of protected areas networks in biodiversity conservation strategies: Insights from an eastern Mediterranean context. *Ecologia Mediterranea*.

Ellenberg, H. (1974). Zeigerwerte der Gefäßpflanzen Mitteleuropas. *Scripta Geobotanica*, 9, 1-97.

Eppink, F. & van den Bergh, J. (2007). Ecological theories and indicators in economic models of biodiversity loss and conservation: A critical review. *Ecological economics*, 61, 284-293.

Ferraro, P. J. & Pressey, R. L. (2015). Measuring the difference made by conservation initiatives: protected areas and their environmental and social impacts. *Philosophical Transactions of the Royal Society B,* 370(1681), 20140270.

Flournoy, P. H. (2003). Marine Protected Areas: Tools for Sustaining Ocean Ecosystems. *Journal of International Wildlife Law and Policy*, 6(1-2), 137-142.

Folke, C. (2007). Social-ecological systems and adaptive governance of the commons. *Ecological Research*, 22, 14-15.

Foster, M.N., Brooks, T.M., Cuttelod, A., De Silva, N., Fishpool, L.D.C., Radford, E.A. & Woodley, S. (2012). The identification of sites of biodiversity conservation significance, progress with the application of a global standard. *Journal of Threatened Taxa*, 4(8), 2733-2744.

Freeman, M.A. (1993). The measurement of environmental and resource values: theory and practice. Washington (DC): Resources for the Future.

Gaines, S. D., Lester, S. E., Grorud-Colvert, K., Costello, C., & Pollnac, R. (2010). Evolving science of marine reserves: new developments and emerging research frontiers. *Proceedings of the National Academy of Science of the United States of America,* 107, 18251-18255.

Game, E. T., Grantham, H. S., Hobday, A. J., Pressey, R. L., *et al*. (2009). Pelagic protected areas: the missing dimension in ocean conservation. *Trends in Ecology and Evolution*, 24, 360-369.

Gaston, K. J., Jackson, S. F., Cantú-Salazar, L., & Cruz-Piñón, G. (2008). The Ecological Performance of Protected Areas. *Annual Review of Ecology, Evolution, and Systematics*, 39, 93-113.

Gauthier, D. (Ed.). (1992). Canadian Council on Ecological Areas Framework for Developing a Nation-wide System of Protected Areas. Part 1: A - Strategy. Canadian Council on Ecological Areas Framework Task Force. Ottawa, Canada.

Gauthier, P., Debussche, M. & Thompson, J-D. (2010). Regional priority setting for rare species based on a method combining three criteria. *Biological Conservation*, 143, 1501-1509.

Gehlbach, F. R. (1975). Investigation, evaluation,-and priority ranking of natural areas. *Biological Conservation*, 8, 79-88.

Geldmann, J., Barnes, M., Coad, L., Craigie, I. D., Hockings, M. & Burgess, N. D. (2013). Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. *Biological Conservation*, 161, 230-238.

Goldsmith, F. B. (1975). The evaluation of ecological resources in the countryside for conservation purposes. *Biological Conservation*, 8, 89-96.

Gorenflo, L. J. (2002). The evaluation of human population in conservation planning: an example from the Sonoran Desert Ecoregion. Publications for Capacity Building, The Nature Conservancy. Arlington, VA.

Gray, N. J. (2010). Sea change: exploring the international effort to promote marine protected areas. *Conservation and Society*, 8, 331-338.

Gubbay, S. (ed.). (1995). Marine protected areas: Principles and techniques for management (London: Chapman & Hall).

Haughton, M., & Siar, S. V. (2006). Socio-economic indicators in integrated coastal zone and community-based fisheries management: case studies from the Caribbean (No. 491). Food & Agriculture Organization. 208pp.

Huwart, J-Y & Verdier, L. (2013). "What is the impact of globalization on the environment?" in Economic Globalization: Origins and consequences, OECD Publishing. http://dx.doi.org/10.1787/9789264111905-8-en

Jacot, M. (2009). Les aires marines protégées comme outils de conservation de la biodiversité marine : application de critères de sélection et considération de la pertinence des critères adoptés dans le cadre de la Convention sur la diversité biologique. Dissertation en vue de l'obtention des grades de maître en écologie internationale et de maître en environnement Sherbrooke, Québec, Canada, août 2009.

Karr, J.R. (1981). Assessment of biotic integrity using fish communities. *Fisheries*, 6, 21-27.

Karr, J.R. (1991). Biological integrity: a long neglected aspect of water resource management. *Ecological Applications*, 1, 66-84.

Karr, J.R. & Dudley, D.R. (1981). Ecological perspective on water quality goals. *Environmental Management*, 5, 55-68.

Kier, G., Kreft, H., Lee, T.M., Jetz, W., Ibisch, P., Nowicki, C., Mutke, J. & Barthlott, W. (2009). A global assessment of endemism and species richness across island and mainland regions. *Proceedings of the National Academy of Sciences*, 106(23), 9322-9327.

Kiringe, J.W. & Okello, M.M. (2007). Threats and their relative severity to wildlife protected areas of Kenya. *Applied Ecology and Environmental Research*, 5(2), 49-62.

Kolkwitz, R. & Marsson, M. (1902). Gründsatze für die biologische Beurtheilung des Wassers nach seiner flora und fauna. Mitteilungen aus der Königlichen Prüfungsanstalt für Wasserversorgung und Abwasserbeseitigung zu Berlin, 1, 33-72.

Kremen, C., Niles, J., Dalton, M., Daily, G., Ehrlich, P., Fay, P., *et al.* (2000). Economic incentives for rain forest conservation across scales. *Science*, 288, 1828-1832.

Lampič, B., Mrak, I. & Slavič, I. (2012). The impacts of globalization in rural areas of Slovenia: examples from the Pomurje and Goriska regions. *Geografski vestnik*, 84(1),151-162.

Lagadeuc, Y. & Chenorkian, R. (2009). Les systèmes socio-écologiques : vers une approche spatiale et temporelle. *Natures Sciences Sociétés*, 2(17), 194-196.

Laguna, E., Deltoro, V.I., Perez-Botella, J., Perez-Rovira, P., Serra, L., Olivares, A. & Fabregat, C. (2004). The role of small reserves in plant conservation in a region of high diversity in eastern Spain. *Biological Conservation*, 119, 421-426.

Langhammer, P.F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall,W., De Silva, N., Edgar, G.J., Eken, G., Fishpool, L.D.C.,3 Fonseca, G.A.B. da, Foster, M.N., Knox, D.H., Matiku, P., Radford, E.A., Rodrigues, A.S.L., Salaman, P., Sechrest, W., & Tordoff, A.W. (2007). Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems. Gland, Switzerland: IUCN.

Le Saout, S., Hoffmann, M., Shi, Y., Hughes, A., Bernard, C., Brooks, T.M., Bertzky, B., Butchart, S.H.M., Stuart, S.N., Badman, T. & Rodrigues, A.S.L. (2013). Protected Areas and Effective Biodiversity Conservation. *Science,* 342(6160), 803-805.

Lepareur F. (2011). Evaluation de l'état de conservation des habitats naturels marins à l'échelle d'un site Natura 2000. Guide méthodologique, Version 1. Février 2011. Rapport SPN 2011 / 3, MNHN, Paris, 55pp.

Lester, S. E., Halpern, B. S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B. I., Gaines, S. D., Airamé, S., & Warner, R. R. (2009). Biological effects within no-take marine reserves: a global synthesis. *Marine Ecology Progress Series*, 384, 33-46.

Lindenmayer, D., Margules, C. & Botkin, D. (2000). Indicators of biodiversity for ecologically sustainable forest management. *Conservation Biology*, 14(4), 941-950.

Liu, J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H. & Taylor, W.W. (2007). Complexity of coupled human and natural systems. *Science*, 317(5844), 1513-1516.

Lubchenco, J., Palumbi, S. R., Gaines, S. D., & Andelman, S. (2003). Plugging a hole in the ocean: the emerging science of marine reserves. *Ecological Applications*, 13, 3-7.

Lubchenco, J., Gaines, S., Warner, R., Palumbi, S. *et al*. (2007). The science of marine reserves, 2nd edition, international version. Available at: www.piscoweb.org [accessed on 25 March 2014].

M.A. (2005). Ecosystems and Human Well-being: Synthesis. Millennium Ecosystem Assessment, Island Press, Washington DC. Under:
http://www.millenniumassessment.org/documents/document.356.aspx.pdf

Margules, C. & Pressey, R.L. (2000). Systematic conservation planning. *Nature*, 405, 243-253.

Margules, C. & Usher, M. (1981). Criteria used in assessing wildlife conservation potential: A review. *Biological Conservation*, 21(2), 79-109.

Médail, F. & Diadema, K. (2006). Biodiversité végétale méditerranéenne et anthropisation : approches macro et micro-régionales. *Annales de Géographie, numéro thématique « Les territoires de la biodiversité »*, 651, 618-649.

Médail, F., & Quézel, P. (1999). Biodiversity Hotspots in the Mediterranean Basin: Setting Global Conservation Priorities. *Conservation Biology*, 13, 1510-1513.

Mittermeier, R.A., Myers, N., Thomsen, J.B., Fonseca, G.A.B. & Olivieri, S. (1998(. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conservation Biology*, 12, 516-520.

Múgica, M., De Lucio, J. V., Martínez, C., Sastre, P., Atauri-Mezquida, J. A. & Montes, C. (2002). Territorial integration of natural protected areas and ecological connectivity within Mediterranean landscapes. Consejerıa de Medio Ambiente, Junta de Andalucia.

Munn, R.E. (1993). Monitoring for ecosystem integrity. Pages 105-116, In: S. Woodley, J. Kay, and G. Francis, eds, Ecological Integrity and the Management of Ecosystems. St. Lucie Press, Ottawa, Canada.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G.A.B. & Kent J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403, 853-858.

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R., Lehner, B., Malcolm, T.R. & Ricketts, T. (2008). Global mapping of ecosystem services and conservation priorities. *Proceedings of the National Academy of Sciences,* 105(28), 9495-9500.

Noss, R. F. (1995). Maintaining Ecological Integrity in Representative Reserve Networks: A World Wildlife Fund Canada/World Wildlife Fund-United States Discussion Paper. WWF. 85pp.

Noss, R.F., Carroll, C., Vance-Borland, K. & Wuerthner, G. (2002). A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone ecosystem. *Conservation Biology,* 16, 895-908.

Oates, J. (1999). Myth and reality in the rain forest: how conservation strategies are failing in West Africa. Berkeley: University of California Press.

Olson, D.M. & Dinerstein, E. (1998). The Global 200: a representation approach to conserving Earth's most biologically valuable ecoregions. *Conservation Biology,* 12, 502-515.

Ostermann, O. 1998. The Need for Management of Nature Conservation Sites Designated Under Natura 2000. *Journal of Applied Ecology* 35(6): 968-973.

Pagiola, S., Von Ritter, K. & Bishop, J. 2004. Assessing the economic value of ecosystem conservation. World Bank, Environment Department. 66pp.

Pearce, D.W. & Warford, J.J. (1993). World without end: economics, environment, and sustainable development. World Bank Publications.

Pimentel, D., Westra, L. & Noss, R. F. (2000). Ecological integrity: integrating environment, conservation, and health. Island Press. 428pp.

Pimm, S.L., Ayres, M., Balmford, A., Branch, G. *et al*. (2001). Can we defy nature's end? *Science*, 293, 2207-2208.

Polasky. (2008). Why conservation planning needs socioeconomic data. *Proceedings of the National Academy of Sciences*, 105(18), 6505-6506.

Pressey, R.L. 1994. Ad Hoc Reservations - Forward or Backward Steps in Developing Representative Reserve Systems. *Conservation Biology,* 8(3), 662-668.

Pressey, R.L. (1998). Algorithms, politics, and timber: an example of the role of science in a public, political negotiation process over new conservation areas in production forests. In R. T. Wills & R. J. Hobbs (Eds.), Ecology for everyone: Communicating ecology to scientists, the public, and politicians (pp. 73–87). Sydney: Surrey Beatty & Sons.

Pressey, R.L. & Taffs, K.H. (2001). Scheduling conservation action in production landscapes: priority areas in western New South Wales defined by irreplaceability and vulnerability to vegetation loss. *Biological Conservation*, 100, 355-376.

Pressey, R.L., Whish, G. L., Barrett, T. W. & Watts, M. E. (2002). Effectiveness of protected areas in north-eastern New South Wales: recent trends in six measures. *Biological Conservation*, 106, 57-69.

Pressey, R.L., Johnson, I.R. & Wilson, P.D. (1994). Shades of irreplaceability: towards a measure of the contribution of sites to a reservation goal. *Biodiversity and Conservation*, 3, 242-262.

Rabinowitz, D. (1981). Seven forms of rarity. In: Synge, H. (Ed.), The Biological Aspects of Rare Plant Conservation. Wiley, New York, pp. 205-217.

Redman, C.L., Grove, J.M., & Kuby, L.H. (2004). Integrating social science into the Long-Term Ecological Research (LTER) network: Social dimensions of ecological change and ecological dimensions of social change. *Ecosystems,* 7, 161-171.

Ricketts, T., Dinerstein, E., Boucher, T., Brooks, T., Butchart, S., Hoffmann, M., Lamoreux, J., Morrison, J., Parr, M., Pilgrim, J., Rodrigues, A., Sechrest, W., Wallace, G., Berlin, K., Bielby, J., Burgess, N., Church, D., Cox, N., Knox, D., Loucks, C., Luck, G., Master, L., Moore, R., Naidoo, R., Ridgely, R., Schatz, G., Shire, G., Strand, H., Wettengela, W. & wikramanayake, E. (2005). Pinpointing and preventing imminent extinctions. *Proceedings of the National Academy of Sciences of the United States of America*, 102, 18497-18501.

Roberts, C. M., Andelman, S., Branch, G., Bustamante, R. H., Carlos Castilla, J., Dugan, J., Halpern, B.S., Lafferty, K.D., Leslie, H., Lubchenco, J., Mcardle, D., Possingham, H.P., Ruckelshaus, M. & Warner, R. R. (2003). Ecological criteria for evaluating candidate sites for marine reserves. *Ecological applications*, 13(1), 199-214.

Rodrigues, A.S.L., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., Fonseca, G.A.B., Gaston, K.J., Hoffman, M., Long, J., Marquet, P.A., Pilgrim, J.D., Pressey, R.L., Schipper, J., Sechrest, W., Stuart, S.N., Underhill, L.G., Waller, R.W., Watts, M.E.J. & Xie, Y. (2003). Global Gap Analysis: towards a representative network of protected areas. Advances in Applied Biodiversity Science 5. Washington DC: Conservation International.

Rodrigues, A., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., da Fonseca, G.A.B. *et al*. (2004). Effectiveness of the global protected area network in representing species diversity. *Nature*, 428(6983), 640-643.

Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M. & Wall, D.H. (2000). Global biodiversity scenarios for the year 2100. *Science*, 287, 1770-1774.

Schiller, A., Hunsaker, C.T., Kane, M.A., Wolfe, A.K., Dale, V.H., Suter, G.W., Russell, C.S., Pion, G., Hadley, M. & Konar, V.C. (2001). Communicating ecological indicators to decision-makers and the public. *Conservation Ecology*, 5(1), 19.

Smith, R., Muir, R. D., Walpole, M. J., Balmford, A. & Leader-Williams, N. (2003). Governance and the loss of biodiversity. *Nature*, 426(6962), 67-70.

Smith, R. & Theberge, B. (1986). A review of criteria for evaluating natural areas. *Environmental Management*, 10(6), 715-734.

Sodhi, N. S. & Ehrlich, P. R. (Eds.). (2010). Conservation biology for all. Oxford, United Kingdom: Oxford University Press. 358pp.

Soulé, M.E. 2005. Marine conservation biology: the science of maintaining the sea's biodiversity. Island Press. 493pp.

Stattersfield, A.J., Crosby, M.J., Long, A.J. & Wege, D.C. (1998). Endemic Bird Areas of the World Priorities for Conservation. BirdLife International, Cambridge.

Sukhdev, P., Wittmer, H., Schröter-Schlaack, C., Nesshöver, C., Bishop, J., Ten Brink, P., Gundimeda, H., Kumar, P. & Simmons, B. (2010). The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesisof the approach, conclusions and recommendations of TEEB, 39pp.

Tans, W. (1974). Priority ranking of biotic natural areas. *Michigan Botanist*, 13, 31-39.

Troumbis, A.Y. & Panayotis, G.D. (1998). Geographic coincidence of diversity threatspots for three taxa and conservation planning in Greece. *Biological Conservation*, 84, 1-6.

Tubbs, C. R. & Blackwood, J. W. (1971). Ecological evaluation of land for planning purposes. *Biolical Conservation*, 3, 169-72.

Turner, I. M., & Corlett, R. T. (1996). The conservation value of small, isolated fragments of lowland tropical rain forest. *Trends in Ecology and Evolution*, 11(8), 330-333.

Turnhout, E., Hisschemöller, M. & Eijsackers, H. (2007). Ecological indicators: Between the two fires of science and policy. *Ecological Indicators*, 7, 215-228.

Underwood, E., Viers, J., Klausmeyer, K., Cox, R. & Shaw, R. (2009). Threats and biodiversity in the Mediterranean biome. *Diversity and Distributions*, 15(2), 188-197.

Usher, M.B. (1980). An assessment of conservation values within a large site of special scientific interest in North Yorkshire. *Field Studies*, 5, 323-348.

Van Der Ploeg, S. W. F. & Vlijm, L. (1978). Ecological evaluation, nature conservation and land use planning with particular reference to methods used in the Netherlands. *Biological Conservation*, 14, 197-221.

Vanderpert, H. 2007. Diagnostic écologique territorial d'un chaînon littoral péri-urbain : Le Massif de la Nerthe/Estaque/Côte Bleue (Bouches-du-Rhône). Mémoire de Master. Expertise Ecologique et Gestion de la Biodiversité. Université Paul Cézanne, Marseille.

Vela, E. & Pavon, D. (2012). The vascular flora of Algerian and Tunisian small islands: if not biodiversity hotspots, at least biodiversity hotchpotchs? *Biodiversity Journal*, 3(4), 343-362.

Viry, D. (2013). État de conservation des habitats humides et aquatiques d'intérêt communautaire, Méthode d'évaluation à l'échelle du site. Guide d'application. Version 1 - Avril 2013. Rapport SPN 2013-13, Service du patrimoine naturel, Museum National d'Histoire Naturelle / Office National de l'Eau et des Milieux Aquatiques, Paris, 33pp.

WDPA. (2014). IUCN World Database on Protected areas [accessed on 12/9/2014]. http://www.iucn.org/about/work/programmes/gpap_home/gpap_biodiversity/gpap_wdpa/

Woodley, S., Francis, G. & Kay, J. (eds). (1993). Ecosystem Integrity and the Management of Ecosystems, St Lucie Press, Boca Raton, FL. 232pp.

Worboys, G.L., Lockwood, M., Kothari, A., Feary, S. & Pulsford, I. (eds). (2015). Protected Area Governance and Management, ANU Press, Canberra. 992pp.

Wright, D. F. (1977). A site evaluation scheme for use in the assessment of potential nature reserves. *Biological Conservation*, 11, 293-305.

Wurtzebach, Z. and Schultz, C. 2016. Measuring Ecological Integrity: History, Practical Applications, and Research Opportunities. *BioScience 66*(6) : 446-457.

Yahi, N., Vela, E., Benhouhou, S. De Belair, G. & Gharzouli, R. (2012). Identifying Important Plants Areas (Key Biodiversity Areas for Plants) in northern Algeria. *Journal of Threatened Taxa*, 4(8), 2753-2765.

CHAPITRE 5

« MedConserve », un outil d'aide à la décision pour orienter la désignation des aires protégées en contexte méditerranéen continental

En milieu méditerranéen de plus en plus contraint par les aléas et les conditions climatiques, mais aussi par une empreinte anthropique de plus en plus impérissable sur les milieux naturels, comprendre les dynamiques socioécologiques est impérative pour mieux orienter les initiatives de conservation. Dans cette logique, l'emploi de descripteurs écologiques et socioéconomiques pertinents et adaptés se révèle incontournable pour une meilleure définition des alternatives de conservation. La compilation de ces derniers en un outil d'aide à la décision, rendra d'autant plus leur utilisation pratique.

Sur base des descripteurs écologiques et socioéconomiques identifiés dans le chapitre précédant, MedConserve, un outil d'aide à la décision informatisé, a été conçu et développé. Cet outil oriente les alternatives de conservation de la biodiversité en orientant les choix de désignation des aires protégées en contexte méditerranéen terrestre.

La structure sous-jacente à MedConserve repose sur une matrice numérique composée d'un algorithme spécifique. Cette matrice consiste en un tableau à double entrée qui affiche :

- En colonnes : 6 « catégories » de zones de protection déclinant chacune un à plusieurs « types spécifiques » d'aires protégées ayant un objectif commun de conservation, indépendamment de leur appellation locale par pays méditerranéen.
- En lignes : les descripteurs avec leurs modalités, variantes et valeurs respectives.

Un algorithme numérique, composé de 3 chiffres (0 ; 0.5 et 1), est ensuite utilisé pour remplir cette matrice tout en accordant à chaque combinaison « Catégorie - Valeur de descripteur » un chiffre approprié. Cette approche reflète comment la variation d'un aspect écologique ou socioéconomique spécifique peut affecter les priorités de conservation. Le renseignement de la matrice par les algorithmes appropriés est basé sur une analyse inspirée de la bibliographie et d'exemples réels d'application des différentes catégories d'aires protégées au Liban et en Méditerranée, et validé par un collège d'experts afin d'évaluer et de confirmer la pertinence des concepts scientifiques sous-jacents.

Pour un site donné dédié à la conservation, l'utilisateur devrait dans un premier temps renseigner le maximum possible de descripteurs écologiques et socioéconomiques en choisissant les valeurs adéquates en fonction des informations dont il dispose. Sur base de cet apport, MedConserve octroie un score pour chacune des catégories de zones protégées. Ce score est converti en pourcentage de pertinence relatif à chaque catégorie. Sur ce, MedConserve fourni à l'utilisateur des choix de conservation priorisés, et ceci, en fonction des particularités écologiques et socioéconomiques préalablement renseignées par ce dernier.

Les résultats du test de MedConserve sur 4 sites naturels terrestres au Liban (la réserve naturelle de Bentael, la réserve naturelle de Horsh Ehden, les falaises de Ras Chekka et la forêt de Baabda), ont permis de vérifier l'efficacité de son fonctionnement. L'examen de ces 4 sites a pu :

- confirmer la pertinence du statut de « réserve naturelle » de Bentael, avec néanmoins une suggestion plus adaptée pour sa conservation : « forêt protégée » ;
- approuver la parfaite adéquation du statut de conservation de la « réserve naturelle » de Horsh Ehden ;
- repenser la mise en « réserve » des falaises de Ras Chekka en orientant le choix de conservation vers un « site et monument naturel » ;
- orienter la désignation de la forêt de Baabda vers une catégorie de conservation qui protègera le foncier en général afin de condamner la construction de l'autoroute prévue par le gouvernement au cœur de cette dernière forêt urbaine.

Néanmoins, le modèle devrait être idéalement testé sur au moins une vingtaine de sites afin d'optimiser son utilisation.

MedConserve est actuellement en cours de conversion en un outil informatisé, accessible en ligne (sous construction), en partenariat avec un développeur web.

Article 3

Compiling key ecological and socioeconomic indicators into a decision support tool to orient protected areas designation in Mediterranean-type continental environments

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Introduction

The world's more than 217,000 protected areas come in many forms, on land and at sea, and occur in every country (Bertzky *et al.*, 2012). They are spread over 15.4% of the Earth's terrestrial area (outside Antarctica) and 3.4% of its marine area (IUCN and UNEP-WCMC 2014). Target 11 of the Aichi targets on protected areas requires that by 2020, at least 17% of terrestrial and inland water, especially areas of particular importance for biodiversity and ecosystem services, are conserved (CBD 2011; 2012). However, expending protected areas networks and designing new reserve areas remain a challenging task for conservationists and practitioners, where not only scientific and ecological values have to be accounted for the establishment of new protected zones, but also cultural, historic, social, economic and aesthetic values (Reynard, 2009). In Mediterranean environments, this challenge is gradually growing as human threats to biodiversity and ecosystems are rapidly increasing. From habitat fragmentation to the mass development of road networks and urbanization, today, the Mediterranean basin is among the four most significantly altered biodiversity hotspots on Earth

(Cuttelod *et al.*, 2008; Underwood *et al.*, 2009). Thus, orienting protected areas designation in the Mediterranean region remains a challenging task in a complex socio-ecological context, where the extent by which existing protected areas are effectively representing, maintaining and conserving key ecological features is still poorly understood, and where protected areas designation seems to follow sociopolitical opportunities rather than being founded on pertinent ecological and socioeconomic criteria that would highlight the relevance and priority for conservation measures (Gaston *et al.,* 2008; El-Hajj *et al.*, *In revision;* Rodrigues *et al.,* 2004).

In that respect, El-Hajj *et al.* (*In revision*) identified a set of ecological and socioeconomic descriptors to pertinently orient conservation priorities and protected areas designation in Mediterranean-type continental environments. These indicators describe maximum ecological and socioeconomic features of a specific site in view of its potential designation as a protected area, while covering key ecological and socioeconomic variables that reflect major processes and aspects orienting protection patterns. They are integrative, easy to measure, practical, and adapted to Mediterranean-type continental environments.

However, bringing together these indicators into a decision support tool can make their use easier and practical. Decision support tools are indeed widely used by conservationists to orient protected areas management, planning and zoning. Marxan software, INFFER™, Zonation software, Zonae Cogito, and SmartConservation®, are among many other decision support tools used by conservationists around the world to provide decision-making support in: i) the efficient and ecologically diligent selection of new conservation areas; ii) assessing and monitoring protected areas sustainability; and iii) facilitating discussions during stakeholder consultation processes on protected areas boundaries setup (Bajracharya, 2010; Delavenne *et al.*, 2011; Pediaditi *et al.*, 2011; Segan *et al.,* 2011; Stortini *et al.,* 2015; Tunesi, 2005; Worboys *et al.,* 2015). Yet, the development and use of decision support tools for identifying, designing and prioritizing new protected areas using ecological criteria and scoring systems is still evolving (Ladle & Whittaker, 2011), despite the presence of a wide set of criteria used for ranking the relative ecological and conservation values of potential reserves (Margules & Usher, 1981; Smith & Theberge, 1986; Usher, 1986). Either web-based or GIS based, the purpose of decision-support tools is not to provide the answer, but to enable decision-makers (from policy advisers to local protected area managers) to systemize and structure decision-making and priority setting processes using the best available knowledge (Pattison *et al.*, 2004; Wood & Dragicevic, 2008). Today, prioritization tools are gaining greater recognition and acceptance as more conservation practitioners realize that “ad-hoc” or “opportunistic” resource protection may not ensure sustainable protection of the regional resource base.

Inspired from this complex set of customized tools for conservation prioritization, this paper presents a new decision support tool (“MedConserve”) aiming to orient protected areas designation in Mediterranean-type continental environments, based on the descriptors developed by El-Hajj *et al.* (*In revision*). Unlike other existing tools tailored to orient the “selection” of “new” areas for conservation in a given territory based on specific ecological and socioeconomic criteria, MedConserve is designed to aid decision makers in orienting conservation priorities of a “preselected” site in view of its “potential conservation”. In other terms, it helps bequeath an adequate “level of protection” (type of protected area) for a given Mediterranean continental site meant to be conserved.

This tool is being converted into a web-based decision support tool available online (under construction). This paper will present the fundamental concepts, methods and algorithms underlying its development.

Methods

MedConserve is a decision support tool developed based on the ecological and socioeconomic descriptors identified by El-Hajj *et al.* (*In revision*) to orient protected areas designation in Mediterranean continental environments. This tool is founded on a double entry matrix taking into account the “conservation areas categories” on an entry level and the “descriptors” on another entry level.

The development of this tool entailed four main steps:

1. Six “broad categories” of conservation areas were defined. Each category regroups one to several “specific types” of protected areas applied in Mediterranean countries (nature reserve, protected forest, RAMSAR site, “Hima”, etc.) and answering a common conservation objective, regardless their official names in the respective countries. MedConserve will orient conservation alternatives of a given site towards the most adequate conservation category, leaving the end-user free to select the specific type of protection according to existing local and national laws and regulations on protected areas in his own country.

2. Modalities, variables and values for each of the nine descriptors identified in Chapter 4 were defined based on bibliographic references. Each descriptor contains one or more separate measures, each of which can be assessed separately to identify whether it is changing and, if so, whether this change will affect or not the conservation priority.

3. A double entry matrix was then developed. In columns were displayed the six categories of conservation areas, and in lines the descriptors with their corresponding modalities, variables and values. This matrix was next filled with a specific numerical algorithm for every value, consisting of three numbers: 0, 0.5, and 1:

- "0" means that for a given value of a given descriptor, specific category/categories of conservation area(s) is/are not applicable (not fitted).
- "0.5" indicates that for a given value of a given descriptor, specific category/categories of conservation area(s) are neither recommended nor ill-advised. They can be applied, but are not yet the optimal options for efficient conservation.
- "1" means that for a given value of a given descriptor, specific category/categories of conservation area(s) perfectly fit.

Numbers were filled in the matrix based on an empirical analyses inspired from literature and actual field cases, where each "descriptor value" was analyzed with regards to each "protected area category" and given a suitable number. This approach reflects how the variation of a specific ecological or socioeconomic aspect can affect conservation patterns/modalities.

4. Finally, the matrix was amended and validated by a college of experts specialized in biodiversity conservation and protected areas management through one to one meetings. This process gave an added value to the primary analyses which made the whole analytical logic semi-empirical and the decision support tool more scientifically pertinent.

The college of experts members are:

- Thierry Tatoni (HDR): Aix-Marseille Université, Institut Méditerranéen de Biodiversité et d'Ecologie Marine et Continentale (IMBE), France
- Samir Safi (HDR) : Lebanese university, Faculty of Sciences, Department of Life and Earth Science, Lebanon
- Carla Khater (HDR): National Council for Scientific Research, Center for Remote Sensing, Lebanon
- Magda Boudagher (HDR): Saint-Joseph University, Faculty of Sciences, Department of Life and Earth Science, Lebanon

- Errol Vela (PhD): Université Montpellier II, Botanique et Bio-informatique de l'Architecture des plantes (AMAP), France
- Marc Beyrouthi (PhD): Holy Spirit University of Kaslik, Faculty of Sciences and Computer Engineering, Lebanon
- Nabil Nemer (PhD): Holy Spirit University of Kaslik, Faculty of Agronomic Sciences, Lebanon
- Julien Viglione (Engineer): Ecomed sarl, France
- Alexandre Cluchier (PhD): Ecomed sarl, France
- Lara Samaha (MSc): Ministry of Environment, Department of Ecosystems Conservation, Lebanon

Results

A. Conservation areas categories

Six broad categories of conservation areas were defined:

- Ranging from the stricter to the most flexible level of protection;
- Encompassing almost all specific types of protected areas implemented in Mediterranean continental environments.

Each category:

- Includes one to several "types of specific protected areas", having a common conservation objective, yet with appellations depending on each country's local laws, usages and languages;
- Defines a certain level of "Protection" associated to a certain level of "Management".

These categories are:

1. **Category A: Strictly protected area (sanctuary).** This category recalls IUCN's category Ia (and to a lesser extent category Ib[3]) which represents "strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas

[3] Category Ib will generally be less strictly protected from human visitation than category Ia. Although not usually subject to mass tourism they may be open to limited numbers of people prepared for self-reliant travel such as on foot, which is not always the case in Ia.

for scientific research and monitoring" (Dudley, 2008). Although continental sanctuaries are rarely encountered in Mediterranean countries, one cannot omit this level of conservation as it represents the strictest type of protection that might occur in Mediterranean areas on sites of very high ecological values. No management interventions are applied in areas fitting this category, as they do not require substantial and ongoing interventions to achieve their conservation objectives, except for being managed for relatively low visitation by humans. Specific types of protected areas falling under this category include for instance wildlife sanctuaries (mainly widespread in the United States, Africa and India), and biological reserves in France.

2. **Category B: Global reserve area.** This category echoes IUCN's category II (National Park). It encompasses small or large protected areas set aside to protect small or large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities (Dudley, 2008). This category includes areas that are generally not as strictly conserved as category 1 (see above) and may include tourist infrastructure and visitation. Management interventions in this category should be focused on maintaining the ecosystem in its entirety. Specific types of protected areas corresponding to this category include inter alia:
    - Nature reserves in Lebanon: terrestrial or marine areas which require the protection of ecosystems, habitats and species of national importance by virtue of their value, rarity (endemism) and threat level. Their conservation requires maintenance or restoration activities, with formalized terms included in a management plan. A nature reserve is entirely or partially made of strict conservation areas and areas of controlled management (GFA/ELARD/MoE/CDR, 2013).
    - National parks and nature reserves in France: areas dedicated to preserve remarkable and fragile natural environments. National parks are created on uninhabited territories. Their conservation rules are strict and sometimes derogate from the national law. Hunting, plant collection, and fishing activities are strictly controlled, whereas construction and extraction activities are severely banned. This type of protected area entails strict nature conservation associated with specific management actions targeting ecosystem conservation and visitors' management (Law n°2006-436 relative to national parks, marine natural parks and regional parks in France).

3. **Category C: Partially protected area with focused management.** This category combines IUCN's categories III, IV and V into one broader category including specific types of protected areas set aside to protect: i) specific natural monuments which are generally quite small and often have high visitor value (landform, sea mount, geological feature such as a cave or even a living feature such as an ancient grove); ii) specific habitat/species; and iii) specific landscapes where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value, and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area (Dudley, 2008).

Protection patterns in this category are not strict and do not target the whole geographical extent of the protected area (partial protection), but rather the "specific element" subject for conservation (monument, habitat, specie, landscape, etc.). Management interventions in areas falling under this category are much focused to address the requirements and provide optimum conditions for particular species or communities, or to maintain the given habitat, monument or landscape within the whole protected extent. This category encloses specific types of protected areas such as:

- Natura 2000 sites in France: Natura 2000 is a network of protected areas scattered in the territory of the European Union. It is made up of Special Areas of Conservation aiming to protect specific habitats under the EU Habitats Directives, and of Special Protection Areas designated under the EU Birds Directive in order to protect all European wild birds and their relative habitats (Ostermann, 1998).
- Natural sites and monuments in Lebanon: areas harboring one or more natural attributes of exceptional ecological, cultural, or patrimonial value, deserving conservation in virtue of their rarity, representativeness, or beauty (GFA/ELARD/MoE/CDR, 2013).
- Protected forests in Lebanon: all forests of cedar (Cedrus libani), fir (Abies cilicica), high juniper (juniperus excelsa), and evergreen cypress (cupressus sempervirens), whether diverse or homogeneous, state-owned or privately-owned, designated to protect the mentioned species under the Lebanese Forest Conservation Law No. 558, 1996.
- Plant micro-reserves (PMR) in Spain and Greece (and other Mediterranean countries): areas of small extent (less than 20ha), specifically set aside to protect rare and threatened wild plants species (Laguna, 2001).

- Ramsar sites: areas designated under the Ramsar convention to protect and sustainably use wetlands of special importance, recognizing their fundamental ecological functions and their economic, cultural, scientific, and recreational values.
- UNESCO World heritage sites: places such as buildings, cities, complexes, deserts, forests, islands, lakes, monuments, mountains, etc. listed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as being of special cultural or physical significance.

4. **Category D: Unmanaged partially protected area.** This category includes areas where protection is mainly focused on conserving the land (estate) in order to protect an exceptional biological, ecological, historic, artistic, legendary, etc. feature. Such areas are protected against urbanization or development attempts and promulgate the prohibition of a given number of activities that may affect the ecological balance of the environment or the survival of protected species. No management interventions are undertaken in these areas. This category includes specific types of protected areas, that do not yet officially exist in Lebanon, such as:
   - "Sites classés" in France: areas or remarkable natural features with historical, artistic, scientific, legendary or picturesque characteristics that call for conservation per se and the preservation from all destructive activities, mainly urban constructions. These sites are designated under law No.57-740, 1957, articles L. 341-1 to L. 341-22, and require no management interventions.
   - "Arrêté préfectoral de protection de biotope" in France: prefectural decree aiming to protect a site from construction or any other destructive activity, in order to protect a natural habitat or biotope harboring one or more wild protected fauna or flora species (Comolet-Tirman *et al.*, 2008). Such sites don't require any management intervention.

5. **Category E: Conservation area with sustainable/concerted use of natural resources.** This category recalls IUCN's category VI which includes protected areas aimed to conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is

seen as one of the main aims of the area (Dudley, 2008). Specific types of protected areas conform to this category include inter alia:

- Himas in Lebanon: Hima means "protection" in Arabic. It is a community based approach used for the conservation of sites, species, habitats, and people in order to achieve the sustainable use of natural resources. It originated more than 1,500 years ago where it was spread along the Arab Peninsula as a "tribal" system of sustainable and participatory management of natural resources (Kilani *et al.*, 2007).
- "Empty" / unclassified zones within French Regional Parks or Man and Biosphere Reserves in Mediterranean countries.

6. **Category F: Space of knowledge (at least) / incitement (at most) for sustainable economic activities.** This category is not a protected area category in the real sense, but rather a kind of conservation approach that can be applied to large areas (such as valleys, agricultural plains, watersheds, etc.), where specific protected areas cannot be created as such due to the presence of vital economic activities that hinder protection initiatives and on which local communities rely for their survival (agriculture, lakes, etc.), but where key ecological features exist and deserve conservation (migrating, nesting or breeding birds, rare flora species, etc.). Thus, these areas do not behold a statutory value, are not legally enforced, are not even designated through local decisions (such as Himas), do not require management, and are only classified as per their confirmed intrinsic ecological values based on naturalist inventories. They act as instruments of knowledge for communities and provide a basis for the establishment of biodiversity conservation areas and the integration of the environment into development projects. Designating these areas is intended to gain awareness and encourage long-term conservation through an ecosystem-based approach. Specific types of nominations corresponding to this category include:
   - Important plant areas (IPA): natural or semi-natural sites exhibiting exceptional botanical wealth and/or supporting an outstanding assemblage of rare, threatened and/or endemic plant species and/or vegetation of high botanic value (Anderson, 2002);
   - Important bird areas (IBA): areas recognized as being a globally important habitat for the conservation of bird populations (Stroud *et al.*, 1990);
   - Key biodiversity areas (KBA): globally important sites that are large enough or sufficiently interconnected to support viable populations of the species for which they are important (Eken *et al.*, 2004);

- "Zones naturelles d'intérêt écologique, faunistique et floristique" (ZNIEFF): natural areas inventoried for their remarkable character. A ZNIEFF does not constitute a measure of regulatory protection, but only an inventoried area (Elissalde *et al.*, 2004).

B. Descriptors: modalities, variables and values

The following section presents the respective modalities (sub-descriptors), variables, and values of each descriptor, defined based on bibliographic references and/or empirical analysis inspired from real case studies. A comprehensive definition of every descriptor is provided in Chapter 4.

1. Rarity or irreplaceability (species and/or habitat level)

Values defined for the following descriptor are given as examples for vascular plants. In case of nonvascular plants or fauna species, the user can adapt the values and thresholds according to pertinent bibliographic references.

1.1. Ratio of rare species if species inventories are comprehensive (number of rare species over total number of species).

	Value	Definition	Reference
1.1.1. Ratio of very rare species (found in one station)	0	Null (0%)	Magnanon *et al.*, 2009; IUCN, 2012
	1	Low (0-1%)	
	2	Medium (1-2%)	
	3	High (2-5%)	
	4	Very high (>5%)	
1.1.2. Ratio of rare species (found in a number of stations/localities < or = to 5)	0	Null (0%)	
	1	Low (0-5%)	
	2	Medium (5-10%)	
	3	High (10-20%)	
	4	Very high (>20%)	

1.2. Presence/number of rare species if species inventories are not comprehensive (only partial).

In order not to miss species which presence might go beyond a rarity threshold - which itself is subjective and arbitrary - while only very partial data is available, it is preferred to measure the irreplaceability value (1 over the number of stations in the study area) of each species onsite, regardless of the number of individuals per species. Thus, the cumulative value (for all species present onsite) will serve as a definition of the indicator value (Vanderpert, 2007).

Value	Definition	Reference
0	Absence of rare species or cumulative value < 0.1	Vanderpert, 2007
1	Presence of one or more rare species with a cumulative value < 1	
2	Presence of one or more rare species with a cumulative value comprised between 1 and 1.9	
3	Presence of one or more rare species with a cumulative value > or = 2	

1.3. Habitat rarity or unicity (ecosystem, biotope or biocenosis) if habitat or bioclimatic or geologic inventories or maps are available for the target area (regardless the availability or not of species inventories).

Same logic as sub-descriptor 1.2

Value	Definition	Reference
0	Absence of rare habitats or cumulative value < 0.1	Vanderpert, 2007
1	Presence of one or more rare habitat with a cumulative value < 1	
2	Presence of one or more rare habitat with a cumulative value comprised between 1 and 1.9	
3	Presence of one or more rare habitat with cumulative value > or = 2	

1.4. Presence/number of endemic species (restricted range and/or site restricted species) with species inventories comprehensive or not.

	Value	Definition	Reference
Presence/number of endemic species restricted to a maximum occurrence range of 10.000Km^2 in the same country or in overlap with a frontier area	0	Absence	Magnanon *et al.*, 2009; IUCN, 2012
	1	1	
	2	Many	
Presence of at least one endemic species restricted to a maximum occurrence range of 100Km^2	3	Presence	

The threshold of 50,000km^2 used to define restricted range for animal taxa (Langhammer *et al.*, 2007) is too large to apply to plant species, for which the threshold 5,000 km^2 is used, particularly in hotspot regions (Yahi *et al.*, 2012). However, in a global approach, we opted for an intermediate threshold of 10,000 km^2, based on the classical threshold of IUCN’s red listing criteria (IUCN, 2012).

2. Habitat extension (representativeness)

2.1. Habitat extension on the territory scale (administrative level): relative surface of the target habitat in the administrative area (e.g. national/county level) compared to the total surface of the administrative area (e.g. country).

Value	Definition	Reference
0	Trivial or "insignificant" element (0.1%)	Extrapolation of the "Formulaire Standard de Données (FSD) Natura 2000" (PNUE CAR/ASP, 2002
1	Element representing a substantial importance[4] (<2%)	
2	Element providing important ecosystem functions[5] (2 to 15%)	
3	Typical element, structuring the landscape, and providing essential ecosystem functions[6] (>15%)	

2.2. Habitat extension within the site of interest: relative area of the target habitat in the potential protected area compared to the total area of the habitat on the administrative level.

Value	Definition	Reference
0	Insignificant presence (0.1%)	Extrapolation of the "Formulaire Standard de Données (FSD) Natura 2000" (PNUE CAR/ASP, 2002
1	Low but significant representativeness (<2%)	
2	Good representativeness (2 to 15%)	
3	Excellent representativeness (>15%)	

3. Spatial connectivity

3.1. Naturalness of the environment (percentage of natural or semi-natural areas in direct contact with the perimeter of the area to be protected)

Value	Definition	Reference
0	Area totally connected with other natural areas	Machado (2004) ; Múgica *et al.* (2002) ; De Calais (2008)
1	Area at least partially connected to other natural areas	
2	Isolated area in an entirely artificialized zone	

3.2. Maximal permeability (of the neighboring ecosystem having the highest permeability with the target ecosystem of the area to be protected)

[4] Such as cedar (*Cedrus libani*) and Fir (*Abies cilicica*) stands in Lebanon
[5] Such as Brutian pines (*Pinus brutia*) stands in Lebanon
[6] Such as Palestine oak (*Quercus calliprinos*) stands in Lebanon

Value	Definition	Reference
0	Total permeability (similar ecosystem with satisfying functional level or good state of conservation)	Inspired from De Calais (2008)
1	High permeability (similar ecosystem with insufficient functional level and/or close type of ecosystem with satisfying functional level)	
2	Low permeability (close type of ecosystem with insufficient functional level and/or different type of ecosystem with satisfying functional level)	
3	No permeability (different type of ecosystem with insufficient functional level)	

4. Functional integrity

4.1. Local dynamic / autonomy of the target ecosystem(s) within the area to be protected

Value	Definition	Reference
0	Regressive dynamic	Alados *et al.* (2003)
1	Progressive dynamic	
2	Stable dynamic	

4.2. Local dynamic / autonomy of the target specie(s) within the area to be protected

Value	Definition	Reference
0	Recipient population	Ellner *et al.* (2002) ; Ricklefs & Miller (2005)
1	Balanced population	
2	Source population	

4.3. Structure of the target ecosystem(s) (vertical structure: soil, litter, herbaceous layer, shrubby layer, tree layer - depending on the nature of the ecosystem: rocks, lawn, scrubland, forest...)

Value	Definition	Reference
0	Only one stratum persists, others have disappear	Frontier *et al.* (2008)
1	Few strata are absent or simplified	
2	All strata are present	

5. Regional dynamic or evolutionary trend

5.1. Of target ecosystem(s)

Value	Definition	Reference
0	Progressive dynamic	Saqib *et al.* (2013)
1	Stable or unknown dynamic	
2	Low regression, alternately, by sector, stopped, projected, assumed	
3	Strong regression, certain, lasting, generalized	

5.2.Of target specie(s) when species inventories are available along with the levels of their regression / progression on the territory scale

Value	Definition	Reference
0	Progressive dynamic	Inspired from Saqib *et al.* (2013)
1	Stable or unknown dynamic	
2	Low regression, alternately, by sector, stopped, projected, assumed	
3	Strong regression, certain, lasting, generalized	

6. External human threats

6.1. Former (past) threat having ended on the site (the main threat in case there are many)

Value	Definition	Reference
0	No previous reported threat	Briassoulis (2004) ; Cooney (2004) ; Palumbi *et al.* (2008) ; Roberts *et al.* (2003)
1	Partial and reversible threat	
2	Partial and irreversible or total and reversible threat	
3	Total and irreversible threat	

6.2. Actual threat taking place on the site (the main threat in case there are many)

Value	Definition	Reference
0	No current threat	Briassoulis (2004) ; Cooney (2004) ; Palumbi *et al.* (2008) ; Roberts *et al.* (2003)
1	Partial and reversible threat	
2	Partial and irreversible or total and reversible threat	
3	Total and irreversible threat	

6.3. Probable, predicted or planned threat (climate change; land-use planning: urbanization, road, construction, dam, quarry; area prone fire, erosion, flood, volcano…)

Value	Definition	Reference
0	No probable/planned threat	Briassoulis (2004) ; Cooney (2004) ; Palumbi *et al.* (2008) ; Roberts *et al.* (2003)
1	Partial and reversible threat	
2	Partial and irreversible or total and reversible threat	
3	Total and irreversible threat	

7. Site economic value (use or non-use value)

7.1. Space of direct use value: supply and/or cultural interest (food, timber, grazing, water, recreation, etc. regardless of whether the service is commercial or non-commercial)

Value	Definition	Reference
0	No reported use	Chevassus-au-Louis *et al.* (2009) ; Somda & Awaiss (2013)
1	Usage of trivial economic value (no source of income generation; area of low frequentation)	
2	Usage of real economic value (regular activities with possible income generation)	
3	Usage of fundamental economic value (of which the local or national economic balance depends)	

7.2. Area of emblematic and/or spiritual value (non-use value)

Value	Definition	Reference
0	No reported value	Chevassus-au-Louis *et al.* (2009) ; Somda & Awaiss (2013)
1	Low and local value (symbolic area, known for the local / indigenous population)	
2	Major national or international value (symbolic site of national, regional or even global interest)	

8. Financial and land-use / property constraints

8.1. Land use status or control pattern (for the establishment of a new protected area)

Value	Definition	Reference
0	Existing control over the land (e.g. Case of public properties in Lebanon)	Inspired from Worboys et al. (2015) and field cases from Lebanon and France
1	Possible/negotiable control (e.g. Private or religious properties in Lebanon), with a land of low property value (e.g. Non constructible terrains in France) and/or strong local willingness for conservation	
2	Possible/negotiable control (e.g. Private or religious properties in Lebanon), with a land of high property value (e.g. Constructible terrains in France) and/or low local willingness for conservation	
3	Almost impossible control over the land (e.g. Military field in Lebanon)	

8.2. Financial means for the implementation of the protection initiative (possibility level of accessing international, national, local, or individual funds)

Value	Definition	Reference
0	Strong and easily accessible funds	Awad & Nasr (2003); Emerton *et al.* (2006); WCPA (2000)
1	Low or hardly accessible funds	
2	Inability to access financial resources	

9. Legislation / level of national legal engagement

9.1. Presence of national regulation(s) related to biodiversity conservation and/or protected areas

Value	Definition	Reference
0	Presence of full and satisfying regulations (e.g. France, Italy)	Inspired from Worboys *et al.* (2015) and country cases
1	Presence of partial regulations (e.g. Lebanon, Algeria)	
2	Absence of regulations	

9.2. Presence of other specific regulations (water, rivers, coastline, forests, etc.) that can be applied to protect the site

Value	Definition	Reference
0	Presence of many regulations	Inspired from Worboys *et al.* (2015) and country cases
1	Presence of at least one regulation	
2	Absence of regulations	

9.3. Level of application / compliance with existing regulations

Value	Definition	Reference
0	Strict and penalized	Inspired from Worboys *et al.* (2015) and country cases
1	Global, with some non-penalized offenses (e.g. France)	
2	Partial, rarely penalized (e.g. Lebanon)	
3	No law application (e.g. Case of an armed conflict)	

C. MedConserve: concept and operating mode

MedConserve is designed to operate as a web-based decision support tool for conservationists and practitioners around the Mediterranean basin to orient protected areas designation patterns on continental ecosystems. It is based on the descriptors defined above and is meant to answer the following query: “What type of conservation should be implemented on a given Mediterranean-type continental ecosystem?”. In order to answer this question, MedConserve offers an easy and user friendly platform consisting of multiple choice questions that the user is asked to answer (wholly or partially). Each question presents one descriptor (or sub-descriptor) and its respective values and definitions (e.g. Define the naturalness of the area’s environment - i.e. the percentage of natural or semi-natural areas in direct contact with the perimeter of the area to be protected: 0: Area totally connected with other natural areas; 1: Area at least partially connected to other natural areas; 2: Isolated area in an entirely artificialized zone). Once the user answers the queries, each response will be saved as a specific algorithm into a “hidden” matrix that will compile all given answers, analyze them, and finally suggest prioritized propositions for potential conservation areas that can be designated on the target site. The user is asked to answer as much questions as possible (according to data availability). The higher the number of answered questions is, the better the tool provides pertinent and reliable orientations to the operator. Thus, MedConserve operates as following:

1. A series of multiple choice questions is addressed to the user who is required to answer as much queries as possible according to data availability.
2. Once queries are answered, responses are converted into specific algorithms based on a complex backbone matrix (that will be presented later in the paper) and analyzed.
3. As an output, the decision support tool delivers/displays to the user the result of the analysis as prioritized suggestions of conservation areas categories to be implemented on the given site. These suggestions come in the form of percentages in which the tool ranks in order of priority the conservation options (broad conservation area category) along with the number and type of difficulties/constraints that might hinder the implementation of each category, leaving the user free to decide upon the specific type of protected area (specific types of protected areas corresponding to each broad category will be presented to the user in a specific section of the web application) to implement, according to existing protected areas, regulations in his country.

An example of output can read as follows (Table 1):

Table 1. Simulated example of output generated by MedConserve

Conservation area category	Percentage of pertinence	Number of difficulties	Type of difficulties

(D) Unmanaged partially protected area	86%	0	
(B) Global reserve area	72%	3	- Private property - Area of high economic value - Low or hardly accessible funds
(A) Strictly protected area (sanctuary)	65%	1	Private property
(E) Conservation area with sustainable use of natural resources	51%	0	
(C) Partially protected area with focused management	22%	3	- Land of high property value - Area of high economic value - Very high rate of rare species
(F) Space of knowledge (at least) / incitement (at most) for sustainable economic activities	10%	2	- Very high rate of rare species - Source population

MedConserve operates on a "site" basis to orient the best conservation priority. On large scale territories, it is recommended to divide the area into smaller sectors or sites in order to take into account socioecological heterogeneities. In such case, by using MedConserve to prioritize conservation priorities for each sector, the tool would have served as a pertinent instrument to orient zoning alternatives/options over large scale territories.

The matrix

The matrix consists of a double entry table in which are displayed:

- In columns, the six broad categories of conservation areas;
- In lines, the descriptors with their corresponding modalities, variables and values.

Then, each "value" is analyzed with regards to each "protected area category" and given a specific algorithm (0, 0.5, or 1) as explained in the Methods section. The algorithm is indeed a representation of the answer to the following question: "For this given value of this descriptor, is it suitable to implement this type of protected area?" Answer: Yes (= 1), Maybe but not preferably (=0.5), absolutely Not (=0). This approach reflects how the variation of a specific ecological or socioeconomic aspect can affect conservation patterns/priorities.

The matrix is only managed by the administrator and is not displayed to the operator. It is the mainstay of the tool which performs the analysis and provides the answers to the user.

Appendix 1 exhibits the full matrix with all algorithms included. Numbers were filled in the matrix based on analysis inspired from literature and field cases, and then validated with a college of experts (mentioned in the "Acknowledgment" section) specialized in biodiversity conservation and protected areas.

Appendix 2 displays a virtual example of input in the matrix where not all the descriptors are answered. This can be the case of a user who was only able to answer few queries out of all the multiple choice questions due to lack of available data.

Algorithms in the matrix are filled based on the following analytical logic:

- Endemism degree *per se* provides information on the biogeography of a site (Greuter, 1991), but neither recommends nor discourages its protection or management unless it is rare. Thereby, if a given species is a common endemic at a regional level (e.g. *Teucrium marum* in Corsica-Sardinia), its protection on the national level wouldn't be of great relevance compared to a rare endemic species on the same territory (e.g. *Seseli praecox)*. Hence, endemism is not considered as such as a descriptor, but is rather included as one of the "rarity or irreplaceability" descriptor's modalities, particularly considering the cases of more or less severe restriction of the distribution range.
- In a given site, the higher the rarity (irreplaceability) rate of species or habitats, the greater the need to implement at least partial, yet preferably strict, protection/management initiatives (Tucker *et al*., 2012), rather than sole incitement for sustainable economic activities.
- Habitat representativeness/extension (in percent) reflects the landscape's structure and the importance of the ecosystem's functions. The more a habitat is widely extended, the better it represents a structuring element of the landscape.
    - The lesser a habitat is extended on the territory scale (administrative level), the greater is the need to apply at least partial conservation and/or management. However, the further this habitat is represented on the country level, the greater is the need to orient conservation patterns towards concerted and sustainable use of natural resources and/or incitement for sustainable economic activities. This is the case of Palestine oaks in Lebanon (*Quercus calliprinos*), the most abundant broadleaved species representing nearly 42% of the total forest cover in the country (MOA/FAO, 2005). The high extension/representation of oak ecosystems in Lebanon (considered as common biodiversity) is not a counter argument for protecting it, but rather a motive for conserving it through concerted actions and sustainable use, as it underlies major and large-scale ecosystem functions (Cox & Underwood, 2011).

- The more the proportion (%) of the national habitat within the site of interest (subject for conservation) is significant, the stricter the conservation/management should be, and the more this extension is trivial, the more concerted management and/or incitement for sustainable economic activities should be encouraged. For instance, if the proportion of *Cedrus libani* in a given site meant to be protected is 1% of Lebanon's cedars, it is not worth to strictly or even partially protect the area. But if this proportion rises to 30%, it would be of utter importance to implement absolute/strict conservation initiatives.

- The more the naturalness/spatial connectivity of a site is likely to be low, the greater is the need to implement management or even restoration actions (not only protection) (Dudley, 2012; Múgica *et al.*, 2002). However, when this naturalness/connectivity is high, all categories of protected areas are applicable, but management is not necessarily required (e.g. case of a forest in the heart of the Amazon).
- The more an ecosystem or specie is in "local" regression in a given site, the greater is the need to privilege concerted/sustainable exploitation or restoration management interventions (Alados *et al.*, 2003; Ellner *et al.*, 2002). Yet, if this ecosystem or specie is in local progression, sole protection (with no management requirements) or even lone sensitization on the ecological importance of the site would be enough, even if this progression could lead to a potential natural evolution towards a closure of the ecosystem (concept of climax, e.g. the Amazon forest).
- The more an ecosystem or specie is in "regional" (sustainable) regression/decline over a territory (e.g. Lebanon), the greater is the need to implement at least partial (and ultimately global) protection and/or management measures, especially in areas of high ecological value.
- The nature and degree of a threat is likely to change over time and though, this criterion has to be assessed independently for every site (Margules & Usher, 1981). For this reason, consideration of past, present, and foreseeable future influence of human activities on a candidate site for conservation is important (Roberts *et al.*, 2003). To be effectively employed as a criterion for prioritizing conservation initiatives and establishing new protected areas, mitigatable and non-mitigatable human threats should be identified and quantified where possible (Roberts *et al.*, 2003). In many cases, a site may be exposed to more than one threat.

- The further a former (past) threat (having ended on the site) is total and irreversible (e.g. quarry), the greater is the need to implement management/restoration schemes. If this threat is less severe (e.g. logging), a sole protection of the site is enough. Either cases, concerted management or incitement for sustainable use and conservation of the site are neither enough nor vital.
- The same principle applies for present threats taking place on the site. However, if the level of actual threat is low or moderate (e.g. logging, grazing), concerted management and/or incitement are already useful.
- The more a future (probable or planned) threat is likely to be strong (e.g. dam, highway), the greater is the need to partially or even globally protect/manage the site of interest in order to avoid it or counteract it. For low level threats (e.g. logging), concerted management and incitement are enough.

- The more the economic value of a site is high, the greater is the necessity to privilege concerted actions and sustainable exploitation of resources rather than protection initiatives. This is for instance the case of New Caledonia, the world's largest producer of nickel, a major economic and income generating activity in the country. Although mined forests are known to harbor very high rates of endemism (Morat *et al.*, 1995), no attempt for their protection can be practically planned. Concerted management and incitement on the importance of sustainably exploiting these areas to preserve species dynamics remain the only options for conservation.
  However, if the use of the site is still diffident, incitement and awareness on the importance of sustainably conserving/exploiting it would be enough.
- If a site has a renowned symbolic value (e.g. Cedar forests in Lebanon), sole protection or concerted management are both easily applicable. If it has no symbolic value, management or incitement activities are adequate options. However, to implement management measures on a site of high symbolic value, it is necessary that the object of the “symbol” has an “ecologically compatible” value (e.g. forest, monument), otherwise (e.g. invasive species, artificial space), this will provoke a conflict of interest between future managers (ecologists) and site users. This is the case of the mimosa tree (*Acacia dealbata*), an invasive species in Côte d’Azur, but yet a very strongly appreciated plant by locals and tourists (Gade, 1987). Ecologically wise, this species has no ecological compatible value. However, it remains impossible to eradicate it due to its high symbolic value.

- The higher the control over the land is (e.g. public lands in Lebanon or France), the greater the possibility to implement strict or global conservation initiatives. When this control becomes almost impossible (e.g. military terrain), only incitement initiatives remain possible.
- Without financial means, only partial protection of a site can be considered. With very limited financial resources, incitement initiatives can already be implemented. The more these funds increase, the better their use is or concerted management. However, the more they get important, the more feasible are strict protection or management initiatives (Worboys *et al.*, 2015).
- The more the national regulations relating to protected areas are comprehensive and respected, the easier are protection and management initiatives to implement. In all cases, with or without laws and legislations, it is always pertinent to envision concerted management and incitement actions over areas of ecological conservation value.
- The presence of specific regulations (e.g. river, coasts, forest, etc.) that can be applied to protect a given site encourages protection and management initiatives. In the absence of such regulations, incitement or concerted management are privileged.

How does the matrix (the tool) operate?

MedConserve is designed to operate based on a scoring system. The following section presents a step by step thorough description of the system's operating mode. Appendix 3 exhibits all along an operational example of the matrix for a virtual site based on the input provided in appendix 2.

1. When the user picks a value of a given descriptor, the system automatically selects the corresponding algorithms matching this value for all categories of conservation areas (see example in **Table 2**).

Table 2. Example of automatic algorithm selection for chosen descriptors' values

			Category of conservation area					
Descriptor	**Modality**	**Value**	**A**	**B**	**C**	**D**	**E**	**F**
3. 3. Spatial connectivity	**3.1. Naturalness of the environment**	0	1	0.5	0.5	1	1	1
		1	1	1	1	1	0.5	0.5
		2	**0.5**	**1**	**1**	**0.5**	**0**	**0**
	3.2. Maximal permeability	0	1	0.5	0.5	1	1	1
		1	1	1	1	1	1	1
		2	**1**	**1**	**1**	**1**	**0.5**	**0.5**
		3	0.5	1	1	0.5	0	0

2. After answering the best possible number of descriptors, the system adds for each category of conservation area the corresponding algorithms, to end up with a “score” for every column (category).

3. This score is then divided by:
   - The “absolute maximum value” which is a **fixed** value in the system, referring to the **overall** sum of maximum scores per descriptor’s modality per category, to achieve the “absolute percentage of category pertinence”. This absolute percentage of category pertinence reflects the liability of the system’s output with regards to the user’s input. In other terms, the higher the number of answered descriptors is, the greater will this percentage be, and vice versa. In the example provided in Appendix 3 (see also Table 3), where the user only answers 20 descriptor modalities out of 25, the tool orients conservation priorities towards categories D and C of protected areas, with the highest achieved absolute percentages of pertinence.

Table 3. Example of absolute percentage of category pertinence

Category of conservation area	A	B	C	D	E	F
Score	15	14	16	17	14.5	12
Absolute maximum value	23	23	23	23	22.5	22.5
% of category pertinence (Absolute)	**65%**	**61%**	**70%**	**74%**	**64%**	**53%**

   - The “relative maximum value”, which in contrast is a **variable** value, referring to the **relative** sum of maximum scores per descriptor’s modality per category for the **only descriptors answered by the user**, to achieve the “relative percentage of category pertinence”. This relative percentage of category pertinence reflects the system’s output based on the actual number of descriptor modalities’ answered by the operator. It varies in parallel with the absolute percentage of category pertinence, but has normally higher records as it divides the score by lower maximum values, unless the user answers all descriptors modalities. Table 4 illustrates the same example displayed in Table 2 with the relative percentage of category pertinence for each conservation area category. As shown, relative percentages go in parallel with absolute percentages, but are yet higher as they exhibit the relative ranking of conservation priorities according to the input provided by the user.

Table 4. Example of relative percentage of category pertinence

Category of conservation area	A	B	C	D	E	F
Score	15	14	16	17	14.5	12
Absolute maximum value	23	23	23	23	22.5	22.5
Absolute % of category pertinence	65%	61%	70%	74%	64%	53%
Relative maximum value	20	20	20	20	19.5	19.5
Relative % of category pertinence	75%	70%	80%	85%	74%	62%

4. Finally, for each category of conservation area, the tool displays the number of zeros (0) that appear according to the user's input. Zeros reflect the number of "difficulties" that might hinder the establishment of the given protected area category.
   Table 5 exhibits, for the same example provided in Appendix 3, the number of difficulties for each category of conservation area. For instance, although the tool orients conservation priority primarily towards category D with 83% of relative pertinence, one difficulty might hamper the implementation of this category which is the "Presence of an actual total and irreversible threat taking place on the site". Not only the tool will list the number of zeros, but it will also display the nature of the difficulties.

Table 5. Example of number of difficulties per category of conservation area

Category of conservation area	A	B	C	D	E	F
Score	15	14	16	17	14.5	12
Absolute maximum value	23	23	23	23	22.5	22.5
Absolute % of category pertinence	65%	61%	70%	74%	64%	53%
Relative maximum value	20	20	20	20	19.5	19.5
Relative % of category pertinence	75%	70%	80%	85%	74%	62%
Number of difficulties	2	2	1	1	0	2
Nature of difficulties	....	....	....	Presence of an actual total and irreversible threat taking place on the site	....	....

In the virtual example illustrated in table 5, the optimal choices for conservation are theoretically respectively categories "D" and "C", with the highest percentages of category pertinence (85% and 80%). However, since the end user is free to adopt the most suited category according to the sociopolitical context of his conservation initiative, while taking into consideration the orientations of the decision support tool, the number of displayed difficulties privilege in order of priority category E over categories A and B, as these latters are hindered by 2 difficulties each, whereas category E isn't hampered by any.

Practically, in its web interface design (under construction), the tool is presented in a way where the user only sees a series of multiple choices questions to which he has to answer as an input, and as an output, the tool will only display the relative and absolute percentages of category pertinence (explaining the difference between both), and the number and the nature of difficulties (Figures 1, 2a, 2b and 2c).

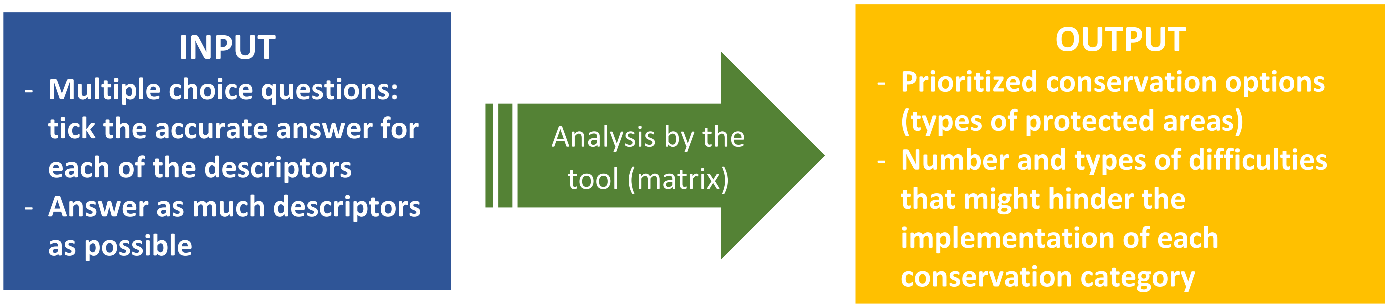

Figure 1. MedConserve operating mode

Figure 2a. MedConserve online step 1: site description

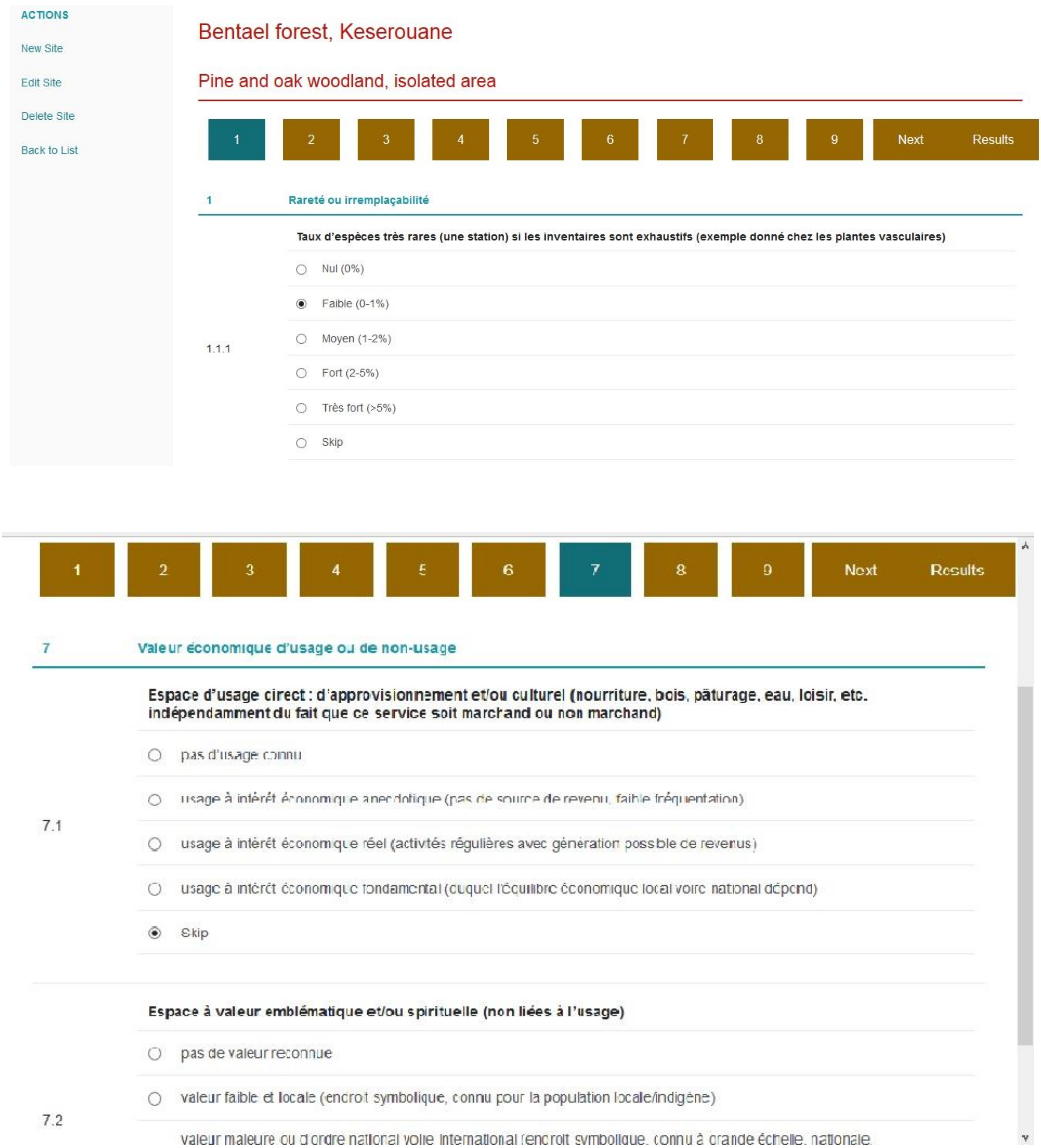

Figure 2b. MedConserve online step 2: multiple choices questions (examples for descriptors 1 and 7)

% Pertinence Catégorie Relative	70%	80%	86%	77%	63%	58%
% Pertinence Catégorie Absolut	67%	76%	83%	74%	60%	56%
Nombre de Difficultés					5	5

Change Values

Figure 2c. MedConserve online final result display (under construction)

Discussion

A strategy at the forefront of biodiversity conservation is the reliance on protected areas (Gaines *et al.,* 2010; Pimm *et al.,* 2001). Opportunities exist indeed to develop reserve networks which preserve biodiversity without adversely affecting existing human settlements and land use, while supporting rural livelihoods. Reconciling biodiversity conservation, people, protected areas and sustainable livelihoods requires thus a focused strategic planning for conservation and development, which maintains biodiversity and ecosystem services without imposing serious restrictions on livelihoods (Brandon *et al.*, 2005; Kremen *et al.*, 2000). Building on such information, it is possible to design protected areas that are integrated into the landscape and that support, rather than detract from, local livelihoods.

Nonetheless, conservation is all about prioritization (Ball *et al.*, 2009; Das *et al.*, 2006; Kukkala & Moilanen, 2013; Reyers, 2004), and prioritization is all about decision support for conservation planning (Ferrier & Wintle, 2009). Prioritization aims to answer questions about when, where, and how we can efficiently achieve conservation goals (Pressey *et al.*, 2007; Wilson *et al.*, 2007). It is usually achieved within a wider decision-making context in which the needs of many land users and stakeholders are acknowledged (Ferrier & Wintle, 2009). In this framework, MedConserve is tailored to provide aid to decision makers in prioritizing conservation patterns on sites of ecological value.

To provide scientific credibility to this tool, a draft backbone matrix was developed then amended and validated by a college of 10 experts through one to one meetings. The validation process took place through a questionnaire (Appendix 4), presenting the concepts inherent to the development of the matrix. The analytical logic underlying algorithms was thus discussed, validated and readapted by experts.

Testing MedConserve

The use of MedConserve is easy and practical. The following section tests the tool on 4 sites in Lebanon:

- Bentael nature reserve: a small (110 hectares) and isolated protected site, located on the coast of Mount Lebanon, in the heart of a highly urbanized area.
- Horsh Ehden nature reserve: a large protected area (1,000 hectares), located in North Lebanon, and recognized as the most biologically diverse reserve in Lebanon, with high rates of species endemism and rarity.
- Ras Chekka cliffs: located northern Lebanon, and currently under classification as a nature reserve by the Lebanese ministry of environment.
- Baabda forest: an unprotected forest, located in Beirut, and exhibiting as per ecologists and conservationists a high ecological conservation value as being a shelter for a wide number of species confined in the heart of the city.

Site 1: Bentael nature reserve

Appendix 5 presents an application of MedConserve on Bentael nature reserve, an existing nature reserve in Lebanon established in 1999 by virtue of law number 11/99. In this example, MedConserve is used to test the pertinence of Bentael's designation. As a result, the tool orients the site's conservation priority towards category C (Partially protected area with focused management) with the highest percentage of category pertinence (86%), followed by category B (Global reserve area) with 80% of category pertinence (Table 6).

Table 6. MedConserve output for Bentael site

Category of conservation area	A	B	C	D	E	F
Absolute % of category pertinence	67%	76%	83%	74%	60%	56%
Relative % of category pertinence	70%	**80%**	**86%**	77%	63%	58%
Number of difficulties	0	**0**	**0**	0	5	5

In its current official designation, Bentael is a nature reserve, and corresponds thus to category B (Global reserve area), which according to MedConserve is a relevant choice. Nevertheless Bentael would fit as well as a protected forest (which corresponds to category C - Partially protected area with focused management). Why?

Although Bentael is home to typical Mediterranean forest stands (mixed pines and oaks), which underlie significant ecological values and are considered as structuring elements of the

Lebanese landscape, it is an isolated ecosystem confined in the heart of a highly urbanized area, with hardly no connectivity to adjacent natural areas, and very low rates of endemism and rarity. The importance of the site *per se* relies in the fact that it is one of the rarest protected low altitude spots (250-500 meters above sea level), located in the heart of the Thermo-Mediterranean vegetation level (0-500m), and valued for its ease of access and the environmental and recreational services it offers to the surrounding communities (mainly schools). However, the progressive dynamic of the ecosystem leading to a continuous closure of the forest requires important restoration interventions. Hence, the designation of Bentael as a partially protected area with focused management would be of greater relevance than a global reserve area, as it entails more management interventions. Besides, a global reserve area is generally characterized by higher rates of species rarity and endemism and highest connectivity to other natural areas, which is not the case of Bentael, and which further justifies the slight difference in category pertinence between categories B (Global reserve area) and C Partially protected area with focused management). The designation of Bentael as a nature reserve remains nonetheless a very pertinent choice as per the results exhibited by MedConserve, which validates the current status of the reserve as officially created in Lebanon.

On another level, an unmanaged partially protected area (category D) or a strictly protected area (category A) would be interesting alternatives to implement, but with less fit pertinence indexes, mainly due to the ecosystem's state of degradation by the peri-urban context, which makes management and/or restauration interventions crucial in some sites of the area.

Last of all, categories E (Conservation area with sustainable/concerted use of natural resources) and F (Space of knowledge (at least) / incitement (at most) for sustainable economic activities) are deemed incompatible, not only because of a relative low percentage of category pertinence, but mostly due to a great number of highlighted difficulties that hinder their designation such as the relative site richness, the vulnerability and endangered biodiversity of the surrounding peri-urban context, and the authorized economic (agricultural and/or industrial) activities in the area's vicinity.

Site 2: Horsh Ehden nature reserve (HENR)

Appendix 6 presents an application of MedConserve on HENR.

Located in North Lebanon, HENR harbors a particularly diverse and pristine remnant forest of mixed conifers and broadleaved species, making the reserve a very important part of the country's cultural and natural heritage. Ranging in altitude between 1,200m and 2,000m and pampered by a multitude of rare and endemic plants species, HENR is home for stands of cedars (*Cedrus libani* A.Rich.), bordered by mixed forests of fir (*Abies cilicica* Ant. & Kotschy), juniper (*Juniperus excelsa* M.Bieb.), and the country's last protected community of wild apple trees (*Malus trilobata* C.K.Schneid.) (Mouterde, 1966). Horsh Ehden has a very distinctive geographic context, being a relatively small forested hillslope area on the upper western flanks of a much larger tract of wilderness zone which includes the main plateau and summit of Lebanon's highest mountain, Qornet Al-Sawda (3,088m). Recognized by most national and international experts as being one of the richest spots in terms of biodiversity in Lebanon with a total number of identified plant species accounting for nearly 40% of the plant species in Lebanon (Khater *et al.*, 2012), HENR was established in 1992 by virtue of Law No. 121 dated 9 March 1992.

MedConserve is used to test the pertinence of HENR's designation. As a result the tool privileges category B (Global reserve area) with 93% of category pertinence (Table 7). This result falls in perfect adequacy with the current classification of HENR as a nature reserve in Lebanon.

Table 7. MedConserve output for HENR

Category of conservation area	A	B	C	D	E	F
Relative % of category pertinence	89%	93%	85%	83%	56%	53%
Number of difficulties	0	0	0	0	5	6

However, as displayed in table 7, categories A (Strictly protected area), C (Partially protected area with focused management) and D (Unmanaged partially protected area) can be potentially applied. Yet, given the fact that i) human visitation is not restricted in HENR, but is allowed for scientific, educational and recreational activities, and that ii) regular management interventions are needed to maintain the ecosystem's health and structure, to manage and control human frequentation, and to prevent species loss, it is preferred not to strictly protect this area (Category A). Similarly, as the ecological value of HENR resides in the ecosystem in its wholeness, as an integral entity, encompassing interdependent functions and interactions, it is better to conserve the ecosystem in its entirety, the whole geographical extent of the protected area, which means the conservation of species, functions, corridors, etc. rather than specific or exceptional elements such as the cedar or the wild apple communities. Therefore, category B (Global reserve area) remains more suitable than categories C (Partially protected area with focused management) and D (Unmanaged partially protected area), which can be still adopted, but are not yet the best options.

The two last categories: E (Conservation area with sustainable/concerted use of natural resources) and F (Space of knowledge (at least) / incitement (at most) for sustainable economic activities) are not relevant to apply due to the great number of highlighted difficulties that underline the incompatibilities between the categories' respective objectives and specific site features (such as the high rates of species richness and the high number of endangered and irreplaceable biodiversity) that hamper their application.

Site 3: Ras Chekka cliffs

Along the way over the North shorelines of Lebanon, Ras Chekka is the first and one of the rarest scenic promontories to spot. As the rocky hills rise up to a peak of 208 meters, an undisturbed maquis covers the steep escarpments of limestone along a plateau of 7km^2 of woodland and scrubland. These types of ecosystems represent only 6% of the land area in Lebanon, revealing the key ecological value of the Ras Chekka cliffs. Designated as a Ramsar site No. 979 since 1999, this coastal limestone promontory (including the cliff and the coastal area all through the supra, medio and infra-littoral zones) represents a bottleneck for soaring birds and a vulnerable zone with no management or conservation plans. Ras Chekka cliffs are under current designation as a nature reserve by the Lebanese ministry of Environment. Is this designation well-adapted as per MedConserve? Appendix 7 presents an application of MedConserve on Ras Chekka cliffs. Results are exhibited in table 8.

As per the output delivered by MedConserve, category C (Partially protected area with focused management) followed by category D (Unmanaged partially protected area) are the best options for the designation of Ras Chekka cliffs with respectively 80% and 77% of category pertinence. This result matches the "natural site and monument" specific type of protected area in Lebanon.

Table 8. MedConserve output for Ras Chekka cliffs

Category of conservation area	A	B	C	D	E	F
Relative % of category pertinence	75%	80%	**86%**	**82%**	74%	60%
Number of difficulties	1	1	**0**	**0**	2	3

Surrounded by intensive quarrying activities (excavation sites and cement industries), and interweaved by road networks and urban complexes, the cliffs of Ras Chekka are increasingly exposed to anthropogenic pressures threatening their structure and integrity (soil erosion, pollution, habitat fragmentation, etc.). These cliffs are home for particular wet habitats and for the historical monastery of Saydet Al-Nourieh, a nationally renowned site for religious pilgrimage with high visitor value. The interaction of people and nature over time has produced this area of distinct character with significant ecological, cultural and scenic values. Hence, a strict protection (categories A or B) of this site wouldn't be of an added value. The protection has to be rather flexible/partial, targeting specific elements such as the geological formation underlying the cliff, the landscape (cliff) itself, the unique wet habitats imprinting the steep slopes of the foothill, the historical monastery, etc. with management interventions focused to address the requirements and provide optimum conditions to maintain and preserve each of these elements (Categories C or D).

Nevertheless, as displayed in table 8, all four categories (A to D) can be quite easy to apply to this site. Yet, the site's fundamental economic value for the local and national economy (quarrying activities in the site's vicinity providing excavation materials nationwide) hinders the establishment of categories A and B that both require the presence of an undisturbed buffer zone around the protected site, while the establishment of categories C and D remains unrestricted by any difficulty, which privileges these two categories. Ras Chekka cliffs can, for instance, fit perfectly as a UNESCO world heritage site (category D).

The current designation of the Ras Chekka cliffs as a nature reserve isn't thus an inconsistent choice, but an adequate one as long as quarrying activities and urban sprawl can be controlled around the protected site through the establishment of an appropriate buffer zone.

Site 4: Baabda forest

Located in the Beirut suburbs, the Baabda forest is the nearest natural wild forest to the capital. Critically confined in the mid of an urban area, this forest accounts for more than 425 types of trees, shrubs and wild flowers, on an approximate area of 110,000m^2 (Ghossain, 2014). Recognized for its high educative value, Baabda forest is frequented by more than 1,000 visitors per month. This mixed pines and oaks forest belongs to the Antonin Monastery in Baabda and is managed by "TERRE Liban", an NGO promoting sustainable development and protection of nature and natural resources in Lebanon. Despite all the efforts invested by this NGO to conserve this area, this forest remains increasingly subject to anthropogenic pressures (hazardous hunting, tree cutting, uncontrolled grazing, irresponsible recreational activities, etc.), which increase its exposure and vulnerability to fire incidences, soil erosion, and habitat fragmentation. And to worsen the situation and contribute to its total demise, the government is planning to build a highway (the "Arab Highway"), passing all through this forest. In this complex contrasted context, is it worth conserving Baabda forest? And if it is, what would be the best option to do so? In an attempt to answer these questions, appendix 8 presents an application of MedConserve on Baabda forest. Results are exhibited in table 9.

Table 9. MedConserve output for Baabda forest

Category of conservation area	A	B	C	D	E	F
Relative % of category pertinence	86%	77%	77%	86%	70%	65%
Number of difficulties	1	1	1	1	2	2

As per the output delivered by MedConserve, the best categories for the conservation of the Baabda forest are equally A (Strictly protected area) and D (Unmanaged partially protected area). The common feature to these two categories is the strict protection of the land (estate), which indeed is the key challenge for the Baabda forest, imperiled by the planned "Arab highway". Ultimately, the site's "estate" has to be protected in order to hamper the highway project. However, as no specific types of protected areas (such as "Site classé" or "integral nature reserve") exist yet in Lebanon to flawlessly answer these two categories, the best remaining option would be to classify this area as a nature reserve or a natural site and monument. This isn't impossible as the control over the land ownership is possible/negotiable (religious terrain) along with a strong local will for conservation of this last forest stand in the heart of Beirut: a shelter for very diverse flora and fauna communities, and most of all, an educational destination for almost all the schools of Beirut and Mount Lebanon for environmental awareness activities.

Conclusion

In view of the socioecological complexity of Mediterranean ecosystems (M'Hirit, 1999), and in a context where the use of ecological and socioeconomic indicators and criteria is gaining further interest in conservation planning, MedConserve brings an added value to conservation prioritization as a support to decision-making processes. It is developed based on a set of pertinent, easy and adapted to Mediterranean continental environments ecological and

socioeconomic descriptors. It accounts for both ecological and socioeconomic aspects of conservation and suggests prioritized conservation alternatives to the user.
MedConserve is not a decision support tool intended to provide the answer, but to enable decision-makers to systemize and structure decision-making and priority setting processes using the best available knowledge, leaving the user free to select the most convenient protected area category.

Even though conservation prioritization requires solid scientific bases, MedConserve remains an objective tool designed to provide recommendations on the priority and orientation of conservation. Still, the process of consultation and participation among stakeholders remains the key approach for any conservation initiative. At the outset of any planning process, it is crucial that objectives (aims, goals) are explicitly set for all of the processes. This also includes the explicit consideration of common objectives, stakeholders' involvement, policy recommendations, quality verification, and monitoring, at all stages of design and implementation.

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References

Alados, C., Pueyo, Y., Giner, M., Navarro, T., Escos, J., Barroso, F., Cabezudo, B. and Emlen, J. 2003. Quantitative characterization of the regressive ecological succession by fractal analysis of plant spatial patterns. *Ecological Modelling*, *163*(1): 1-17.

Anderson, S. 2002. Identifying important plant areas. London: Plantlife International. 52pp.

Awad, N. and Nasr, W. 2003. Exploring Options for Sustainable Financing of Protected Areas in the Mediterranean Context: Lebanon's Experience. In Vth world Parks Congress: sustainable Finance Stream.

Bajracharya, B., Pradhan, S. and Salerno, F. 2010. An Integrated Decision Support Toolbox (DST) for the Management of Mountain Protected Areas. *Mountain Research and Development,* 30(2): 94-102.

Ball, I. R., Possingham, H. P. and Watts, M. 2009. Marxan and relatives: software for spatial conservation prioritization. Spatial conservation prioritization: quantitative methods and computational tools. Oxford University Press, Oxford, 185-195.

Bertzky, B., Corrigan, C., Kemsey, J., Kenney, S., Ravilious, C., Besancon, C. and Burgess, N. 2012. Protected Planet Report 2012: Tracking progress towards global targets for protected areas, IUCN, Gland, and UNEP-WCMC, Cambridge.

Brandon, K., Gorenflo, L. G., Rodrigues, A. S. L., & Waller, R. W. (2005). Reconciling Biodiversity Conservation, People, Protected Areas, and Agricultural Suitability in Mexico. *World Development,* 33(9): 1403-1418.

Briassoulis, H. 2004. Land-use, land-cover changes and global aggregate impacts. Land cover and land use, Encyclopedia of Life Support Systems. EOLSS-UNESCO Publ., Oxford.

Chevassus-au-Louis, B., Salles, J. M., Pujol, J. L., Bielsa, S., Martin, G., & Richard, D. (2009). Approche économique de la biodiversité et des services liés aux écosystèmes : contribution à la décision publique. Documentation française.

Comolet-Tirman, J., Grech, G., Siblet, J. P. and Trouvilliez, J. 2008. Le patrimoine naturel protégé grâce aux Arrêtés préfectoraux de Protection de Biotope (APB) : milieux naturels, faune et flore. Un bilan après trente années d'existence d'un outil de protection souvent méconnu et sous-estimé. Rapport SPN, 2.

Convention on Biological Diversity (CBD). 2011. Strategic Plan for Biodiversity 2011-2020 and the Aichi Targets, Secretariat of the Convention on Biological Diversity, Montreal. <www.cbd.int/doc/ strategic-plan/2011-2020/Aichi-Targets-EN.pdf>

Convention on Biological Diversity (CBD). 2012. Conference of the Parties Decision XI/24, para. 7. <www.cbd.int/doc/decisions/cop-11/cop-11-dec-24-en.pdf>

Cooney, R. 2004. The Precautionary Principle in Biodiversity Conservation and Natural Resource Management: An issues paper for policy-makers, researchers and practitioners (No. 2). IUCN.

Cox, R.L., and Underwood, E.C. (2011). The Importance of Conserving Biodiversity Outside of Protected Areas in Mediterranean Ecosystems. *Plos One,* 6(1), e14508.

Cuttelod, A., García, N., Abdul Malak, D., Temple, H. and Katariya, V. 2008. The Mediterranean: a biodiversity hotspot under threat. In: J.-C. Vié, C. Hilton-Taylor and S.N. Stuart (eds). The 2008 Review of the IUCN Red List of Threatened Species. IUCN Gland, Switzerland.

Das, A., Krishnaswamy, J., Bawa, K. S., Kiran, M. C., Srinivas, V., Kumar, N. S. and Karanth, K. U. 2006. Prioritization of conservation areas in the Western Ghats, India. Biological Conservation, 133(1): 16-31.

De Calais, BIOTOPE GREET Nord-Pas. 2008. Analyse des potentialités écologiques du territoire régional. Direction Régionale de l'Environnement Nord-Pas de Calais, Région Nord-Pas de Calais. 66pp.

Delavenne, J., Metcalfe, K., Smith, R., Vaz, S., Martin, C., Dupuis, L., Coppin, F. and Carpentier, A. 2011. Systematic conservation planning in the eastern English Channel: comparing the Marxan and Zonation decision-support tools. ICES Journal of Marine Science, 69(2): 75-83.

Dudley, N. (Editor). 2008. Guidelines for Applying Protected Area Management Categories. Gland, Switzerland: IUCN. x + 86pp.

Eken, G., Bennun, L., Brooks, T. M., Darwall, W., Fishpool, L. D., Foster, M., Knox, D. et al. 2004. Key biodiversity areas as site conservation targets. *BioScience*, *54*(12): 1110-1118.

Elissalde-Videment, L., Horellou, A., Humbert, G. and Moret, J. 2004. Guide méthodologique sur la modernisation de l'inventaire des zones naturelles d'intérêt écologique, faunistique et floristique. Mise à jour 2004. Coll. Patrimoines Naturels. Muséum National d'Histoire Naturelle, 14.

El-Hajj, R., Khater, C., Tatoni, T., Ali, A. and Vela, E. 2016. What indicators for ecosystems conservation? Orienting conservation priorities and protected areas designation in Mediterranean continental environments. *Conservation & Society*. *In revision.*

El-Hajj, R., Khater, C., Vela, E. and Tatoni, T. 2016 (*Accepted*). Pertinence of protected areas networks in biodiversity conservation strategies: Insights from an eastern Mediterranean context. *Ecologia Mediterranea.*

Ellner, S., Fieberg, J., Ludwig, D. and Wilcox, C. 2002. Precision of population viability analysis. *Conservation Biology*, 16(1): 258-261.

Emerton, L., Bishop, J. and Thomas. L. 2006. Sustainable Financing of Protected Areas: A global review of challenges and options, No. 13. IUCN WCPA, Gland. 109pp.

Ferrier, S. and Wintle, B.A. 2009. Quantitative approaches to spatial conservation prioritization: matching the solution to the need. In: Moilanen, A., Wilson, K.A., Possingham, H.P. (Eds). Spatial conservation prioritization: quantitative methods and computational tools. Oxford University Press, Oxford, pp. 1-13.

Frontier, S., Pichod-Viale, D., Leprêtre, A., Davoult, D. and Luczak, C. 2008. Écosystèmes, Structure, Fonctionnement, Évolution. 4ème édition. Dunod. 576pp.

Gade, D. 1987. "Tropicalisation" de la végétation ornementale de la Côte d'Azur. *Méditerranée*, 62(4):19-25.

Gaines, S. D., Lester, S. E., Grorud-Colvert, K., Costello, C., & Pollnac, R. 2010. Evolving science of marine reserves: new developments and emerging research frontiers. *Proceedings of the National Academy of Science of the United States of America*, 107: 18251-18255.

Gaston, K. J., Jackson, S. F., Cantú-Salazar, L. and Cruz-Piñón, G. 2008. The Ecological Performance of Protected Areas. *Annual Review of Ecology, Evolution, and Systematics*, 39, 93-113.

GFA/ELARD/MoE/CDR. 2013. Rapport de la mission d'appui : Définition du statut, du rôle, de la fonction et des mécanismes de gestion des Parcs naturels nationaux et régionaux au Liban et rédaction du cadre réglementaire y afférent. 240pp.

Ghossain, C. 2014. La biodiversité végétale de la forêt de Baabda. Etude floristique d'une forêt méditerranéenne Libanaise. Editions Universitaires Européennes. 296pp.

Greuter, W. 1991. Botanical diversity, endemism, rarity, and extinction in the Mediterranean area: an analysis based on the published volumes of Mad-Checklist. *Botanika Chronika*, 10:63-79.

International Union for Conservation of Nature (IUCN) and United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). 2014. The World Database on Protected Areas: August 2014, UNEP-WCMC, Cambridge.

IUCN. 2012. Guidelines for Application of IUCN Red List Criteria at Regional and National Levels: Version 4.0. Gland, Switzerland and Cambridge, UK: IUCN. iii + 41pp.

Kilani, H., Serhal, A. and Llewlyn, O. 2007. Al-Hima: A way of life. IUCN West Asia regional office, Amman, Jordan - SPNL, Beirut, Lebanon. 72pp.

Khater, C., Awad, L. and El-Hajj, R. 2012. Management plan of Horsh Ehden Nature Reserve, 2012-2016. Projet d'appui aux réserves naturelles du Liban. MOE/AFD. Lebanon. 199pp.

Kremen, C., Niles, J., Dalton, M., Daily, G., Ehrlich, P., Fay, P., *et al.* 2000. Economic incentives for rain forest conservation across scales. *Science*, 288: 1828-1832.

Kukkala, A. S. and Moilanen, A. 2013. Core concepts of spatial prioritization in systematic conservation planning. *Biological Reviews*, 88(2): 443-464.

Ladle, R. and Whittaker, R. 2011. Conservation Biogeography. John Wiley & Sons, Science, 320 pages.

Langhammer, P., Bakarr, M., Bennun, L., Brooks, T., Clay, R., Darwall, W., De Silva, N., Edgar, G., Eken, G., Fishpool, L., da Fonseca, G., Foster, M., Knox, D., Matiku, P., Radford, E., Rodrigues, A., Salaman, P., Sechrest, W. and Tordoff, A. 2007. Identification and gap analysis of key biodiversity areas: targets for comprehensive protected area systems. Gland, Switzerland: IUCN (Best Practice Protected Area Guidelines Series 15).

Lumbreras, L.E. 2001. The Micro-reserves as a Tool for Conservation of Threatened Plants in Europe. Issues 121-125. Council of Europe, Jan 1, 2001 - Nature. 119pp.

Machado, A. 2004. An index of naturalness. *Journal for nature conservation*, 12(2): 95-110.

Magnagnon, S., Geslin, J., Hardegen, M., Lacroix, P., Le Bail, J., Zambettakis, C., Bioret, F. & De Montmollin. B. 2009. Méthode utilisée par le CBN de Brest pour l'élaboration de listes rouges (UICN) et de listes de taxons rares et/ou en régression à l'échelle régionale ou départementale. Document technique. Outils et méthodes. Conservatoire Botanique National de Brest. France.

Margules, C. and Usher, M. 1981. Criteria used in assessing wildlife conservation potential: A review. *Biological Conservation*, 21(2): 79-109.

M'Hirit, O. 1999. La forêt méditerranéenne : espace écologique, richesse économique et bien social. Unasylva (FAO).

Ministry of Agriculture (MoA), Directorate of Rural Development and Natural Resources (DRDNR). 2005. National Forest and Tree Assessment and Inventory tcp/leb/2903. Beirut: Food and Agriculture Organization of the United Nations FAO.

Morat, P., Jaffré, T. & Veillon, J.M. (1995) Grande Terre. Centres of plantdiversity (eds S.D. Davis, V.H. Heywood V.H. and Hamilton A.C, editors. Volume 2: Asia, Australasia and the Pacific. WWF and IUCN.

Mouterde P. 1966. Nouvelle flore du Liban et de la Syrie. Volume 1. Beirut : Dar El-Machreq (Imprimerie Catholique).

Múgica, M., De Lucio, J. V., Martínez, C., Sastre, P., Atauri-Mezquida, J. A. & Montes, C. 2002. Territorial integration of natural protected areas and ecological connectivity within Mediterranean landscapes. Consejerıa de Medio Ambiente, Junta de Andalucia.

Ostermann, O. 1998. The Need for Management of Nature Conservation Sites Designated Under Natura 2000. *Journal of Applied Ecology*, 35(6): 968-973.

Palumbi, S., McLeod, K. and Grünbaum, D. 2008. Ecosystems in action: lessons from marine ecology about recovery, resistance, and reversibility. *BioScience,* 58(1): 33-42.

Pattison, D., DosReis, D. and Smillie, H. 2004. An inventory of GIS-Based Decision Support Tools for MPAs. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Protected Areas Center.

Pediaditi, K., Buono, F., Pompigna, F., Bogliotti, C., Nurlu, E., Ladsia, G. and Petropoulos, G.P. 2011. A decision support system-based procedure for evaluation and monitoring of protected areas sustainability for the Mediterranean region. *Journal of Earth System Science,* 120(5): 949-961.

Pimm, S.L., Ayres, M., Balmford, A., Branch, G. *et al*. 2001. Can we defy nature's end? *Science*, 293: 2207-2208.

PNUE/CAR/ASP. 2002. Formulaire standard des données (FSD) pour les inventaires nationaux de sites naturels d'intérêt pour la conservation. Programme des Nations Unies pour l'Environnement, Plan d'action pour la Méditerranée, Centre d'activités régionales pour les aires spécialement protégées (CAR/ASP). Tunis. 64pp.

Pressey, R. L., Cabeza, M., Watts, M. E., Cowling, R. M. and Wilson, K. A. 2007. Conservation planning in a changing world. *Trends in ecology & evolution*, 22(11): 583-592.

Reyers, B. 2004. Incorporating anthropogenic threats into evaluations of regional biodiversity and prioritisation of conservation areas in the Limpopo Province, South Africa. *Biological Conservation*, 118(4): 521-531.

Reynard, E. 2009. Geomorphosites: definitions and characteristics', in E. Reynard, P. Coratza and G. Regolini-Bissig (eds) Geomorphosites, pp. 9-20, Verlag Dr. Friedrich Pfeil, Munich.

Ricklefs, R. and Miller, G. 2005. Ecologie. De Boeck Supérieur. 858pp.

Roberts, C. M., Andelman, S., Branch, G., Bustamante, R. H., Carlos Castilla, J., Dugan, J., Halpern, B.S., Lafferty, K.D., Leslie, H., Lubchenco, J., Mcardle, D., Possingham, H.P., Ruckelshaus, M. & Warner, R. R. 2003. Ecological criteria for evaluating candidate sites for marine reserves. *Ecological applications*, 13(1), 199-214.

Rodrigues, A., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., da Fonseca, G.A.B. *et al*. 2004. Effectiveness of the global protected area network in representing species diversity. *Nature*, 428.

Saqib, Z., Malik, R., and Von Wehrden, H. 2013. Landcover dynamics in relation to western Tragopan occurrence in Pakistan: a regional assessment. *Pakistan Journal of Botany*, 45(1): 551-559.

Segan, D., Game, E., Watts, M., Stewart, R. and Possingham, H. 2011. An interoperable decision support tool for conservation planning. *Environmental Modelling & Software*, 26:1434-1441.

Smith, R. and Theberge, B. 1986. A review of criteria for evaluating natural areas. Environmental Management, 10(6): 715-734.

Somda, J. and Awaiss, A. 2013. Evaluation économique des fonctions et services écologiques des écosystèmes naturels : guide d'utilisation de méthodes simples. Ouagadougou, Burkina Faso. IUCN. 32pp.

Stortini, C., Shackell, N. and O'Dor, R. 2015. A decision-support tool to facilitate discussion of no-take boundaries for Marine Protected Areas during stakeholder consultation processes. *Journal for Nature Conservation*, 23: 45-52.

Stroud, A., Mudge, P. and Pienkowski, W. 1990. Protecting internationally important bird sites: a review of the EEC Special Protection Area network in Great Britain. Ornithology Branch, Chief Scientist Directorate, Nature Conservancy Council.

Tucker, C., Cadotte, M., Davies, T. & Rebelo, T. 2012. Incorporating geographical and evolutionary rarity into conservation prioritization. *Conservation Biology*, 26(4): 593-601.

Tunesi, T., Mo, G., Nora D.T. and Agnesi, S. 2005. A GIS-Based Decision -Suport Tool for Zoning Italian Marine Protected Areas. Impact 2005.

Underwood, E., Viers, J., Klausmeyer, K., Cox, R. and Shaw, R. 2009. Threats and biodiversity in the Mediterranean biome. *Diversity and Distributions*, 15:188-197.

Usher M.B. (ed.) 1986. Wildlife conservation evaluation. Chapman & Hall, London and New York. 394 pages.

Vanderpert, H. 2007. Diagnostic écologique territorial d'un chaînon littoral péri-urbain : Le Massif de la Nerthe/Estaque/Côte Bleue (Bouches-du-Rhône). Mémoire de Master. Expertise Ecologique et Gestion de la Biodiversité. Université Paul Cézanne, Marseille.

Wilson, K. A., Underwood, E. C., Morrison, S. A., Klausmeyer, K. R., Murdoch, W. W., Reyers, B., Wardell-Johnson, G., Marquet, P.A., Rundel, P.W., McBride, M.F., Pressey, R.L., Bode, M., Hoekstra, J.M., Andelman, S., Looker, M., Rondinini, C., Kareiva, P., Shaw, M.R. & Possingham, H. P. (2007). Conserving biodiversity efficiently: what to do, where, and when. *PLoS Biology*, 5(9): e223.

World Commission on Protected Areas (WCPA). 2000. Financing Protected Areas: Guidelines for protected area managers, No. 5, Financing Protected Areas Task Force, IUCN WCPA in collaboration with the Economics Unit of IUCN, Gland.

Wood, L. J. and Dragicevic, S. 2007. GIS-based multicriteria evaluation and fuzzy sets to identify priority sites for marine protection. *Biodiversity and Conservation*, 16(9): 2539-2558.

Worboys, G.L., Lockwood, M., Kothari, A., Feary, S. and Pulsford, I. (eds). 2015. Protected Area Governance and Management, ANU Press, Canberra.

Yahi, N., Vela, E., Benhouhou, S., De Belair, G. and & Gharzouli, R. 2012. Identifying Important Plants Areas (Key Biodiversity Areas for Plants) in northern Algeria. *Journal of Threatened Taxa*, 4(8): 2753-2765.

CHAPITRE 6
Synthèse générale

« Planifier la conservation c'est aussi et avant tout comprendre le territoire autour de l'analyse du passé, du présent et du futur » (Brunet, 1987).

La préservation de la biodiversité et des services écosystémiques associés prend une place de plus en plus importante dans la société et en politique. De véritables débats scientifiques se développent sur les dimensions sociales et économiques de la conservation (Czech, 2000 ; Mangel *et al.,* 1996). En contexte méditerranéen, la place de l'homme apparaît plus que jamais comme déterminante, puisque ses impacts et ses choix de gestion déterminent le maintien de la biodiversité du bassin méditerranéen.

Le terme de « biodiversité » proposé par Rosen en 1986 est apparu pour la première fois dans une publication de Wilson en 1988. Toutefois, si le terme n'apparaît qu'en 1986, c'est bien parce que la biodiversité n'est pas seulement une mesure du vivant, mais témoigne d'un problème qui se pose à l'humanité : « La biodiversité, c'est la diversité biologique problématisée, offerte à l'humanité comme objet de souci et de protection » (Maris, 2006).

Le besoin de conservation de la biodiversité a été supporté au fil de l'histoire et devient au fur et à mesure un enjeu critique au cœur des relations entre l'homme et la nature (Aubertin et Vivien, 1998 ; Callicott *et al.*, 1999 ; Larrère et Larrère, 1997; Rodary *et al.*, 2004). Depuis trois décennies, c'est une vision utilitariste qui justifie le besoin de protéger la nature qui se fonde principalement sur la notion de services écosystémiques (MEA, 2005). L'homme prend conscience du fait qu'il vit au sein d'espaces fragiles dont le maintien conditionne sa qualité de vie. Penser à une conservation de la biodiversité exige d'intégrer des facteurs économiques, écologiques, sociaux, culturels et politiques (Gallopín *et al.*, 2001; Aubertin et Vivien, 2006) et suppose donc d'être en mesure de considérer toute la complexité des systèmes naturels et humains et leurs interrelations aux différentes échelles spatio-temporelles (Berkes et Folke, 1998). Si le territoire est support, enjeu et produit des interactions entre les hommes et leur environnement (Ferrier, 1984; Di Méo, 1998), la planification de la conservation vise à organiser ces interactions dans le temps et dans l'espace (Brunet, 1987). Planifier c'est comprendre le fonctionnement du territoire, prioriser les objectifs de conservation, et programmer des actions à mener avec des moyens et des connaissances limitées.

En réponse à ces enjeux, les outils de protection se sont diversifiés, agissant d'abord sur des espaces fermés et ensuite sur des réseaux (Bonnin et Rodary, 2008). Si environ 13% de la surface mondiale est déjà couverte par des aires protégées (Chape *et al.*, 2005 ; Jenkins & Joppa, 2009 ; Rodrigues *et al.*, 2004) avec une progression constante, de nombreuses études ont montré que les stratégies d'aires protégées sont insuffisantes pour répondre aux enjeux de biodiversité, et que les périmètres de protection ne sont pas toujours en accord avec la réalité écologique (Brooks *et al.*, 2004 ; Rodrigues *et al.*, 2004). Ils peuvent en effet avoir été définis par des opportunités ou peuvent malheureusement dépendre de décisions ou de pressions politiques, ne reflétant pas du tout les intérêts écologiques. Les scientifiques soulignent par ailleurs que bien souvent le choix des sites à conserver s'est fait de manière *ad hoc* sur base de critères peu explicites et privilégiant des zones à faibles enjeux de développement socioéconomique (Pressey, 1994 ; Scott *et al.*, 2001).

Dans les années 70, l'avènement des outils de géomatique a cependant permis de prendre du recul et d'évaluer la pertinence de ces choix stratégiques. Ces années ont constitué une étape cruciale dans la modification du rapport de la conservation à la science, en particulier en intégrant la dimension planétaire dans l'identification des critères écologiques à prendre en compte dans la mise en place et la gestion des aires protégées. Ainsi la méthode de « gap analysis » (Scott *et al.*, 1993) a permis par exemple de mettre en évidence les lacunes et le manque de représentativité des dispositifs existants en croisant par superposition le réseau d'aires protégées avec la répartition des enjeux de biodiversité (présence d'espèce, d'habitat, richesse, etc.), (e.g. Scott *et al.*, 2001 ; Rodrigues *et al.*, 2004 ; Gaston *et al.*, 2006 ; Maiorano *et al.*, 2006).

Les méthodes de priorisation développées dans les années 1990 ont poursuivi cet effort d'inventaire et d'identification des espaces à conserver. La priorisation est un outil d'identification des enjeux écologiques, développé pour servir de référentiel méthodologique et guider les nouvelles créations d'espaces protégés. Des outils de priorisation ont été ainsi développés pour sélectionner des aires prioritaires pour la conservation en se basant sur des approches quantitatives de fait plus explicites, transposables et bénéficiant d'une légitimité scientifique (Sarkar *et al.*, 2006).

Cependant, la définition de ces outils pose avant tout la question de leur applicabilité et donc de leur transfert du champ scientifique au champ de l'action. Prendergast *et al.* (1999) s'interrogent quant au peu de succès des outils calibrés et des méthodes de priorisation de la conservation dans le champ de l'action. Ils constatent que bien souvent les acteurs de la conservation n'ont même pas conscience de leur existence, n'ont pas les moyens financiers pour les mettre en œuvre, ou ne sont tout simplement pas réceptifs à des approches prescriptives venant du champ scientifique. La complexité des techniques utilisées et le manque de communication entre science et acteurs de la conservation, limitent ainsi l'applicabilité de ces derniers.

Aujourd'hui les récentes avancées conceptuelles en matière de protection de la nature, mettant en avant le besoin d'intégrer les enjeux de conservation au développement humain, représentent de véritables défis en termes d'outils d'aide à la décision. L'enjeu est de prendre en charge la complexité des connaissances qui caractérisent le vivant, tout en réconciliant les besoins et priorités socioéconomiques afin de promouvoir une vision partagée de la conservation, qui se heurte actuellement à des défis croissants et requiert l'établissement d'une échelle de priorités permettant de mieux caractériser les enjeux afin d'optimiser l'orientation des choix de conservation (Margules et Pressey, 2000). Plusieurs méthodes sont actuellement développées, reposant sur des lectures spécifiques de ce qui doit être protégé en priorité, et en particulier des approches analytiques différentes de la représentativité de la biodiversité.

L'établissement de priorités demeure désormais nécessaire non seulement pour planifier les actions de conservation, mais aussi pour évaluer les actions déjà réalisées. Les méthodes de priorisation étant censées guider les efforts de conservation *in situ*, la hiérarchisation des différents enjeux de conservation en fonction de leur intérêt socio-écologique peut largement influencer l'évaluation des réseaux existants et de prioriser les choix de conservation de nouvelles zones pour la conservation.

Dans cet esprit, MedConserve apporte une nouvelle approche, simple et efficace, pour la priorisation des initiatives de conservation. Alliant l'histoire du site à son état actuel et son futur anticipé, c'est un outil pluridimensionnel répondant aux enjeux socioécologiques d'un site voué à la conservation.

Relevant d'un besoin réel identifié par les acteurs de la conservation au Liban (ministères, municipalités, organisations non-gouvernementales, etc.), MedConserve s'articule selon une approche déclinée en deux niveaux d'analyse :

- Un niveau écosystémique prioritaire ou « filtre brut », décrit par les descripteurs écologiques et soulignant les priorités à la conservation. Ce niveau exprime les urgences d'action sous-jacentes aux attributs et aux fonctionnalités écologiques du site.
- Un niveau plus spécifique ou « filtre fin », décrit par les descripteurs socioéconomiques et sous-tendant les contraintes à la conservation. Ce niveau met en avant les risques, les difficultés et les défis associés au site destiné à la conservation.

Il s'agit de structurer ces descripteurs, de les prioriser, et d'étudier les liens entre l'existant et les paramètres pour appréhender et comprendre ce qui existe.

Conçu non seulement pour orienter la désignation des aires protégées en priorisant les meilleures alternatives de conservation d'un site donné, MedConserve peut également servir :

- à valider / invalider un choix actuel de conservation (tel le cas des 4 sites testés dans le chapitre 5) - indépendamment du choix de protection qui risque de ne pas pouvoir changer pour des raisons administratives voire politiques ou économiques évidentes - en apportant des arguments scientifiques, déployant les « réalités » écologiques et socio-économiques prédominantes sur un site donné. Le type de protection existant est ainsi justifié ou remis en question en fonction de critères bien déterminés. Toutefois, dans le contexte libanais où l'absence d'un cadre législatif relatif aux aires protégées freine la mise en place d'espaces de conservation répondant à de vraies priorités socioécologiques, la mesure dans laquelle l'orientation de l'outil sera prise en compte dépendra du contexte sociopolitique sous-jacent à l'initiative de protection. Dans d'autres pays méditerranéens où le cadre légal régissant la création d'aires protégées est presque complet et en vigueur (France, Italie, etc.), l'application de MedConserve facilitera l'évaluation des réseaux existants et les processus de prise de décision relatifs ;
- dans la zonation de larges territoires (parcs naturels régionaux, réserves de biosphères, etc.), en accordant des niveaux de protection appropriés par parcelle de territoire - l'outil étant applicable sur un site « homogène », notamment de points de vues écosystémique et foncier ;
- à ouvrir des pistes de réflexions et d'actions et à prioriser les choix de conservation de nouvelles zones pour la conservation (zones encore non classées), en fournissant des éléments de réflexion scientifiques, permettant d'explorer les risques et les enjeux socio-écologiques prédominants sur un site donné et conditionnant, directement ou indirectement, les potentielles modalités de protection à long-terme.

Cet outil est modulable. Dans ce sens, quelques descripteurs peuvent facilement être adaptés à l'exemple de la faune (tel que la rareté), et des sous-descripteurs (et valeurs) supplémentaires ainsi éventuellement déclinés (sur base bibliographique). En l'état, il décline des descripteurs formalisés, dont certains ne sont applicables qu'à l'exemple de la flore vasculaire.

MedConserve est en outre applicable tant au niveau local (Liban) que régional (méditerranéen). Dans un contexte où les besoins de conservation des espaces naturels sont comparables dans les pays du bassin méditerranéen, et les enjeux de conservation dans leur majorité convergents, l'application de MedConserve se veut une opportunité vers la création d'un réseau méditerranéen d'aires protégées, cohérent au niveau conceptuel. Les descripteurs sous-jacents à la structure de cet outil représentent des mesures écologiques caractéristiques du contexte méditerranéen (endémisme, rareté, typicalité, etc.) et reflètent des contraintes communes aux différents pays (contraintes financières, foncières, législatives, etc.). La diversité des régimes sociopolitiques et des systèmes de gouvernance des ressources naturelles d'un territoire à un autre, soulignée par les différentes déclinaisons (valeurs) d'un même descripteur, permet ainsi l'orientation des initiatives de protection dans un principe de compensation écologique.

Si les États doivent être encouragés à créer un réseau d'aires protégées qui corresponde à de vraies priorités écologiques et socioéconomiques, il faut les munir :

- des moyens de le faire (cadre législatif adéquat et complet, financements nécessaires, etc.), et
- d'un outil d'aide à la décision, qui soit à la fois complet (tous les critères, tous les besoins) et modulable (critères manquants, non-applicables), leur proposant plusieurs solutions parmi lesquelles ils pourront choisir la meilleure parmi celles qui ne sont pas bloquantes (applicables au niveau local).

Bien entendu, l'application de MedConserve (au Liban en particulier) se heurte à quelques lacunes découlant :

- du besoin de compléter et d'approfondir les inventaires de biodiversité (notamment ceux de la flore vasculaire et de la faune) ;
- de la disponibilité, de l'accessibilité et de la fiabilité des données existantes, notamment quantitatives ;
- de la nécessité de développer un système standardisé de collecte des données de terrain au niveau national, traduit par une base de données compréhensive, et régulièrement mise à jour ;

- de la nécessité d'intégrer les priorités de conservation de la biodiversité dans les stratégies et les politiques nationales, et d’élaborer des plans visant une conservation optimale des ressources naturelles du pays ;
- du manque de compétences naturalistes au niveau national (botanique, herpétologie, dynamique des populations, etc.), enrayant la réalisation d’inventaires biologiques ;
- du manque de communication et de coordination entre les acteurs de la conservation (scientifiques, gestionnaires, autorités locales et nationales, etc.), limitant l’applicabilité de tout outil d’aide à la décision ;
- de la « politisation » de toute décision de conservation d’un site, indépendamment de ses attributs socio-écologiques.

En outre, les limites d’application de MedConserve se déclinent à plusieurs niveaux, notamment :

- l’outil n’est applicable que sur un site « homogène », notamment aux niveaux foncier et écosystémique. Ceci dit, en cas d’hétérogénéité d’un site (présence de différents types de propriétés foncières : privée, publique, religieuse, etc. ; présence de différents écosystèmes : forestier, urbain, péri-urbain, etc.), une sectorisation est recommandée afin de mieux évaluer les attributs écologiques et socio-économiques inhérents à chaque parcelle de la zone. C’est dans un cas pareil que l’utilisation de MedConserve pour la zonation d’un territoire voit son application ;
- l’outil, tel que conçu pour le moment, décline quelques descripteurs écologiques (tel que l’endémisme et la rareté) qui ne sont applicables qu’au cas de la flore vasculaire. L’intégration de sous-descripteurs renseignant des dimensions relatives à la faune demeure néanmoins possible ;
- l’impact des changements globaux sur la dynamique des écosystèmes n’est pas explicitement pris en compte parmi les descripteurs identifiés et ce, notamment, à cause de la nature complexe des mesures relatives à cet aspect ; les descripteurs identifiés étant choisis pour être relativement faciles à renseigner ;
- l’outil n’est applicable qu’au cas des écosystèmes méditerranéens continentaux, sauf les zones humides continentales dont la caractérisation écologique exige la prise en compte de dimensions non renseignées par les descripteurs de l’outil (stratification hydrologique, qualité des eaux, etc.). Toutefois, au cas où une zone humide continentale fait partie intégrante d’un site terrestre à intérêt de conservation, dans ce cas-là, elle sera uniquement considérée comme entité structurante du site apportant une diversité

biologique et des valeurs esthétiques supplémentaires à ce dernier. Pas de données écologiques spécifiques lui y seront renseignées.

Néanmoins, émanant d’un besoin réel d’intégrer à la fois les dimensions socio-écologiques dans l’orientation des initiatives de conservation (au Liban en particulier), MedConserve offre une première tentative de structuration de descripteurs écologiques et socio-économiques sous forme d’outil permettant de prioriser la désignation des aires protégées au Liban, qui, jusqu’à ce jour, sont désignées au cas par cas.

Ce travail de thèse s’adresse ainsi :

- à la communauté scientifique, qui pourra se servir désormais de l’outil élaboré comme base pertinente et robuste pour orienter les priorités de désignation des aires protégées ;
- aux ministères compétents, aux municipalités et aux autorités locales qui se serviront de l’outil pour orienter des initiatives concrètes de conservation.

Il est préconisé de continuer à tester l'outil sur un plus grand nombre de sites au Liban et dans les divers pays méditerranéens, afin de l'améliorer et de le raffiner au besoin, avant de le généraliser au Liban, voire à la méditerranée.

De haute importance pour le Liban, ce sujet répond concrètement aux recommandations et aux exigences de la CBD (Convention pour la Biodiversité) signée et ratifiée par le Liban en 1994, au NBSAP, 1998 (National Biosafety Strategy and Action Plan) et au NAPPA, 2006 (National Action Plan for Protected Areas).

CHAPITRE 7
Conclusion et perspectives

« …C'est pour documenter les succès, les échecs et les leçons tirées et servir d'outil d'aide à la décision, en vue d'un meilleur réajustement de nos choix de politique de conservation de la biodiversité » (colonel Babacar Guèye, 2015, interview avec l'Agence de la presse Sénégalaise).

Dans un contexte de très forte érosion de la biodiversité, la consolidation d'un savoir scientifique directement applicable par les politiques et les gestionnaires des espaces protégés est très certainement un atout. Mais la délimitation et la formulation de ce savoir sont en eux-mêmes des enjeux de pouvoir.

Près de 40 ans après l'émergence d'une écologie conçue comme science de l'homme et de la nature, et de la problématisation des interactions entre dynamiques sociales et politiques de conservation, la diffusion d'un discours global organisé sur l'efficacité économique et l'intégrité écologique doit être appréhendée dans toute l'épaisseur de ses incidences sociales, économiques et politiques.

La constitution d'outils d'évaluation des dynamiques socio-environnementales pourrait constituer une étape majeure pour l'avenir de la biodiversité, une étape qui doit émerger au sein des grands organismes qui s'occupent aujourd'hui des politiques de conservation.

Au sein de la vague participationniste et des expériences de gestion communautaire qui ouvrent la conservation aux problématiques d'interconnexion entre sociétés et nature, et qui certainement fondent les bases primordiales d'une stratégie de conservation optimale, les méthodes de priorisation ne sont que des outils objectifs destinés à fournir des recommandations quant à la priorisation des choix de protection.

Aujourd'hui comme hier, la place de l'humain (depuis l'utilisateur local de la ressource jusqu'aux institutions mondiales de conservation) sera toujours une piste d'interrogations et de défis aux chercheurs et conversationnistes aspirant à une harmonie platonique entre l'être et son environnement.

Ce travail de thèse ne s'arrête pas là. MedConserve verra son application sur tout le territoire Libanais, du Nord au Sud, de l'Est à l'Ouest, en octroyant des priorités de conservation à tout espace naturel encore existant, protégé ou pas.

Je termine ce manuscrit par un rêve que j'ai en esprit depuis que j'ai visité le parc Yellowstone aux Etats-Unis en 2013 dans le cadre de mes travaux de thèse. Durant cette aventure, je me suis rendue compte que la surface de ce parc est presque égale à celle de mon Liban ; un constat qui m'a d'ores et déjà, apporté à rêver du « Parc National du Liban », un parc au cœur de la Méditerranée, un éclat de biodiversité au Moyen-Orient…

Bibliographie citée

Abdul-Nour, H. 2001. Les inscriptions forestières d'Hadrien : Mise au point et nouvelles découvertes. *Archaeology & history in Lebanon*, 14, 64-95.

Abi-Saleh, B. 1978. Etude Phytosociologique, Phytodynamique et Ecologique des Peuplements Sylvatiques du Liban : Signification Bioclimatique et Essai de Cartographie Dynamique. Dissertation. Université d'Aix-Marseille III, Marseille, France.

Abi-Saleh, B. et Safi, S. 1988. Carte de la Végétation du Liban au 1/500 000 + Notice explicative. *Ecologia Mediterranea,* 14(1/2), 123-142.

Abis, S. 2006. Les dynamiques démographiques en Méditerranée. *Les notes d'analyse du CIHEAM*, 11, 27.

Anderson, S. 2002. Identifying Important Plant Areas. Plantlife International, London. 52pp.

Angermeier, P.L. and Karr, J.R. 1994. Biological integrity versus biological diversity as policy directives: protecting biotic resources. *BioScience,* 44, 690-697.

A-Rocha and SPNL (Society for the Protection of Nature in Lebanon). 2008. The Identification and Conservation of New Important Bird Areas in Lebanon. IBA's map. Project funded by MAVA foundation.

Aubertin, C. et Vivien, F.D. 1998. Les enjeux de la biodiversité, Economica, Paris, France.

Aubertin, C. et Vivien, F.D. 2006. Le développement durable : enjeux politiques, économiques et sociaux, La Documentation française, Paris, France.

Bagader, A. A., El Chirazi El Sabbagh, A. T., As Sayyid Al Glayand, M., Izzi Deen Samarrai, M. Y. et Abd Ar Rahman Llewellyn, O. A. 1994) La protection de l'environnement en Islam. Environmental protection in Islam. Environmental Policy and Law Paper (IUCN), 20.

Ball, I. R., Possingham, H. P. and Watts, M. 2009. Marxan and relatives: software for spatial conservation prioritization. Spatial conservation prioritization: quantitative methods and computational tools. Oxford University Press, Oxford, 185-195.

Balmford, A. and Long, A. 1994. Avian endemism and forest loss. *Nature,* 372, 623-624.

Berkes, F. et Folke, C. 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience, Cambridge University Press, New York, USA.

Bibby, C.J., Crosby, M.J., Heath, M.F., Johnson, T.H., Long, A.J., Stattersfield, A.J. *et al.* 1992. Putting Biodiversity on the Map: Global Priorities for Conservation. ICPB, Cambridge.

Bode, M. Wilson, K., Brooks, T. Turner, W., Mittermeier, R., McBride, M., Underwood, E. and Possingham, H. 2008. Cost-effective global conservation spending is robust to taxonomic group. *Proceedings of the National Academy of Sciences of the United States of America*, 105, 6498-6501.

Bonnin, M. et Rodary, E. 2008. Gouvernance et connectivité écologique. Vers une responsabilité partagée de la conservation de la nature in Eberhard C. (Ed), Traduire nos responsabilités planétaires. Recomposer nos paysages juridiques, Bruylant, Bruxelles, Belgique.

Brandon, K. 2002. Getting the basics right: key actions in designing effective parks. In J. Terborgh, L. C. Davenport, & C. Van Schaik (Eds.), Making parks work: Identifying key factors to implementing parks in the tropics (pp. 443–466). Covelo, CA, Washington, DC: Island Press.

Brooks, T.M., Bakarr, M.I., Boucher, T., Da Fonseca, G.A.B., Hilton-Taylor, C., Hoekstra, J.M., Moritz, T., Olivier, S., Parrish, J., Pressey, R.L., Rodrigues, A.S.L., Sechrest, W., Stattersfield, A., Strahm, W. and Stuart, S.N. 2004. Coverage provided by the global protected-area system: Is it enough? *Bioscience*, 54(12), 1081-1091.

Brunet, R. 1987. La carte comme mode d'emploi. Fayard/Reclus, Paris, France.

Callicott, J.B., Crowder, L.B. and Mumford, K. 1999. Current normative concepts in conservation. *Conservation Biology,* 13(1), 22-35.

CBD (Convention on Biological Diversity). 1992. http://www.cbd.int/doc/legal/cbd-en.pdf [accessed on 3.04.2014]

CEPF.2011. Bassin Mediterraneen, profil d'écosystème. Critical Ecosystem Partnership Fund. http://www.cepf.net/Documents/Mediterranean_Summary_Booklet_Francais.pdf

Chanvallon, S. 2009. Anthropologie des relations de l'Homme à la Nature : la Nature vécue entre peur destructrice et communion intime. Social Anthropology and ethnology. Université Rennes 2 : Université Européenne de Bretagne, 2009.

Chape, S., Blyth, S., Fish, L., Fox, P. and Spalding, M. 2003. United Nations List of Protected Areas. IUCN, Gland, Switzerland and Cambridge, UK and UNEP-WCMC, Cambridge, UK. ix + 44pp.

Chape, S., Harrison, J., Spalding, M. and Lysenko, I. 2005. Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Philosophical Transactions of the Royal Society of London*, 360(1454), 443-455.

Cowling, R. M. and Pressey, R. L. 2003. Introduction to systematic conservation planning in the Cape Floristic Region. *Biological Conservation*, 112, 1-13.

Cox, R.L., and Underwood, E.C. 2011. The Importance of Conserving Biodiversity Outside of Protected Areas in Mediterranean Ecosystems. *Plos One*, 6(1), e14508.

Czech, B. 2000. The importance of ecological economics to wildlife conservation. *Wildlife Society Bulletin*, 28, 2-69.

Davis, S., Heywood, V. & Hamilton, A. (1994-95). Centers of Plant Diversity. A Guide and Strategy for their Conservation. IUCN/WWF, Cambridge, 3 volumes.

Das, A., Krishnaswamy, J., Bawa, K. S., Kiran, M. C., Srinivas, V., Kumar, N. S. and Karanth, K. U. 2006. Prioritization of conservation areas in the Western Ghats, India. *Biological Conservation*, 133(1): 16-31.

Derous, S., Agardy, T., Hillewaert, H., Hostens, K., Jamieson, G., Mees, J., Moulaert, I., Olenin, S., Paelinckx, D., Rabaut, M., *et al.* 2007. A concept for biological valuation in the marine environment. *Oceonologia*, 49, 99-128.

Devictor, V., Mouillot, D., Meynard, C., Jiguet, F., Thuiller, W. and Mouquet, N. 2010. Spatial mismatch and congruence between taxonomic, phylogenetic and functional diversity: the need for integrative conservation strategies in a changing world. *Ecology letters*, 13(8), 1030-1040.

Di Meo, G. 1998. De l'espace aux territoires. *L'information géographique*, 3(62), 99-110.

Dudley, N. (Ed.). 2008. Guidelines for Applying Protected Area Management Categories. Gland, Switzerland. IUCN. x + 86pp.

Eken, G., Bennun L., Brooks, T., Darwall, W., Fishpool, L., Foster, M., Knox, D., Langhammer, P., Matiku, P., Radford, E., Salaman, P., Sechrest, W., Smith, M., Spector, S. & Tordoff A. (2004). Key Biodiversity Areas as Site Conservation Targets. *BioScience*, 54(12), 1110-1118.

El-Hajj, R., Khater, C., Vela, E. & Tatoni, T. 2016 (*Accepted*). Pertinence of protected areas networks in biodiversity conservation strategies: Insights from an eastern Mediterranean context. *Ecologia Mediterranea*.

Faour, G., Hamze, M., Khater, C., Darwish C., Khalaf G., Abdallah C., Shaban A., Kabbara N. 2013. Space Atlas of Lebanon. CNRS-L.

Ferrier, J.P. 1984. Antée 1. La géographie, ça sert d'abord à parler des territoires ou le métier des géographes, Edisud, Aix-en-Provence.

Ferrier, S. and Wintle, B.A. 2009. Quantitative approaches to spatial conservation prioritization: matching the solution to the need. In: Moilanen, A., Wilson, K.A., Possingham, H.P. (Eds). Spatial conservation prioritization: quantitative methods and computational tools. Oxford University Press, Oxford, pp. 1-13.

Folke, C. 2007. Social-ecological systems and adaptive governance of the commons. *Ecological Research*, 22, 14-15.

Gaines, S. D., Lester, S. E., Grorud-Colvert, K., Costello, C., & Pollnac, R. 2010. Evolving science of marine reserves: new developments and emerging research frontiers. *Proceedings of the National Academy of Science of the United States of America*, 107, 18251-18255.

Gallopín, G., Funtowicz, S., O'Connor, M. et Ravetz, J. 2001. La science pour le XXIe siècle : du contrat social aux fondements scientifiques. *Revue internationale des sciences sociales*, 168, 239-250.

Game, E. T., Grantham, H. S., Hobday, A. J., Pressey, R. L., *et al*. 2009. Pelagic protected areas: the missing dimension in ocean conservation. *Trends in Ecology and Evolution*, 24, 360-369.

Garnier, E. et Moriceau, J. M. 2004. Terre de conquêtes : la forêt vosgienne sous l'Ancien Régime. Fayard. 628pp.

Gaston, K.J., Charman, K., Jackson, S.F., Armsworth, P.R., Bonn, A., Briers, R.A., Callaghan, C.S.Q., Catchpole, R., Hopkins, J., Kunin, W.E., Latham, J., Opdam, P., Stoneman, R., Stroud, D.A. and Tratt, R., 2006. The ecological effectiveness of protected areas: *The United Kingdom. Biological Conservation*, 132, 1, 76-87.

Gaston, K. J., Jackson, S. F., Cantú-Salazar, L. and Cruz-Piñón, G. 2008. The Ecological Performance of Protected Areas. *Annual Review of Ecology, Evolution, and Systematics,* 39, 93-113.

Gauthier, P., Debussche, M. and Thompson, J.D. 2010. Regional priority setting for rare species based on a method combining three criteria. *Biological Conservation*, 143, 1501-1509.

Gehlbach, F. R. 1975. Investigation, evaluation,-and priority ranking of natural areas. *Biological Conservation*, 8, 79-88.

Goldsmith, F. B. 1975. The evaluation of ecological resources in the countryside for conservation purposes. *Biological Conservation*, 8, 89-96.

Gray, N. J. 2010. Sea change: exploring the international effort to promote marine protected areas. *Conservation and Society*, 8, 331-338.

Gubbay, S. (ed.). 1995. Marine protected areas: Principles and techniques for management (London: Chapman & Hall).

Halpern, B. S. and Warner, R. R. 2002. Marine reserves have rapid and lasting effects. *Ecology Letters*, 5, 361-366.

Haughton, M., and Siar, S. V. 2006. Socio-economic indicators in integrated coastal zone and community-based fisheries management: case studies from the Caribbean (No. 491). Food & Agriculture Organization. 208pp.

Jacot, M. 2009. Les aires marines protégées comme outils de conservation de la biodiversité marine : application de critères de sélection et considération de la pertinence des critères adoptés dans le cadre de la Convention sur la diversité biologique. Dissertation en vue de l'obtention des grades de maître en écologie internationale et de maître en environnement Sherbrooke, Québec, Canada, août 2009.

Jenkins, C.N. and Joppa, L. 2009. Expansion of the global terrestrial protected area system. *Biological Conservation*, 142(10), 2166-2174.

Johnson, M. C., Poulin, M. and Graham, M. 2003. Towards an integrated approach to the conservation and sustainable use of biodiversity: lessons learned from the Rideau River Biodiversity Project. *Human Ecology Review*, 10(1), 40-55.

Karr, J.R. 1991. Biological integrity: a long neglected aspect of water resource management. *Ecological Applications*, 1, 66-84.

Khater, C. 2015. L'écologie appliquée : une responsabilité scientifique au carrefour de l'interdisciplinarité. HDR. Université Aix-Marseille. 71pp.

Kier, G., Kreft, H., Lee, T.M., Jetz, W., Ibisch, P., Nowicki, C., Mutke, J. and Barthlott, W. 2009. A global assessment of endemism and species richness across island and mainland regions. *Proceedings of the National Academy of Sciences*, 106(23), 9322-9327.

Kritzer, J. P. 2004. Effects of noncompliance on the success of alternative designs of marine protected-area networks for conservation and fisheries management. *Conservation Biology*, 18, 1021-1031.

Kukkala, A. S. and Moilanen, A. 2013. Core concepts of spatial prioritization in systematic conservation planning. *Biological Reviews*, 88(2): 443-464.

Laguna, E., Deltoro, V.I., Perez-Botella, J., Perez-Rovira, P., Serra, L., Olivares, A. and Fabregat, C. 2004. The role of small reserves in plant conservation in a region of high diversity in eastern Spain. *Biological Conservation*, 119, 421-426.

Lagadeuc, Y. and Chenorkian, R. 2009. Les systèmes socio-écologiques : vers une approche spatiale et temporelle. *Natures Sciences Sociétés*, 2(17), 194-196.

Larrère, C. et Larrère R. 1997. Du bon usage de la nature, Aubier, Paris, France.

Lazzarotti, O. 2011. Patrimoine et tourisme : histoire, lieux, acteurs, enjeux. Belin Sup. 302pp.

Lefebvre, T. et Moncorps, S. (coordination). 2010. Les espaces protégés français : une pluralité d'outils au service de la conservation de la biodiversité. Comité français de l'UICN, Paris, France. 100pp.

Legay, J. M. 2006. La conservation et la gestion de la biodiversité : un défi pour l'interdisciplinarité. *Dans :* L'interdisciplinarité dans les sciences de la vie. Editeurs : Quæ, Cemagref. 174pp.

Lepareur F. 2011. Evaluation de l'état de conservation des habitats naturels marins à l'échelle d'un site Natura 2000. Guide méthodologique, Version 1. Février 2011. Rapport SPN 2011 / 3, MNHN, Paris, 55pp.

Le Saout, S., Hoffmann, M., Shi, Y., Hughes, A., Bernard, C., Brooks, T.M., Bertzky, B., Butchart, S.H.M., Stuart, S.N., Badman, T. & Rodrigues, A.S.L. 2013. Protected Areas and Effective Biodiversity Conservation. *Science*, 342(6160), 803-805.

Lester, S. E., & Halpern, B. S. 2008. Biological responses in marine no-take reserves versus partially protected areas. *Marine Ecology Progress Series*, 367, 49-56.

Lester, S. E., Halpern, B. S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B. I., Gaines, S. D., Airamé, S., & Warner, R. R. 2009. Biological effects within no-take marine reserves: a global synthesis. *Marine Ecology Progress Series,* 384, 33-46.

Lindenmayer, D., Margules, C. and Botkin, D. 2000. Indicators of biodiversity for ecologically sustainable forest management. *Conservation Biology,* 14(4), 941-950.

Liu, J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H. and Taylor, W.W. 2007. Complexity of coupled human and natural systems. *Science*, 317(5844), 1513-1516.

Lovejoy, T. 2008. Climate change and biodiversity. *Revue Scientifique de l'Office Internationale des Épizooties,* 27(2).

Lubchenco, J., Palumbi, S. R., Gaines, S. D., & Andelman, S. 2003. Plugging a hole in the ocean: the emerging science of marine reserves. *Ecological Applications*, 13, 3-7.

Lubchenco, J., Gaines, S., Warner, R., Palumbi, S. *et al*. 2007. *The science of marine reserves*, 2nd edition, international version. Available at: www.piscoweb.org [accessed on 25 March 2014]

Maiorano, L., Falcucci, A. and Boitani L. 2006. Gap analysis of terrestrial vertebrates in Italy: Priorities for conservation planning in a human dominated landscape. *Biological Conservation,* 133, 4, 455-473.

Mangel, M., Talbot, L.M., Meffe, G. K., Agardy, M. T., Alverson, D. L., Barlow, J. *et al.* 1996. Principles for the conservation of wild living resources. *Ecological Applications*, *6*(2), 338-362.

Margules, C. and Usher, M. 1981. Criteria used in assessing wildlife conservation potential: A review. *Biological Conservation*, 21(2), 79-109.

Margules, C. and Pressey, R.L. 2000. Systematic conservation planning. *Nature*, 405, 243-253.

Maris, V. 2006. La protection de la biodiversité - entre science, éthique et politique. Pages, Montréal, Université de Montréal.

Maurin H., Theys J., Feraudy (de) E. et Duhautois L. 1997. Guide méthodologique sur la modernisation de l'inventaire des zones naturelles d'intérêt écologique, faunistique et floristique. ColI. Notes de Méthode. Institut Français de l'Environnement. Orléans. 66pp.

MEA, 2005. Ecosystems and Human Well-Being, Island Press, Washington Covelo London, USA, UK.

Médail, F. and Myers, N. 2004. Mediterranean Basin. In: Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions (eds. Mittermeier RA, Gil PR, Hoffmann M, et al.), pp. 144–147. CEMEX, Monterrey, Conservation International, Washington and Agrupacio´n Sierra Madre, Mexico.

Médail, F. and Quézel, P. 1999. Biodiversity hotspots in the Mediterranean Basin: setting global conservation priorities. *Conservation Biology*, 13, 1510-1513.

Micheli, F., Halpern, B.S., Botsford, L.W., & Warner, R.R. 2004. Trajectories and correlates of community change in no-take marine reserves. *Ecological Applications*, 14, 1709-1723.

Mittermier, R.A., Gil, P.R., Hoffmann, M., *et al*. 2005. Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions. CEMEX, Mexico.

Mittermeier, R.A., Myers, N., Thomsen, J.B., Fonseca, G.A.B. & Olivieri, S. 1998. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. *Conservation Biology*, 12, 516-520.

MOE/GEF/UNDP. 2009. Fourth national report of Lebanon to the convention of biological diversity. "Towards 2010 Biodiversity Target". 246pp.

Mora, C. and Sale, P.F. 2011. Ongoing global biodiversity loss and the need to move beyond protected areas: a review of the technical and practical shortcomings of protected areas on land and sea. *Marine Ecology Progress Series*, 434, 251-266.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G.A.B. & Kent J. 2000. Biodiversity hotspots for conservation priorities. *Nature*, 403, 853-858.

Naughton-Treves, L., Buck Holland, M., & Brandon, K. 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods. *Annual Review of Environment and Resources*, 30, 219-252.

Noss, R. F. 1995. Maintaining Ecological Integrity in Representative Reserve Networks: A World Wildlife Fund Canada/World Wildlife Fund-United States Discussion Paper. WWF. 85pp.

Noss, R.F., Carroll, C., Vance-Borland, K. and Wuerthner, G. 2002. A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone ecosystem. *Conservation Biology*, 16, 895-908.

Olivier, L., Galland, J.P., Maurin, H., and Roux, J.P. 1995. Livre Rouge de la flore menacée de France. Tome I : Espèces prioritaires. Muséum National d'Histoire Naturelle, Conservatoire Botanique National de Porquerolles, Ministère de l'Environnement, Paris.

Olson, D.M. & Dinerstein, E. 1998. The Global 200: a representation approach to conserving Earth's most biologically valuable ecoregions. *Conservation Biology*, 12, 502-515.

Pimm, S.L., Ayres, M., Balmford, A., Branch, G. *et al*. 2001. Can we defy nature's end? *Science*, 293, 2207-2208

Prendergast, J.R., Quinn, R.M. and Lawton J.H. 1999. The gaps between theory and practice in selecting nature reserves. *Conservation Biology*, 13(3), 484-492.

Pressey, R.L. 1994. Ad Hoc Reservations - Forward or Backward Steps in Developing Representative Reserve Systems. *Conservation Biology,* 8(3), 662-668.

Pressey, R.L. 1998. Algorithms, politics, and timber: an example of the role of science in a public, political negotiation process over new conservation areas in production forests. In R. T. Wills & R. J. Hobbs (Eds.), Ecology for everyone: Communicating ecology to scientists, the public, and politicians (pp. 73–87). Sydney: Surrey Beatty & Sons.

Pressey, R.L. and Taffs, K.H. 2001. Scheduling conservation action in production landscapes: priority areas in western New South Wales defined by irreplaceability and vulnerability to vegetation loss. *Biological Conservation*, 100, 355-376.

Pressey, R.L., Johnson, I.R. and Wilson, P.D. 1994. Shades of irreplaceability: towards a measure of the contribution of sites to a reservation goal. *Biodiversity and Conservation*, 3, 242-262.

Quézel, P. 1995. La flore du bassin méditerranéen : origine, mise en place, endémisme. *Ecologia mediterranea*, 21, 19-39.

Quézel, P. 1999. Biodiversité végétale des forêts méditerranéennes, son évolution éventuelle d'ici à trente ans. *Forêt méditerranéenne*, T. XX, n°1, 1999, pp.3-8.

Rabinowitz, D. 1981. Seven forms of rarity. In: Synge, H. (Ed.). The Biological Aspects of Rare Plant Conservation. Wiley, New York, pp. 205-217.

Radford, E.A., Catullo, G., & Montmollin, B. (eds.). 2011. Important Plant Areas of the south and east Mediterranean region: priority sites for conservation. IUCN, Gland, Switzerland and Malaga, Spain. Gland, Switzerland and Malaga, Spain: IUCN. VIII + 108pp.

Radford, E.A., Otte, D.K.S., Otte, L.J., Massey, J.R. and Whitson, P.D. 1981. Natural heritage: classification, inventory and information. University of North Carolina Press, Chapel Hill, North Carolina, 485 pp.

Ratcliffe, D. 1977. A Nature Conservation Review. Nature Conservancy Council, UK.

Redman, C.L., Grove, J.M., and Kuby, L.H. 2004. Integrating social science into the Long-Term Ecological Research (LTER) network: Social dimensions of ecological change and ecological dimensions of social change. *Ecosystems,* 7, 161-171.

Reyers, B. 2004. Incorporating anthropogenic threats into evaluations of regional biodiversity and prioritisation of conservation areas in the Limpopo Province, South Africa. *Biological Conservation*, 118(4): 521-531.

Ricketts, T., Dinerstein, E., Boucher, T., Brooks, T., Butchart, S., Hoffmann, M., Lamoreux, J., Morrison, J., Parr, M., Pilgrim, J., Rodrigues, A., Sechrest, W., Wallace, G., Berlin, K., Bielby, J., Burgess, N., Church, D., Cox, N., Knox, D., Loucks, C., Luck, G., Master, L., Moore, R., Naidoo, R., Ridgely, R., Schatz, G., Shire, G., Strand, H., Wettengela, W. & wikramanayake, E. (2005). Pinpointing and preventing imminent extinctions. *Proceedings of the National Academy of Sciences of the United States of America*, 102(51), 18497-18501.

Roberts, C. M., Andelman, S., Branch, G., Bustamante, R. H., Carlos Castilla, J., Dugan, J., Halpern, B.S., Lafferty, K.D., Leslie, H., Lubchenco, J., Mcardle, D., Possingham, H.P., Ruckelshaus, M. and Warner, R. R. 2003. Ecological criteria for evaluating candidate sites for marine reserves. *Ecological applications*, 13(1), 199-214.

Rodary, E., Castellamet, C. et Rossi, G. 2004. Conservation de la nature et développement, l'intégration impossible?, Karthala, Paris.

Rodrigues, A.S.L., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., da Fonseca, G.A.B., Gaston, K.J., Hoffmann, M., Long, J.S., Marquet, P.A., Pilgrim, J.D., Pressey, R.L., Schipper, J., Sechrest, W., Stuart, S.N., Underhill, L.G., Waller, R.W., Watts, M.E.J. and Yan, X. 2004. Effectiveness of the global protected area network in representing species diversity. *Nature* 428(6983), 640-643.

Salafsky, N. and Wollenberg, E. 2000. Linking livelihoods and conservation: a conceptual framework and scale for assessing the integration of human needs and biodiversity. *World development*, 28(8), 1421-1438.

Sarkar, S., Pressey, R.L., Faith, D.P., Margules, C.R., Fuller, T., Stoms, D.M., Moffett, A., Wilson, K.A., Williams, K.J., Williams, P.H. and Andelman, S. 2006. Biodiversity conservation planning tools: Present status and challenges for the future. *Annual Review of Environment and Resources*, 31, 123-159.

Schmeller, D.S., Gruber, B., Budrys, E., Framsted, E., Lengyel, S. and Henle. K. 2008. National responsabilities in European species conservation: a methodological review. *Conservation Biology*, 22: 593-601.

Scott, J.M., Davis, F., Csuti, B., Noss, R.F., Butterfield, B., Groves, C., Anderson, H., Caicco, S., D'Erchia, F., Edwards, T.C., Uliman, J. and Wright, R.G. 1993. Gap analysis: a geographical approach to protection of biological diversity. *Wildlife Monographs*, 123, 1-41.

Scott, J.M., Davis, F.W., McGhie, R.G., Wright, R.G., Groves, C. and Estes, J. 2001. Nature reserves, do they capture the full range of America's biological diversity? *Ecological Applications*, 11, 999-1007.

SDATL. 2004. Schéma directeur d'aménagement du territoire libanais. Rapport final, Dar El Handassah (Liban) et IAURIF (France), 239pp.

Smith, R. and Theberge, B. 1986. A review of criteria for evaluating natural areas. *Environmental Management*, 10(6), 715-734.

Stattersfield, A.J., Crosby, M.J., Long, A.J. & Wege, D.C. 1998. Endemic Bird Areas of the World Priorities for Conservation. BirdLife International, Cambridge.

Tans, W. 1974. Priority ranking of biotic natural areas. *Michigan Botanist*, 13, 31-39.

Thompson, I., Mackey, B., McNulty, S., & Mosseler, A. 2009. Forest Resilience, Biodiversity, and Climate Change. A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 43, 67pp.

Tordoff A. 2004. Key Biodiversity Areas as Site Conservation Targets. *BioScience*, 54(12), 1110-1118.

Tubbs, C. R. and Blackwood, J. W. 1971. Ecological evaluation of land for planning purposes. *Biolical Conservation,* 3, 169-72.

Underwood, E., Viers, J., Klausmeyer, K., Cox, R. and Shaw, R. 2009. Threats and biodiversity in the Mediterranean biome. *Diversity and Distributions*, 15(2), 188-197.

Usher M.B. (ed.) 1986. Wildlife conservation evaluation. Chapman & Hall, London and New York. 394pp.

Van Der Ploeg, S. W. F. and Vlijm, L. 1978. Ecological evaluation, nature conservation and land use planning with particular reference to methods used in the Netherlands. *Biological Conservation*, 14, 197-221.

Viry, D. 2013. État de conservation des habitats humides et aquatiques d'intérêt communautaire, Méthode d'évaluation à l'échelle du site. Guide d'application. Version 1 - Avril 2013. Rapport SPN 2013-13, Service du patrimoine naturel, Museum National d'Histoire Naturelle / Office National de l'Eau et des Milieux Aquatiques, Paris, 33pp.

Wright, D. F. 1977. A site evaluation scheme for use in the assessment of potential nature reserves. *Biological Conservation*, 11, 293-305.

Annexes

Les annexes de la thèse sont fournies en pièces jointes au manuscrit.

Annexe 1. Structure et algorithme de la matrice **s**ous-jacente à MedConserve

Annexe 2. Exemple virtuel de saisie de données dans la matrice sous-jacente à MedConserve

Annexe 3. Exemple opérationnel de la matrice sur base des données virtuelles saisies dans l'annexe 2

Annexe 4. Questionnaire adressé au collège d'experts pour validation de la matrice sous-jacente à MedConserve

Annexe 5. Application de MedConserve au site de la réserve naturelle de Bentael

Annexe 6. Application de MedConserve au site de la réserve naturelle de Horsh Ehden

Annexe 7. Application de MedConserve au site de Ras Chekka

Annexe 8. Application de MedConserve au site de la forêt de Baabda

Annexe 9. Article El-Hajj, R., Varese, P., Nemer, N., Tatoni, T. and Khater, C. 2015. Mediterranean ecosystems challenged by global changes and anthropogenic pressures: vulnerability and adaptive capacity of forests in North Lebanon. *Revue Écologique (La Terre et la Vie)*, 70(1): 3-15